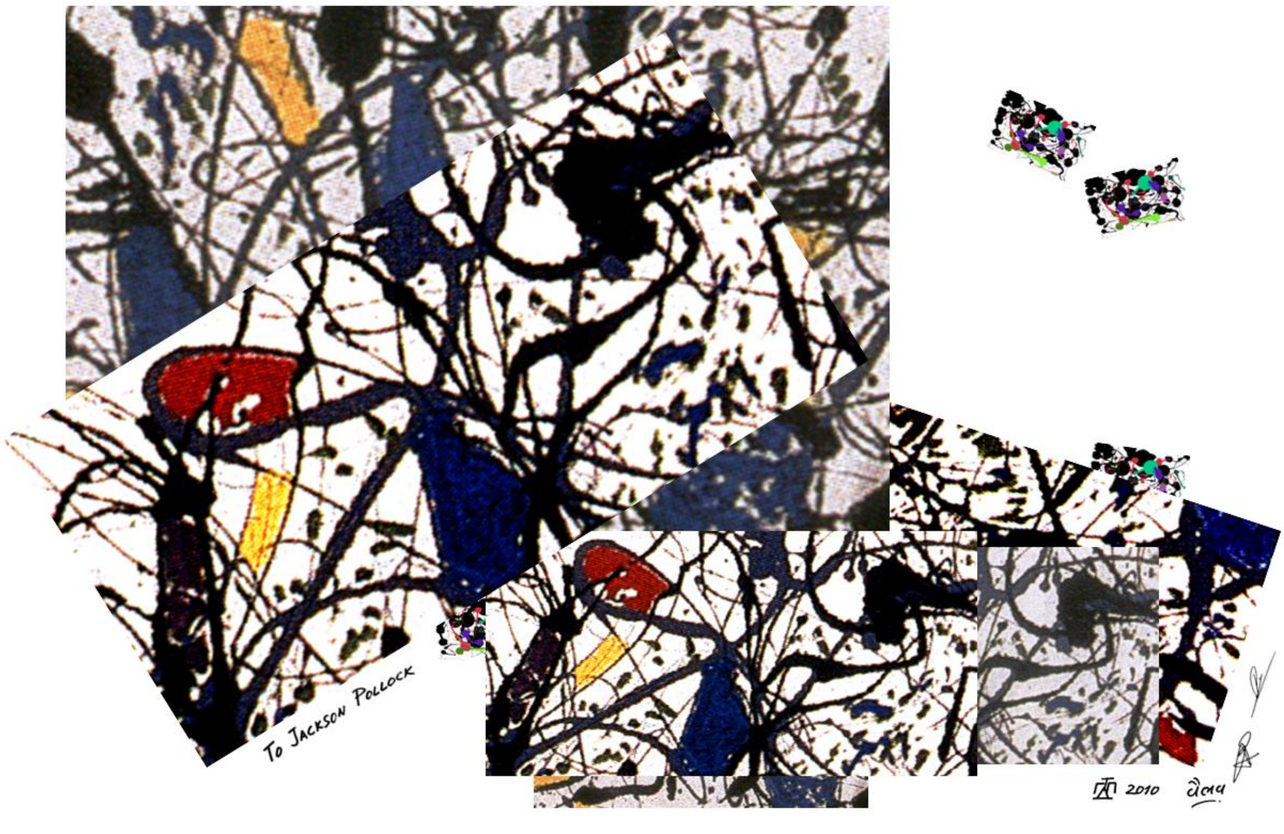
BUSINESS SUSTAINABILITY I

Management, Technology and Learning for Individuals, Organisations and Society in Turbulent Environments

Edited by:

Goran D. Putnik

Paulo Ávila



Chaos and Sustainability – the 2nd Order

Universidade do Minho
isep Instituto Superior de Engenharia do Porto

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2010

For catalogue record

Title:	BUSINESS SUSTAINABILITY I Management, Technology and Learning for Individuals, Organisations and Society in Turbulent Environments
Author(s):	Goran D. Putnik / Paulo Ávila
Year:	2010
Month:	June
Publishers:	School of Engineering – University of Minho, Guimarães, Portugal **ISBN 978-972-8692-48-3** ISEP – School of Engineering – Polytechnic of Porto, Porto, Portugal **ISBN 978-989-95907-1-7**
Number of pages:	xix + 334
Cover design:	Π
Printing:	COPISSAURIO LDA., Braga

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COMMUNICATIONS

FOREWORD

This book presents the collection of fifty two papers which were presented on the First International Conference on BUSINESS SUSTAINABILITY ’08 - *Management, Technology and Learning for Individuals, Organisations and Society in Turbulent Environments,* held in Ofir, Portugal, from 25th to 27th of June, 2008. The main motive of the meeting was the growing awareness of the importance of the sustainability issue. This importance had emerged from the growing uncertainty of the market behaviour that leads to the characterization of the market, i.e. environment, as turbulent. Actually, the characterization of the environment as uncertain and turbulent reflects the fact that the traditional technocratic and/or socio-technical approaches cannot effectively and efficiently lead with the present situation. In other words, the rise of the sustainability issue means the quest for new instruments to deal with uncertainty and/or turbulence.

The sustainability issue has a complex nature and solutions are sought in a wide range of domains and instruments to achieve and manage it. The domains range from environmental sustainability (referring to natural environment) through organisational and business sustainability towards social sustainability. Concerning the instruments for sustainability, they range from traditional engineering and management methodologies towards “soft” instruments such as knowledge, learning, creativity. The papers in this book address virtually whole sustainability problems space in a greater or lesser extent. However, although the uncertainty and/or turbulence, or in other words the dynamic properties, come from coupling of management, technology, learning, individuals, organisations and society, meaning that everything is at the same time effect and cause, we wanted to put the emphasis on business with the intention to address primarily the companies and their businesses.

From this reason, the main title of the book is “Business Sustainability” but with the approach of coupling Management, Technology and Learning for individuals, organisations and society in Turbulent Environments.

Concerning the First International Conference on BUSINESS SUSTAINABILITY, its particularity was that it had served primarily as a learning environment in which the papers published in this book were the ground for further individual and collective growth in understanding and perception of sustainability and capacity for building new instruments for business sustainability. In that respect, the methodology of the conference work was basically dialogical, meaning promoting dialog on the papers, but also including formal paper presentations. In this way, the conference presented a rich space for satisfying different authors’ and participants’ needs. Additionally, promoting the widest and global learning environment and participativeness, the Conference Organisation provided the broadcasting over Internet of the Conference sessions, dialogical and formal presentations, for all authors’ and participants’ institutions, as an innovative Conference feature. In these terms, this book could also be understood as a complementary instrument to the

Conference authors' and participants', but also to the wider readerships' interested in the sustainability issues.

The book brought together 97 authors from 10 countries, namely from Australia, Finland, France, Germany, Ireland, Portugal, Russia, Serbia, Sweden and United Kingdom. The authors "ranged" from senior and renowned scientists to young researchers providing a rich and learning environment.

At the end, the editors hope and would like that this book will be useful, meeting the expectation of the authors and wider readership and serving for enhancing the individual and collective learning, and to incentive further scientific development and creation of new papers.

Also, the editors would use this opportunity to announce the intention to continue with new editions of the conference and subsequent editions of accompanying books on the subject of BUSINESS SUSTAINABILITY, the second of which is planned for year 2011.

Guimarães, 01-May-2010

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Porto, Portugal

Figure 1. Logo of the First International Conference Business Sustainability

Figure 2. People in the centre

Figure 3. The natural environment

GUIDELINE FOR CITING

An example of how to cite a paper published in this book:

Pires A., Putnik G. D. and Ávila P. (2010). An analysis about the resources selection process in agile/virtual enterprises. In Putnik G. D., Ávila P. (Eds.), *Business Sustainability I* (pp. 196-202). Guimarães: School of Engineering – University of Minho; Porto: ISEP – School of Engineering – Polytechnic of Porto.

ABOUT THE COVER

Designs on the exterior of this book and the accompanying disc are co-authored by Goran Putnik, João Pinho, Paulo Ávila, and Vaibhav Shah, whose signatures are depicted on the designs. These designs are partly inspired from / influenced by the works of the legendary American painter artist Paul Jackson Pollock, famous for his abstract expressionist style. The designs describe / are metaphors of chaotic order of events and processes, and sustainability as a major/sought requirement/approach in usually complex and chaotic multifaceted multi-group job – i.e. collaborative business. The authors of the designs have given a tribute to the artist and his work and given a message of Business Sustainability from their interpretation / metaphor of a complex system.

Note about the creation of the cover designs: The building block of the designs is “cropped” from an image of Jackson Pollock’s art work titled “Summertime: Number 9A” (1948).

Vaibhav Shah

Goran D. Putnik

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We acknowledge the sponsorship and support given to the First International Conference on BUSINESS SUSTAINABILITY ’08 - *Management, Technology and Learning for Individuals, Organisations and Society in Turbulent Environments* and to this book, by the following institutions and their representatives:

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COMMUNICATIONS

AN INTEGRAL METATHEORY FOR ORGANISATIONAL SUSTAINABILITY: LIVING WITH A CROWDED BOTTOM LINE IN CHAOTIC TIMES

Mark Edwards, University of Western Australia, Perth, Australia

Abstract: A metatheoretical approach to sustainability is proposed that attempts to resolve some fundamental paradoxes facing organisations. The urgency for organisations to respond to the challenges of global environmental imperatives is reaching a critical point. The issues are complex, chaotic and involve deep-seated paradoxes. On the one hand, we have growing competition in the economic arena and a consequent increase in the daily pressure on organisations to survive and prosper. On the other hand, the social demands on organisations are increasing and have been greatly complexified by an expanding set of additional bottom line factors for assessing their performance. All this has come at a time of increasing turbulence in organisational environments. Individual businesses as well as, national and international economies are caught in the paradoxical situation of responding to increasing pressure to generate economic growth while it is this very development in economic production and consumption that is causing immense environmental change and contributing to the irrevocable social disruption that results. This article uses some metatheoretical lenses identified from the relevant sustainability, transformation and organisational learning literatures to explore a number of fundamental paradoxes facing organisations – the growth, learning and sustainability paradoxes. A set of metatheoretical are identified and used to see how organisations might respond to these challenges. From this analysis some new avenues for achieving authentic sustainability and for living with the "a crowded bottom" are also identified.

1. INTRODUCTION

There is growing pressure on organisations to include several broad measures of performance that traditionally have been regarded as lying outside their orbit of responsibility. To the profit/economic survival imperative we must now add the additional bottom lines of environmental and social accountability (Elkington, 1999). This triple bottom line has been amended more recently to also include the criterion of governance and there appear to be other candidates in the wings waiting to be added to this list of factors for assessing an organisation's overall performance (Armstrong, 2003; Henriques & Richardson, 2004; Horrigan, 2002; Inayatullah, 2005).

While there has been somewhat of a backlash against this development, there are very good reasons for the organisational bottom line becoming increasingly crowded. First, the multiple responsibilities that organisations currently face reflect their growing power in the world. As organisations grow larger and/or attain global reach in their use of labour, natural resources, financing and political influence, so too does their responsibility broaden to embrace the complexities of their various spheres of operation. Second, a corollary to this growing organisational power is that globalisation cannot be quarantined to include only commercial interests of trade, finance and labour markets. Globalisation will necessarily entail aspects of environmental sustainability, social equity, global governance and international relations. Accompanying this globalisation of social and environmental concerns there will also need to be a concern for the local and the situated needs of the host communities in which organisations operate. Third, the growing number of indicators of organisational performance reflects the postmodern concern for plurality and diversity (Schoenberger-Orgad & McKie, 2005). Where modernism and the scientific approach to management sought to bring together multiple concerns under the single banner of economic performance, postmodernity seeks multiple means for assessing the usefulness and trustworthiness of social entities. The voices of multiple stakeholders must now be acknowledged and heard. The increasing size and influence of organisations means that there is a commensurate increase in the number and diversity of consumers, community members, small shareholders, employees and their advocacy groups. These stakeholders represent a variety of opportunities for, and demands on, organisations and the growing number of bottom line indicators taps into their multiple experiences. In essence, the bottom line is a way of expressing the core purpose of an organisation. In postmodern society purposes are multifarious and the bottom lines of organisation are beginning to reflect that diverse reality.

All this requires a corresponding shift in the understanding of organisations and their purposes from a research and theory building perspective (Ghoshal, 2005). Theories of organisations and their responses to contemporary social demands must be able to accommodate the multiplicity of perspectives that are present in contemporary societies. One way of developing multi-perspectival capacities in our scientific understandings is through the building of metatheory. Nowhere is this task more urgently needed than in the study of organisational sustainability. To be sustainable, organisations must not only meet economic, environmental, social and governance requirements but also embody them in their practices and values (Brown, 2005) even during times of turbulence and extraordinary upheaval. In the following article, a metatheoretical approach to organizational sustainability is proposed that can accommodate this plurality. First, some introductory comments are presented on the development of an integral metatheory. This is followed by a presentation of some core theoretical lenses that have relevance to issues of organisational learning and transformation in turbulent environments. Next, the model is applied to some central paradoxes in the pursuit of sustainability. Finally, the discussion looks at the general prospects for integrative metatheorising and its use in organisational change in turbulent times.

2. INTEGRAL METATHEORISING

Metatheory is concerned with "the study of theories, theorists, communities of theorists, as well as the larger intellectual and social context of theories and theorists" (Ritzer, 1988. p. 188). Scientific metatheory building takes other scientific theory as its subject matter: Scientific metatheories transcend (i.e., 'meta') theories and methods in the sense that they define the context in which theoretical and methodological concepts are constructed. Theories and methods refer directly to the empirical world, while metatheories refer to the theories and methods themselves (Overton, 2007, p. 154). Metatheorising is the process of developing metatheory or performing metatheoretical research. Metatheorising is similar to other forms of sense-making in that it attempts to structure and derive meaning from some body of knowledge, information, data or experience. It is different to mainstream theory building in that the body of information it draws on, its "data", is other theories (van Gigch & Le Moigne, 1989) or "unit theories" as Werner and Berger (1985) call the individual theories that are the focus of study for metatheorists. Figure 1 shows the relationship between theory and metatheory. The metatheoretical domain (meta-level research) is one where the connections and differences between theories (unit-level research) and their respective research programmes are analysed and integrated. The "so what" of metatheory is that it provides an orienting perspective where previously there was only an eclectic mix of isolated theoretical positions.

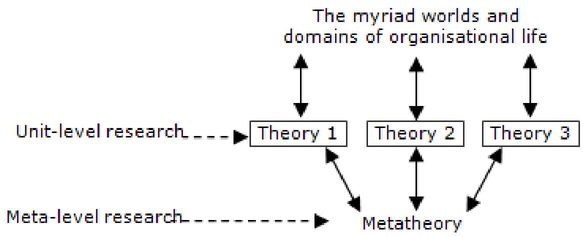

Fig. 1. The relationship between theory and metatheory

An integral metatheory for organisational sustainability draws on multiple theoretical approaches to develop a overarching framework that can accommodate a wide range of "endogenous elements" of theories (Klein, Tosi & Cannella, 1999). These conceptual building blocks are referred to here as conceptual lenses and, together with their inter-relationships, they form the "archetechtonic" or conceptual infrastructure of a metatheory (Ritzer, 2001). Because lenses are developed at the metatheoretical level, they are able to resolve some fundamental paradoxes that exist within and between unit-level theories. For example, many theories of organisational change are based on the concept of growth (Lester, Parnell & Carraher, 2003). Yet, in many ways, it is the unquestioned pursuit of economic growth that is associated with unsustainable organisational practices (Choi & Pattent, 2001). This growth-sustainability paradox can only be resolved at a dialectical level that acknowledges the need for both development and stability (Stacey, 2005). Metatheoretical lenses are often developed out of the resolution of these kinds of paradox (Van de Ven & Poole, 1988). In the following sections, some fundamental conceptual lenses for understanding sustainability and its relationship to turbulent organisational environments are described.

3. SOME CONCEPTUAL LENSES FOR SUSTAINABILITY

3.1 The developmental lens

Meeting the sustainability challenge inherently involves transformation. The radical changes required for some sustainable form of global ecology and economy will involve paradigmatic shifts not only in the external worlds of individual and organisational behaviours and economic structures economic factors but also in the internal worlds of values, purposes and visions for the future (Bradbury, 2003). Theories of transformation towards sustainability are diverse and offer multiple explanations for how organisations can move towards more sustainable principles and modes of practice. Every organisation is different in its purpose and mission, culture, structural design, business goals and human make-up. There are, however, patterns of similarities that exist between individuals and groups, the social structures that they create and the goals that they pursue through organised social arrangements. These regularities can be described in terms of stage-based models of development (Cacioppe & Edwards, 2005).

The developmental lens is sensitive to the deep structures (Gomez & Jones, 2000) or design archetypes (Cooper, Hinings, Greenwood & Brown, 1996) that are associated with qualitatively different levels of organisational sustainability. Several developmental models have been proposed that describe multiple levels of sustainability. A metatheoretical combination of these models results in a developmental lens for organisational sustainability (based on the work of Dunphy, Griffiths & Ben, 2003; van Marrewijk, 2003; van Marrewijk & Becker, 2004; van Marrewijk & Hardjono, 2003; van Marrewijk & Werre, 2003). This developmental lens for sustainability identifies the spectrum of transformations that are potentially available to organisations. Each form of organisational sustainability is associated with certain kinds of internal qualities and environmental conditions. These are as follows:

<u>Subsistence organisation</u>: Sustainability is seen in terms of survival. The values base is one of working hard and getting by without doing obvious damage to individuals or environments. Survival and maximisation of profit are regarded as the sole purpose of organisational activities.

<u>Avoidant organisation</u>: Sustainability is seen as an attack by oppositional groups. There is a general ignorance of ethical standards and legal responsibilities. Disinterest is the prevailing attitude towards the impact of organisational activities on the workforce and community (at least until profits are affected).

<u>Compliant organisation</u>: Sustainability is regarded as an impost. The Compliant organisation supports industry regulation as a way of circumventing more demanding regulations regarding sustainability. Reactively responds to regulatory requirements as they arise.

<u>Efficient organisation</u>: Here sustainability is valued as a source of cost saving, i.e. the “business case” for sustainability. This stage sees broader sustainability demands as imposing on an individual’s freedom to do business. Sustainability is defined in terms of helping the organisation to continue trading.

<u>Committed organisation</u>: The organisation is committed in principle to economic, environmental and social sustainability and goes beyond legal compliance.

<u>Sustaining organisation (local)</u>: Sustainability is valued as a way of developing the organisation and its stakeholders on all fronts. Transformational strategies are enacted for moving the organisation towards triple bottom line goals that support local communities whatever the regulatory environment.

<u>Sustaining organisation (global)</u>: Sustainability is embedded within all aspects of organisation and is seen in global and intergenerational terms. Promotes and actively creates sustainable communities of organisations. Sustainability refers to numerous layers of purpose including physical, economic, environmental, emotional, social and spiritual/deep meaning.

As with many developmental qualities, the stages in organisational sustainability emerge inclusively in that later stages are built on and are inclusive of the core capacities of previous stages. The inclusive nature of the stage is shown in Figure 2. For example, organisations at the post-conventional stage, which are committed to embedding broad-ranging sustainability principles and practices within their culture and systems, will also retain the capacity to function at the conventional stages of “efficiency” and “conforming”. These conventional stages in turn will include the pre-conventional requirements to survive and compete as an organisation in a competitive market place. Stage-based capacities build on and support each other and are not exclusive to each other. The inclusive emergence of stages of sustainability means that later stages have a greater capacity for engaging with the complexities of large and intricate environmental

and social systems. The more ambitious the type of sustainability aimed for, the more complex will be the organisational culture and structure needed to achieve those ambitions (van Marrewijk & Were, 2003)

The developmental lens is structured according to the pattern of pre- to conventional to post- stages where there is progressive inclusion of formative stages. This structural pattern shows up repeatedly in developmental studies at multiple levels of social organisation. Figure 2 shows the inclusive nature of stages of organisational sustainability. The inclusive emergence of these deep structures means that transformation has a general direction towards more complex and more responsive forms of organisational sustainability.

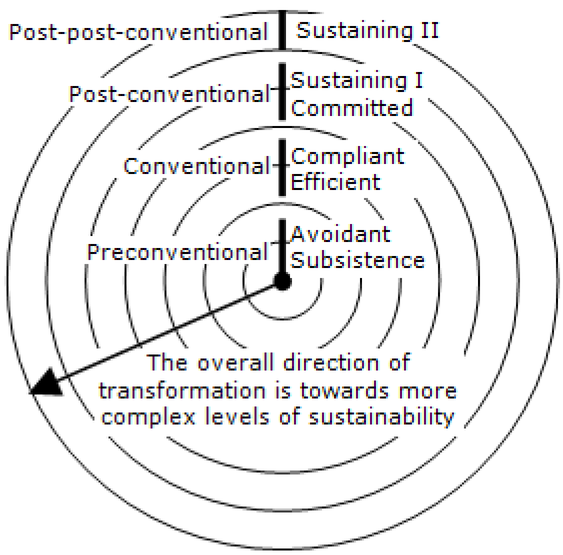

Fig. 2. A developmental lens for organisational sustainability

However, there can be considerable variation in the developmental pathways undertaken by any particular organisation. Developmentally speaking, organisations have a number of options in navigating through the challenges of environmental crises, regulatory environments and raised community expectations while trying to survive in a competitive global marketplace. Organisations can retain conventional modes of minimal compliance and pursue system efficiencies for cost-saving goals, or they can regress into pre-conventional forms of rejection and avoidance to pursue, what they regard as, the core purpose of wealth maximisation or, lastly, they can create their own particular path towards more inclusive and just forms of sustainability. The latter choice is frequently referred to in management and change literature but, because true transformation always involves considerable organisational disruption and "pain", it is less frequently undertaken and remains the exception rather than the rule (Anderson, 2003; Colombo & Delmastro, 2002).

3.2 The internal-external lens and the field of turbulence

Sustainability is not simply a characteristic of the isolated organisation but a complex mix that emerges out of the myriad exchanges that exist between an organisation and its external environment (Hanley, 2000). The internal-external lens is sensitive to the connections that exist across an organisation's boundaries. Both internal and external environments are intimately involved in the transformation equation and when either pole of the internal-external lens is omitted from a theory's explanatory ambit some form of reductionism will ensue. The movement towards more sustainable forms of organising can be stimulated through both internal and external factors. And the many different theories of organisational transformation can be located with regard to these distinctions. Of particular interest here are theories of organizational environments which focus on change.

In their seminal work on organisational environments, Emery and Trist (1965) developed a typology based on the interaction of the systems dimensions of dynamism and complexity. The field of high dynamism and high complexity is called the "turbulent field" and it is a highly perturbed and disordered category where fluctuations in the whole environment of the organisation leads to "gross levels of organisational uncertainty" (Edelman & Benning, 1999, p. 80). Figure 3 shows the typology of environmental fields that are generated by Emery and Trist model. The dynamism dimension is sensitive to the degree of movement in an organisation's external environment while the complexity dimension assesses the intricacy and density of the structural nature of the external environment.

	Low Dynamism	High Dynamism
High Complexity	Placid Clustered	Turbulent
Low Complexity	Random Placid	Disturbed Reactive

Fig. 3. The Turbulent field typology of Emery and Trist (1965)

From a metatheoretical point of view it is useful to combine the take the complexity dimension and consider it in more detail. Complexity is also a characteristic of the stage-based lens of organisational development. More developed organisational forms have a greater internal complexity and more elaborate interactions with their environments. Complexity is also a fundamental aspect of turbulent and unpredictable environments and organisations can respond to that complexity through development to a correspondingly more complex internal structure or, alternatively, to a more regressive and simplistic operational form (Kilburg, Stokes & Kuruvilla, 1998). Development is not a simple linear progression from one stage to the next and "organisations can transform themselves both to higher and to lower levels of complexity" (Levy and Merry, 1986, p. 300). In terms of sustainability, organisations, and their subunits, can move towards a higher functioning level of sustainability or, alternatively, they can regress to lower levels. Inclusive emergence not only means that organisations become more complex as they develop but that they are also become more vulnerable to instability because of that complexity. In their paper on multiple levels of corporate sustainability Marrewijk and Were point out that (2003, p. 109):

Because of this instability and vulnerability to environmental circumstances, large organisations can present a very mixed sustainability profile. This is evidenced in the behaviour of multinational organisations where, in response to very weak regulatory environments, their operations in Third World countries can be at pre-conventional stages of organisational sustainability while at the same time those in the "home office" country may aspire to much higher standards. Similarly, where survival of the organisation is seen to be under threat then earlier stages of organisational sustainability can once more predominate. Basic manufacturing operations and their workforces can be "moved offshore" to unregulated environments. New CEO's can be taken on who "refocus" from "non-core activities" such as sustainability and human resource development to competitiveness, cost efficiencies, and workforce downsizing (Dunphy, 2000). Hence, there can be a regressive move from, for example, the commitment stage to the compliance and even an avoidance stage of organisational sustainability.

Turbulent external environments can act as mediating means by which organisations develop from one stage of sustainability to another (or alternatively by which they regress to more basic organisational forms). Figure 4 describes the types of turbulence in external organisational environments that can mediate organisational development from one form of sustainable organising to another. For example, turbulence in an organisation's physical environment through depleted physical

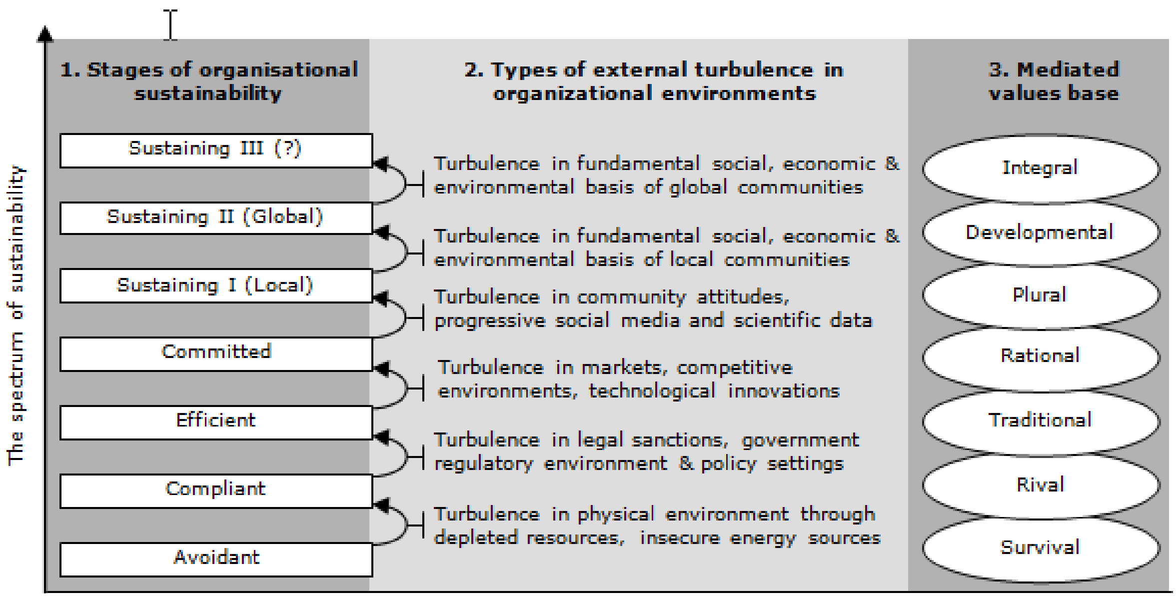

Fig. 1. Turbulent environments as mediating means for transformation towards more expansive forms of sustainability

Since instability increases at higher complexity levels, entities can shift to lower levels if circumstances turn unfavourable or if competencies fail to meet the required specifications.

resources or insecure sources of energy may signal the need to shift to a compliancy approach to meeting sustainability demands. Similarly, turbulence in government regulations and policy settings may stimulate an efficiency approach which supersedes concerns about sanctions and regulations to focus on the cost savings and processing advantages available from more efficient technologies.

From this perspective, turbulence in an organisation's external environment can become a trigger for more visionary types of organising and planning. This is why, as Eijnatten (2005) points out, one of the definitive characteristics of dealing with the complexity of turbulent organisational environments is that "planning is done by developing desirable future scenarios". The development from one stage to another is fundamental to the future-oriented kind of planning that is definitive of authentic understandings of sustainability.

3.3 The learning lens

The third and final metatheoretical lens to be considered here is the learning lens (Edwards, 2005; Polito & Watson, 2002). Many learning theorists have proposed cycles of learning (Dixon, 1999) that involve interiors and exteriors (Miller, 1996) and individual and collective dimensions of learning (Casey, 2005; Fry & Griswold, 2003; Jorgensen, 2004; Mumford, 1992; Murray, 2002; Schwandt & Marquardt, 1999). A metatheoretical comparison between these and other learning models (Edwards, 2008) finds that learning can be very broadly represented as a cycle of four basic phases - an active behavioural phase, a reflective thinking phase, an interpretive sense-making phase and a social validation or evaluative phase. Consequently, the learning process can be represented as a cycle of active physical engagement, conceptual reflection, cultural interpretation and social validation that, through multiple iterations, can result in knowledge and insight in individuals and social collectives. Figure 5 depicts what might be called the integral cycle of learning (Edwards 2005). Each learning phase utilises different learning skills that can be classified according to two dimensions: the concrete experience-abstract conceptualisation dimension and the individual task-interpersonal relationship dimension (Mainemelis, Boyatzis & Kolb, 2002).

Figure 5 shows the learning cycle as it relates to a single-loop learning situation. In double- and triple-loop learning, this cycle is built into a multidimensional view that describes "different hierarchical levels of learning" (Stewart, 2001, p. 3). Akbar (2003) has argued that there are clear links between knowledge levels and learning and has proposed a model for integrating "the knowledge creation view and single and double-loop learning models" (2003, p. 1997). Drawing together these views, i.e. the learning cycle, stage-based models of transformation and the knowledge levels model, it is possible to develop a more integrated view for combining learning process cycles, learning loops and hierarchies of knowledge (Romme & Witteloostuijn, 1999).

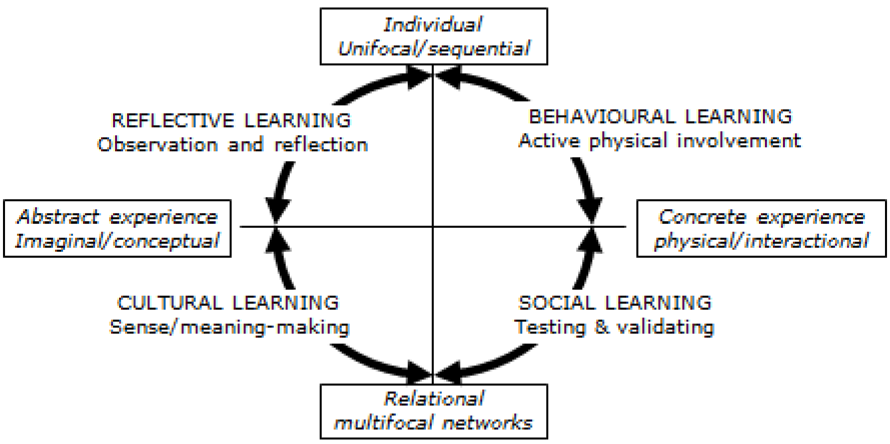

Fig. 2. The integral cycle of learning (single loop)

In the context of sustainability, Molnar and Mulvihill (2003) have called this kind of learning "Sustainability-Focused Organisational Learning" (SFOL). The pursuit of SFOL requires the questioning of "core business values and basic assumptions" and the opportunity for employees to have input into the organisation's core values and long-term vision is "a crucial part of SFOL". SFOL combines the idea of organisational learning with the transformation of core values to propose a model of radical change that includes multiple levels of learning. Similarly, Halme (2001) has described two different types of learning that can occur in inter-organisational sustainability networks. "Lower-level learning" produces translational outcomes and provides support and improvement in sustainability principles and practices but does not challenge the underlying systems and philosophies of the organisation. The second type of learning Halme refers to as "higher-level learning". High-level learning producers "transformational outcomes" which fundamentally change the way the organisation and its members think and act with regard to sustainability issues.

Translational learning, i.e. learning that supports the status quo, cannot produce the types of shifts necessary for movement to occur through the basic stages of organisational sustainability described, for example, by Griffiths, Benn and Dunphy (2007). This confers with the multiple learning models which propose that "one cannot engage in 'double-loop learning' (the type that re-evaluates basic assumptions) with single-loop models" (Daneke, 2001, p. 518). Solutions to sustainability problems that are caused by deeply held values and which are performed through institutionalised systems of practice cannot be found via single-loop or incremental learning. Only generative transformational learning approaches such as double- and triple-loop learning (Jensen, 2005), which require frame-breaking insights and behaviours to be experienced and institutionally implemented, can result in such transformations. This is not, however, a simple process of linear progression. In Figure 6 the learning lens is combined with the developmental lens to show the variability that can occur over time as an organisation struggles to balance translational with transformational modes of learning in a sustainability context. Translational learning maintains the organisation's current stage of sustainability while transformational learning enables a shift to a new level of identity. Regressive shifts can also occur as when an organisation responds to internal and external pressures to abandon sustainability initiatives to resume its former focus on, for example, mere compliance.

The learning lens engages with many of the elements that have been identified and described as fundamental to the transformational task of sustainable organising. The learning lens can be combined with the developmental lens to uncover the multi-loop nature of learning (as shown in Figure 6) and it can also be combined with the internal-external lens to consider the role that learning place in dealing with turbulent environments and transformational imperatives.

4. METATHEORISING SUSTAINABILITY PARADOXES

A metatheoretical approach to sustainability that uses integrative lenses such as the ones described above has the potential to resolve fundamental paradoxes in the study of organisational sustainability. In the following sections the developmental, interior-exterior (turbulence) and learning lenses are used to consider the growth, learning and sustainability paradoxes.

4.1 The growth paradox

The urgency for organisations to respond to the challenges of global environmental imperatives is reaching a critical point. The issues are complex, chaotic and involve deep-seated paradoxes. On the one hand, we have growing competition in the economic arena and a consequent increase in the daily pressure on organisations to survive, grow and prosper. On

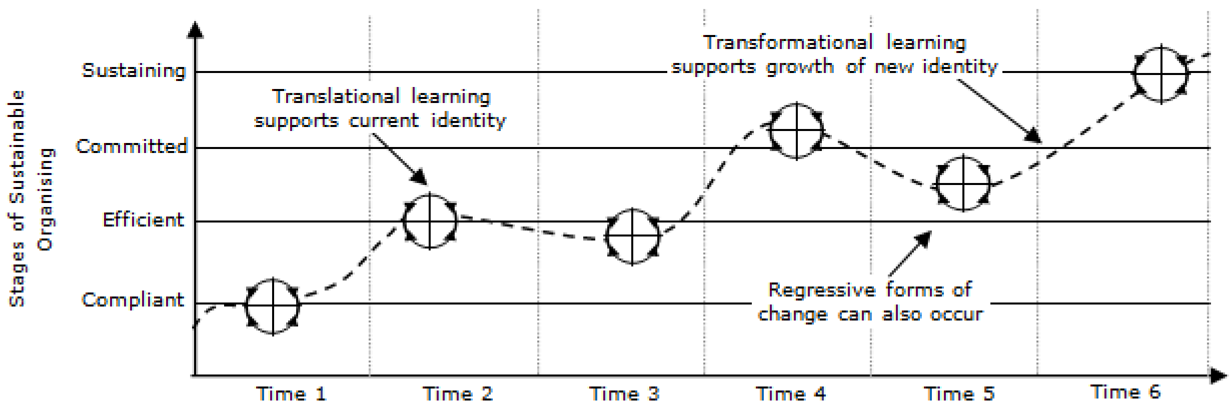

Fig. 3. The ups and downs of organisational learning and sustainable development

the other hand, the social demands on organisations are increasing and have been greatly complexified by an expanding set of additional bottom line factors for assessing their performance. All this has come at a time of increasing turbulence in organisational environments. Individual businesses as well as, national and international economies are caught in the paradoxical situation of responding to increasing pressure to generate economic growth, while it is this very development in economic production and consumption that is causing immense environmental disorder and contributing to the irrevocable social dislocation. Conventional understandings of economic growth is a fundamental contributor to our current environmental and social crises while, at the same time, economic growth is seen as the only possible solution to these problems.

The developmental lens offers a meta-view that can resolve the growth paradox. The developmental lens proposes that growth is not simply a question of economic increase and that if the maximisation of economic wealth continues as the main aim of organisational purpose then unsustainable practices and environmental and social degradation will continue and probably increase in the coming decades. Organisational growth can also to be seen within a developmental context that involves transformation to qualitatively new forms of organising. Growth from this perspective is not necessarily tied to ever-increasing cycles of the consumption and production of goods and services. This understanding of vertical, transformative growth and development lies in direct contrast to the current understanding of horizontal, translational growth. If we remain stuck within the same horizontal level of conventional sustainability (in either its Compliant or Efficient forms) we will always regard growth as a question of translational increase and our innate need for vertical, transformative development (in both personal and communal domains) will continue to be sublimated towards translational avenues for creating economic wealth.

Translational dynamics are ongoing and never-ending because they continuously stabilise identity structures and behavioural systems. These day-to-day transactions and exchanges create and recreate the organisational system moment by moment. However, they can never result in qualitative transformations of the kind that can meet the challenges posed by turbulent ecological and social environments. No amount of translation results in transformation. It is only qualitative transformation (the development lens) that can address this paradox. In pursuing largely translational change strategies to address problems that require authentic transformation, organisations are locking themselves and their communities into ways of thinking and acting that exacerbate the problem. They look to growth and the creation of even more economic "wealth" as a solution to the sustainability dilemma. Luke (2006) calls this approach "sustainable degradation". He argues that the "strategies of sustainable degradation" offer justifications for ongoing translational growth so that the deep cultural and structural changes that environmental sustainability actually calls for can be evaded. There is an appearance of ecological issues being represented in managerial, commercial and judicial decision-making, but, as Luke contests (2006, p, 112),

> … in reality, the system of sustainable degradation enables capital to extract even more value by maintaining the appearances of creating ecological sustainability while exploiting the realities of environmental degradation.

And so we have the vicious circle of increased economic activity being seen as the solution to problems caused by increasing levels of production and consumption (Sonntag, 2000). In other words, organisations are ramping up their translational growth goals and activities to address problems largely caused by excessive translational growth. The demands and benefits of true interior and exterior transformation are being eschewed in favour of translational cycles of change that do not question the basic issues of excessive production and consumption (Kimerling, 2001).

All organisations must deal with transformational and translational imperatives. From a metatheoretical perspective however, there is deep confusion and lack of awareness over the role of these two forms of development. Translation enables organisational stability through the ongoing maintenance of an organisation's status quo structures, processes, purpose and culture. Translation supports and legitimates the current stage of organising to be "sustained" and it is this conventional understanding of sustainability that currently dominates the organisational literature on sustainable development (Luke, 2006). Development in translational terms means increasing that activity. Authentic transformation of the kind described in the stage-based models of organisational sustainability is supplanted by a concern for ongoing economic growth. Social researcher Clive Hamilton (2003) in his book "The Growth Fetish" has described this obsession with endless cycles of production and consumption leading to ever-increasing growth.

The transformational instinct is sublimated into a one-sided concern for quantitative increase rather than qualitative development. Organisations and their leaders see the importance of change, but are unaware or avoidant of authentic transformational growth and focus instead on "the malfunctioning source code" of financial increase, material wealth creation and the profit motive (Henderson, 2006). The result is that transformational energies are thwarted and redirected into hyper-translational focus on economic growth with the ensuing degradation and devaluation of the natural world in both developing and developed countries.

Transformation from a Compliant to an Efficient stage of organisational sustainability will not fundamentally address this dilemma. At the Efficient stage, greater throughput efficiencies often result in even greater volumes of outputs being produced, rather than any fundamental change in processes that are driving the system (see Polimeni & Polimeni, 2006 for a discussion of the Jevon's paradox). The lack of consciousness around valid transformational goals and the ubiquitous pursuit of translational efficiencies and productivity mean that the sustainability crisis is being exacerbated by the efficiency and technology innovations that are being touted as the solution.

A metatheoretical understanding of the forms of development provides a more complete view of sustainability. The application of this lens sees the enthusiastic drive to improve and increase translational growth as a distraction from the main task of transformative development. In many ways, translational growth masquerades as transformation. "Sustainability" is reframed as "sustainable growth", "sustainable profit margins" and "sustainable levels of production and consumption". These types of "weak" sustainability (Pennington, 2006) reframe concepts of transformation and radical change into a discourse based on incremental adaptation and more efficient wealth creation. They dilute the transformational imperative into a transactional imperative. The environmental and social challenges of radical development to new forms of sustainable organising are placed within a context of maintaining profits, preserving the hegemony of economic values over other types of values and defending material wealth creation over other forms of well-being. The rapid changes we see occurring in the world of organisations can be considered as a complex mix of both transformational and translational dynamics. It is critical, however that they not be confused. Without including both in our explanations of sustainable development, we run the risk of producing inadequate understandings of each.

4.2 The learning paradox

Prawat (1999) defines the learning paradox as the attempt "to explain how it is that new and better knowledge is fashioned out of prior, less complex knowledge". With regard to sustainability, how can we learn to develop sustaining organisations when the current levels of organisational functioning so demonstrably lacks such a capability? Single-loop learning models are not up to the task of resolving this paradox because this level of learning is embedded within the conventional adaptive cooperation between a social entity and its environment (Emery, 2000). It is not adaptive reactions that are required here but proactive transformations. Sustainable organising requires the adoption of innovative behaviours and new forms of consciousness. These changes do not emerge without some form of transformational learning taking place. The strong connections between organisational learning and transformation towards organisational sustainability have been pointed out by many theorists (Molnar & Mulvihill, 2003; Senge, 2003; Tilbury, 2004). As Nattrass and Altomar note

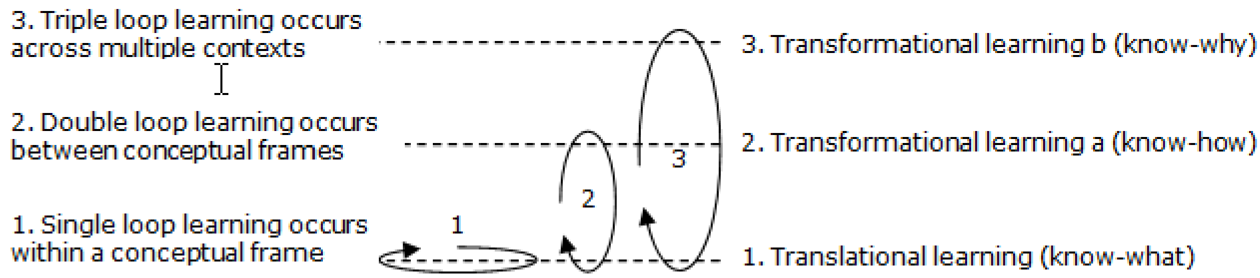

Fig. 4. Multiple loop learning

(1999, p. 5) “the understanding and practice of the organisational learning disciplines will be the indispensable prerequisite of a successful transformation to sustainability”.

Figure 7 depicts the different forms of learning within a multi-level context of different levels of organisational sustainability. Single-loop learning, “know what”, can be thought of as a translational form of learning because it performs a stabilising function that sustains and legitimates the current structures of the social entity. Where transformation is required, double- and triple-loop forms of learning are needed to create qualitatively new forms of organisational development. Double-loop learning, “know how”, is concerned with challenging a learner’s own values and assumptions. In triple-loop learning, “know why”, the participants move “beyond questioning their own values and consider the values of the societal tradition system in which their actions are taking place” (Foldy & Creed, 1999, p. 208). There is a challenge to the conventional paradigm that results in a type of learning that is “frame breaking” and transformational. It is this type of frame-breaking change that is required for the development of sustaining organisations.

So where does the potential for triple-loop learning come from? What distinguishes this type of frame-breaking change from naïve social revolution or directionless relativism? One answer to this learning paradox can be found in the spectrum of inherent values that underpins the developmental lens. Stage-based models of sustainable organising (such as those on which the developmental lens for sustainability is based) are proposing that the latter, more complex stages are more suited to meeting the challenges of emerging global crises then the formative stages. The values, mindsets and assumptions of the postconventional forms of organisational sustainability have a much greater capacity for including the plurality of human and ecological concerns than the preconventional and conventional forms. The conventional forms of organisational sustainability, i.e., Compliance and Efficiency, must be radically integrated within the leading-edge forms of sustainability, that Committed and Sustaining. And this must occur in a widespread fashion across the globe if the learning, growth and sustainability paradoxes are to be resolved.

4.3 The sustainability paradox

Turbulent environments place immense stress on organisations and the individuals that work in them. In such environments we are faced with the paradox of retaining a coherent identity and stability while also embracing radical change to develop adaptive capabilities (Emery, 2000). In other words, organisations need to sustain a coherent and cohesive identity while also sustaining a transformative identity that can meet the sustainability imperative. This problem of balancing sustainable change with sustainable stability escalates as further development proceeds. Complex structures made up of several qualitatively different developmental levels can experience multiple levels of this paradox. Particularly when fundamental levels of a system’s environment are threatened, there can be a type of cascading turbulence where disorder in more were all basic environmental conditions initiates a chain off rapid changes at multiple levels. This cascading turbulence, or “vortical environment” as it has been called by Babüroðlu (1988), can come about through the institutionalisation of “maladaptive responses” (Babüroðlu, 1988) that actually accentuate that turbulence. In many ways, this is precisely what we see in the multitude of global crises that currently beset the planet.

A metatheoretical analysis of reductive and distorted applications of lenses provides a way of breaking this vicious cycle of maladaptation and the creation of cascading turbulence. For example, the use of the developmental lens provides a way of untangling maladaptive from adaptive understandings of change. In knowing that there are qualitatively distinct forms of organisational sustainability, we become aware of the differences between translational and transformational growth. Translational growth provides stability and the capacity to sustain a coherent and cohesive identity, while transformational growth encourages the shift to more progressive and integrative forms of organising. Understanding the nature of single, double and triple loop learning also supports this differentiated awareness of horizontal and vertical types of sustainability. Both are needed to adequately meet the challenges of developing sustaining organisations on the 21st century.

5. CONCLUSION

In the foregoing a metatheoretical approach to sustainability has been proposed that attempts to resolve some fundamental paradoxes facing organisations. Without such an approach, the development of more paradigms and models of sustainability runs the risk of increasing the fragmentation and parochial nature of theory building in this important area. There is also the risk that the fundamental paradoxes characteristic of sustainability issues will not be resolved because current perspectives are actually embedded within those paradoxical frameworks. More importantly, our current theoretical orientations might be contributing to the growing turbulence and ecological, economic and social domains across the globe. A metatheoretical analysis of the conceptual frameworks we use to understand and explain sustainability is called for so that a transformation in our intellectual framings can also occur. Metatheorising is inherently critical (Colomy, 1991) in that it can not only locate theoretical positions within a broader framework but also identify their conceptual limitations. The emergence of apparent chaos and paradox in critical situations typically flags the need for meta-perspectives to be urgently pursued and this is evidently the case for the study of organisational sustainability.

References

Akbar, H. 2003, 'Knowledge Levels and their Transformation: Towards the Integration of Knowledge Creation and Individual Learning', *The Journal of Management Studies*, vol. 40, no. 8, pp. 1997-2022.

Anderson, R. 2003, 'Introduction: Envisaging the prototypical company of the 21st century', in *Ants, Galileo, and Gandhi: Designing the Future of Business through Nature, Genius and Compassion*, S. Waage, ed., The Natural Step, San Francisco.

Armstrong, A. 2003, 'Whither the QBL (Quadruple Bottom Line): Should it wither on the vine?' *Corporate Citizen*, vol. 3, no. 1, pp. 28-31.

Baburoglu, O. N. 1988, 'The Vortical Environment: The Fifth in the Emery-Trist Levels of Organizational Environments', *Human Relations*, vol. 41, no. 3, pp. 181-210.

Bradbury, H. 2003, 'Sustaining inner and outer worlds: A whole-systems approach to developing sustainable business practices in management', *Journal of Management Education*, vol. 27, no. 2, p. 172.

Brown, B. C. 2005, 'Theory and practice of Integral sustainable development - an overview, Part 2: Values, developmental levels, and natural design', *AQAL Journal of Integral Theory and Practice*, vol. 1, no. 2.

Cacioppe, R. & Edwards, M. G. 2005, 'Seeking the Holy Grail of Organisational Development: A Synthesis of Integral Theory, Spiral Dynamics, Corporate Transformation and Developmental Action Inquiry', *The Leadership and Organizational Development Journal*, vol. 26, no. 2, pp. 86-105.

Casey, A. 2005, 'Enhancing Individual and Organizational Learning: A Sociological Model', *Management Learning*, vol. 36, no. 2, p. 131.

Choi, J. S. & Pattent, B. C. 2001, 'Sustainable Development: Lessons from the Paradox of Enrichment', *Ecosystem Health*, vol. 7, no. 3, pp. 163-178.

Colombo, M. G. & Delmastro, M. 2002, 'The Determinants of Organizational Change and Structural Inertia: Technological and Organizational Factors', *Journal of Economics & Management Strategy*, vol. 11, no. 4, pp. 595-635.

Colomy, P. 1991, 'Metatheorizing in a Postpositivist Frame', *Sociological Perspectives*, vol. 34, no. 3, pp. 269-286.

Cooper, D. J., Hinings, B., Greenwood, R. & Brown, J. L. 1996, 'Sedimentation and transformation in organizational change: The case of Canadian law firms', *Organization Studies*, vol. 17, no. 4, p. 623.

Daneke, G. A. 2001, 'Sustainable Development as Systemic Choices', *Policy Studies Journal*, vol. 29, no. 3, pp. 514-532.

Dixon, N. M. 1999, '*The Organizational Learning Cycle: How We Can Learn Collectively*', Gower, New York.

Dunphy, D. 2000, 'Embracing paradox: Top-down versus participative management of organizational change - a commentary on Conger and Bennis', in *Breaking the Code of Change*, M. Beer & N. Nohria, eds, Harvard Business School Press, Boston, Mass., pp. 123-135.

Dunphy, D., Griffiths, A. & Ben, S. 2003, '*Organisational Change for Corporate Sustainability: A Guide for Leaders and Change Agents of the Future*', Routledge, London.

Edelman, L. F. & Benning, A. L. 1999, 'Incremental revolution: Organizational change in highly turbulent environments', *Organization Development Journal*, vol. 17, no. 4, p. 79.

Edwards, M. G. 2005, 'The integral holon: A holonomic approach to organisational change and transformation', *Journal of Organizational Change Management*, vol. 18, no. 3, pp. 269-288.

Edwards, M. G. 2008, 'Where's the method to our integral madness (And an outline of an integral meta-studies)', *AQAL Journal of Integral Theory and Practice*, vol. (under review).

Eijnatten, F. M. v. 2005, 'A Hybrid Model for Analysing the Complexity of Inter- and Intra- Organisational Environments', in *Fifth Annual Meeting of the European Chaos and Complexity in Organisations Network (ECCON)*, ed. F. M. v. Eijnatten, Eindhoven University of Technology, Mennorode, Elspeet, Netherlands.

Elkington, J. 1999, '*Cannibals with Forks:The Triple Bottom Line of 21st Century Business*', Capstone, Oxford.

Emery, F. E. & Trist, E. C. 1965, 'The causal texture of organisational environments', *Human Relations*, vol. 18, no. 1, pp. 21-32.

Emery, M. 2000, 'The Current Version of Emery's Open Systems Theory', *Systemic Practice and Action Research*, vol. 13, no. 5, p. 623.

Foldy, E. G. & Creed, W. E. D. 1999, 'Action learning, fragmentation, and the interaction of single-, double-, and triple-loop change: A case of gay and lesbian workplace advocacy', *The Journal of Applied Behavioral Science*, vol. 35, no. 2, p. 207.

Fry, B. R. & Griswold, J. S. 2003, 'Defining and implementing the learning organization: Some strategic limitations', *Public Administration Quarterly*, vol. 27, no. 3/4, p. 311.

Ghoshal, S. 2005, 'Bad management theories are destroying good management practices', *Academy of Management Learning and Education*, vol. 4, no. 1, pp. 75-91.

Gomez, P.-Y. & Jones, B. C. 2000, 'Conventions: An interpretation of deep structure in organizations', *Organization Science*, vol. 11, no. 6, p. 696.
Griffiths, A., Benn, S. & Dunphy, D. 2007, '*Organizational Change for Corporate Sustainability: A Guide for Leaders and Change Agents of the Future*', Routledge, New York.
Halme, M. 2001, 'Learning for sustainable development in tourism networks', *Business Strategy and the Environment*, vol. 10, no. 2, p. 100.
Hamilton, C. 2003, '*The Growth Fetish*', Allen & Unwin., Sydney.
Hanley, N. 2000, 'Macroeconomic Measures of 'Sustainability'', *Journal of Economic Surveys*, vol. 14, no. 1, pp. 1-30.
Henderson, H. 2006, 'Twenty-first century strategies for sustainability', *Foresight : the Journal of Futures Studies, Strategic Thinking and Policy*, vol. 8, no. 1, p. 21.
Henriques, A. & Richardson, J., 2004, 'The Triple Bottom Line, Does It All Add Up?: Assessing the Sustainability of Business and CSR', London ; Sterling, VA : Earthscan, [xxii, 186 p. : ill. ; 25 cm.] Available from: http://www.loc.gov/catdir/toc/ecip0410/2003022772.html
Materials specified: Table of contents http://www.loc.gov/catdir/toc/ecip0410/2003022772.html
Horrigan, B. 2002, *Fault Lines in the Intersection between Corporate Governance and Social Responsiblity*, University of New South Wales, Faculty of Law, Port Melbourne, Vic.
Inayatullah, S. 2005, 'Spirituality as the fourth bottom line?' *Futures*, vol. 37, no. 6, pp. 573-579.
Jensen, P. E. 2005, 'A contextual theory of learning and the learning organization', *Knowledge and Process Management*, vol. 12, no. 1, pp. 53-64.
Jorgensen, B. 2004, 'Individual and organisational learning: a model for reform for public organisations', *Foresight : the Journal of Futures Studies, Strategic Thinking and Policy*, vol. 6, no. 2, p. 91.
Kilburg, R. R., Stokes, E. J. & Kuruvilla, C. 1998, 'Toward a conceptual model of organizational regression', *Consulting Psychology Journal: Practice & Research*, vol. 50, no. 2, pp. 101-119.
Kimerling, J. 2001, ' 'The Human Face of Petroleum': Sustainable Development in Amazonia?' *RECIEL*, vol. 10, pp. 65–81.
Klein, K. J., Tosi, H. & Cannella, A. A. 1999, 'Multilevel theory building: Benefits, barriers,and new developments', *Academy of Management. The Academy of Management Review*, vol. 24, no. 2, pp. 243-248.
Lester, D. L., Parnell, J. A. & Carraher, S. 2003, 'Organizational life cycle: A five-stage empirical scale', *International Journal of Organizational Analysis*, vol. 11, no. 4, pp. 339-54.
Luke, T. W. 2006, 'The System of Sustainable Degradation', *Capitalism, Nature, Socialism*, vol. 17, no. 1, pp. 99-112.
Mainemelis, C., Boyatzis, R. E. & Kolb, D. A. 2002, 'Learning styles and adaptive flexibility: Testing experiential learning theory', *Management Learning*, vol. 33, no. 1, pp. 5-33.
Miller, D. 1996, 'A Preliminary Typology of Organizational Learning: Synthesizing the Literature', *Journal of Management*, vol. 22, no. 3, pp. 485-505.
Molnar, E. B. & Mulvihill, P. R. 2003, 'Sustainability-focused organizational learning: Recent experiences and new challenges', *Journal of Environmental Planning and Management*, vol. 46, no. 2, pp. 167-176.
Mumford, A. 1992, 'Individual and Organizational Learning: The Pursuit of Change', *Management Decision*, vol. 30, no. 6, p. 143.
Murray, P. 2002, 'Cycles of organisational learning: A conceptual approach', *Management Decision*, vol. 40, no. 3, p. 239.
Nattrass, B. & Altomare, M. 1999, '*The Natural Step for Business; Wealth, Ecology, and the Evolutionary Corporation*', New Society Publishers, Gabriola Island, BC.
Overton, W. F. 2007, 'A coherent metatheory for dynamic systems: Relational organicism-contextualism', *Human Development Vol 50(2-3) Jun 2007, 154-159*.
Pennington, M. 2006, 'Sustainable development and British land use planning: A Hayekian perspective', *The Town Planning Review*, vol. 77, no. 1, p. 75.
Polimeni, J. M. & Polimeni, R. I. 2006, 'Jevons' Paradox and the myth of technological liberation', *Ecological Complexity*, vol. 3, no. 4, pp. 344-353.
Polito, T. & Watson, K. 2002, 'Toward an interdisciplinary organizational learning framework', *Journal of American Academy of Business, Cambridge*, vol. 2, no. 1, p. 162.
Prawat, R. S. 1999, 'Dewey, Peirce, and the Learning Paradox', *American Educational Research Journal*, vol. 36, no. 1, pp. 47-76.
Ritzer, G. 1988, 'Sociological Metatheory: A Defense of a Subfield by a Delineation of Its Parameters', *Sociological Theory*, vol. 6, no. 2, pp. 187-200.
Romme, A. G. L. & Witteloostuijn, A. v. 1999, 'Circular organizing and triple loop learning', *Journal of Organizational Change Management*, vol. 12, no. 5, pp. 439-454.
Schoenberger-Orgad, M. & McKie, D. 2005, 'Sustaining edges: CSR, postmodern play, and SMEs', *Public Relations Review*, vol. 31, no. 4, pp. 578-583.
Schwandt, D. R. & Marquardt, M. J. 1999, '*Organisational learning: From first-class theories to global best practice*', St Lucie Press, Boca Raton, FL.
Senge, P. M. 2003, 'Taking personal change seriously: The impact of Organizational Learning on management practice', *The Academy of Management Executive*, vol. 17, no. 2, p. 47.
Sonntag, V. 2000, 'Sustainability -- in light of competitiveness', *Ecological Economics*, vol. 34, no. 1, pp. 101-113.
Stacey, R. 2005, 'Organisational identity: The paradox of continuity and potential transformation at the same time', *Group Analysis*, vol. 38, no. 4, pp. 477-494.
Tilbury, D. 2004, 'Rising to the Challenge: Education for sustainability in Australia', *Australian Journal for*

van Marrewijk, M. 2003, 'European corporate sustainability framework for managing complexity and corporate transformation', *International Journal of Business Performance Management*, vol. 5, no. 2,3, p. 213.

van Marrewijk, M. & Becker, H. M. 2004, 'The Hidden Hand of Cultural Governance: The Transformation Process of Humanitas, a Community-driven Organization Providing, Cure, Care, Housing and Well-being to Elderly People', *Journal of Business Ethics*, vol. 55, no. 2, p. 205.

van Marrewijk, M. & Hardjono, T. W. 2003, 'European corporate sustainability framework for managing complexity and corporate transformation', *Journal of Business Ethics*, vol. 5, no. 2,3, pp. 121-132.

van Marrewijk, M. & Werre, M. 2003, 'Multiple levels of corporate sustainability', *Journal of Business Ethics*, vol. 44, no. 2/3, pp. 107-119.

Wagner, D. G. & Berger, J. 1985, 'Do Sociological Theories Grow?' *American Journal of Sociology*, vol. 90, no. 4, pp. 697-728.

CARBON MARKET

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KEYWORDS: Carbon market, Portugal, European Community, Kyoto Protocol

This presentation is a brief notice about the new market: the Carbon Market. With it we try to show how Kyoto Protocol changes the business in order to become sustainable.

The Planet weaknesses are felt each time with greater intensity.

The Man activity, the industrial and demographic growth, the technological boom that halloo the civilization, had brought serious disturbs in the environmental balance.

Catastrophes are increasing. A little from all over the world arrive news of floods in Africa, hurricanes is America, heat waves in Australia. And with it, fires and destruction of public and private infrastructures. People die, raw material become to scarce, goods are failing, buildings collapse, prejudices are multiplied, the economies are affected, the human life is called in question and world-wide solidarity is definitively tested.

The environmental preservation has become a collective peremptory in our days. The law is called to order this new environmental dimension of the human behaviour.

Despite all opinions the climate changes public and politic discussion has been a constant.

Economic and environmental issues reveal themselves indissociables and the answers to the climate changes became to merge the economic and social development.

The international cooperation is assumed has the only manner to balance the reduction of the greenhouse gases emissions (GHG) in the developed countries, with the promotion of the sustainable development in the undeveloped ones.

If the ancestors resort to the migration in order to escape of the environmental adversities, the actual poisoning of the Planet – that is global and of incalculable dimension – becomes that possibility inefficacious.

It is an imperative tutor/protect the climatic system, in order that the present and future generations could have the Hearth as habitable.

Thus, the UNFCCC, the Kyoto Protocol and others subsidiary agreements (among those we can select the Marrakech agreements) had established a new legal framing about the global reduction of greenhouse gases emissions. With it, the possibility of negotiation of the legal dues traced on this reduction, extinction or sequestration of greenhouse gases emissions.

It appears a new law sphere where new goods are transacted – the certificates – through an electronic label between registers that embody a certain quantity of carbon dioxide.

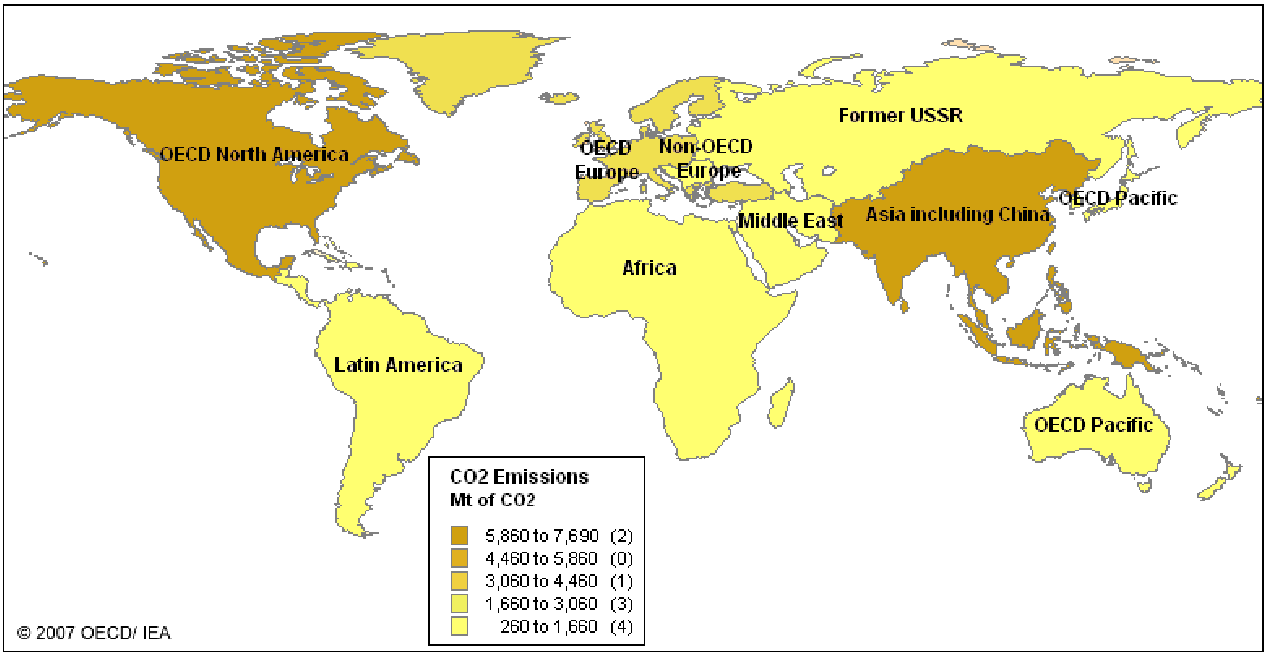
Finally is given the possibility to sell something that seems inexhaustible, the AIR!

Despite the effectiveness of the system created, a new market appears. With it, new contractual patterns.

Prejudices for ones, business opportunities for others. As any other system, his effectiveness will always depend of his generalized apprehension and comprehension.

The truth is that the continuous growth of the GHG emissions has became clear that only a stable and obligatory agreement/commitment between developed countries, in order to reduce the emissions, will be able to convince the economic operators, the communities and the citizens to act in the scope of the climate changes.

According to the OCDE information we can resume the emissions on:



Conscientious of this need, 20 years after the Stockholm Convention, 192 States signed, in 1992, a United Nations Framework Convention on Climate Change, whose objective, according to its article 2nd "is to achieve, in accordance with the relevant provisions of the convention, stabilization of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure the food production is not threatened and to enable economic development to proceed in sustainable manner."

In the third conference of Parties, after two and half years of intense negotiations, is approved the Kyoto Protocol, in Kyoto, Japan, in 11th December 1997[1].

The Kyoto Protocol comes to share the scope and the institutions of the Convention (UNFCCC), but it is distinguished from it, in a manner that, as long as the Convention encourages the developed countries to establish the GHG emissions, in the Protocol are assumed quantified commitments in order to do it.

Ruled in 2001, in Marrakech – Marrakech Accords – the Kyoto Protocol was considered the higher accord ever adopted in environmental matter.

With it, it is demanded that the developed countries reduce their GHG emissions for the levels specified in the treaty to each one of them, and that should be found between 2008-2012, having as reference base the year of 1990.

It is certain that one of the biggest achieves of the Kyoto Protocol was the ability to establish "ceilings" in the GHG emissions to the leader economies of the world that accepted it. These objectives or "ceilings" range from 8% to 10% of the individual levels for each country referenced to the year of 1990, with the scope to reduce their share in the GHG emissions in, at least, 5% above the existent levels in 1990, in the period of 2008 to 2012.

Thus, the Protocol commitments shall differ from nation[2] to nation.

In order to counterbalance the fulfillment of these "binding targets", as it is called, the

[1] According to Convention article 17: "The Conference of the Parties may, at any ordinary session, adopt protocols to the Convention."

[2] Actually the 5% objective to the developed countries will be achieved with cuts in the order of 8% in European Union, Switzerland and large part of the Central and East Europe; 6% to Canada and 7% to USA (that didn't signed) and 6% to Hungary, Japan and Poland. The New Zeeland, Russia and Ukraine will have to stabilize their emissions; wile Norway has a margin of 1% and Australia 8%.

Protocol offers flexibility to each country in the achievement of their own goals, creating three innovator mechanisms – Emissions trading (known as "the carbon market"), Joint Implementation, and Clean Development Mechanism.

An all new market is created, "the carbon market", referred in the Protocol's article 17th, in order to make possible to the Parties of the Annex I the acquisition of other units from other Parties of the Annex I and to use the in order to achieve their goals of emission. The new trade international legal board was established by the Marrakech Agreements which had furnished the components in order that the Parties and the private sector may accede to it, either by AAUs, RMUs negotiation, either by CERs and ERUs, respectively through Clean Development Mechanism and Joint Implementation.

Having in mind that only the Parties of the Annex I of the Kyoto Protocol, with emission bounds CER's reduction commitments enrolled in the Annex B[3] of the Kyoto Protocol may take part in this trade.

The units or commodities that are transferred in the terms of this article – each one equal to a metric tone of emissions (in CO2 – equivalent terms) – has one of the following configurations:

AAU (Assigned Amount Unit) issued by a Partie of the Annex I in the basis of its account attributed in the terms of the article 3.7 and 3.8 of the Protocol;

RMU (Removal Unit) issued by a Partie of the Annex I in the basis of the use of the land – LULUCF,activities under the article 3.3 and 3.4 of the Kyoto Protocol;

ERU (Emission Reduction Unit) generated by a joint implementation project under the article 6 of the Kyoto Protocol;

CER (Certified Emission Reduction) generated by clean development mechanism Project under the terms of the article 12 of the Kyoto Protocol;

All of these transfers and acquisitions are "reported" trough the register systems created under the Kyoto Protocol and ruled in the Marrakech Agreements[4].

A tight register system is created. Indeed, the emissions targets are expressed in aloud emissions levels or "Assigned Amounts" to period of commitment 2008-2012, named in CO2 tones, known informally as "Kyoto Units".

Thus, only an effective register system may follow/control the trajectory of the "Kyoto Units".

In order to start running the system were implemented two types of registers, the Annex B governments' national register and the Clean Development Mechanism register to issue the MDL credits and to distribute them to the national registers. These registers record the emissions transactions trough the delivery of units from the sellers' accounts to the buyers' accounts, shaping the "backbone" of the carbon market.

In what concerns the flexibility mechanisms, the Marrakech Agreements approved the standard treatment of the reduction units proceeding from these mechanisms.

In fact, in order that the GHG emission reduction goals where fulfilled, each Partie may resort to three types of action: Reduce the domestic emissions; increase the GHG absorption, obtaining absorption units (Removal Unit); and acquiring other units to other Parties through the EU, CER or ERU acquisition.

Starting by CDM (Clean Development Mechanism), this mechanism has the scope to aloud that the parties not included in the Annex I, could fulfill the sustainable development accepting "investment" of the Parties included in the Annex I. Once that these ones by doing it may, by the augment of their share, fulfill the limitation commitments and/or emissions reductions commitments.

The Clean Development Mechanism is defined in the article 12 of the Kyoto protocol, whose purpose shall be "to assist Parties not included in the Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under article 3". The Clean Development Mechanism came precisely to "render lucrative" the international solidarity. With it, the countries of the Annex I have the possibility to finance emission reduction projects that would be developed in the countries of the Non Annex I (undeveloped countries), receiving in trade the CERs, the same is saying, receiving the aids to achieve the environmental targets.

To those who are the most septic is a manner to pay to someone to stop smoking in order that, how pays, can smoke. The truth is it was the only mean found so that "the activities of the clean development mechanism project could lead to the technology transfer and Know How

[3] The annex B represents the quantified commitments of limitation or reduction of emissions.
[4] Each Partie is obliged to create and maintain his national register.

environmentally safe and healthy" – decision 17 COP7.

Besides the requirements (to be an activity between countries that are Parties of the Kyoto Protocol[5]; voluntary and authorized participation; the activity must result in a measurable emissions reduction; the reductions beyond measurable have to be additional to those who would occur in the absence of the project certified activity, and it always has to contribute to the host country could reach the sustainable development) the CDM levels are those who follows:

- Attainment of the formal written approval of the project by the Host Country DNA and the confirmation that the project will aloud the Host Country to develop itself in a sustainable manner;

- Evidence that the participation of the partie is voluntary;

- Creation of a PDD according to the formalities of the Executive Board and that oblige the inclusion of all the details of the project activities (methodology description; baseline; project period; participants identification; communication methods; stakeholders participation…);

- DOE revision and validation;

- Emissions reduction monitoring achieved by the Project according with the plan;

- Periodic revision, verification, and certification of the emission reduction;

- Finally the CERs emission by the CDM Executive Board.

- It should be noted that the Project must help the Host Country to achieve the sustainable development.

In fact, the main objective of this mechanism is to "promote" the help to the countries of the non Annex I, in order that they achieve a sustainable development. So, the project must bring real and measurable benefits in terms of GHG emission reductions. Certainly is that the GHG emissions reduction brought by the project had to be additional to any other emission that could occur in the absence of the project activity.

With an identical structure at the level of the development, but with specificities at the level of the reduction units' creation, we have the Joint Implementation Mechanism. In this mechanism the international cooperation ceases to be between developed and undeveloped countries and passes to be between developed countries. At the end the reduction units are designated by ERU's.

Finally, the AUs direct commercialization between the Parties and that, generally, we could define as a simple titles transaction that rises between Parties with excess of licenses and Parties that have lack of it, in order to achieve their targets. The procedure is similar to title's trade.

At an European level the Kyoto Protocol was immediately absorbed and the "carbon market started to run to and half years earlier than the Kyoto period.

In fact, the European Community formalized the communitarian commitment of Protocol approval and Share of Responsibility between State Members Agreement, in April 2002, trough the decision nº 2002/358/CE, of the Consil of April 25th.

The E.U. obliged itself to reduce in 8% it's emissions in the first period, the same is saying, between 2008-2012.

Thus, and besides the Directives about one of the sectors largely responsible by the CO2 emissions, the energy, in 2003, the E.U. approved the Directive about the emission trade, the directive 2003/87/CE of the European Parliament and the Council, in October 13th, who created a system in which the industries may acquire or sell the GEE emission credits, in the sequence of market mechanisms and adopted in the Protocol.

Modified by the 2004/101/CE Directive, known as the CELE Directive, which came to anticipate the calendars imposed by Kyoto. This change seek also the introduction of dispositions in order to guarantee the connection with the Kyoto mechanisms, JI and CDM, that's why is also used the CELE designation, LinKing Directive.

As we all new, the first phase of the European system, the Pre-Kyoto period, had the purpose to familiarize the addressees with the trade of the emission rights, the price determination, the procedures development and the creation of regulation agencies and, obviously, the environmental scope.

The activities comprehended are led back, basically, to Energy, Paper and Paper Pulp, Cement, Glass and Ceramics, Brick and Roof-tile.

Portugal was not an exception.

As any other E.U. country, transformed into national law the CELE Directive, by the DL 233/2004, of December 14th.

In the bounds of his obligations approved the PNAL III.

[5] Those Parties may be public or private, as long as duly authorized by the Partie and with a performance always under his responsibility.

The ministerial order 121/2005 came in the sequence of the European Commission Decision 2004/156/CE of January 29th, who established certain orientation in this subject matter, to receive have to be achieved with resort to the market mechanisms.

We are in the first year of the Kyoto Protocol

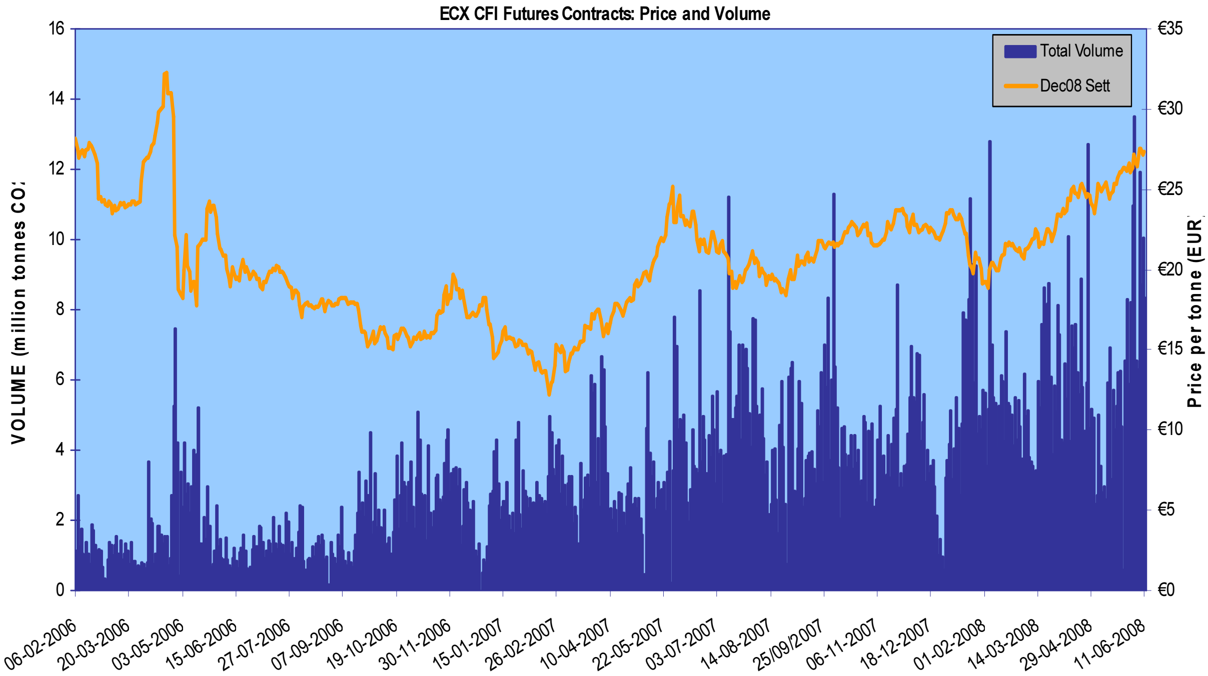


Fig. 2. European climate change

and rule such orientations.

With the DL 233/2004, of December 14th, Portugal had transformed into the national law the Directive nº 2003/87/CE of the European Parliament and Council, of October 13th. As previously referred E.U. global reduction target is in the amount of 8% of the GEE emissions.

This DL (statute) has already been target of two modifications, the DL 243-A/2004, of December 31 and 230/2005, of December 29, with the scope of improving the operability of the licenses trade regime.

Concretely Portugal is obliged to limit the increase of his emissions in 27% comparatively to the numbers of 1990.

In a scenario without measures the national economy evolution pointed to an increase of 54% to 63% of GEE emissions in 2010, comparatively to the reference year of 1990. Thus, in order to achieve Kyoto, the same is saying, to limit the increase of his emissions to 27%, Portugal needs of a reduction of 16Mt to 21Mt of Carbon Dioxide equivalent to (Mt CO2 º). For sure is that this PNAC measures, when totally fulfilled, allows us to predict a potential reduction until 16.8 Mt Co2 º, what becomes necessary a supplementary reduction until 5.6 Mts Co2, that necessarily will

Commitment, but as we referred the EU begun in 2005, in order to have an idea of what we are talking about, in volume of transaction we show this European climate Change information:

This is a general overview on the Kyoto functioning, this was the manner that the World found in order to reduce its GHG emissions.

The system effectiveness must be tested and today is discussed the Post-Kyoto and is also stimulated the voluntary market.

No one knows how will be the future, how the world will be adapted, but the duration of the emission control system is here to stay.

We can’t forget that the best new is that the struggle against the climatic changes obliged the economic agents to invest in environmental efficiency.

But this investment will only have profit if the governments guarantee the measures continuity. And, finally, we can firmly state that: the Environmental protection is a condition to economic development and this one is, in turn a condition of the Environmental Protection.

References

[1] Kyoto Protocol
[2] UNFCCC Convention
[3] Marrakech Accords
[4] LINKING Directive - 2004/101/E of the European Parliament and of the Council
[5] CELE Directive – 2003/87/CE of the European Parliament and of the Council
[6] DL 72/2006 de 24/03
[7] DL 233/2004 de 14/12
[8] www.oecd.org
[9] www.europeanclimatechange.com

BUSINESS SUSTAINABILITY AND COLLECTIVE INTELLIGENCE

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Keywords: new_organisational_models_or_paradigms; new_economy_business_enterprises; networked_economy; collective_intelligence.

1. INTRODUCTION

What has collective intelligence to contribute for the knowledge on business sustainability?

This paper gives some answers. They stand on engineer-minded, systemic and cybernetic points of view. As such, one devotes Section 2 and 3 to state the intended meanings of terms and a preliminary analysis of them, so that the answers given follow in Sections, 4 and 5, hopefully, in a deductively sound way. Section 6 concludes and sketches perspectives for development.

2. OF BUSINESSES AND SUSTAINABILITY

Businesses

In this paper, one understands a business as i) a human organization producing and delivering goods or services in exchange for money. Straightforward this definition may sound, it is clearly incomplete as non-profit organizations and states also satisfy it. Many non-profit, privately owned organizations exchange goods or services for money, both in a generalized as a specific sense. Also states or states' agencies exchange goods or services for money, both in the specific sense of a given service being got only through payment of a fee, as in the generalized sense that public servants produce services for the society in exchange for salaries deduced from the total amount collected as taxes.

So, what makes businesses different from non-profit organizations and states or states' agencies? The fact that, besides i), ii) business *owners* are entitled to appropriate a fraction of the money received by the organization, this fraction being termed *net profit*. Such appropriation is bound to rules, e.g., it can only occur if net profit is positive and it is distributed among owners according to the percentage of ownership of the business each owner detains.

Differently, such an appropriation is by definition forbidden by law in a non-profit organization if it has owners at all, or its ownership maybe assigned to someone. In addition, in a state organization such an appropriation either is devoid of meaning (ownership of the state rests undefined) or simply not made effective (the assumption that citizens own the state seems to have no expression in thinking, discourse and practice).

The above expresses that the concept of 'owner of a human organization' is clearly defined only for businesses.

In an economy, one refers businesses as the private sector by contrast with the public sector (state) or the voluntary sector (non-profit) [1]. Although it was impossible for this author to get an assessment of the share of gross domestic products generated by businesses, it is clear that they are prevalent worldwide and so their sustainability is linked to the sustainability of the emerging global way of life or civilization as-we-know-it.

Roles

If, as by predicate i), a business is a human organization, who belongs to it? Or, in other terms, who are the people constituting the business? Thinking pragmatically, it seems inescapable to include in such a set of people owners and employees. If one takes out 'owners' one would fail to account for people who are essential to the concept of business as a distinct type of human organization and to the understanding of its behavior, as by predicate ii). If one takes out 'employees' then one would fail to account for the people that actually run the business, or are "orchestrated" by the organization in actually producing the goods or services.

In fact, one may find inside a business people that

a) are owners but not employees;

b) are owners *and* employees;

c) are employees but not owners.

Being an owner or an employee corresponds to different functions or behaviors inside a business and to different drives or personal interests to participate in it. Given that these functions and interests may coincide in the same person, one makes resort in this paper to the concept of *roles*. One will say that inside a business a person may have the role of owner, of employee or both.

The concept of roles is not of course restricted to businesses and may be of interest to analysis elsewhere. In a country, a person may be a citizen but not a public servant (if not an employee of the state) or both a citizen and a public servant (if an employee of the state). In an economic analysis upon the notions of producer and consumer, a person may be a consumer but not a producer, or both a producer and a consumer.

A two-way perspective on human organizations

It is generally assumed that predicate i) expresses the reason to exist ("raison d'être") of businesses, non-profits and states. They exist because their activity results in something sought useful for people in general. One may find or present counter-examples to such a reasoning in individual cases, but the argument is compelling[1] in a statistical sense, because one cannot see how human societies could persist in time if that was not so for the vast majority of cases.

Yet, this reasoning is incomplete. It sees organizations – businesses, non-profits and states – as sources of goods or services for people in general. That is a necessary social function they implement, but not the only one. Goods and services are not created out of nothing, but out of people creativity, knowledge, abilities, and work, coordinated through their participation in the organization. So, organizations are "sources" of goods and services as long as they are "sinks" for people's activity and possessions, monetary or other. Accordingly, one must recognize that the social function of engaging people in socially useful modes of activity is a necessary correlate of the production of goods or services.

And this has the following consequence. Organizations not only provide for goods and services for people in general but also for returns to their members, which can go from the rather objective making for a living or maintaining and accruing monetary wealth, to more intangible planes of self-realization. Being distinguished by the possibility (predicate ii) of making profit for owners does not take businesses out of this function.

It becomes difficult to understand the behavior of organizations – businesses in particular – if the correlation between the production of goods or services fulfilling needs of people in general and the generation of opportunities for fulfilling needs of people that in particular participate in the organization is not kept in mind.

Sustainability

Simply put, sustainability of something means persistence in time of the thing. If a building is left without maintenance, the aging of materials and the aggressions of environment will make the building enter a state where it cannot sustain itself and will collapse.

Human organizations are dynamic arrangements of living beings and these, in turn, are dynamic arrangements of molecules. Given the dynamic nature of the arrangements at stake, it will be more appropriate to say that sustainability of them means that they *re-produce* in time, rather than they persist in time.

Drawing on the autopoietic theory and interpretation of life [2][3][4][5][6] one will say that a living being is a molecular network of chemical reactions that continually remakes itself[2]. This concept leads to the necessity of the living being having a *boundary* through which exchanges of matter and energy take place with the *environment*, a broad term to denote everything that is outside the boundary.

Because the molecular network continually remakes itself from itself no first cause can be devised for its functioning. Rather, if one depicts graphically the functioning of the network one arrives at a circle, as the form abstractly representing what is going on as in Figure 1. One may say that in a living being causality is configured in a closed loop.

While internal conditions are maintained such that the loop goes on functioning, the being will live or one may say that the being (or its life) is sustainable.

[1] The fact that organizations must receive money in exchange for the goods or services produced as expressed by predicate i) is not truly essential to the argument, given that one reasons from an assumption of a monetary economy.

[2] An oversimplified description: … DNA that makes PROTEINS that make DNA that makes PROTEINS that make …

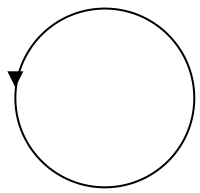


Fig. 1. Abstract illustration of causality in a living being.

When internal conditions diverge so much that the loop breaks, then the being dies or is extinguished, and one may say that the being (or its life) has become unsustainable.

One will refer to the maintaining of the internal conditions inside a domain compatible with the continuous re-producing of itself as *self-coherence*.

Self-coherence is a condition necessary for sustainability, but not sufficient. Because the being is in a constant process of exchange of matter and energy with the environment, the being triggers changes in the environment and the environment triggers changes in the being. Depicting graphically this process leads again to a circular diagram configuring a closed loop as in Figure 2.

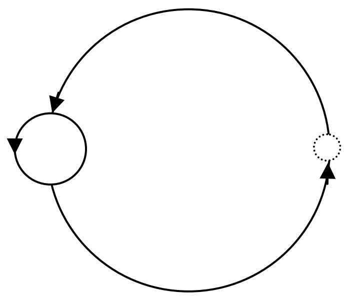


Fig. 2. Abstract illustration of causality in the relation between a living being and its environment.

It is true that the being will live only or will be sustainable as long this closed loop of causality goes on. If the loop breaks the being dies or becomes unsustainable. One will refer to the maintaining of the conditions inside a domain compatible with the continuous re-producing of itself as *coherence* of the being with the environment.

Coherence can be broken either by the being or the environment. This one continuously changes as the result of natural (non-living) forces, other beings and the being itself. To maintain coherence in an ever changing environment, the being must *adapt*, tuning its internal functioning, or *evolve*, changing its structure to some degree.

The intrinsic constraints of multi-cellular living beings imply that they are not able to maintain self-coherence or coherence past a limited time span, measurable as life expectancy.

On the grounds of the observation that multi-cellular living beings are made of cells, it is tempting to consider species as living beings (of an upper order) made up of individuals (the individuals having with regard to the species a role analog of cells to the individual) [7].

Species have a much larger time span for their lives, possibly open ended, although they are prone to extinction, as individuals. But by their intrinsic nature they have a much broader potential to evolve than individuals – and for maintaining coherence. Evolution allows a species to transform itself, in the limit becoming another species.

Sustainability of life is surely a desirable property for any individual living being, but, if individual living beings were sustainable for an unlimited time span, evolution of species would be impossible – and one would not be here talking about sustainability. Evolution carries a deeper meaning than sustainability.

Sustainability of organizations

If, by analogy, one talks of the human species as a living being and of individual humans as their cells, what meaning can one assign to human organizations?

To answer this question, one must observe that the analogy is of great interest and functions very well in many areas, but it does not mean a complete equivalence. When one goes from cells to a human being, one goes from a living being to another, sharing some properties with the first including "lifeness", but also with different properties. When one goes from a human to the species, the same happens. For example, in a human, cells are physically connected in space. That is not the case for the species.

One could envision human species as a moving "liquid" at the surface of Earth[3]. Now a closer look to the "liquid" would reveal that its "molecules" present definite patterns of coordinated behavior. In particular, some of the patterns result in the production of goods and services for the consumption or benefit of other than the producing "molecules". These patterns of activity are the human organizations one is talking about.

Having framed human organizations this way, framing sustainability of them may be understood as follows. If the human species is a living being it

[3] From which some very little "drops" suddenly step out in space shuttles…

must be self-coherent (or cohere with itself) and coherent with the environment (or cohere with the environment). Otherwise the species will enter a regression[4] or put its own sustainability at risk. From this standpoint, a human organization is sustainable if its net contribution to the self-coherence and coherence with the environment of the species is positive[5].

The argument can be stated in a slightly different form. Let one consider how will be the species some time from now in the future. Taking out the limit case of being extinct or at risk of extinction, two cases may step out for consideration:

1. The species is healthier and more developed than now.
2. The species has regressed.

The second case is not furthered considered, as it is sought devoid of meaning. Does it really make sense to consider the sustainability of organizations if it is linked to the regression of the species?

If it is not the second case and the first case happens then self-coherence and coherence of the species must be greater than now. Organizations are key factors to this, so they must have evolved accordingly. This means that the organizations that will exist at that time to come are now those that are now sustainable or those that change to become sustainable or those to be born sustainable. In any case their sustainability is linked to their net contribution to self-coherence and coherence with environment of the species.

Yet, this should not be taken as an infallible specific criterion or prescription to test for or make a given organization sustainable against everything and for all, but just as a general guidance. First, because for a system with complex dynamics as a species, one can elicit general trends or properties, but one cannot predict local behavior. Second, because species have a long term genetic dynamics: patterns are formed, tested and recombined. Organizations that are only near-sustainable in the above sense may be very useful as components for a next generation of sustainable ones. Third, because species are a blatant example of the principle of requisite variety [8]: a system must have enough variety to cope with environment disturbances. Species strive to maintain as much diversity as possible in order to augment the spectrum of environment changes to which they can adapt or for which they can maintain coherence. Organizations which do not present now a net contribute to coherence may be maintained in the expectation that they may become net contributors for coherence sometime in the future[6].

Sustainability of human organizations is often desirable, but it hardly can be taken as an absolute value. 'Evolvability' seems a more interesting concept[7].

Sustainability, adaption and evolution

In a very *strict* sense, one may say that making an organization sustainable is *impossible*. By the simple reason that if an organization *X*0 is unsustainable, making it sustainable means *to change* *X*0 into an organization *X*1 that is strictly *different* from *X*0.

The consequence of this comes as follows: to solve the (un)sustainability problem it is necessary but not sufficient to have a criterion to distinguish sustainable from unsustainable. One must also devise a 'roadmap for sustainability'. The meaning for this expression taken in this paper focus on change and the conditions for change internal to an organization. Furthermore, one distinguishes change as adaption or as evolution.

Both adaption and evolution have the effect of rising coherence of the individual living being or the organization with the environment. But adaption is reversible and stressing in general. Evolution is irreversible and prevents the need for further adaptation, actually relieving from the associated stress. In the way evolution is defined here, it be taken as a synonymous for learning. Some examples illustrate the idea.

An organism may be vulnerable to an infectious agent. This is incoherence with the environment that manifests if the organism is actually infected. Then it adapts through immediate changes, e.g., fever and cough. If given enough time its immune system eventually will synthesize an antigen that will destroy the infectious agent. This change is evolutionary: it is memorized by the immune system, preventing any further infection by the same agent and the

[4] As when a person becomes ill or enters a worse period in his / her life.

[5] And, presumably, above a given minimal threshold.

[6] Although, such cases cannot be significant in a statistical sense, as it may become obvious.

[7] The Roman state lasted for a little less than a thousand years, and the Chinese state allegedly has more than four thousand years of existence. Yet, it was from the ashes of the Roman state that evolved the civilization beginning, one thousand years past its end, the movement to the emerging global civilization. It could have happened the other way. Were the Chinese state more flexible and open to evolution and the discoveries and colonization could have happened in the reverse direction.

adaptive stress associated. The immune system has learned to deal with the agent.

For another example one may consider a business with an environmental aggressive practice. That will end up in protests from people, or the business incurring in legal prosecution. In a first phase, the business may adapt by opposing legislation, starting public relations actions, paying fines, or putting in effect immediate changes to its operations scheme. One may say that the business is adapting because all these moves are stressing to the business – they lead to extra costs without long term payoff – and reversible – if external pressure relinquishes, “business as usual” will go on. Eventually the business will revise deeply their practices, change culture and find technologies compatible with its functioning and non-aggressive to the environment. This change is evolutionary. The business has learnt to deal with the fact that environmental resources are finite.

Or yet for another example one may consider a state agency that indulged in a growing annual budget without a correlative bettering of quality of service. When the growing dissatisfaction of citizens turns into cuts in the budget, the first response of the agency may be to adapt with actions similar to the business as above. Eventually the agency may find a way to evolve, restoring coherence in the long term and will learn to deal with the fact that the social resources it may take are finite.

The relation between coherence with the environment, changes in this one lowering coherence and the dynamics of adaption is illustrated in Figure 3.

Capabilities of an organism to evolve are limited. An organism may evolve by growth, which is genetically determined, through learning of the immune system, or through learning of the nervous system. Capabilities of learning for organizations are wider. Organizations can change people, change culture or change technological process and artifacts – all giving a wider spectrum for evolution.

3. OF COLLECTIVE INTELLIGENCE

The reader may notice that the intended meaning assumed for adaptation in this paper has been set to a change that fosters coherence but only in a stressing, non-permanent way. And that the intended meaning for evolution has been set to equate with learning. Learning is an ability of a system that is intelligent and maintains its intelligence in a changing environment.

In fact, what this paper proposes with regard to the roadmap of sustainability for businesses is this being searched through their intelligence – not in the restrict sense of gathering strategic information but in the wider sense that one deems of somebody as being intelligent.

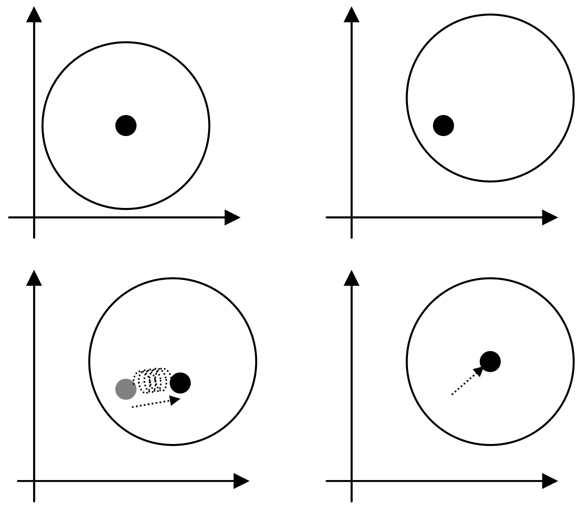


Fig. 3. One supposes that the plane represents the possible spaces of configurations for an organization in some suitable referential. The organization can only be inside a set of configurations that correspond to coherence with the environment. This set is represented by a circle; if the organization goes outside the circle it will be extinct. In the image up and left, the organization lies at the most comfortable configuration possible, i.e., at the center of the circle. Because the environment changes the organization finds itself nearer the critical limit. This is depicted in the image up and right. The organization reacts by adapting, which involves stress. This situation is depicted in the image down and left. If the organization evolves it can reach the center of the circle again and relief stress.

Intelligence

As in [9] “Intelligence is taken here as the ability for attaining goals or for solving problems that puts at work responsiveness of the solver to the situation where the goal or problem arises and use of its previous knowledge and experience.” This statement of the intended meaning of intelligence makes it relative to the goal or problem and to the previous knowledge or experience of the solver. Fabricating weapons may be very intelligent from the standpoint of one’s military capabilities but very stupid from the standpoint of peace. If a child solves a high school math problem with no perceived previous teaching or training he or she will be considered more intelligent than a graduate who solves the same problem.

Intelligence as a property of collectives

Usually one perceives intelligence as a property of individuals. Humans or other animals or even computer programs are common examples.

Research in the natural and social sciences has shown this conception to be too narrow. Intelligence is a property of collectives. For the purposes of this paper one takes a collective to be some entity distinguished as being non-atomic. Ant colonies, swarms, flocks or herds are examples among the non-human animals. Collectives of people may exhibit superior problem solving capabilities than any of their most intelligent members. Even individual intelligence may be conceived as the intelligence of the collective of neurons that constitute one person's brain.

Researchers in Artificial Intelligence (AI) have long proposed Distributed AI and Multi-Agent Systems (MAS), systems of running computer programs communicating through adequate channels, as more intelligent artifacts than single programs. In 1980 [10] presented a model for the mind as a society of interacting units or agents.

In recent years the concept of a Global Brain has been proposed as "a metaphor for the intelligent network formed by the people of this planet together with the knowledge and communication technologies that connect them together" [11]. These were some of the strands conducting to the emerging field of Collective Intelligence [9][11][12][13].

In the perspective of collective intelligence it becomes quite natural, when one thinks of a system – an interconnected set of parts –, a collective in general, to ask: how intelligent is it? Which is its intelligence?

4. COLLECTIVE INTELLIGENCE OF HUMAN ORGANIZATIONS

In [14], Noubel distinguishes the collective intelligence of human organizations (societies) to have undergone three stages of development. The first is 'natural collective intelligence' (Natural CI) or the collective intelligence of the small groups of hunter-gatherers prevalent as the social form of humankind organization at its origins. This form of collective intelligence manifests itself when the collective has a small number of people, as in jazz bands or sport teams, which allows for:

– The group being an emerging *whole* continuously (re)created by mutual trust and sharing of values among the members of the group;

– The group being a 'holoptical space', i.e., a space small enough and open enough so that all its members access a vision of the situation of all the other members and of the challenges the group faces, leading to the existence of a highly efficient 'collective mental map'.

– A polymorphic architecture which maximizes the probability of the best person for a given task coming into the lead when the situation arises.

– An object-link, i.e. a physical or symbolical object that catalyzes the collective and its intelligence, as a collectively pursued object, as the ball in a soccer game, the prey in a hunting expedition, an outstanding performance of a band, the goals of a meeting, the mission of an organization.

– The group being a learning organization whereas individual and collective errors are properly recognized and integrated into collective learning.

Natural CI breaks down when the number of people in the group augments past a given threshold, as the necessary communication and information exchange become physically impossible. When societies grew, they solved this problem by evolving to pyramidal intelligence, a type of social intelligence manifested in hierarchical modes of social organization. Pyramidal intelligence has prevailed by thousand of years, succeeding to coordinate hundreds of millions of people in societies, in the absence of the physical possibility of having people communicating enough for collective intelligence to exist.

The recent development of computer and communication technologies creates the prospect for the development of *Global CI*, the re-creation of Natural CI in groups, societies, collectives, many times bigger.

Drawing on [14] [15] Garrido has proposed in [9] a roadmap for fostering Global CI in organizations, supposing computer and communications support. The main points of it can be given in a wider formulation as follows.

1. To promote and implement a culture of mutual trust, contract of the individual with the collective, stewardship and organizational learning, the leaders being prime examples.
2. To cut hierarchical levels and to promote free flow and openness of information inside the organization so that:

a) Decisions are more robust;

b) The holoptical space and the associated mental map are continuously developed and enriched;

c) To prevent and better deal with collective disrupting modes of individual action.

Socially supported decisions

The ‘apex’ of intelligence comes as decision. An entity makes something intelligent if it takes the “right” decisions; it makes something “stupid” otherwise. What does collective intelligence views have to contribute to the decision process inside an organization?

Quality of decision rests on five processes of perception:

1. Perception of the goals to be attained;
2. Perception of both the environment and the internals of the organization whatever the decision is local or global;
3. Perception of the possible actions from which to select one or more for effective action;
4. Perception of the possible strategies to follow or course of actions to take;
5. Perception of the values of alternative actions or strategies.

The wider these perceptions are the greater is the probability to get a “right” decision. A knowledgeable or competent person is one that (besides eventually acting in a skilful way) takes the right decisions in general because it has enough wealth of the above five types of perceptions.

In the “pyramidal intelligence” culture legated by hierarchical dominated organizations, one tends to see decision as a process restricted to people in charge of taking decisions. This is not necessarily bad (although it can be quite bad), but it is less than collective intelligence has to offer.

From a collective intelligence stand, decision is to be seen as a distributed process inside an organization, those who decide having the role of collecting as much as information as possible to make sense of the results of the five perception processes among people, so as to arrive at the best decisions. Quality of decisions should augment as bigger pools of perceptions are made available.

Harnessing this “wisdom of crowds” [16] inside organizations was impossible before the computer and communications era. But since one has them available, software targeted for this aim may be developed. One arrives then to the concept of socially supported decision systems. These systems may be targeted for very large collectives, independent of its particular nature. Garrido and Faria report in [17] the development of a free / open source software system specifically designed to be used in organizations for social support of the decision process.

Besides bettering the quality of the overall decision process, it can be expected that the sense of engagement of people with the organization will grow as well as the collective mental maps and the holoptic vision will develop in extension and in precision.

5. THE CASE OF BUSINESSES

Businesses are organizations and everything said in the last section applies to them if in quest of the evolution leading to sustainability or “sustained sustainability” (!). But businesses are also special inside organizations as it is possible for those people in the organization having the role of owners to share profit.

As one lives in a prevalent monetary economy, profit has two functions:

1. To measure the viability of an organization;
2. To compensate for the owners’ investment of their effort or surplus money in the organization.

The first function results from the requirement that profit *does not become negative*. It is generally assumed that if profit is negative, then the business has become socially inefficient absorbing from society a value of resources greater than the value it supplies. As a consequence if profits are repeatedly negative, either the business will be extinct or will be integrated in another business with a presumable reconfiguration geared towards recovering social efficiency.

The second function is the rationale for the very existence of businesses under the current economic mode of functioning. Profit is sought as the main incentive for people applying their surplus money in them as capital to be remunerated. Or for people initiating businesses as owners in the expectation that they will receive through profits an income greater than it will be possible only through current values for salaries.

The double function of profit hinges on its nature of being the difference of two values:

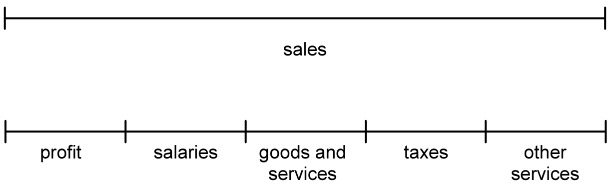
1. The value society gives to the products and services sold by the business in a year.
2. The value society requires for the products and services paid by the business in a year.

It is the possibility that value 1 may be consistently and repeatedly greater than value 2, together with the fact that the difference may be distributed among the owners, which incentives people to start and operate businesses, and surely led to their vital role and prevalence in modern economy.

Yet it should be recognized that the profit predicate is a potential source of incoherence for the business as a productive organization, if it is the case that not all the people in the business have the role of owners. Or in other words, if it is the case that some of the people in the business have the role of employees, but not the role of owners. Let P the profit, R the revenue of sales, S the amount of salaries paid, GS the amount of goods and services necessary and purchased to run the business, T the total amount of taxes paid, and OS the total amount paid for other expenses as investment in equipment, financial or banking interests. Then

$$P = R - S - GS - T - OS$$

This equation is visually illustrated as follows.



Now, it is clear that to augment P, either R is augmented or any or some of S, GS, T or OS are diminished. Pressure to diminish GS, T or OS will be exercised towards people *outside* the business or organization. But pressure to diminish salaries (or its fraction in the sales revenue) will be exercised against people *inside* the organization – all the employees of the business. If these have simultaneously the roles of owners and employees such pressure should not result in conflict among people, as the question should be more of bookkeeping than real. But if people with only the role of employees exist, then conflict is most probable to happen, worsening the self-coherence of the business.

It is to be recognized that the conflict spotted above has the potential to undermine mutual trust among people and individual engagement with the collective; to shatter the holoptical space or to divide the "collective mental map" in two different types: that of owners and that of employees; to create two different (monetary) object-links: profits on one side, salaries on the other; to block the business in becoming a learning organization. Depending on their intensity, all these effects, as by the referred in the previous section, are detrimental to the collective intelligence of the organization. Upon a vision of collective intelligence as founding the discovery of a business roadmap to sustainability, it follows that they are detrimental to business sustainability.

It follows that from a collective intelligence perspective businesses should tend to turn their employees into owners. Of course one is not speaking here of making any employee automatically an owner; or that restrictions on the trade of ownership rights should not be applied; or that the business starters or entrepreneurs should loose control of the business. But one is speaking of finding solutions that by preventing, diminishing or eliminating the potential conflict between owners and employees, will maximize the conditions for the business to develop its collective intelligence.

6. CONCLUSIONS AND PERSPECTIVES

In this paper several ways have been pointed of how the emerging knowledge in collective intelligence may be applied for a business to discover or set-up its roadmap to sustainability and follow it. One has begun by a preliminary analysis of businesses and sustainability.

Businesses have been considered a special case of productive human organizations, where a) people can take the roles of owners or employees and b) owners have available the sharing of profit.

As any other productive human organization, a business performs a double social function[8]. On one side it produces goods and services for people in general. On the other side it engages its members in socially useful modes of activity and ensures to them monetary income. These two functions are correlate and inseparable.

Sustainability has been framed drawing on autopoietic theory. One has assumed that human organizations, like living beings, are amenable to be understood as a circular pattern of activity that continuously re-produces itself in time. This led to the concept of self-coherence of an organization as a property determining its sustainability. An organization is sustainable (in the inside) while its configuration lies in a space of self-coherence which allows for its continuous self re-production.

Organizations exist in a social environment, exchanging with it goods, services and money. Again a circular pattern of activity leading to its self-reproduction in time can be devised. This led to the concept of coherence of an organization with its environment as another property determining its sustainability. An organization is sustainable (in the outside) while its configuration lies in a space of coherence with the environment which allows for its continuous self re-production.

Because the environment is continuously changing, the space of coherence of an

[8] Most mission statements refer one function only.

organization is continuously changing. As a result, the organization will find itself moving towards the limits of the space of coherence. If these limits are traversed, the circular pattern of activity and flux will be broken and the organization will be extinct.

So, an organization must continuously change heading towards the centre of the space of coherence, maximizing its sustainability. In a first step, an organization changes in a way that has been termed 'adaption'. This is a type of change that betters coherence in the short term, but has a stressing nature. It may be enough if changes in the environment are fluctuations. But if changes have a definite trend, the organization must evolve, to cope with the depth of changes needed and to relief stress. The concept of evolution presented is synonymous with learning – more exactly with deep learning. While adaption is a change inside the known repertory of behaviors of the organization, evolution implies acquiring a behavior unknown till the moment.

Evolution as learning may best establish the connection with collective intelligence, because learning is the hallmark of an intelligent being in a changing environment. Following this preliminary analysis, one has presented the notion of collective intelligence. This notion is unavoidable when on simply observes that an organization is not a monolithic entity, but an entity made up of other entities. Its intelligence cannot be ascertained to a single locus, or, more exactly, it can be improved by assuming that it depends on all the people inside the organization and the interactions modes among people that are in effect at a given time. This notion also stands as one which application will lead to sustainability, as intelligence has been defined as the capability to attain a goal or solve a problem and being or becoming sustainable, and hence evolutionary, is a goal or problem to solve for every organization.

One has listed some known properties of intelligent collectives with a small number of people – Natural CI. The constraints in human communication which made impossible that these properties be maintained when the number of people in societies grows by hundreds, thousands or millions, can be overcome, in principle, trough the use of computer and communications technology leading to Global CI. Basic actions have been indicated to foster collective intelligence in an organization. In particular attention has been given to the social support of decision, indicating results of recent research in the subject.

To end up this excursion one has considered, through the perspective of collective intelligence, the distinctive feature of businesses inside organizations: the simultaneous existence of owners and employees and access to profit. It has been argued that this is a source of a potential conflict among people in a business, incoherent with the development of its collective intelligence. It has been argued that from the standpoint of collective intelligence it makes complete sense, indeed it becomes of necessity, that businesses will extend the role of owners to all their people.

Perspectives for future research are very wide as the study of collective intelligence is in its infancy and so are the development of techniques and systems following from insights given by the study and investigation.

ACKNOWLEDGEMENTS

FCT (the Portuguese Foundation for Science and Technology) has funded the research underlying this paper through its Programa Plurianual.

The author wishes to thank Goran Putnik for incentive to write the paper and Jane Cull for patience in calling his attention to circularity in autopoiesis.

References

[1] Private Sector. Wikipedia – The Free Encyclopedia. Retrieved 2008-06-03 from: http://en.wikipedia.org/wiki/Private_sector
[2] Maturana, H. & Varela, F., Autopoiesis and Cognition: the Realization of the Living. Boston Studies in the Philosophy of Science 42, R. Cohen and M. Wartofsky, Eds. (1st ed. 1973) 1980, Dordecht: D. Reidel Publishing Co.
[3] Maturana, H. & Varela, F., The Tree of Knowledge: The Biological Roots of Human Understanding. 1987, Boston: Shambhala Publications.
[4] Varela, F., The Creative Circle: Sketches on the Natural History of Circularity, in From the Invented Reality, P. Watzlavick Editor. 1984, New York: Norton Publishing. Available from : http://www.lifesnaturalsolutions.com.au/articles.php
[5] Mingers, J., Self-Producing Systems. 1994, Kluwer Academic/Plenum Publishers.
[6] Autopoiesis. Wikipedia – The Free Encyclopedia. Retrieved 2008-06-03 from: http://en.wikipedia.org/wiki/Autopoiesis
[7] Heylighen, F., The Global Superorganism, in Principia Cybernetica Web (Principia Cybernetica, Brussels) F. Heylighen, C. Joslyn & V. Turchin, Eds. 2005. Retrieved 2006-12-02, from: http://pespmc1.vub.ac.be/papers/PapersFH2.html
[8] Ashby, W. R. An Introduction to Cybernetics. 1956, London: Chapman & Hall.
[9] Garrido, P., Collective Intelligence, in Encyclopedia of Virtual and Networked Organizations, G. Putnik & M. Cunha, Eds. 2008, New York: IGI Global.
[10] Minsky, M., The Society of Mind. 1987, Simon and Schuster.

[11] Szuba, T. M., Computational Collective Intelligence. 2001, John Wiley & Sons.
[12] Handbook of Collective Intelligence. 2008, The MIT Center for Collective Intelligence. Retrieved 2008-06-03 from: http://scripts.mit.edu/~cci/HCI/index.php?title=Main_Page
[13] Collective Intelligence. Wikipedia – The Free Encyclopedia. Retrieved from: http://en.wikipedia.org/wiki/Collective_intelligence
[14] Noubel, J. F., Collective Intelligence, the Invisible Revolution. 2004, TheTransitioner.org. Retrieved 2006-12-02 from: http://www.thetransitioner.org/wen/tiki-list_file_gallery.php?galleryId=1
[15] Zara, O., Managing Collective Intelligence: towards a new corporate governance. 2004, Axiopole Publishing. Retrieved 2006-12-02 from http://www.axiopole.com/pdf/Managing_collective_intelligence.pdf
[16] Surowiecki, J., The Wisdom of Crowds. 2004, Doubleday.
[17] Garrido, P. & Faria, N., Design of a Social Decision Support System for Organizations, accepted for publication in Proceedings of the Controlo 2008 – The Eight Portuguese Conference on Automatic Control, J. Boaventura, Editor.

HOW TO ORGANIZE FOR LOCAL RESOURCE GENERATION

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Abstract Generation of recourses is a central issue for sustainability of companies. The paper deals with two research questions: "Is decentralized generation of recourses a possible way to reach sustainability in modern work life?" and "What prerequisites have to be formed by organizations and managers to reach decentralized generation of recourses? ".

Theoretical base for the discussion is complex adaptive systems theory. Three requirements for sustainable decentralized resource production are deduced; worker's autonomy, worker's integration in the organization and demands on increased fitness.

Empirical bas for answering the questions is studies of four different Pharmacy-districts, each with a different organizational solution. Three sources of data are used: Interviews with the four Pharmacy-district managers. Questionnaire to all employees. The balance scorecard of the company.

Two of the districts may have reached an unbalance at system level between autonomy and integration. The other two districts have similar scores of medium for both autonomy and feeling of integration. One of the balanced districts has also a manager focusing bottom-up change processes. This district has both the strongest resource generation and a leading position in increasing efficiency and customer satisfaction, and thus sustainability.

Decentralized recourse generation is one way to reach sustainability, and co-existence of both autonomy and integration of employees combined with a leadership of transformative character is favorable for this.

Keywords: Research paper, sustainability, complex systems, autonomy, integration, resource generation.

1. INTRODUCTION

"The core concept of sustainable work systems is that the resources deployed are regenerated by the system" (Docherty et al., 2002), p 11). The aim of this paper is to describe one way to organize for generation and regeneration of resources. One may differentiate between finite, regenerative (e.g. technology, material and peoples physical and mental health) and generative resources. (Moldaschl, 2002). This paper will focus on the management of generative resources, i.e. resources which are created and amplified when they are used, e.g. human capacities like skill, creativity, knowledge and trust.

Centralized and decentralized resource management are two fundamentally different ways to organize for generation and regeneration of resources. A historical review over human societies (Diamond, 2006) show examples of both of them. Japan 1650-1868 is an example of successful centralized resource generation. Before 1650 Japan had an era with peace and prosperity resulting in a population boom. Growing population and richness led to an extensive need of wood to make houses, elite monuments and ships. This resulted in deforestation and a similar situation that led to a collapse of societies like Eastern Islanders, Maya, Rwanda and Haiti. But in Japan the Shoguns formed a strategy 1650 including: official sparing ideology, stable population, more seafood less farming, new fishing techniques, ownership of sea adjacent to land, fertilizers, inventory and control of cutting of trees. A condition for long term strategies with strong short term disadvantages, is a ruling class who believe that their descendants are dependent on the long term success of the society (ibid p 305). The Shoguns of Japan were examples of such long term committed leaders.

Translating the example of Japan to work life; for sustainable centralized resource production in companies to function, managers have to be long term committed to the enterprise. This is not the case in most companies. Modern corporate governance is characterized with impersonal ownership and frequent change of CEO. The turnover rate of CEO:s was over 13 % in a study of 683 non-financial UK listed companies from 1993 to 1998 (Hillier et al., 2005). Of the 2,500 largest companies worldwide, close to 15% appointed a new chief executive in 2004 (McKeon, 2005). If sustainability based on centralization seems to be questionable in a modern work life, how about a decentralized solution?

An example of successful decentralized resource generation is New Guinea Highlands with 7.000 years of sustainable food production in an isolated area, a unique historical record (Diamond, 2006). They have developed an advanced agri- and silvi-culture. In New Guinea Highlands decisions are traditionally reached by everyone sitting down together talking. There are ”big-men” – influential personalities, but there are no chiefs. Sustainable decentralized resource production is dependent on interaction giving members of society a possibility to see and take interested in the entire society (ibid p 427).

The first conclusions of this article are that sustainability based on centralization may not be applicable in most modern work life and that there exist historical examples of sustainable decentralized generation and regeneration of recourses. The research questions of the paper are, based on these conclusions:

What prerequisites have to be formed by organizations and managers to reach decentralized generation of recourses?

Is decentralized generation of recourses a possible way to reach sustainability in modern work life?

Resource generation is measured as an ability of the company to adapt and innovate. This article deals with sustainability for organizations; pharmacy districts, and focus two of the stakeholders: the owner, and the customers. Sustainability is measured as a growth in both efficiency and customer satisfaction.

2. COMPLEX ADAPTIVE SYSTEMS THEORY

Sustainable decentralized resource production is dependent on interaction. Complex adaptive systems theory is dealing with emergence of structures and resources in interaction between autonomous and integrated actors (Marion, 1999). Complex systems is also meant to be the natural way of living objects and creatures to reach sustainability (Cohen and Steward, 1994).

2.1. Complex systems and autopoiesis

Complexity lies on the edge between order and chaos (Kauffman, 1995). Order will reign in a system where the actors are well integrated and have small chances to act autonomously. In a classical industrial productions system for example, standardization and centralized control is used to integrate specialized work processes ensuring that they act together producing the goal. Such high degree of integration and low degree of autonomy give an ordered and stable production, but adaptation and creativity will be a problem. In a system where actors are autonomous, but not integrated, the opposite will occur. Each competent actor will be able to autonomously ensure good adaptation to the respectively local situation. But since they are not integrated they will soon act individually towards individual goals, and the company will dissolve into a bunch of individual entrepreneurs.

The dynamics of complex systems gives possibilities of sustainability, because of two reasons. Firstly, adaptation on system level, through autonomy of parts the adaptation and innovation towards increased fitness is possible and, through integration, co-operation towards the same goal and thus increased fitness for the whole system is possible. Secondly, complex systems have autopoiesis, meaning that they produce themselves and resources needed (Maturana and Varela, 1987). The system is emerging from inside, not designed by an outsider (Capra, 2002). It is the co-workers who generate it and its resources through a self-generative and auto-catalytic processes where the resources needed, and thus used, will be strengthen. This self-production, or decentralized production of resources, is the focus of this paper.

2.2. Autonomy and integration in organizations

Theoretically an organization with integrated autonomy for co-workers will be a complex system (Backström, 2004). Different kinds of control used in organizations to integrate the actions of the workers into the operation of the company are: direct control, bureaucratic control, technological control and normative control. A mixture of these is normally used in companies. A high degree of normative control may be a way to have both autonomy and integration at the same time. Normative control consist of socially constructed structures like a common vision (Källström, 1995), a company culture (Alvesson and Willmott, 2002), an institutionalized praxis (Berger and Luckmann, 1966), a relatonic (Backström and Döös, 2008) and a membership (Luhmann, 1990).

Interaction is important to make social construction possible. Quantity and quality of interaction are central themes in articles about leadership from a complexity perspective, see e.g. (Backström et al., 2006, Surie and Hazy, 2006, Uhl-Bien et al., 2004). Studies of team work has shown that normative control may develop into concertive control, where colleagues restrict each others autonomy more strict than any leader possibly could (Barker, 1999). A former study at one of the organizations studied in this paper, below named the Integrative Organization, indicate signs of concertive control (Göransson, 2003).

2.3. Urge for fitness

There must be a need for adaptation for complex dynamics to develop. In complex systems there is no leader recognizing the need to adapt, but the aggregation of individual actors. Some feedback mechanisms on system level give individual actors reasons to adapt their actions to increase the fitness of the system. To reach sustainability through decentralization, the urge to change has to be felt by the co-workers. Feed-back processes, showing the consequences of how you choose to work in specific situations, are important motives for development. The leadership is also important for this. Transformational leadership, developed in the end of 20th century, focus development and uses interaction motives like a common vision (Bass, 1998, Burns, 1978).

Using the model the research questions of the paper can be translated into two hypotheses to be tested:

1. Autopoiesis, or decentralized generation of recourses, occur in complex organizations, where co-workers to a high degree are autonomous, integrated in the organization and recognize an urge to change the organization toward increased fitness.
2. Organizations with decentralized generation of recourses exist and are sustainable.

3 METHOD AND DATA

Multiple sources of evidence (Yin, 1989) have been used to give a more solid base for conclusions. This includes:

1. Interviews with district managers.
2. A questionnaire given to all employees.
3. Material from Apoteket's scorecard system, from 2nd quarter 2002 to 1st quarter 2004.

To enhance the validity, a first version of synthesis and interpretations of data have been reproduced to the districts and been discussed and improved.

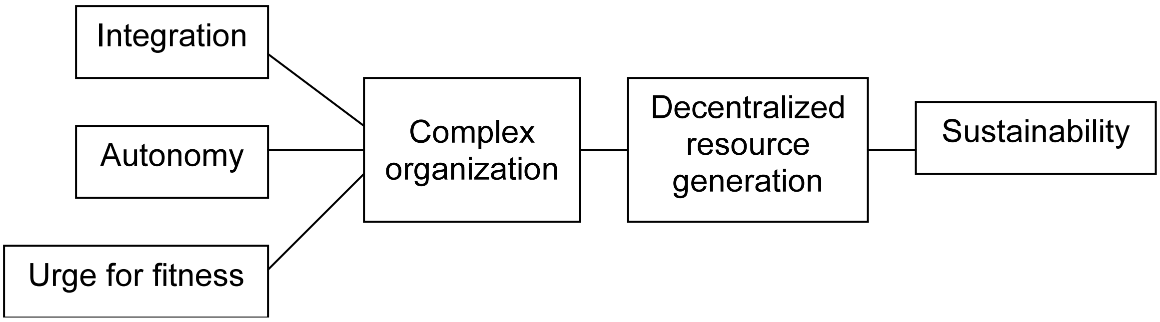

Fig. 1. The model of the article

3.1. Interview with the District Manager

The interviews conducted with the four district managers were semi structured, and lasted approximately 60 minutes each. The questions concerned the way the organization was supposed to function and revolved around five main themes, and each theme contained several subtopics.

The themes were:

- Organizational structure.
- Information flow.
- Management control.
- Leadership.
- Learning.

The interviews were taped and transcribed. Results of the interviews are used to describe each pharmacy-district under heading *4.3. Descriptions of the four cases* and in the interpretation of the results in the discussion.

3.2. Questionnaire study

The questionnaire is designed to measure conditions of collective learning and learning according to a model of collective learning (Backström, 2004). The number of people at the districts at the moment of the study was 254. All of them were asked to answer the questionnaire and the answering number was 226 (89%). The frequency of missing answers varies between 2-14

% for different questions. All measured differences between districts are real and significant, since almost all people have answered the questionnaire.

Questions used in this paper and variables formed

Questions from the questionnaire used in this paper are presented below, translated from Swedish to English. Answers are given on Likert scales with 1 as "I do not agree" and 7 as "I agree fully", except questions concerning Integration where alternatives are No=1 or Yes=2. Scales based on mean values for several questions have been used to measure some phenomenon. Cronbach's alpha is above 0,7 for all scales except for "Ability to adapt" with alpha=0,57.

Autonomy. Scale of three statements:

- I decide myself what to do in work. (Hagström and Sconfienza, 1995)
- I have influence on the contents of work. (Hagström and Sconfienza, 1995)
- I may take my own initiatives in work. (Hagström and Sconfienza, 1995).

Hinders to autonomy:

- I sometimes feel hindered to choose the way to work I consider best.

Integration. Scale of three questions:

- Do you use to reflect upon how your work influences the achievement of goals for the district?
- Do you use to reflect upon how your work influences colleagues in the district?
- Do you feel solidarity with colleagues in the district?

Style of leadership of the district manager. One question for each manager's task; reproduction, transformation respectively integration (Backström et al., 2006):

- My district manager devotes a lot of time to manager tasks like e.g. planning, giving instructions and standpoints, administration etc.
- My district manager devotes a lot of time to the thinking of the personnel (e.g. formulate and disseminate visions, values, strategies etc.).
- My district manager devote a lot of time to the social climate (e.g. listening, trouble-shooting, emphasizing team-spirit and co-operation, formulating conflicts, arranging talks etc)

Organization's ability to adapt. Scale of two statements:

- At my pharmacy we are quick to learn from other workplaces, even from outside the Apoteket AB.
- We rapidly find new ways to work at my pharmacy when conditions change (e.g. introduction of new technology, changes in staffing, new routines).

Organization's ability to innovate. Scale of four statements:

- We develop new goals of our own at my pharmacy (e.g. goals for additional aspects than the district).
- We develop new goals of our own at my district (e.g. goals for additional aspects than the Apoteket Hälsa).
- We are sometimes first with new ideas and ways to work at my pharmacy.
- We are sometimes first with new ideas and ways to work at our district.

3.3. Balanced scorecard

Computer printouts from Apoteket AB's balance scorecard system were provided by the region managers.

Efficiency is measured by the operational costs divided by the weight of volume. Operational costs are calculated using total costs, excluding costs of goods. Weight of volume is the sum of different weights of order items relating to the sales of goods. The company is state owned and has monopoly in selling drugs in Sweden. It does not have control of the price setting of their products, which makes this measure more suitable than ones based on receipts in relation to costs.

Customer satisfaction is measured by Apoteket's own Scorecard survey, named *Very satisfied customer*, a questionnaire conducted quarterly that contains five questions with 1 is "I do not agree" and 5 is "I agree fully". Each question contains the possibility to answer, "I don't know". Questions were:

- Today I could get service fast.
- Today I got the products I needed.
- Today I was treated well.
- Today I got the advice I needed.
- Today I am satisfied with my visit to the pharmacy.

4. CASES INCLUDED IN THE STUDY

The study is performed 2004 at Apoteket AB, a the state owned Swedish pharmacy chain with monopoly in selling drugs in Sweden. The revenues of 2002 were about 3.500 million Euros. Apoteket AB's business plan from 2001 was the start of a re-organization process for the whole company:

- new divisions developed
- more time to be used for competence demanding tasks like guidance concerning drugs and of pro-active health care
- a shift in the focus towards the customers
- a shift from planning and control towards involvement and meaning.

Apoteket AB's new organization has been studied from a perspective of learning organization by (Ekman, 2004). The study shows e.g. that senior managers have perceived the control signals and started to lead through ideas in order to create a greater responsibility, and to use market value thinking (p 206).

4.1. Apoteket Hälsa

The pharmacies studied in this paper belong to the division Apoteket Hälsa (Pharmacy Health). This division includes all 800 pharmacies in Sweden situated outside hospitals, with about 10.000 employees. The division where divided into 10 geographical regions, and each region into districts, which is the lowest level in the organizational structure. Each district includes typically 5-10 pharmacies. The District Manager is the first-line manager, with responsibility for about 70 employees. There was no supervisor at each pharmacy anymore; this lowest level of hierarchy was taken away and the number of managers was reduced from about 800 to 144.

Apoteket Hälsa has further developed the re-organization with thoughts similar to integrated autonomy. The instructions for the Districts Managers includes: *"Everybody takes the risk and will act autonomously within the frames of the laws and regulations, and guiding principles and policies* that *are well known to each co-employee"*. The task of the District Manager was described as not to supervise daily work, but to design an organization with distributed responsibility. The greatest amount possible of responsibility and authority should be situated as local as possible. A balanced scorecard was developed, with five areas of goals: Financial, Customers, Processes, Co-employees and Development.

The design of organization of each pharmacy district was a decision for respectively District Manager. The result was districts with almost the same conditions, tasks and types of customers, but with different types of organization.

4.2. Included districts

This paper includes four pharmacy-districts, each with different organizational solutions. The districts where selected by two middle managers as being in front when it comes to the re-organization among their districts. The included districts are:

1. The district with Team Organization (Team-org), with 73 employees in five pharmacies.
2. The district with an Integrative Organization (Integrat), with 43 employees in five pharmacies.
3. The district with Learning Organization (Learn-org), with 56 employees in four pharmacies.
4. The Ordinary district (Ordinary), with 82 employees in eight pharmacies.

For the first three, the names are the characterization of the districts made by the middle managers, when they first presented them for us. Characteristics that later were confirmed by the researchers as fitting their way to function. The fourth district was introduced as the district with reflection groups, but since it turned out that this activity was not in full operation when the study was performed, this district has been named Ordinary.

The district with Team Organization (Team-org)

The district has teams as its main organizational structure. The district manager is using the team managers when giving information, instructions etc to the employees. The district manager describes the Teams as a solution to problems caused by one of the pharmacies being unusually large. This pharmacy was divided into three virtual pharmacies of normal size within the old premises, each with its own team leader and staff. There are seven team leaders with a group of less than 15 employees each. Five of the Teams are the same as the staff of the five pharmacies of normal size and team leader for them is the previous pharmacy supervisor. Three Teams are the teams of the virtual pharmacies in the large pharmacy. Their leaders have been selected as potential top-managers and received a formally established post as team leader. The district manager organizes only one type of recurrent scheduled meetings; the Manager meeting each second week.

The district with an Integrated Organization (Integrat)

The manager describes the organization as flat and decentralized. She used a model developed by (Ekstedt and Jönsson, 2001) based on Senge (Senge, 1993) when she formed the organization. She emphasizes a wish of broad participation, where every employee is included and where no one has more power than others. There is no level of managers under her. This was the only pharmacy district in the study that followed the intention of the re-organization to take away the lowest level of managers. She talks about the hard work to erase the old role as managers of the previous pharmacy supervisors.

The organizational structure of the district is described as the structure of two types of meetings:

- Responsibility Meetings.
- Pharmacy Meetings.

Each employee is part of both a group with an area of responsibility and a pharmacy and has to attend to a scheduled and obligatory one and a half hour meeting each week, alternately of the two types.

At Responsibility Meetings the group has to manage their area of responsibility:

- to analyze, make decisions and follow up,
- to write the plan of activity to the company,
- to deal with the goals set by the company and with the scorecard from the company showing how things went on in the district over the last year.

At Pharmacy Meetings suggestions from Responsibility Meetings are processed and decisions made in the Responsibility Meetings are implemented.

The district with Learning Organization (Learn-org)

The operative organization is the same as before the organizational change of Apoteket AB 2002. The pharmacy supervisor is still in charge; all her former responsibilities and authorities are re-delegated to her from the district manager. The district manager and the four pharmacy supervisors attend to weekly manager meetings.

The re-organization of the Learning Organization concerned self-organized change. It consists of the manager's communication of visions and models about learning and development, and some structures and activities. The Egg is the more solid part of the Learning Organization. It consists of a group of four employees with an area of responsibility each, they meet weekly. The task of the Egg is to regularly communicate with other employees, encourage problem solving and creativity, notice all the ideas among the employees and support employees with ideas to form projects around the idea. The development projects are called Clouds. The Egg is giving resources to the Clouds and protecting them from short sighted demands. The Egg is also producing an internal paper (The Eggs-press) informing about new Clouds and the work of the Clouds.

The Ordinary district (Ordinary)

The manager describes an organization that almost is the same as before the organizational change of Apoteket AB 2002. Pharmacy supervisors are still in charge of each respectively pharmacy. The manager in this district underlines that the start up of two new pharmacies in her district have taken a lot of effort and resources from the reorganizing agenda. It is a reasonable conclusion from the interviews that most is as before when it comes to the practice in this district. The Ordinary district may thus be seen as a "control group" in this study.

5. RESULTS

5.1. Prerequisites for sustainability through decentralized generation

Autonomy

Autonomy varies between 4,86 and 5,13 in the different districts, Hinders to autonomy varies more; between 3,12 and 4,27 (see table 1). The management style of the team managers of the Team Organization give room for more autonomy compared to the other districts. The Integrative organization district has more Hinders to autonomy than the others.

	Team-org	Integrat	Learn-org	Ordinary
Autonomy	5,13	4,97	4,86	5,11
Hinders to autonomy	3,12	4,27	3,51	3,69

Table 1 Degree of autonomy in the four districts.

Integration

Employees feels most integrated to the Integrative District and least in the Team organization (see table 2).

	Team-org	Integrat	Learn-org	Ordinary
Integration with district	1,75	1,90	1,84	1,79

Table 2 Feeling of integration with the district, for each of the four districts.

Leadership

The manager of Learning Organization is spending much time on transformation, i.e. formulate and disseminate ideas and visions and the manager of Integrative organization on integration, i.e. on social interaction and co-operation (see table 3).

Time of manager spent on:	Team-org	Integrat	Learn-org	Ordinary
Reproduction	5,70	5,37	5,34	4,89
Transformation	4,89	5,51	5,92	4,98
Integration	4,52	5,17	4,56	4,65

Table 3 Type of leadership of the district manager in the four districts. How much time the employees think the manager spend on different tasks.

5.2. Resource generation

The Ordinary District has less resource generation than the other three (see table 4). Especially the ability to innovate is higher in the Learning Organized District.

	Team-org	Integrat	Learn-org	Ordinary
Ability to adapt	4,39	4,27	4,44	3,76
Ability to innovate	4,27	4,55	5,12	3,34

Table 4 Degree of resource generation in the four districts.

5.3. Sustainability in the four districts

All four districts have about the same costs for operation per weight volume during year 2002, 40-44 SEK, and 2003, 43-46 SEK (see figure 2). But in 2004 the three districts that made an organizational change have decreased their costs, 38-41 SEK, while the Ordinary District has continued to increase its costs to a bit more than 46 SEK.

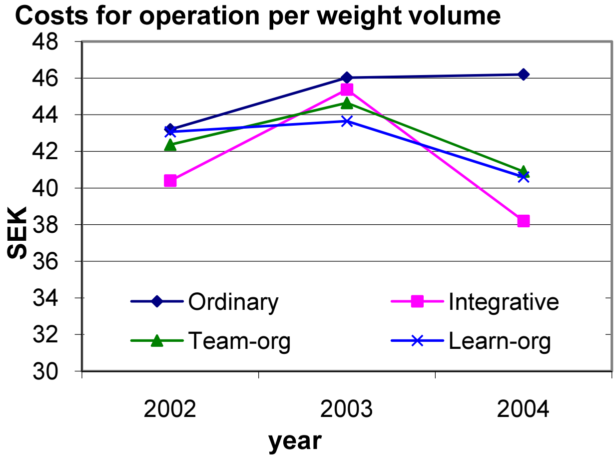

Fig. 2. Efficiency, measured as cost for operation per weight volume, in respective district, average per year 2002, 2003 and 2004 respectively.

Customer satisfaction of the pharmacies in the districts has changed differently for different districts (see figure 3). The Team Organization made a great improvement between 2002 and 2003 and stayed at the higher level in 2004. The Integrative Organization and the Learning Organization made a dip in 2003, but came back to higher values in 2004, where the Learning Organization has the highest values of all four. The Ordinary Organization has had a slow but steady increase over the two years.

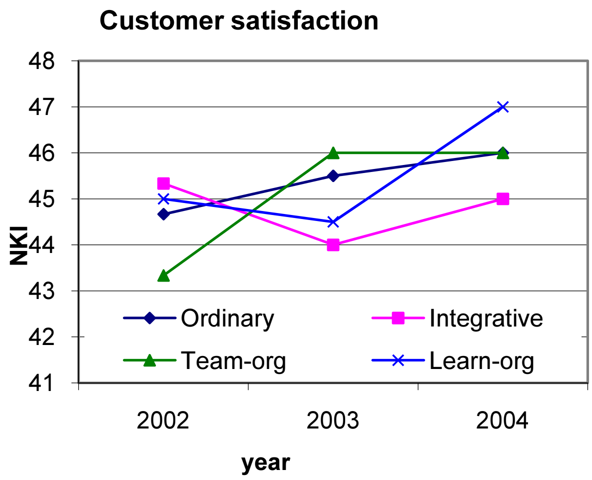

Fig. 3. Customer satisfaction in respective district, average per year 2002, 2003 and 2004 respectively.

6. DISCUSSION AND CONCLUSIONS

The study has some obvious weaknesses, e.g. it includes only four cases, and the phenomena studied are complex and context sensitive. But it also has strengths. The setting is relatively controlled, including four organizations with a lot in common, but with different organizational structures. The study can be seen as an empirical experiment, where the theoretically based model is tested in reality. Is the model strengthened by the results, or do the results give reasons to question the thinking presented in the theory section?

6.1. Prerequisites needed to be a complex organization

The Integrative Organization has a higher value of Hinders for autonomy than the others. This may be due to concertive control in this district. Low autonomy and high integration in this district may cause unbalance at system level. The Team Organization district may have an unbalance in the other direction; high autonomy and low integration.

The districts with Learning Organization and Ordinary organization have similar scores of medium for both autonomy and feeling of integration, both may have a balance. But there is a huge difference between them when it comes to the time their manager spends on the transformation task.

The results indicate that the Learning Organization has the best prerequisites for complex dynamics and thus for decentralized resource generation. For the other three it is more unclear, it depends on what is most important; autonomy, integration, the balance between them or an urge for bottom-up transformation.

6.2. Existence of resource generation and sustainability

The Learning Organization has the top scores when it comes to resource generation, especially the ability to innovate, but also the ability to adapt. The Ordinary Organization has the lowest scores for resource generation, the other two districts lie in the middle.

The efficiency of all four districts was about the same for the first two years after the organizational renewal of Apoteket AB, but in the third year there is an increased efficiency for all districts except the ordinary organization that kept about the same efficiency. It naturally takes some time for effects on output, after an organizational renewal.

The implementation of a Team-Organization seems to have had almost immediate positive effects on customer satisfaction. The Learning Organization district did not change its operative organization very much and consequently their customer satisfaction is about the same in the beginning, but after two years there is a considerable increase in customer satisfaction, which may be due to continuous improvements initiated by their Learning Organization. The Integrative Organization has a heavy decrease in customer satisfaction in the beginning, which may be due to the renewal being most revolutionary at this district. But in the third year they have almost got back to their initial figures. The customer satisfaction has increased steadily for the Ordinary Organization over the three years. But compared to the changes of the other districts this increase is less pronounced than the decrease of efficiency. They may have bought customer satisfaction at the expense of more costs, most likely personnel costs, per weight of volume.

6.4. Conclusions

The first research question of the paper is “What prerequisites have to be formed by organizations and managers to reach decentralized generation of recourses?”. The theory based hypothetical answer was that autonomy, integration and urge for fitness are important. The empirical results strengthen this hypothesis. The three districts that implemented organizational activities towards integrated autonomy all have better resource development than the Ordinary district. The Learning district has the strongest resource generation suggesting that there is better with a balance on system level when it comes to integration and autonomy.

The second research question of the paper is “Is decentralized generation of recourses a possible way to reach sustainability in modern work life?”. Both the theory based hypothesis and the empirical results give yes as the answer to this question. The three organizations with higher resource generation have also a better development in efficiency. The picture when it comes to customer satisfaction is more unclear, but at least two of the three have a good development also in this indication of sustainability.

High degree of autonomy and integration, a balance between autonomy and integration at system level and an urge for bottom-up transformation co-varies with a high degree of resource generation. And a high degree of resource generation co-varies with a high degree of sustainability.

References

ALVESSON, M. & WILLMOTT, H. (2002) Identity regulation as organizational control: Producing the appropriate individual. *Journal of Management Studies,* 39**,** 619-644.

APPELBAUM, S. H., HÉBERT, D. & LEROUX, S. (1999) Empowerment: power, culture and leadership - a strategy or fad for the millennium? *Journal of Workplace Learning,* 11**,** 233-254.

BACKSTRÖM, T. (2004) Collective learning: a way over the ridge to a new organizational attractor. *The Learning Organisation,* 11**,** 466-477.

BACKSTRÖM, T. & DÖÖS, M. (2008) Relatonics - a key concept for networked organizations. IN PUTNIK, G. D. & CUNHA, M. M. (Eds.) *Encyclopedia of networked and virtual organizations.* Hershey, PA, Idea Group Inc.

BACKSTRÖM, T., DÖÖS, M. & WILHELMSON, L. (2006) Chefen som regissör - ledarskap och medarbetarskapets självorganiserande processer. IN OTTER, C. V. (Ed.) *Ledarskap för fria medarbetare - En antologi.* Stockholm, Arbetslivsinstitutet.

BARKER, J. R. (1999) *The discipline of teamwork - Participation and concertive control,* Thousand Oaks, California, SAGE.

BASS, B. M. (Ed.) (1998) *Transformational leadership: Industry, military, and educational impact.,* London, Lawrence Erlbaum Associated, Publishers.

BERGER, P. L. & LUCKMANN, T. (1966) *The social construction of reality. A treatise in the sociology of knowledge.,* New York, USA, Doubleday & Company.

BURNS, J. M. (Ed.) (1978) *Leadership.,* New York, Harper & Row.

CAPRA, F. (2002) *The hidden connections,* London, Harper Collins Publishers.

COHEN, J. & STEWARD, I. (1994) *The collapse of chaos - Discovering simplicity in a complex world,* Harmondsworth, England, Penguin books.

DIAMOND, J. (2006) *Collapse - How societies choose to fail or survive,* London, Penguin Books.

DOCHERTY, P., FORSLIN, J., SHANI, A. B. R. & KIRA, M. (2002) Emerging work systems - From intensive to sustainable. IN DOCHERTY, P., FORSLIN, J. & SHANI, A. B. R. (Eds.) *Creating sustainable work systems - Emerging perspectives and practice.* London, Routledge.

EKMAN, A. (2004) Lärande organisationer i teori och praktik. Apoteket lär. Uppsala, Department of Education.

EKSTEDT, E. & JÖNSSON, G. (2001) *Att leda platta organisationer - utan att själv bli tillplattad - En praktisk arbetsmodell.,* (To manage flat organisations - without beeing flattened - A practical model) Stockholm, Norstedts Juridik.

FLAMHOLTZ, E. G. (1986) *How to make the transition from entrepreneurship to a professional managed firm,* San Fransisco, Jossey-Bass.

GÖRANSSON, S. (2003) Från struktur till delaktighet på apoteket Gladan - Individens handlingsutrymme samt stressupplevelse i den decentraliserade organisationen. (From structure to participation at the pharmacy Gladan - the allowed space to act of the individual and the experience of stress in the decentralised organisation.). *Department of Education.* Paper #60. Stockholm, University of Stockholm.

HAGSTRÖM, T. & SCONFIENZA, C. (1995) Den goda arbetsmiljön. Ungdomars villkor nu och i framtiden. (The favourable work environment. Young people's situation now and in future.) Stockholm, National Institute for Working Life.

HILLIER, D., LINN, S. C. & MCCOLGAN, P. (2005) Equity issuance, CEO turnover and corporate governance. *European Financial Management,* 11**,** 515-538.

KAUFFMAN, S. (1995) *At home in the universe - the search for laws of self-organization and complexity,* New York, USA, Oxford University Press.

KÄLLSTRÖM, A. (1995) *I spetsen för sin flock - Normer för svenskt management,* Göteborg, Gothenburg Research Institute, Handelshögskolan, Göteborgs Universitet.

LUHMANN, N. (1990) *Essays on self-reference,* New York, Colombia University Press.

MANZ, C. (1992) Self-Leadership . . . The Heart of Empowerment. *The Journal for Quality and Participation,* 15**,** 80.

MARION, R. (1999) *The edge of organization. Chaos and complexity theories of formal social systems,* Thousand Oaks, CA, USA, SAGE Publications.

MARION, R. & UHL-BIEN, M. (2002) Complexity v. Transformation: The new leadership revisited. *Conference on complex systems and the management of organizations.* Ft. Meyers, Florida.

MATURANA, H. & VARELA, F. (1987) *The three of knowledge,* Boston, Shambhala.

MCKEON, M. (2005) Facing change, CEO adapt. *Wall Street Journal***,** B.2.

MOLDASCHL, M. F. (2002) A resource-centered perspective. IN DOCHERTY, P., FORSLIN, J. & SHANI, A. B. (Eds.) *Creating sustainable work systems. Emerging perspectives and practice.* London, Routledge.

SENGE, P. M. (1993) *The fifth discipline : the art and practice of the learning organizationt,* London, Century Business.

SURIE, G. & HAZY, J. K. (2006) Generative leadership: Nurturing innovation in complex systems. *Emergence: Complexity & Organization,* 8**,** 13-26.

UHL-BIEN, M., MARION, R. & MCKELVEY, B. (2004) Complexity leadership theory: Shifting leadership fron the industrial age to the knowledge era. *Academy of Management.* New Orleans, LA.

YIN, R. K. (1989) *Case study research. Design and methods,* Newbury Park, SAGE publications.

TOWARDS COMMUNICATION BASED LEADERSHIP IN KNOWLEDGE ORGANIZATIONS

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Abstract: We analyse the challenges arising from the interaction of top-down type management and the research built on a bottom-up basis. We present four central constructions that the management and personnel of a research organization tend to interpret very differently: These are the tension between freedom and control, formation of research strategies, applicability of business management models to research organizations, and the meaning of structural changes. Finally, we suggest some arenas and tools for facilitating a constructive interaction between the standpoints of top management and research personnel.

Keywords: Organizations, strategies, emerging, learning, managing, research & development

ABSTRACT

We analyse the challenges arising from the interaction of top-down type management and the research built on a bottom-up basis. We present four central constructions that the management and personnel of a research organization tend to interpret very differently: These are the tension between freedom and control, formation of research strategies, applicability of business management models to research organizations, and the meaning of structural changes. Finally, we suggest some arenas and tools for facilitating a constructive interaction between the standpoints of top management and research personnel.

BACKGROUND

”I feel that creating a discussion atmosphere is extremely important, because there is a huge energy in people. If you succeed in focusing it towards creative activities, it definitely shows up in the results.” Päivi Kärkkäinen, the new General Director of the Finnish National Opera, recently crystallized her management philosophy this way on the TV news. In our opinion, crucial aspects in managing creative knowledge organizations today are the ability of top and middle managers to rationalize necessary changes and to act as bridge builders between the efficiency pressures arising from the operating environment and the strategic initiatives created by personnel.

In Finland, the public sectoral research organizations are facing strong pressure both to increase their functional efficiency and to redirect the contents of the work. As described in the report of the Finnish Sectoral Research Council [1], it has now been proposed to renew the guidance system to correspond to the content areas defined by the Council of State. To guarantee the impact of tax-paid research, in future a third of the research funding from the state budget should be distributed through orders by various ministries. An active public discussion is ongoing concerning the reasonability of this model. Professors of research organizations in particular have expressed their concerns that the model could further agitate the already tough competition for research funding, thus jeopardizing the opportunity to do long-term research.

The research organizations suspect that the architects of these changes may not be sufficiently aware of the dynamics and challenges of research work at the “grassroots level”. Taking the purchaser-provider model into use in research work would mean determining the research focus outside the organization, by whoever orders the work. In fact, the public research organizations are already familiar with this situation, because only part of their budget is covered by government funding. They are thus obliged to apply for further funding from various other sources. Altogether, the way in which the focus of research strategies is defined seems to evolve towards a more top-down directed process, while the research groups so far have had a lot of freedom to create new knowledge according to the needs of their customers and their own interests.

The recent discussion demonstrates a mismatch between top-down type managerial reforms and actual research work, which by contrast emerge from below. Within a single research organization it can happen that the striving by top managers towards coherent strategic management, and the inclination of research groups towards its autonomy easily form a communication gulf between management and personnel.

TENSION BETWEEN CONTROL AND FREEDOM IN RESEARCH WORK

Managing research work means constant balancing between two perspectives: on the one hand the research groups need adequate organizational freedom; and on the other new managerial tools for systematizing and controlling the functions are coming to the public sector. Research on product development teams has shown that both excessive freedom and excessive control tend to limit their creativity and ability to produce new ideas. In a study on product development groups at twelve industrial sectors, the sectoral development rate proved to be a central explaining factor. Product development teams in rapidly changing sectors benefited mostly from organisational freedom, while successful teams in more slowly developing sectors adopted practices more easily to make their operations more efficient and systematic. [3]

During their organic growth phase the Finnish public research organizations and research groups working within them were remarkably free to expand into new topics of research. They were allowed to recruit new researchers to create new openings, and the growth made them agile in captivating new research fields. Currently, many of those research groups, which are now in the mature phase of the life cycle, are facing a new problem: how can they redirect their knowledge towards new research topics and questions? Researchers' knowledge and motivation tend to be intertwined with the questions and applications that they already have been working on. Refocusing the knowledge and interests of existing personnel is considerably more challenging for organizations than educating a new generation of researchers.

Our studies on organizational changes and the dynamics of research groups have shown that the activities of research groups are strongly guided by the strategies created by individual pioneer researchers and research professors, which also can be termed the construction of a local research program [4 – 7]. The policy and focus definitions of top management are important as enablers of growth and in redirecting competences by allocating resources, distributing the governmental budget funding and providing funding for research infrastructure and means for internationalization.

As things stand, research groups working in fields that top managers consider promising and strategically important are allowed to grow, whereas those in “marginal” areas have to contend themselves with lesser managerial support. Top management desires to control the whole organization by e.g. using enterprise resource planning systems (ERP). At the same time, research groups struggle with the challenges posed by content renewal: how to be able to do research for solving problems at national, European and even global level. Research groups attempt to spread towards new application areas, which seems to be a prerequisite for being creative and producing something new. When a group has created an innovation in a certain application area, e.g. a new method or measurement tool, it can flexibly be transferred to another application area and provide an innovative new solution and new application areas [5]. The managerial logics, from its part, favours focusing and forming a ”critical mass” of experts. In these cross-swells the role of middle management becomes increasingly important.

It is thus obvious that the concerns and operational logics of management and research personnel do not always converge. Two world views seem to coexist simultaneously in the organizations: on the one hand the managerial view, being manifested in the classical organization theory and in the concept of managed change, and on the other hand the world of continuous change, unceasingly progressing according to the terms of mundane activities [7]. In our opinion, a major challenge for present research organizations is to enhance the interaction between these two different world views and the strategies emerging and created at different hierarchical levels of the organization, and to find new ways of combining them.

RESEARCH STRATEGIES – ARE THEY FORMED FROM THE BOTTOM OR TOP?

The literature on company strategies comprises roughly two different views on strategy formation mechanisms: The traditional, so-called planning school emphasizes the importance of rationality [e.g. 2, 8] and considers strategy formation as a managerial activity. The strategies are thus plans that are created by top management and implemented by personnel. As put by Mintzberg & McHugh [9], strategy then means essentially an intention. The other, incremental view sees the strategy as formed piecemeal, in small steps. It is then equally generated in a multifaceted developmental process by all actors in the organization. Mintzberg & McHugh [9] define strategy as a pattern in the stream of decisions or action. For instance, in research organizations strategies and research directions have been found to be strongly formed by the views and activities of individual pioneer researches and teams emerging around them [5, 6]. Mintzberg [10] and Currie & Procter [11] call this an emergent formation of strategy, occurring bottom up, as a combination of individual persons' strategies.

In applied research, new ideas are typically created in interaction with other research groups and the users of the research results. The researchers even often consider the connections to their own customers and global research community as more important than the connections within their own organization. E.g. VTT's present top areas of knowledge and expertise have been developed with strong connection to customers, in which the collaborative definition of research problems has played a crucial role.

What is thus the significance of top management in directing research? It provides research groups with prerequisites for growth and development by creating and maintaining connections at the strategic level, allocating funding, opening opportunities for creating the infrastructure (such as high-tech research tools, databases etc.) and recruiting new scientists and showing appreciation. The top management makes choices concerning research groups, for example what kinds of groups are allowed to grow and develop. This has also been perceived by Mintzberg and McHugh [9], who saw the role of management in strategy formation in creative organizations as that of a gardener: Strategies can take root anywhere in the organization where people have the capacity to learn and the resources to support it. Concerning managers, the most important thing is that they recognize the emerging bottom-up type strategies, or "weeds". The management can then effectively intervene in the unfolding actions when appropriate. Unconstructive weeds should be uprooted immediately, but if a weed seems to be capable of bearing fruit, it is worth watching, perhaps cultivating or even building a hothouse around, as Mintzberg and McHugh put it.

The development of a research group that is doing applied research could be characterized as that of a stem cell, for which the surrounding organization and working environment either provide favourable preconditions for growing or not. In exactly the same way as a stem cell is able on the one hand to sustain its non-differentiation or, on the other, to transform into differentiated cell types, a research group can simultaneously possess certain cumulating core of knowledge and a capability to expand into new knowledge application areas. Virkkunen [12] proposes that the group's realized strategy can then be seen as a combination, sometimes even internally ambiguous, of functional ideas produced by "grass-root-level" actors and managerial policy definitions. These initiatives are very different and arise from various directions. Often they are initiated in network contacts at different hierarchical levels. To make them confront, vital dialogue is needed between the hierarchical levels in the organization.

APPLICABILITY OF BUSINESS MANAGEMENT MODELS IN RESEARCH WORK

In the public sector, there is growing interest in the productivity of work and economical aspects. In the management of research organizations this is manifested by establishing models and tools of business management as dominant managerial tools and "spectacles" in assessing the organization's activities and status. It even seems that public research organizations have recently adopted models that were developed in the 1960s and 1970s for the needs for rational planning, follow-up and measurement in mass production, as presented by e.g. Galbraith [13] or Thompson [14]. The management monitors its organization using such concepts as share of project work, offer and order book and the forecasts related to them. The mental vitality of the organization is regularly assessed using personnel surveys covering the whole enterprise. In order to have an understanding of the condition of the entire organization it is necessary to keep watch on these issues, but from the research personnel's point of view it is problematic, because the content and qualitative results of research work is easily relegated to the background compared to these examinations.

While the top level of the organization attempts to stress the importance of structures, working processes and the brand and imago aspects, many internationally recognized researchers feel that the significance of the unique expertise and efforts of an individual or research team have almost faded out. The research group leaders are forced to balance between two different time spans: the long-term efforts in accumulating knowledge and short-term projects for satisfying the needs of their customers [5]. The present economically orientated management tools do not seem to provide adequate support for this dilemma. For long-term guidance, intra-organizational dialogue over the contents and future directions of research work is increasingly called for.

IMPORTANCE OF THE ORGANIZATIONAL STRUCTURE FOR RESEARCH WORK

Structural changes are today frequently used means with which management tries to adjust the functioning of an organization. According to the classical view, the organizational structure is a tool for implementing strategy [8, 13]. Indeed, modifying the internal boundaries of an organization both creates new connections between the actors and breaks well-functioning ones. Especially research groups that already have a strong and solid local research programme often see structural changes just as a disturbance to their work. The researchers feel that continuous internal organizational discussion and the need to re-establish their position in the new organizational structure require too much time and energy, which impairs concentration on the work and the development of external networks. Our studies have shown that successful and strong research groups survive and find their ways despite their surrounding organizational structure. Besides, the vision and strong network contacts of a research group may even make a transfer or growth into another organization possible, if the parent organization considers the group as incompatible with its current strategy or does not provide it possibilities for growth. Due to the common history, connections between researchers in this kind of ”hybrid group” that crosses boundaries may be even stronger than in an customary network between research organizations.

Personnel often experience structural changes as chaotic processes, which makes it impossible for them to recognize that they can also have positive effects in the long run. At VTT a major structural change was implemented in early 2006 to demolish the “silo-type” unit structure, which the top management saw as a source of internal barriers. According to Saari [6], this structural change has evoked increasing collaboration between researchers working in different fields and the emergence of new knowledge combinations. Similarly, merging VTT’s two research units in early 2002 created new organizational entities whose struggle with lifelines forced them to search for and find completely new strategic directions [7; cf. 15]. Structural changes tend thus to have ambiguous effects at the ”grassroots level”. For this reason they should only be assessed using a time span of several years; changes which personnel initially consider as disturbing or even destructive may still provide the research work with favourable growth and development impulses with delayed effects. Time and improvisation are needed before a structural change is realized at the practical level, as put forward by Weick & Quinn [16] and Tsoukas & Chia [17]. Recent research has shown that also the initiatives and motives of individuals and research groups play an important role in actively creating their own future in the new organizational context [18].

ARENAS FOR CONFRONTING THE REALITIES OF MANAGEMENT AND PERSONNEL

We feel that developing the dialogue between organizational hierarchy levels has crucial importance in constructing the future of a research organization. But how could the different realities of top management and personnel better meet, creating an atmosphere for mutual learning? In our opinion different arenas for face-to-face meetings have a central role. For instance, personnel meetings could be more functional if both management and personnel gave prepared presentations. Otherwise, the communication may easily become unidirectional and the discussion falters to an ”are there any questions?” structure. Even common coffee break meetings between management and personnel, without strict agendas, might prove useful. Basically, the point is simply everyday encounters and formation of a common learning process, for which the management has to ”dismantle” to meet the researchers and discuss future directions and challenges with them. This may at first require courage from both sides, but it also removes the necessity for managers to appear as “heroes” and emphasizes the view that leadership is something occurring between people, as phrased by Wilke et al. [19].

In building a bridge between the strategic goals emerging bottom-up and created top-down, the top and middle management are in key roles [20]. Nonaka and Takeuchi [21] even consider middle management as the core of an organization’s continuous innovativeness, so that the ideal organization is of a “from-the-middle-up-and-down” type. In our view, management and personnel should more actively discuss about the research strategies. As the direction of research seems to be made up of a stream of single research projects that are interconnected to each other, the management should not only assess this stream from an economical point of view but also on the basis of content. If the focus of the management’s communication is on monitoring parameters indicating economical profit and functional effectiveness, it does not optimally tune the dialogue between management and personnel.

In a research organization the top management plays the key role in starting and maintaining a discussion on the impact of realized projects and future directions of research. Today, research is expected to provide answers to societally important questions, which requires crossing the boundaries between different disciplines and interaction between various actors in the research field. To solve this challenge, the power sources based both on expertise and on hierarchical status should meet around the same table.

Completed research projects can be used for learning just as well at organizational level as within research teams. For instance, a research group could pause now and again to evaluate, firstly, what kind of impacts its work has had on their customers; secondly, how it has accumulated the organization's own knowledge capital; and thirdly, what kind of knowledge it has produced for solving a societal question [22]. These ingredients could bring to the organization a critical discussion on the impact of the work and ideas on its future directions. A new developmental impact evaluation method based on the theory of expansive learning has been developed and verified by Saari et al. [23] for this purpose.

In our opinion it is essential to create an atmosphere that respects research and researchers in a research organization. This means personalizing the work by fading out structures and emphasizing the importance of human knowledge and actors. If there is a need for redirecting knowledge areas, the organizations should look for procedures that would enable researchers to find their own ways into new areas before they are classified as outdated resources that the organization wants to get rid off.

In addition, the role of middle managers as bridge builders between top management and personnel should be appreciated and supported. Especially middle managers should be sensitive to new, creative research ideas and proposals. New research topics often emerge from small and risky innovation embryos, and thus it may be of crucial importance to make sure that they have an opportunity to grow in the critical initial stage. In directing research it is ever necessary to balance between wider political interests at different levels and matching local research programmes formed by the long-term accumulation of knowledge in research groups. The key question in this sensitive balancing between renewing research work and economical success is encouraging a constructive dialogue between the management directing the research, financing bodies and the research groups acting in the field.

References

[1] Memorandum of the Finnish Sectoral Research Working Group. 2006, Helsinki: Publication Series of the Office of Finnish Council of State 21/2006. Dnro: VKN003:00/2006. (in Finnish)

[2] Ansoff, I. Corporate Strategy. 1965, New York: McGraw-Hill.

[3] Perez-Freije, J., Enkel, E. Creative Tension in the Innovation Process. How to Support the Right Capabilities. European Management Journal, 2007. **SE-25**(1), p. 11-24.

[4] Saari, E. Can Research Groups be Founded? A Case Study on a Group Experiment in the Metals Laboratory of the Technical Research Centre of Finland during 1989-1991. 1995, Espoo: VTT, VTT Research Notes 1627. (in Finnish)

[5] Saari, E. The Pulse of Change in Research Work. A Study of Learning and Development in a Research Group. 2003: Helsinki, Helsinki University Press.

[6] Saari, E. Success Factors and Functioning Methods Promoting Learning in VTT's Top Teams. Interview report 27.3.2007. 2007, Espoo: Technical Research Centre of Finland, internal report. (in Finnish)

[7] Talja, H. Expert Organization in a Time of Change. Espoo: 2006. Technical Research Centre of Finland, Publications 620. (in Finnish)

[8] Chandler, A. D. Strategy and Structure. 1962, Cambridge, Mass.: MIT Press.

[9] Mintzberg, H., McHugh, A. Strategy Formation in an Adhocracy. Administrative Science Quarterly, 1985. **SE-30**(2): p. 160–197.

[10] Mintzberg, H. Structure in Fives. Designing Effective Organizations. 1983, London: Prentice Hall.

[11] Currie, G. & Procter, S. J. The Antecedents of Middle Manager's Strategic Contribution: The Case of a Professional Bureaucracy. Journal of Management Studies, 2005. **SE-42**(7): p. 1325–1356.

[12] Virkkunen, J. Rationalizing Control or Managing Development? Concept of Efficience in the Management by Results and Possibilities for Overcoming it. 1990, Helsinki: Hakapaino Oy.

[13] Galbraith, J. R. Organization Design. 1977, Reading, Mass.: Addison-Wesley.

[14] Thompson, D. Organizations in Action. 1967, McGraw-Hill.

[15] Giddens, A. The Constitution of Society. 1984, Berkeley: University of California Press.

[16] Weick, K. E. & Quinn, R. E. Organizational Change and Development. Annual Review of Psychology, 1999. **SE-50**, p. 361–386.

[17] Tsoukas, H. & Chia, R. On Organizational Becoming: Rethinking Organizational Change. Organization Science, 2002. **SE-13**(5): p. 567–582.

[18] Talja, H., Miettinen, A., Buhanist, B. Navigating and Managing in an Environment of Flux. 2008. Submitted to Scandinavian Journal of Management.

[19] Wilke, G., Binney, G. & Williams, C. Living Leadership. A Practical Guide for Ordinary Heroes. 2005, Philadelphia: Trans-Atlantic Publications.

[20] Bower, J.L., Gilbert, C.G. How Managers' Everyday Decisions Create or Destroy your Company's Strategy. Harvard Business Review, 2007. February: p. 72-79.

[21] Nonaka, I., Takeuchi, H. The Knowledge Creating Company. How Japanese Companies Create the Dynamics of Innovation. 1995, New York: Oxford University Press.

[22] Saari, E., Hyytinen, K. & Lähteenmäki-Smith, K. Developmental Impact Evaluation as a Method for Directing Research and Development Work and Learning. 2008. Hallinnon Tutkimus (Administrative Studies) 27(1): p. 35-48. (in Finnish)

[23] Saari, E., Kallio, K., Hyytinen, K. Learning from the Users of Research: Defences, Insights and Fragile Endeavours as Manifestations of Expansive Learning. 2008: Copenhagen, The Danish School of Education, University of Aarhus Organizational Learning, Knowledge and Capabilities (OLKC) 2008, 28-30 April 2008

SUSTAINABLE COMPETENCE: REPRODUCTION AND INNOVATION IN A BANK

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1. BACKGROUND

Post industrial structural conditions involve constantly increasing flexibility demands on organizations (Castell, 1996) in order to generate both short term competitiveness and long term sustainability. Such efforts can be seen in the decentralized work system and are comparatively common in Sweden in the form of e.g self organized teams (Sisson, 2000, Benders, Huijen, Pekruhl & O´Kelly, 1999)

However, this does not necessarily result in sustainable organizational conditions. Sustainability appears to be related to long term orientation and results (Moldaschl, 2002), a broad system oriented perspective (Docherty, Forslin & Shani, 2002) and the ability to maintain both competitiveness and competence development among the personnel, a "win win" situation. Which type of competence and what form of competence development among staff can be considered to generate such conditions? This paper presents an approach to answer the above question. Possibilities for the development of individual and collective competence to act are assumed to be important, as are those to develop this competence from external to internal regulation of actions on higher levels of complexity.

Moreover, internal regulation of actions is assumed to be related to increased ability to master dualities. Dualities refer to contrasting forces that have to be balanced as, although they may appear paradoxical, they can in fact be considered complementary. They are perceived as necessary and mutual parts of a process rather than a contradiction that should be avoided or fought against (Sanchez, Runde & Pettigrew, 2003). Consequently, dualities are likely to be mastered successfully by choosing either of the contrasting poles as the only "right way" and can be considered as a possibility for development, learning and innovation. Consequently, contrasting poles such as centralization – decentralization and autonomy – integration in the organization can be regarded as complementary. The central issue concerns their mutual dynamic and balance rather than the hegemony of either pole à priori.

Flexibility demands are particularly evident in banking. Globalization and IT have contributed to a more or less explosive development within the financial market in terms of economic transactions and speculation. The international recession during the early 1990s had a significant effect on banking, resulting in governmental decisions in Sweden to provide extensive financial support for this sector. However, Svenska Handelsbanken, a Swedish merchant bank was less affected by these tendencies, which can be assumed to be due to a more conservative strategy towards speculative aspects of the market economy at that time. This strategy, in turn, seems to be related to the corporate culture.

Svenska Handelsbanken has been highly competitive for many years, which can be related to a decentralized work organization attempting to master dualities such as centralization - decentralization and autonomy - integration within the framework of the company culture. The duality between reproduction and innovation appears to be of importance in the organization, as it is associated with more or less competent ways of carrying out activities. Reproduction refers to activities and actions that promote continuity and short term stability in the performance of traditional and routine tasks, while innovation is associated with developmental processes and results in qualitative changes in the organization in order to e.g. master changing external demands.

The aim of the paper is to outline a theoretical, methodological and empirical approach in progress within the framework of a case study of a merchant bank, in order to elucidate if and how individual and collective competence and competence development can contribute to sustainable conditions in a highly competitive organizational context.

2 A CASE STUDY AND ABDUCTIVE METHODOLOGICAL APPROACH

The choice of Svenska Handelsbanken as the study object was motivated by the ambition to identify an organization already striving to achieve sustainability by combining competitiveness with good health and developmental possibilities for its staff members (for a discussion, see Docherty, 2002).

The research is an ongoing process that is neither purely inductive nor deductive but rather abductive, requiring integration of empirical findings and conceptual considerations (see Hagström, 2007). This approach also appeared to be compatible with a case study design, an empirical investigation of a contemporary phenomenon “within its real-life context” (Yin, 1989, p. 23). The bank can be considered as a natural real life context, while the core phenomenon concerns sustainability in terms of learning and developmental characteristics of decentralized work systems in a company culture context. The possibilities for generalization are mainly based on theoretical considerations and multiple empirical data rather than statistical representativity (see e.g. Bryman, 2004).

The article is structured as follows. Firstly the company culture of the bank will be briefly described, followed by the presentation of previous explorative empirical results and some theoretical lines of reasoning. After that some empirical tendencies from a survey developed on the basis of earlier empirical findings will be outlined and finally some concluding considerations for the next research step will be provided.

3. COMPANY CULTURE AND DECENTRALIZATION: CHARACTERISTICS

The bank studied has been highly competitive on the national and international market. A sweeping re-organization was carried out in the early 1970’s by the then president Jan Wallander. The lines of reasoning behind this move were based on a humanistic view of man as proactive and meaning making. The employees were seen as capable and motivated in terms of utilizing the increased scope for action provided by the decentralization, which enhanced their possibilities of making decisions at local branch level. Core characteristics introduced by Wallander (Wallander, 2002) were:

- No central budgeting since the 1970’s, which made the bank differ substantially from other banks and companies in Sweden at that point in time. Decisions about credit, employment, work tasks, promotion and salaries took place at local level.
- Generous pension funds for all employees including profit-sharing, which has been quite substantial due to the high competitiveness of the company over the past decades.
- A regulation system for improving competitiveness. All local units have access to result and balance sheet information and are thus aware of if and how they and other units and banks contributed to profitability. The aim is to achieve above-average cost-income quota levels compared with other branches, which is intended to generate continuous pressure and ensure that each branch remains competitive.
- A regulation system for improving competitiveness. All local units have access to result and balance sheet information and are thus aware of if and how they have contributed to profitability compared with other units and banks. The aim is to achieve above average cost-income quota levels compared with other branches, which is intended to generate continuous pressure and ensure that each branch remains competitive.
- A “humanistic” view of man as (potentially) active, responsible and development oriented. The point of departure was based on Maslow’s hierarchical theory (Maslow, 1954). Consequently, the operative level of the organization consists of relatively small units (local branches) with quite a high level of decision-making possibilities.
- Efforts to maintain decentralization by avoiding tendencies to return to centralization, described in terms of an “optimal balance” problem.
- Efforts to maintain a balance between harmonious social relations and self-assertiveness among employees, where failure to do so is described as having the potential to generate conflicts
- Management by objectives. As a consequence of the humanistic view, the employees are considered sufficiently competent to regulate their work on a local level. The aim is the formulation of clear and meaningful goals, which make it possible to evaluate how individual performance contributes to goal fulfilment

The company culture can be perceived as a way of mastering dualities such as centralization - decentralization and autonomy (e.g. self assertiveness) - integration (e.g. harmonious social relations). The first three characteristics listed above mainly concern the external ("hard"-formal) regulation of work, while the following three are for the most part associated with the internal ("soft"-informal) regulation of work. The final characteristic, management by objectives, may be regarded as a mixture of external and internal regulational aspects, more or less in balance or lacking balance as a result of a number of internal and external influences. Such disparate dynamics may hamper as well as promote the individual and collective development of staff competence.

4. RESEARCH ISSUES

Issues that emerged in relation to the case study as a whole are as follows:

- How do staff members perceive their work related scope of action?
- What characterizes the external-internal regulation of work in terms of competence to act and to influence one's work situation and ability to master dualities such as centralization-decentralization and autonomy-social integration?
- What characterizes the interaction patterns between individuals on different levels of external – internal regulation of actions in the work situation?
- What hampers and promotes transitions from external to internal individual and collective regulation of work related actions?
- How does the company culture influence all these aspects?

In the present paper these questions will be neither theoretically nor empirically answered in full. Instead, the aim is to present some theoretical methods of reasoning that have been elucidated to some degree by explorative empirical findings. Theoretical considerations will be further elaborated upon below following a description of results from earlier explorative empirical findings in the present case study.

5. MASTERING DUALITIES AND THE EXTERNAL – INTERNAL REGULATION OF WORK. INITIAL EMPIRICAL FINDINGS AND MEASURES

An explorative study was carried out during the autumn of 2004 and the winter of 2005 (Wilhelmson et al. 2006). Interviews were conducted (N=65) with staff members in twelve local bank branches, half in the Stockholm region and half in a rural region of northern Sweden. Within each of these regions, the local branches varied in terms of competitiveness (half of them had a high and half of them a low rating) and customer orientation. Thus the sample was chosen in order to obtain width and variation regarding competitiveness and work practices due to e.g. external local differences. Central issues concerned the conception of dualities such as "win – win" situation, centralization – decentralization and autonomy – integration.

Conceptions of a "win-win" situation showed wide variation. The positive aspects concerned a satisfactory level of personal responsibility, which was perceived as promoting personal development and social relations in the workplace. The negative aspects involved a high work load, often reported as increasingly burdensome. The arguments supporting centralization tendencies underlined e.g. the advantages of a large organization for coordinating routine matters as well as the capacity to supply broad information. The arguments in favour of a higher degree of decentralization stressed negative aspects of detailed regulations issued by e.g. the regional organizational level, such as campaign drives or difficulties deciding about recruitment at local branch level. The informants mentioned many advantages related to decentralization, such as personal freedom to carry out work tasks in close customer contact.

In spite of the varied picture, the perception of the company culture was mainly positive. Confidence was expressed in the humanistic outlook. Some interviewees employed before the re-organization carried out by Wallander (ibid.) expressed this process of change in terms of a "decentralization revolution".

Finally, the interviews indicated that the manager of the local branch was important in both a positive and a negative sense. A well functioning local manager was often described as collaborating with employees, considered a good salesperson, contributing to the autonomy of his/her branch and increasing its scope of action in relation to the bank as a whole. However, a manager who functioned poorly in terms of communication and social relations could leave colleagues in a social vacuum, since they had less direct contact channels "upwards" in the organization. The local branch managers seemed to be perceived as a mediating link with the rest of the bank.

These tendencies indicated strong identification with the company culture. At the same time, a more differentiated picture concerning the way of handling dualities such as "win-win", centralization – decentralization and autonomy – integration emerged. These differences were investigated by elucidating different ways of conceiving the dualities mentioned by employees on different levels of the external-internal regulation of action (Göransson, 2007). These levels were revealed by results from a "half-projective" test, namely the Washington University Sentence Completion Test (WUSC, see Loevinger, 1970), used for many years all over the world and the object of exhaustive analyses (see Westenberg, 1998, Fisher et al. 2003, Hy & Loevinger, 1995, Loevinger, 1970). Göransson (ibid.) developed a Swedish work related version of this test.

The persons studied were mainly found to vary between a "conformistic" and a "conscious" level of development (ibid). They differed in terms of their perception of dualities such as decentralization-centralization and individual autonomy-social integration. Among those categorized as conformistic, this was manifested in a more static "either – or" conception of the balance and dynamic between the contrasting poles, while those characterized as "conscious" tended to reason more in terms of "both- and" conceptions of the same contrasting poles. Many transitions in adult life seem to concern these or similar stages of development (Kegan, 2003, concerning leadership, see Rooke & Torbert, 2005).

Although the present results constitute only fragmented and tentative illustrations, they nevertheless support the theoretically based assumptions that the measured developmental levels can be regarded as useful indicators of the level of external – internal regulation of work. Those that are more externally regulated can, in turn, be assumed to be guided to a greater extent by the formal regulations associated with the "company culture", while those more internally regulated are probably capable of guiding themselves on the basis of the informal regulations related to the same culture.

6. THEORETICAL APPROACH

The theoretical approach has been applied and further developed during the research process. As also mentioned, it attempts to combine different lines of reasoning, which, in turn, can roughly be divided into two main fields, namely a "transform – actional" approach and a complexity theory approach. The former focuses on the individual level of action while the latter deals with system levels. These two main lines of reasoning seem to have some important aspects in common, which provides opportunities for linking ideas about individual and collective competence and competence development in a fruitful way.

6.1. A "transform – actional" approach

The conception of competence and the development of such competence on the individual level is influenced by work related action theory (see e.g. Frese & Zapf, 1994); value-socialization theory (Hagström & Kjellberg, 2007), adult transformative theory (Mezirow, 1991, 2003) and adult developmental theory (see e.g. Kegan, 1982, 1994, 2003, Loevinger, 1970). Taken together, these lines of reasoning constitute a "transform - actional" approach in progress (see Hagström & Hanson, 2003, Hagström 2003, Hagström, 2007).

According to this approach, competence in a general sense seems to comprise at least four basic dimensions, namely:

1. Cognitive competence, which refers to instrumental, goal-oriented aspects of actions and their goal-plan sequential character in relation to logical thinking on different abstraction levels
2. Communicative competence, which refers to action in terms of communication and social interaction between individuals
3. Collective competence, which refers to social-societal aspects of actions aimed at relating to and integrating within a collective context of norms, values and rules as well as in the production and reproduction of goods and services.
4. Existential competence, which refers to deep and long term aspects of actions that create meaning in life and may be existential in character.

Dimensions (1) and (4) refer to autonomy and dimensions (2) and (3) to social integration.Each of these four dimensions encompasses individual capability and possibilities related to the surrounding environment, thus highlighting the fact that competence is an interaction between man and the external world. There are no clear distinctions between the four dimensions and competence is considered an indivisible whole, here referred to as action competence. Competence is perceived as being involved in a more or less dynamic process, where learning is considered as relatively permanent changes of competence as a consequence of the interaction between the individual and the external world (Ellström, 1992). Such changes may also be of a more deeply rooted transformative character and range from external to internal regulation of action.

Values can be regarded as a link between the individual and society that provides internal motives as well as motivation to act and orient one's goals towards social, cultural and societal contexts. Such goals are in turn discernible as affordances (Gibson, 1979), perceived as tasks to be carried out and as values in the environment (see Reed, Turiel & Brown, 1996). The competence to act on the basis of internalized values in rapidly changing and complex external situations seems to call for a meta cognitive competence in order to be able to orient oneself in a broad and long term perspective. This kind of competence has been given different labels in e.g. transformative learning theories (Mezirow, 2000) and adult developmental theories (Kegan, 1982, Cook Greuter, 1999, Loevinger, 1970), both of which underline the possibilities inherent in beneficial external conditions of experiencing personal growth throughout adulthood towards more inclusive and complex frames of reference, e.g. cognitive, motivational and moral. The dynamic and balance between autonomy and social integration is considered as a chance mechanism that has the potential to generate transformations towards an internally regulated action competence.

Management research in these areas has mainly emerged in Great Britain and the USA (see e.g. Torbert, 2004). Among other things, the significance of the manager's developmental level in terms of how he/she carries out the act of leadership as well as conditions that promote change has been studied (Fischer et al., 2003). Thus, research in this area has stressed the management of organizations rather than focusing on co-workers, work groups and organizations. In Sweden, learning, competence and competence development in a work and organizational context have been studied in recent years (see e.g. Ellström, Löfberg and Svensson, 2005). However, the connection between individual and collective competence and competence development has not been investigated sufficiently.

6.2. A complexity theory approach

Our conceptions of the relations and mutual influences of the individual and collective levels in developmental processes are influenced by complex adaptive systems (CAS) theories (see e.g. Backström, 2004). Processes and patterns in organizations and among groups have been interpreted as manifestations of complex systems (Stacey, 1996). Complex system theory has been suggested as a useful base when studying long term sustainability related to organizations (Backström, Eijnatten and Kira, 2002). However, there appears to be little application of complex system theory as a means of studying how competence can emerge in organizations and groups in ordinary companies.

From this perspective work groups can be conceived as complex systems consisting of individuals who express autonomic ways of thinking and acting and who are integrated into the collective and organizational context. Competence formation and other phenomena on group level can be regarded as something that emerges in non linear processes of interaction between the group members. This approach makes it possible to grasp and understand how learning can emerge even without formal education and how central day to day interactions between colleagues and between staff members and the surrounding world are for knowledge generation within the organization.

Change mechanisms such as the dynamic and balance between autonomy and integration are described in similar ways in both adult developmental and complex system theory. Furthermore, the same conditions that according to the adult developmental theories referred to above promote the development of the individual are also described within complex system theory. A work group with open and rich interaction can be conceived as a complex system of individuals who are mutually dependent and, consequently, integrated into a collective context. Social network theories are also applied in order to study interactions between individuals and the social network structures that consequently emerge and to understand collective phenomena such as culture, praxis and collective competence (Wasserman and Faust, 1994).

From the complexity perspective, the competence of a work group can be understood as a wholeness of integrated individuals. The individuals shape common ways of understanding the activity tasks of the organization that constitute the base for collaboration. This is accentuated if the group is motivated to develop its competence and obtains feedback that makes a common orientation of the development possible (Marion, 1999) and constitutes a collective competence beyond the aggregated sum of individual competencies (Backström and Döös, 2008)

7. PRELIMINARY RESULTS

7.1 Eight indices

Following these two lines of reasoning, we concluded that individual and collective competence can vary considerably and manifest itself in e.g. varying balance between reproductive and innovative activities, resulting in tendencies towards both experience expanding and experience narrowing spirals. If and how such processes can lead to competence development seems to depend on the scope of action provided, how these possibilities are perceived on different levels of the external-internal regulation of work and whether they are considered worth using.

Some of these issues can be elucidated by empirical illustrations from a survey carried out in the bank. The ongoing and future research process comprises two steps. In the first step a survey was conducted in order to obtain a broad picture of the engagement of the employees in bank activities, values and norms. Based on this survey, a selection of work groups with differing levels of engagement etc. will be made in order to elucidate reproductive and innovative ways of working in greater depth.

This survey focused on engagement and involvement in regular individual and organizational planning and execution of activities as well as on conceptions of the company's culture and work group integration. Activities in the bank provide possibilities for staff development as well as practical models and tools in order to generate feedback on results on individual and group operational levels. As briefly outlined above, company culture can be regarded as a strategy for making staff members personally aware of their responsibility for the collective goals of the bank as well as for their own learning and development. The decentralization is structured to be capable of generating an ongoing process on the local level rather than a mainly centralized, regulated one.

One such model, entitled "the wheel", includes the bank employees on both individual and group levels, where the stated goals are followed up on a regular basis. The results of the explorative interviews referred to above (Wilhelmson et al., 2006) indicated that this model tends to be used as either a static structure (some kind of check list) or as a process (involving the whole work group dynamic). This may indicate variation of activities in the reproductive – innovative direction.

The survey was designed on the basis of the above results which some of these are previously published (Wilhelmson, ibid, Göransson, ibid) and is summarized in section five above and discussed with representatives of the bank in regular collaboration meetings. The survey consisted of 48 items and was distributed to all bank personnel (response rate 70%, N=5347). On the basis of the answers, eight indices were constructed by performing factor analyses and summarising the results. Table 1 contains the titles of these indices, the number of items in each index and their reliability (Cronbach´s alpha coefficients).

Index (factor)	No items	Alpha coefficient
(1) Culture integration	6	0.79
(2) Bank is too cautious	5	0.79
(3) Conception of and attitudes towards "the wheel" (activity plans etc.)	5	0.84
(4) Engagement in individual activity planning	5	0.88
(5) Opinion of wage planning	2	0.89
(6) Engagement in collective activity planning	3	0.89
(7) Integrated work group	7	0.87
(8) Autonomic and creative local manager	3	0.91

Table 1 Index reliability and number of items in each index measuring engagement in bank activities, norms and values.

As can be seen in Table 1, the reliability of the indices is quite robust. The answers had seven response alternatives ranging from "don't agree at all" to "agree completely". Index (1) Culture integration includes items such as "I'm committed and engaged in the Handelsbank-culture" and "In Handelsbanken we work to a high degree in a centralized way". Index (2) Bank is too cautious contains items such as "We are far too cautious in Handelsbanken" and "New thinking is far too rare in Handelsbanken". Index (3) Conception of and attitudes towards "the wheel" (activity plans etc.) consists of items such as "The different parts of 'the wheel' (activity plans, individual planning and development interviews, follow up, wage planning interviews) are, in my opinion, mutually connected in a consistent way" and "The application of 'the wheel' (activity plans etc.) increases the social solidarity in my work group". Index (4) Engagement in individual activity planning comprises items such as “My activity plan provides stimulating challenges” and “My individual plan of action consists of both short and long term goals”.

Index (5) Judgement of wage planning includes the items “the wage interview functions well as a check of what I have done and how I have developed” and “My wage interview provided a good framework for setting my wage rate”. Index (6) Engagement in collective activity planning contains items such as “I really feel I’m engaged in our efforts to fulfil the goals of the (collective) activity plans” and “I’m actively involved in the work process that creates our activity plan”. Index (7) Integrated work group, consists of items such as “In my work group we have many common values” and “In my work group we often talk about goals, visions and strategies related to our work”. Finally, index (8) Autonomic and creative local manager included items such as “My local manager adequately represents the interests of my work group in other central units of the organization” and “My local manager supports new thinking”

7.2. Interpretation of the index

Seven out of the eight indices appear to reflect passive – active engagement dimensions, which engagement in turn seems to express autonomy and social integration dimensions considered central to both the theoretical approach and the company culture. Index (4) Engagement in individual activity planning indicates individual autonomic efforts while index (6) Engagement in collective activity planning reveals social integrative efforts.

Indices (5) and (7) express both individual autonomy engagement and collective social integrative engagement. Index (5) Opinion of wage planning highlights individual aspirations and career plans as well as perceived fairness in relation to others, relating this to a social context and social status in such a context. In index (7) Integrated work group, the social-integrative aspect refers to, on the one hand, the spirit of community (social integration) and on the other, being recognized and accepted as an individual in the group (individual autonomy). More general integration in the organization as a whole is indicated by index (1) Culture integration. Furthermore, index (3) Conception of and attitudes towards the wheel can be assumed to reflect how such general integration is manifested in goal directed routine work that formulates and fulfils activity plans.

Thus, the dimensions of the indices can be assumed to reflect the degree of passive – active engagement and involvement in the work as well as the degree to which it varies in autonomic and/or social integrative directions. Reproductive – innovative ways of working can be related to the passive – active engagement dimension.

Innovative ways of acting and working seem to be compatible with active engagement in terms of problem solving, while the opposite may be assumed for reproductive methods of acting and working.

However, the relation between reproduction and innovation on the one hand, and directions of engagement towards individual autonomy or social integration on the other, appears slightly more complicated. Low engagement in both these directions does not seem to correlate with innovative ways of working. These two directions can be regarded as balancing each other in more or less dynamic ways, indicating both reproductive and innovative ways of working. At the same time, high engagement levels do not necessarily generate long term competence development.

As has been outlined in the theoretical lines of reasoning, it can be assumed that new and more innovative ways of thinking and acting are stimulated by differing opinions e.g. criticism of taken for granted conceptions of the company culture. It is possible that index (2) Bank is too cautious reflects such critical opinions. High levels of agreement in this index appear to indicate negative attitudes towards aspects of the company culture.

However, contrasting or conflicting values and attitudes as well as alternative ways of thinking may also contribute to less innovation or even stagnation due to static polarization and unfruitful conflicts. The definition of fruitful conflicts remains to be investigated empirically. On a work group level, autonomy seems to be related to the integrity and autonomy of the local manager, indicated by index (8) Autonomic and creative local manager. However, as can be seen in Table X above, this index is positively correlated with all other indices except index (2) Bank is too cautious.

8. SOME TENTATIVE TENDENCIES

The mean values of the indices reflecting gender and age differences are presented in Figure 1 and Figure 2 below

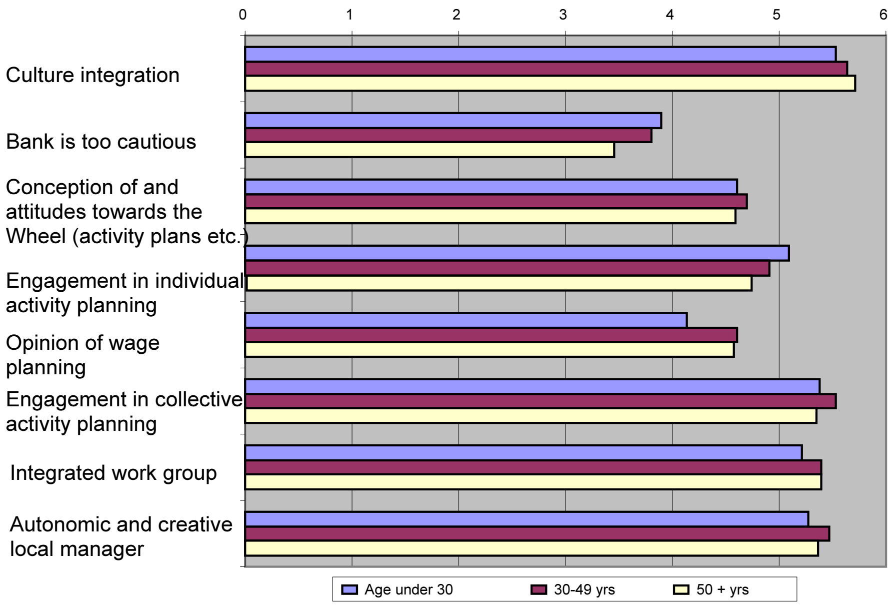

Fig. 2. Engagement in and commitment to bank activities. Age groups (N= 5347)

The overriding impression, which is also supported by the explorative interview results summarized above, is the high level of culture integration within the organization as well as an almost equally high degree of collective and individual involvement and engagement in the indices indicating various aspects of organizational activities. At the same time, some interesting differences related to age were revealed. In five of the indices, the engagement levels are lower in the youngest group, which

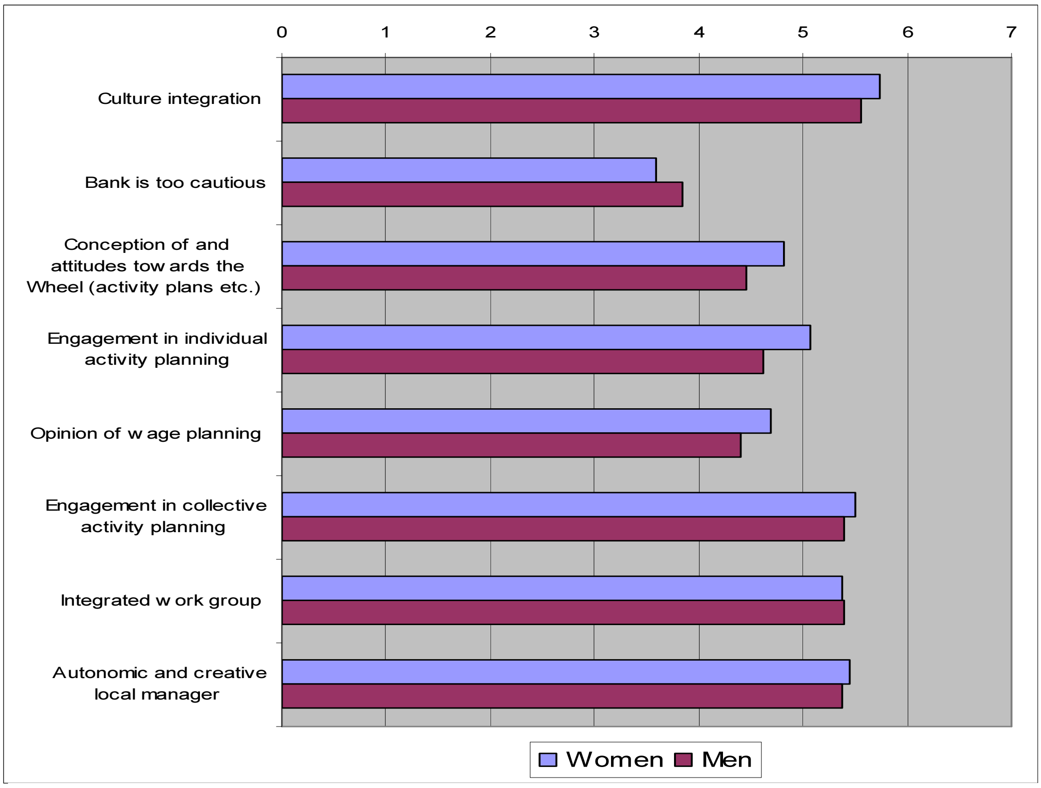

Fig. 1. Engagement in and commitment to bank activities. Gender differences (N=5347)

may indicate that these persons have had less time to become involved and engaged in the various bank activities. At the same time, the youngest group was more engaged in individual activity plans than the other age groups. The fact that the youngest group is more critical towards certain norms and values was revealed by their higher ratings in the Bank is too cautious index, which may indicate that the lower involvement and engagement levels are not only due to the shorter duration of employment.

The overriding impression in terms of gender differences is that women tend to score slightly higher in all indices with the sole exception of Bank is too cautious. These tendencies can be interpreted as higher involvement and engagement among women in general. However, the more critical attitude among men and younger people may be regarded as potentially innovative. This will be elaborated statistically as well as in a multi methodological investigation in the next research step.

9. CONCLUSIONS AND CONSIDERATIONS FOR FURTHER RESEARCH

The company culture based on Wallander's ideas (2002) seems to mainly stress the importance of "harmonious balances", which is reflected in the way of reasoning about the relations between social integration – individual autonomy and decentralization – centralization. This perspective may reflect an implicit or explicit idea of an ideal and permanent state of balance. Such a conception does not seem to include a vision of transformations towards more dynamic ways of reasoning and acting.

Further research will focus on such potential for change in the bank. In a more long term generational perspective, the continuation of the company "culture" may be problematic, due to the fact that new "generations" of employees may have difficulties reproducing the main elements of the company's management tradition. The "new generations" employed after the main changes of the 1970s have no firsthand experience of the challenging guiding concepts and values of the persons who carried through this organizational transformation.

The forthcoming multi-methodological study will elucidate in greater depth what characterizes, promotes and hinders innovative and reproductive work activities as well as further investigating the "new generations" aspects and the influence of individual complexity developmental levels among employees. Several methods will be applied, namely interviews, the Loevinger meaning completion test (WUSC, see Loevinger, 1970) and two surveys, the first aimed at deepening the knowledge of the extent and character of the interactions and social communication within work groups both quantitatively and qualitatively (Wasserman and Faust, 1994) and the second for the purpose of measuring work values (Gamberale et al, 1996, Hagström and Kjellberg, 2007).

References

Backström, T. (2004). Collective learning: a way over the ridge to a new organizational attractor. The Learning Organization, 11(6, Special Issue "Chaordic systems thinking for learning organizations"), 466-477.

Backström, T., F. M. van Eijnatten and M. Kira (2002). A complexity perspective on sustainable work systems. *Creating sustainable work systems: Perspectives and practices*. P.

Backström, T & Döös, M. 2008. Relationics a key concept in networked organizations. In *Encyclopaedia of networked and virtual organizations* G. D. Putnik, M. M. Cunha, Eds. (Idea Group Inc.

Benders, J., Huijgen, F., Pekruhl, U. & O'Kelly, K., P. (1999) Useful but unused – Group work in Europe. Dublin: European Foundation for Improvement of Living and Working Conditions

Bryman, A. (2004) *Social research methods*. New York: Oxford University Press Inc.

Cook-Greuter, S.R. (1999) Post autonomous ego development. A study of its nature and measurement. Doctoral thesis. The Graduate School of Education, Harvard University.

Docherty, P. (2002) Values and stakeholder relations. In P. Docherty, J. Forslin, J. & A. B. Shani (Eds). *Creating sustainable work systems. Emerging perspectives and practice*. p. 114–125. London: Routledge.(?)

Docherty, Forslin & Shani (2002) Creating sustainable work systems. Emerging perspectives and practice. New York: Routledge.

Ellström, P: E: (1992) Kompetens, utbildning och lärande i arbetslivet. Problem, begrepp och teoretiska perspektiv. Stockholm: Publica, Allmänna förlaget.

Ellström, P.E., Löfberg, A. & Svensson, L. (2005) Pedagogik i arbetslivet. Ett historiskt perspektiv. Pedagogisk Forskning i Sverige, 10 34.

Fisher, Torbert & Rooke (2003). Personal and Organisational Transformations: through action inquiry. Edge\Work Press, UK

Frese, M. & Zapf, D. (1994) Action as the core of work psychology. In: Dunette, M.D. & Leaetta, M.H. (Eds) Handbook of Industrial and Organizational Psychology- Palo Alto, CA.

Gamberale, F., Sconfienza, C. & Hagström, T.(1996) Värderingar och förhållningssätt till arbete bland ungdomar i Sverige. En kartläggning av ett representativt urval. Arbete och Hälsa 1996:19, Stockholm: Arbetslivsinstitutet.

Gibson, J.J. (1979) The ecological approach to visual perception. Boston.

Göransson, S (2007) Jagutveckling och arbetsorganisationen – en metodansats. Licentiatuppsats vid Pedagogiska institutionen, Stockholms universitet

Hagström, T. (Ed) (2003) Adult development in post-industrial society and working life. Stockholm Lectures in Educology, Lecture Series No. 2, Department of Education, Stockholm University.

Hagström, T & Hanson, M. ((2003) Flexible work contexts and human competence. An action-interaction frame of reference and empirical illustrations. In Bron, A. & Schemmann, M (Eds) Knowledge Society, Information Society and Adult Education. Challenges, Trends, Issues. Hamburg and London, Lit Verlag Münster (pp 148-180).

Hagström, T. & Kjellberg, A. (2007) Stability and change in work values among male and female nurses and engineers. Scandinavian Journal of Psychology, 48, 143-151

Hagström, T (2007) Arbetslivspedagogik och det gränslösa arbetet. En transaktionell ansats. Pedagogisk forskning i Sverige**,** Årg 12, Nr 4.

Hy, L. X. & Loevinger, J. (1996) Measuring ego development Second Edition. Mahwah, NJ: Lawrence Erlbaum Associates Inglehart, R. (1997) Modernization and post modernization. Cultural, economic and political change in 43 societies. Princeton, N.J.

Kegan, R (1982) The evolving self. Problems and process in human development. Cambridge MA, Harvard University Press.

Kegan R (1994) In Over Our Heads. The Mental Demands of Modern Life. Cambridge, MA, Harvard University Press

Kegan, R. (2003) Hidden curriculum of adult life: An adult developmental perspective. In Hagström, T. (Ed) Adult development in post-industrial society and working life. Stockholm Lectures in Educology, Lecture Series No. 2, Department of Education, Stockholm University.

Loevinger J, Wessler R (1970) *Measuring Ego Development Vol 1+2.* San Fransisco, CA, USA, Jossey-Bass

SUSTAINABLE COMPETENCE: REPRODUCTION AND INNOVATION IN A BANK

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1. BACKGROUND

Post industrial structural conditions involve constantly increasing flexibility demands on organizations (Castell, 1996) in order to generate both short term competitiveness and long term sustainability. Such efforts can be seen in the decentralized work system and are comparatively common in Sweden in the form of e.g self organized teams (Sisson, 2000, Benders, Huijen, Pekruhl & O´Kelly, 1999)

However, this does not necessarily result in sustainable organizational conditions. Sustainability appears to be related to long term orientation and results (Moldaschl, 2002), a broad system oriented perspective (Docherty, Forslin & Shani, 2002) and the ability to maintain both competitiveness and competence development among the personnel, a “win win” situation. Which type of competence and what form of competence development among staff can be considered to generate such conditions? This paper presents an approach to answer the above question. Possibilities for the development of individual and collective competence to act are assumed to be important, as are those to develop this competence from external to internal regulation of actions on higher levels of complexity.

Moreover, internal regulation of actions is assumed to be related to increased ability to master dualities. Dualities refer to contrasting forces that have to be balanced as, although they may appear paradoxical, they can in fact be considered complementary. They are perceived as necessary and mutual parts of a process rather than a contradiction that should be avoided or fought against (Sanchez, Runde & Pettigrew, 2003). Consequently, dualities are likely to be mastered successfully by choosing either of the contrasting poles as the only “right way” and can be considered as a possibility for development, learning and innovation. Consequently, contrasting poles such as centralization – decentralization and autonomy – integration in the organization can be regarded as complementary. The central issue concerns their mutual dynamic and balance rather than the hegemony of either pole à priori.

Flexibility demands are particularly evident in banking. Globalization and IT have contributed to a more or less explosive development within the financial market in terms of economic transactions and speculation. The international recession during the early 1990s had a significant effect on banking, resulting in governmental decisions in Sweden to provide extensive financial support for this sector. However, Svenska Handelsbanken, a Swedish merchant bank was less affected by these tendencies, which can be assumed to be due to a more conservative strategy towards speculative aspects of the market economy at that time. This strategy, in turn, seems to be related to the corporate culture.

Svenska Handelsbanken has been highly competitive for many years, which can be related to a decentralized work organization attempting to master dualities such as centralization - decentralization and autonomy - integration within the framework of the company culture. The duality between reproduction and innovation appears to be of importance in the organization, as it is associated with more or less competent ways of carrying out activities. Reproduction refers to activities and actions that promote continuity and short term stability in the performance of traditional and routine tasks, while innovation is associated with developmental processes and results in qualitative changes in the organization in order to e.g. master changing external demands.

The aim of the paper is to outline a theoretical, methodological and empirical approach in progress within the framework of a case study of a merchant bank, in order to elucidate if and how individual and collective competence and competence development can contribute to sustainable conditions in a highly competitive organizational context.

2 A CASE STUDY AND ABDUCTIVE METHODOLOGICAL APPROACH

The choice of Svenska Handelsbanken as the study object was motivated by the ambition to identify an organization already striving to achieve sustainability by combining competitiveness with good health and developmental possibilities for its staff members (for a discussion, see Docherty, 2002).

The research is an ongoing process that is neither purely inductive nor deductive but rather abductive, requiring integration of empirical findings and conceptual considerations (see Hagström, 2007). This approach also appeared to be compatible with a case study design, an empirical investigation of a contemporary phenomenon "within its real-life context" (Yin, 1989, p. 23). The bank can be considered as a natural real life context, while the core phenomenon concerns sustainability in terms of learning and developmental characteristics of decentralized work systems in a company culture context. The possibilities for generalization are mainly based on theoretical considerations and multiple empirical data rather than statistical representativity (see e.g. Bryman, 2004).

The article is structured as follows. Firstly the company culture of the bank will be briefly described, followed by the presentation of previous explorative empirical results and some theoretical lines of reasoning. After that some empirical tendencies from a survey developed on the basis of earlier empirical findings will be outlined and finally some concluding considerations for the next research step will be provided.

3. COMPANY CULTURE AND DECENTRALIZATION: CHARACTERISTICS

The bank studied has been highly competitive on the national and international market. A sweeping re-organization was carried out in the early 1970's by the then president Jan Wallander. The lines of reasoning behind this move were based on a humanistic view of man as proactive and meaning making. The employees were seen as capable and motivated in terms of utilizing the increased scope for action provided by the decentralization, which enhanced their possibilities of making decisions at local branch level. Core characteristics introduced by Wallander (Wallander, 2002) were:

- No central budgeting since the 1970's, which made the bank differ substantially from other banks and companies in Sweden at that point in time. Decisions about credit, employment, work tasks, promotion and salaries took place at local level.
- Generous pension funds for all employees including profit-sharing, which has been quite substantial due to the high competitiveness of the company over the past decades.
- A regulation system for improving competitiveness. All local units have access to result and balance sheet information and are thus aware of if and how they and other units and banks contributed to profitability. The aim is to achieve above-average cost-income quota levels compared with other branches, which is intended to generate continuous pressure and ensure that each branch remains competitive.
- A regulation system for improving competitiveness. All local units have access to result and balance sheet information and are thus aware of if and how they have contributed to profitability compared with other units and banks. The aim is to achieve above average cost-income quota levels compared with other branches, which is intended to generate continuous pressure and ensure that each branch remains competitive.
- A "humanistic" view of man as (potentially) active, responsible and development oriented. The point of departure was based on Maslow's hierarchical theory (Maslow, 1954). Consequently, the operative level of the organization consists of relatively small units (local branches) with quite a high level of decision-making possibilities.
- Efforts to maintain decentralization by avoiding tendencies to return to centralization, described in terms of an "optimal balance" problem.
- Efforts to maintain a balance between harmonious social relations and self-assertiveness among employees, where failure to do so is described as having the potential to generate conflicts
- Management by objectives. As a consequence of the humanistic view, the employees are considered sufficiently competent to regulate their work on a local level. The aim is the formulation of clear and meaningful goals, which make it possible to evaluate how individual performance contributes to goal fulfilment

The company culture can be perceived as a way of mastering dualities such as centralization - decentralization and autonomy (e.g. self assertiveness) - integration (e.g. harmonious social relations). The first three characteristics listed above mainly concern the external ("hard"-formal) regulation of work, while the following three are for the most part associated with the internal ("soft"-informal) regulation of work. The final characteristic, management by objectives, may be regarded as a mixture of external and internal regulational aspects, more or less in balance or lacking balance as a result of a number of internal and external influences. Such disparate dynamics may hamper as well as promote the individual and collective development of staff competence.

4. RESEARCH ISSUES

Issues that emerged in relation to the case study as a whole are as follows:

- How do staff members perceive their work related scope of action?
- What characterizes the external-internal regulation of work in terms of competence to act and to influence one's work situation and ability to master dualities such as centralization-decentralization and autonomy-social integration?
- What characterizes the interaction patterns between individuals on different levels of external – internal regulation of actions in the work situation?
- What hampers and promotes transitions from external to internal individual and collective regulation of work related actions?
- How does the company culture influence all these aspects?

In the present paper these questions will be neither theoretically nor empirically answered in full. Instead, the aim is to present some theoretical methods of reasoning that have been elucidated to some degree by explorative empirical findings. Theoretical considerations will be further elaborated upon below following a description of results from earlier explorative empirical findings in the present case study.

5. MASTERING DUALITIES AND THE EXTERNAL – INTERNAL REGULATION OF WORK. INITIAL EMPIRICAL FINDINGS AND MEASURES

An explorative study was carried out during the autumn of 2004 and the winter of 2005 (Wilhelmson et al. 2006). Interviews were conducted (N=65) with staff members in twelve local bank branches, half in the Stockholm region and half in a rural region of northern Sweden. Within each of these regions, the local branches varied in terms of competitiveness (half of them had a high and half of them a low rating) and customer orientation. Thus the sample was chosen in order to obtain width and variation regarding competitiveness and work practices due to e.g. external local differences. Central issues concerned the conception of dualities such as "win – win" situation, centralization – decentralization and autonomy – integration.

Conceptions of a "win-win" situation showed wide variation. The positive aspects concerned a satisfactory level of personal responsibility, which was perceived as promoting personal development and social relations in the workplace. The negative aspects involved a high work load, often reported as increasingly burdensome. The arguments supporting centralization tendencies underlined e.g. the advantages of a large organization for coordinating routine matters as well as the capacity to supply broad information. The arguments in favour of a higher degree of decentralization stressed negative aspects of detailed regulations issued by e.g. the regional organizational level, such as campaign drives or difficulties deciding about recruitment at local branch level. The informants mentioned many advantages related to decentralization, such as personal freedom to carry out work tasks in close customer contact.

In spite of the varied picture, the perception of the company culture was mainly positive. Confidence was expressed in the humanistic outlook. Some interviewees employed before the re-organization carried out by Wallander (ibid.) expressed this process of change in terms of a "decentralization revolution".

Finally, the interviews indicated that the manager of the local branch was important in both a positive and a negative sense. A well functioning local manager was often described as collaborating with employees, considered a good salesperson, contributing to the autonomy of his/her branch and increasing its scope of action in relation to the bank as a whole. However, a manager who functioned poorly in terms of communication and social relations could leave colleagues in a social vacuum, since they had less direct contact channels "upwards" in the organization. The local branch managers seemed to be perceived as a mediating link with the rest of the bank.

These tendencies indicated strong identification with the company culture. At the same time, a more differentiated picture concerning the way of handling dualities such as "win-win", centralization – decentralization and autonomy – integration emerged. These differences were investigated by elucidating different ways of conceiving the dualities mentioned by employees on different levels of the external-internal regulation of action (Göransson, 2007). These levels were revealed by results from a "half-projective" test, namely the Washington University Sentence Completion Test (WUSC, see Loevinger, 1970), used for many years all over the world and the object of exhaustive analyses (see Westenberg, 1998, Fisher et al. 2003, Hy & Loevinger, 1995, Loevinger, 1970). Göransson (ibid.) developed a Swedish work related version of this test.

The persons studied were mainly found to vary between a "conformistic" and a "conscious" level of development (ibid). They differed in terms of their perception of dualities such as decentralization-centralization and individual autonomy-social integration. Among those categorized as conformistic, this was manifested in a more static "either – or" conception of the balance and dynamic between the contrasting poles, while those characterized as "conscious" tended to reason more in terms of "both- and" conceptions of the same contrasting poles. Many transitions in adult life seem to concern these or similar stages of development (Kegan, 2003, concerning leadership, see Rooke & Torbert, 2005).

Although the present results constitute only fragmented and tentative illustrations, they nevertheless support the theoretically based assumptions that the measured developmental levels can be regarded as useful indicators of the level of external – internal regulation of work. Those that are more externally regulated can, in turn, be assumed to be guided to a greater extent by the formal regulations associated with the "company culture", while those more internally regulated are probably capable of guiding themselves on the basis of the informal regulations related to the same culture.

6. THEORETICAL APPROACH

The theoretical approach has been applied and further developed during the research process. As also mentioned, it attempts to combine different lines of reasoning, which, in turn, can roughly be divided into two main fields, namely a "transform – actional" approach and a complexity theory approach. The former focuses on the individual level of action while the latter deals with system levels. These two main lines of reasoning seem to have some important aspects in common, which provides opportunities for linking ideas about individual and collective competence and competence development in a fruitful way.

6.1. A "transform – actional" approach

The conception of competence and the development of such competence on the individual level is influenced by work related action theory (see e.g. Frese & Zapf, 1994); value-socialization theory (Hagström & Kjellberg, 2007), adult transformative theory (Mezirow, 1991, 2003) and adult developmental theory (see e.g. Kegan, 1982, 1994, 2003, Loevinger, 1970). Taken together, these lines of reasoning constitute a "transform - actional" approach in progress (see Hagström & Hanson, 2003, Hagström 2003, Hagström, 2007).

According to this approach, competence in a general sense seems to comprise at least four basic dimensions, namely:

1. Cognitive competence, which refers to instrumental, goal-oriented aspects of actions and their goal-plan sequential character in relation to logical thinking on different abstraction levels
2. Communicative competence, which refers to action in terms of communication and social interaction between individuals
3. Collective competence, which refers to social-societal aspects of actions aimed at relating to and integrating within a collective context of norms, values and rules as well as in the production and reproduction of goods and services.
4. Existential competence, which refers to deep and long term aspects of actions that create meaning in life and may be existential in character.

Dimensions (1) and (4) refer to autonomy and dimensions (2) and (3) to social integration.Each of these four dimensions encompasses individual capability and possibilities related to the surrounding environment, thus highlighting the fact that competence is an interaction between man and the external world. There are no clear distinctions between the four dimensions and competence is considered an indivisible whole, here referred to as action competence. Competence is perceived as being involved in a more or less dynamic process, where learning is considered as relatively permanent changes of competence as a consequence of the interaction between the individual and the external world (Ellström, 1992). Such changes may also be of a more deeply rooted transformative character and range from external to internal regulation of action.

Values can be regarded as a link between the individual and society that provides internal motives as well as motivation to act and orient one's goals towards social, cultural and societal contexts. Such goals are in turn discernible as affordances (Gibson, 1979), perceived as tasks to be carried out and as values in the environment (see Reed, Turiel & Brown, 1996). The competence to act on the basis of internalized values in rapidly changing and complex external situations seems to call for a meta cognitive competence in order to be able to orient oneself in a broad and long term perspective. This kind of competence has been given different labels in e.g. transformative learning theories (Mezirow, 2000) and adult developmental theories (Kegan, 1982, Cook Greuter, 1999, Loevinger, 1970), both of which underline the possibilities inherent in beneficial external conditions of experiencing personal growth throughout adulthood towards more inclusive and complex frames of reference, e.g. cognitive, motivational and moral. The dynamic and balance between autonomy and social integration is considered as a chance mechanism that has the potential to generate transformations towards an internally regulated action competence.

Management research in these areas has mainly emerged in Great Britain and the USA (see e.g. Torbert, 2004). Among other things, the significance of the manager’s developmental level in terms of how he/she carries out the act of leadership as well as conditions that promote change has been studied (Fischer et al., 2003). Thus, research in this area has stressed the management of organizations rather than focusing on co-workers, work groups and organizations. In Sweden, learning, competence and competence development in a work and organizational context have been studied in recent years (see e.g. Ellström, Löfberg and Svensson, 2005). However, the connection between individual and collective competence and competence development has not been investigated sufficiently.

6.2. A complexity theory approach

Our conceptions of the relations and mutual influences of the individual and collective levels in developmental processes are influenced by complex adaptive systems (CAS) theories (see e.g. Backström, 2004). Processes and patterns in organizations and among groups have been interpreted as manifestations of complex systems (Stacey, 1996). Complex system theory has been suggested as a useful base when studying long term sustainability related to organizations (Backström, Eijnatten and Kira, 2002). However, there appears to be little application of complex system theory as a means of studying how competence can emerge in organizations and groups in ordinary companies.

From this perspective work groups can be conceived as complex systems consisting of individuals who express autonomic ways of thinking and acting and who are integrated into the collective and organizational context. Competence formation and other phenomena on group level can be regarded as something that emerges in non linear processes of interaction between the group members. This approach makes it possible to grasp and understand how learning can emerge even without formal education and how central day to day interactions between colleagues and between staff members and the surrounding world are for knowledge generation within the organization.

Change mechanisms such as the dynamic and balance between autonomy and integration are described in similar ways in both adult developmental and complex system theory. Furthermore, the same conditions that according to the adult developmental theories referred to above promote the development of the individual are also described within complex system theory. A work group with open and rich interaction can be conceived as a complex system of individuals who are mutually dependent and, consequently, integrated into a collective context. Social network theories are also applied in order to study interactions between individuals and the social network structures that consequently emerge and to understand collective phenomena such as culture, praxis and collective competence (Wasserman and Faust, 1994).

From the complexity perspective, the competence of a work group can be understood as a wholeness of integrated individuals. The individuals shape common ways of understanding the activity tasks of the organization that constitute the base for collaboration. This is accentuated if the group is motivated to develop its competence and obtains feedback that makes a common orientation of the development possible (Marion, 1999) and constitutes a collective competence beyond the aggregated sum of individual competencies (Backström and Döös, 2008)

7. PRELIMINARY RESULTS

7.1 Eight indices

Following these two lines of reasoning, we concluded that individual and collective competence can vary considerably and manifest itself in e.g. varying balance between reproductive and innovative activities, resulting in tendencies towards both experience expanding and experience narrowing spirals. If and how such processes can lead to competence development seems to depend on the scope of action provided, how these possibilities are perceived on different levels of the external-internal regulation of work and whether they are considered worth using.

Some of these issues can be elucidated by empirical illustrations from a survey carried out in the bank. The ongoing and future research process comprises two steps. In the first step a survey was conducted in order to obtain a broad picture of the engagement of the employees in bank activities, values and norms. Based on this survey, a selection of work groups with differing levels of engagement etc. will be made in order to elucidate reproductive and innovative ways of working in greater depth.

This survey focused on engagement and involvement in regular individual and organizational planning and execution of activities as well as on conceptions of the company's culture and work group integration. Activities in the bank provide possibilities for staff development as well as practical models and tools in order to generate feedback on results on individual and group operational levels. As briefly outlined above, company culture can be regarded as a strategy for making staff members personally aware of their responsibility for the collective goals of the bank as well as for their own learning and development. The decentralization is structured to be capable of generating an ongoing process on the local level rather than a mainly centralized, regulated one.

One such model, entitled "the wheel", includes the bank employees on both individual and group levels, where the stated goals are followed up on a regular basis. The results of the explorative interviews referred to above (Wilhelmson et al., 2006) indicated that this model tends to be used as either a static structure (some kind of check list) or as a process (involving the whole work group dynamic). This may indicate variation of activities in the reproductive – innovative direction.

The survey was designed on the basis of the above results which some of these are previously published (Wilhelmson, ibid, Göransson, ibid) and is summarized in section five above and discussed with representatives of the bank in regular collaboration meetings. The survey consisted of 48 items and was distributed to all bank personnel (response rate 70%, N=5347). On the basis of the answers, eight indices were constructed by performing factor analyses and summarising the results. Table 1 contains the titles of these indices, the number of items in each index and their reliability (Cronbach´s alpha coefficients).

Index (factor)	No items	Alpha coefficient
(1) Culture integration	6	0.79
(2) Bank is too cautious	5	0.79
(3) Conception of and attitudes towards "the wheel" (activity plans etc.)	5	0.84
(4) Engagement in individual activity planning	5	0.88
(5) Opinion of wage planning	2	0.89
(6) Engagement in collective activity planning	3	0.89
(7) Integrated work group	7	0.87
(8) Autonomic and creative local manager	3	0.91

Table 1 Index reliability and number of items in each index measuring engagement in bank activities, norms and values.

As can be seen in Table 1, the reliability of the indices is quite robust. The answers had seven response alternatives ranging from "don't agree at all" to "agree completely". Index (1) Culture integration includes items such as "I'm committed and engaged in the Handelsbank-culture" and "In Handelsbanken we work to a high degree in a centralized way". Index (2) Bank is too cautious contains items such as "We are far too cautious in Handelsbanken" and "New thinking is far too rare in Handelsbanken". Index (3) Conception of and attitudes towards "the wheel" (activity plans etc.) consists of items such as "The different parts of 'the wheel' (activity plans, individual planning and development interviews, follow up, wage planning interviews) are, in my opinion, mutually connected in a consistent way" and "The application of 'the wheel' (activity plans etc.) increases the social solidarity in my work group". Index (4) Engagement in individual activity planning comprises items such as “My activity plan provides stimulating challenges” and “My individual plan of action consists of both short and long term goals”.

Index (5) Judgement of wage planning includes the items “the wage interview functions well as a check of what I have done and how I have developed” and “My wage interview provided a good framework for setting my wage rate”. Index (6) Engagement in collective activity planning contains items such as “I really feel I’m engaged in our efforts to fulfil the goals of the (collective) activity plans” and “I’m actively involved in the work process that creates our activity plan”. Index (7) Integrated work group, consists of items such as “In my work group we have many common values” and “In my work group we often talk about goals, visions and strategies related to our work”. Finally, index (8) Autonomic and creative local manager included items such as “My local manager adequately represents the interests of my work group in other central units of the organization” and “My local manager supports new thinking”

7.2. Interpretation of the index

Seven out of the eight indices appear to reflect passive – active engagement dimensions, which engagement in turn seems to express autonomy and social integration dimensions considered central to both the theoretical approach and the company culture. Index (4) Engagement in individual activity planning indicates individual autonomic efforts while index (6) Engagement in collective activity planning reveals social integrative efforts.

Indices (5) and (7) express both individual autonomy engagement and collective social integrative engagement. Index (5) Opinion of wage planning highlights individual aspirations and career plans as well as perceived fairness in relation to others, relating this to a social context and social status in such a context. In index (7) Integrated work group, the social-integrative aspect refers to, on the one hand, the spirit of community (social integration) and on the other, being recognized and accepted as an individual in the group (individual autonomy). More general integration in the organization as a whole is indicated by index (1) Culture integration. Furthermore, index (3) Conception of and attitudes towards the wheel can be assumed to reflect how such general integration is manifested in goal directed routine work that formulates and fulfils activity plans.

Thus, the dimensions of the indices can be assumed to reflect the degree of passive – active engagement and involvement in the work as well as the degree to which it varies in autonomic and/or social integrative directions. Reproductive – innovative ways of working can be related to the passive – active engagement dimension.

Innovative ways of acting and working seem to be compatible with active engagement in terms of problem solving, while the opposite may be assumed for reproductive methods of acting and working.

However, the relation between reproduction and innovation on the one hand, and directions of engagement towards individual autonomy or social integration on the other, appears slightly more complicated. Low engagement in both these directions does not seem to correlate with innovative ways of working. These two directions can be regarded as balancing each other in more or less dynamic ways, indicating both reproductive and innovative ways of working. At the same time, high engagement levels do not necessarily generate long term competence development.

As has been outlined in the theoretical lines of reasoning, it can be assumed that new and more innovative ways of thinking and acting are stimulated by differing opinions e.g. criticism of taken for granted conceptions of the company culture. It is possible that index (2) Bank is too cautious reflects such critical opinions. High levels of agreement in this index appear to indicate negative attitudes towards aspects of the company culture.

However, contrasting or conflicting values and attitudes as well as alternative ways of thinking may also contribute to less innovation or even stagnation due to static polarization and unfruitful conflicts. The definition of fruitful conflicts remains to be investigated empirically. On a work group level, autonomy seems to be related to the integrity and autonomy of the local manager, indicated by index (8) Autonomic and creative local manager. However, as can be seen in Table X above, this index is positively correlated with all other indices except index (2) Bank is too cautious.

8. SOME TENTATIVE TENDENCIES

The mean values of the indices reflecting gender and age differences are presented in Figure 1 and Figure 2 below

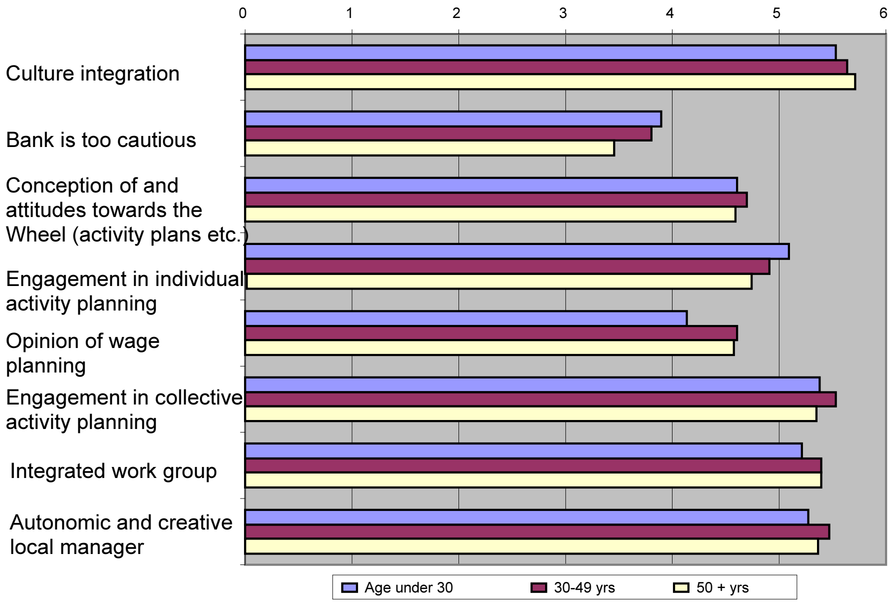

Fig. 2. Engagement in and commitment to bank activities. Age groups (N= 5347)

The overriding impression, which is also supported by the explorative interview results summarized above, is the high level of culture integration within the organization as well as an almost equally high degree of collective and individual involvement and engagement in the indices indicating various aspects of organizational activities. At the same time, some interesting differences related to age were revealed. In five of the indices, the engagement levels are lower in the youngest group, which

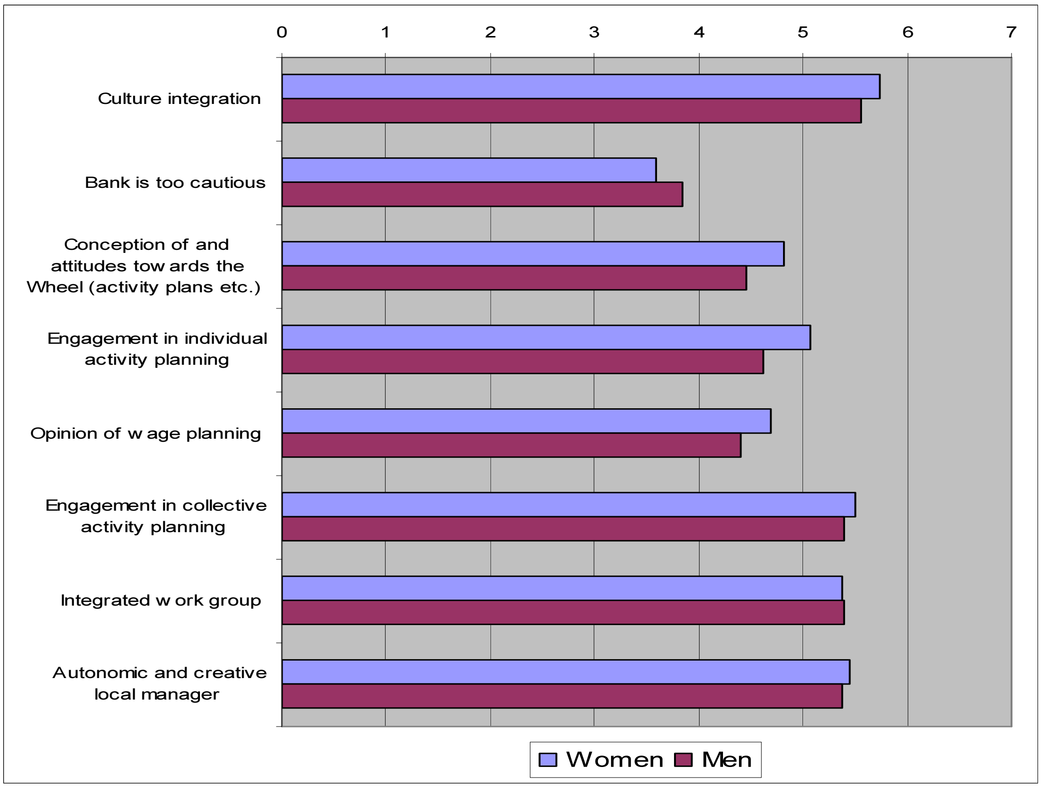

Fig. 1. Engagement in and commitment to bank activities. Gender differences (N=5347)

may indicate that these persons have had less time to become involved and engaged in the various bank activities. At the same time, the youngest group was more engaged in individual activity plans than the other age groups. The fact that the youngest group is more critical towards certain norms and values was revealed by their higher ratings in the Bank is too cautious index, which may indicate that the lower involvement and engagement levels are not only due to the shorter duration of employment.

The overriding impression in terms of gender differences is that women tend to score slightly higher in all indices with the sole exception of Bank is too cautious. These tendencies can be interpreted as higher involvement and engagement among women in general. However, the more critical attitude among men and younger people may be regarded as potentially innovative. This will be elaborated statistically as well as in a multi methodological investigation in the next research step.

9. CONCLUSIONS AND CONSIDERATIONS FOR FURTHER RESEARCH

The company culture based on Wallander's ideas (2002) seems to mainly stress the importance of "harmonious balances", which is reflected in the way of reasoning about the relations between social integration – individual autonomy and decentralization – centralization. This perspective may reflect an implicit or explicit idea of an ideal and permanent state of balance. Such a conception does not seem to include a vision of transformations towards more dynamic ways of reasoning and acting.

Further research will focus on such potential for change in the bank. In a more long term generational perspective, the continuation of the company "culture" may be problematic, due to the fact that new "generations" of employees may have difficulties reproducing the main elements of the company's management tradition. The "new generations" employed after the main changes of the 1970s have no firsthand experience of the challenging guiding concepts and values of the persons who carried through this organizational transformation.

The forthcoming multi-methodological study will elucidate in greater depth what characterizes, promotes and hinders innovative and reproductive work activities as well as further investigating the "new generations" aspects and the influence of individual complexity developmental levels among employees. Several methods will be applied, namely interviews, the Loevinger meaning completion test (WUSC, see Loevinger, 1970) and two surveys, the first aimed at deepening the knowledge of the extent and character of the interactions and social communication within work groups both quantitatively and qualitatively (Wasserman and Faust, 1994) and the second for the purpose of measuring work values (Gamberale et al, 1996, Hagström and Kjellberg, 2007).

References

Backström, T. (2004). Collective learning: a way over the ridge to a new organizational attractor. The Learning Organization, 11(6, Special Issue "Chaordic systems thinking for learning organizations"), 466-477.

Backström, T., F. M. van Eijnatten and M. Kira (2002). A complexity perspective on sustainable work systems. *Creating sustainable work systems: Perspectives and practices*. P.

Backström, T & Döös, M. 2008. Relationics a key concept in networked organizations. In *Encyclopaedia of networked and virtual organizations* G. D. Putnik, M. M. Cunha, Eds. (Idea Group Inc.

Benders, J., Huijgen, F., Pekruhl, U. & O'Kelly, K., P. (1999) Useful but unused – Group work in Europe. Dublin: European Foundation for Improvement of Living and Working Conditions

Bryman, A. (2004) *Social research methods*. New York: Oxford University Press Inc.

Cook-Greuter, S.R. (1999) Post autonomous ego development. A study of its nature and measurement. Doctoral thesis. The Graduate School of Education, Harvard University.

Docherty, P. (2002) Values and stakeholder relations. In P. Docherty, J. Forslin, J. & A. B. Shani (Eds). *Creating sustainable work systems. Emerging perspectives and practice*. p. 114–125. London: Routledge.(?)

Docherty, Forslin & Shani (2002) Creating sustainable work systems. Emerging perspectives and practice. New York: Routledge.

Ellström, P: E: (1992) Kompetens, utbildning och lärande i arbetslivet. Problem, begrepp och teoretiska perspektiv. Stockholm: Publica, Allmänna förlaget.

Ellström, P.E., Löfberg, A. & Svensson, L. (2005) Pedagogik i arbetslivet. Ett historiskt perspektiv. Pedagogisk Forskning i Sverige, 10 34.

Fisher, Torbert & Rooke (2003). Personal and Organisational Transformations: through action inquiry. Edge\Work Press, UK

Frese, M. & Zapf, D. (1994) Action as the core of work psychology. In: Dunette, M.D. & Leaetta, M.H. (Eds) Handbook of Industrial and Organizational Psychology- Palo Alto, CA.

Gamberale, F., Sconfienza, C. & Hagström, T.(1996) Värderingar och förhållningssätt till arbete bland ungdomar i Sverige. En kartläggning av ett representativt urval. Arbete och Hälsa 1996:19, Stockholm: Arbetslivsinstitutet.

Gibson, J.J. (1979) The ecological approach to visual perception. Boston.
Göransson, S (2007) Jagutveckling och arbetsorganisationen – en metodansats. Licentiatuppsats vid Pedagogiska institutionen, Stockholms universitet
Hagström, T. (Ed) (2003) Adult development in post-industrial society and working life. Stockholm Lectures in Educology, Lecture Series No. 2, Department of Education, Stockholm University.
Hagström, T & Hanson, M. ((2003) Flexible work contexts and human competence. An action-interaction frame of reference and empirical illustrations. In Bron, A. & Schemmann, M (Eds) Knowledge Society, Information Society and Adult Education. Challenges, Trends, Issues. Hamburg and London, Lit Verlag Münster (pp 148-180).
Hagström, T. & Kjellberg, A. (2007) Stability and change in work values among male and female nurses and engineers. Scandinavian Journal of Psychology, 48, 143-151
Hagström, T (2007) Arbetslivspedagogik och det gränslösa arbetet. En transaktionell ansats. Pedagogisk forskning i Sverige**,** Årg 12, Nr 4.
Hy, L. X. & Loevinger, J. (1996) Measuring ego development Second Edition. Mahwah, NJ: Lawrence Erlbaum Associates Inglehart, R. (1997) Modernization and post modernization. Cultural, economic and political change in 43 societies. Princeton, N.J.
Kegan, R (1982) The evolving self. Problems and process in human development. Cambridge MA, Harvard University Press.
Kegan R (1994) In Over Our Heads. The Mental Demands of Modern Life. Cambridge, MA, Harvard University Press
Kegan, R. (2003) Hidden curriculum of adult life: An adult developmental perspective. In Hagström, T. (Ed) Adult development in post-industrial society and working life. Stockholm Lectures in Educology, Lecture Series No. 2, Department of Education, Stockholm University.
Loevinger J, Wessler R (1970) *Measuring Ego Development Vol 1+2.* San Fransisco, CA, USA, Jossey-Bass

SUSTAINABLE CONVERSION PROCESSES OF MINING HERITAGE IN A SECOND LIFE CYCLE: A GEOCONSERVATION PERSPECTIVE

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Abstract This work emphasizes the importance of recovery processes of abandoned mining heritage in geomining museums, as an example of the transformative process of an organization towards a second life cycle. This reflects an important measure for sustainability, either for the organization and the surrounding environment.

Mining was an important pillar of development over the centuries, having suffered a decrease in its activity, both nationally and an European level. This decline resulted in the closure of many mining operations, with consequent degradation for both the mining and geological heritage, as well as the environment.

Keywords: Business-process, organizational culture, natural resources, geoconservation, sustainability.

GEOMINING MUSEUMS

Europe has a long tradition of mining activity, dating back as far as records of human settlement of Europe with the development of flint mines in France over 10,000 years ago. Georg Bauer, or as you preferred to be known by his Latin name *Georgius Agricola*, a local physician recorded methods of mining including dewatering and the environmental impacts associated with mining and mineral dressing in his classic book, *De Re Metallica* (1556) [21].

A few decades ago prosperous mining activities of geological resources were developed nevertheless the environmental damage caused by them. Nowadays, this scenario is completely imbalanced with a dual degradation: environmental and social.

One should ask is if the exhaustion of a mine necessarily implies the society disinterest for this kind of organizational structures. The answer for many people is to ignore this heritage. Nevertheless, is important to remind that some of the geological outcrops worldwide became to light, along with ethnographic and archaeological remains.

The unique opportunity to restore the dignity to these mining activities is to give them a second life cycle. The conversion into a thematic park and geomining museum can be an important way to the organizational sustainability, both internally and in interaction with the environment.

Mining parks are ancient mining exploitation areas, where a heritage protection is applied whether in terms of geological features or mining ones. These parks are designed to permit public visits with entertainment, didactical or scientific investigation purposes. This way there is a triple objective [15, 16, 18]: i) to recover a degraded area with an important patrimonial value; ii) to rehabilitate socially and economically a specific community and iii) to offer the public the possibility to contact with mining activity.

In this type of intervention distinction is made between natural resources and resources of anthropogenic character, as laid down in 1972 by *the Convention for the Protection of World Cultural and Natural Heritage* of UNESCO.

SUSTAINABILITY

At a social-economic level the main advantage is the promotion of regions where the economy depends on the exploitation of the mineral resources, and which have been made huge investments of capital for the extraction of raw materials, which range from the opening of tunnels and underground galleries to the installation of railway lines, roads and buildings.

More sustainable issues are achieved when local workers are involved in the project, as it generates local jobs and friendly environment between the community and the project itself. Generally, local workers are more advantageous for all the aspects of the project, since they may have special knowledge of the area and experience that can help against future problems related to the local conditions of the area.

The possibility of re-using old structures will improve the sustainable aspect of the project, as it reduces costs, save materials and decrease the use of natural resources. The final result will be environmentally friendlier if old structures are used.

The exploitation of cultural tourism is a sustainable alternative to mining areas that have ceased activity, creating a forum for teaching the history of the region as well as techniques and materials associated with mining operations, thereby creating new economic alternatives to regions that traditionally subsisted of mining. It must be highlighted that a geological mining park should include leisure, cultural, pedagogical and scientific research activities (fig. 1), [19].

Fig. 1. Aspect of a visit tour to a mine, guided by a former local miner [23].

Playful, cultural and pedagogical activities

Among the entertainment activities primarily recommended there is a guided tour to the mine, exhibiting geological features, mining extraction processes, as well as exploitation itself.

It is possible to create a scenario where the mining labour environment is shown, simulating activities and using restored equipment (figs. 2, 3).

Fig. 2. Appearance of recreation of a mining activity in a mining museum [22].

Fig. 3. A few artefacts from the Hall Coal Mine Museum in Scotland [24].

The same means of transportation used on mining activities can be utilized on routes inside and outside the mine (fig. 4).

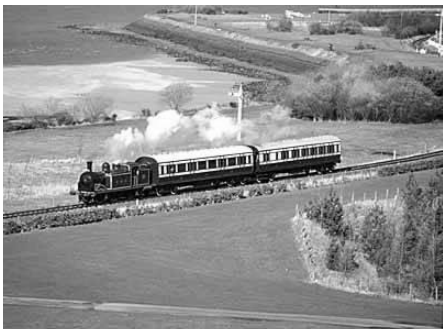

Fig. 4. Bo’ness & Kinneil Railway at Birkhill Fireclay Mine in Scotland [24].

The converted outdoor spaces can accommodate children's theme parks, picnic and camping areas, as well as thematic tours on foot, horseback, by boat, train or off-road vehicle, to assess the specific geological and mining of the site.

Scientific activities

When the park includes elements of scientific value — typically minerals and/or ore mining — they should be given special protection so that their study can be done by specialists.

The appropriateness of creating a centre for conservation and documentation enabling the study of the mining legacy, in terms of mining history and archaeology, history, geology and archaeology industrial, is also an added value from the scientific point of view.

Costs

The economical analysis of a project can only be made if we take into consideration the evaluation of the different costs involved. Its determination is therefore fundamental. The costs estimation requires the handling of an high number of factors, as well as variables, that is necessary to deal with in a systematical and organized way, in order not to commit mistakes or to forget compounds.

We must take into consideration that the thematic park is composed by several subprojects that may be totally different between them, which implies a relatively complex process of costs determination. It is necessary to distinguish between: capital, operational, general and control costs.

The necessary amount to invest is rarely owned by the promoting company, so it implies the financing of part of the project by special protection heritage founds, that implies viability studies.

BACKGROUND

The valuable of the historical legacy left over by centuries of mining activities in Europe is reflected in more than five hundred former holdings slightly across Europe that has been converted into museums, parks or protected natural areas for recreation [10, 14].

The first museum of a technical nature in the world was created in Paris at the end of the eighteenth century. Among the inventory of machines and documentation, were also collected equipments from mining operations.

Either way, the first major museum devoted entirely to mining activities was the Bergbau Deutsches Museum, which opened its doors in Bochum, Germany, 1930. It consists of a series of realistic and historically authentic scenes depicting working conditions in a mine. Original equipment and machinery from all periods of European mining can be seen. On a 900m guide-line through mine galleries the different techniques and methods of mining are displayed: Mining engineering in the proper sense with sections like shaft sinking, shaft hoisting, mine safety etc.; the mines with displays on the mining of ore, salt and coal; and a third section with mining machinery, ore preparation and coal treatment. It is a museum that is still in full activity, currently receiving an annual average of 400.000 visits. This was the first of hundreds of mining museums spread throughout all Europe, but whose implementation has suffered significant increase from the *First Congress of Industrial Archaeology* held in 1968 in Coalbrokdale in England [7]. The figure 5 gives a clear picture of working conditions for a miner in the 1950's.

Fig. 5. Working in an inclined coal seam, 20th century, in Upper Bavaria [25].

European Mining Museums

In England, the *National Association of Mining History Organizations*, counts more than 20 geomining museums as members, and points out for 300.000 visitors per year for the most visited mining museum, at the Iron Bridge region.

In France amongst the many mining museums, we can refer the *Historic Mining Centre of Lewarde* with 150.000 visits per year and the Noyant-la-Gravoyère Mining Museum with 250.000 visits per year.

Germany, as pioneer in this area, has the highest number of mining museums. The *Historisches Kupferberwerk* in Fisbac notes 80.000 and the *Ramsbeck Sulfur Mining Museum* 100.000 visits per year.

To refer just a few more number, we can point out to the *Mijnmuseum of Kerkrade* in Holland, with 300.000 visits/year; the *Golden World Museum* in Finland with 100.000 visits/year and the famous *Wieliczka Museum* in Poland, with 800.000 visitants per year.

Portuguese Mining Museums

In Portugal, there is evidence of mining from pre-Roman times, especially for Cu-Au-Ag and Fe-Cu-Sn. The Roman epoch exploited mainly Au in the north of the country, and Cu, Au, and

Ag in the Iberian sulphide province. Most mining occurred in the 20th century, exploiting deposits of Fe and Mn, Sn and W, radioactive ores for Ra and U, as well as deposits of Ag and Au (fig.6), [21].

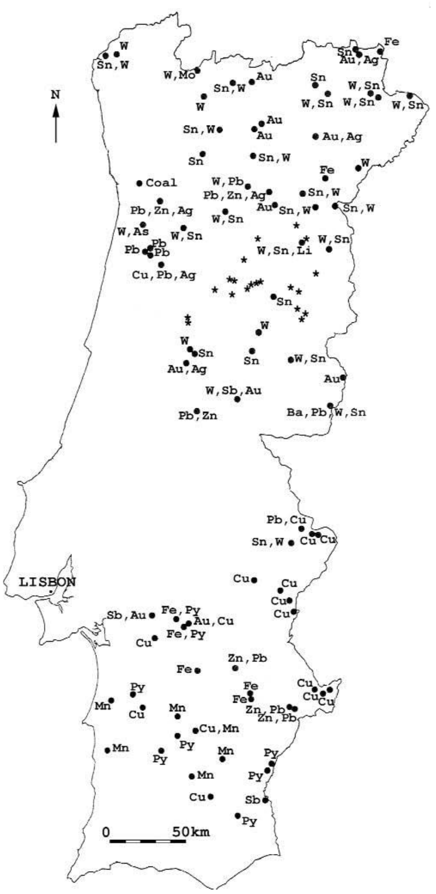

Fig. 6. Major abandoned mines in Portugal: an overview [12,21].

In Portugal there are also some projects running but still a few mining museums working properly. The main institutions supporting these mining heritage protection actions are the *Instituto Nacional de Engenharia, Tecnologia e Inovação*, the *Instituto Português do Património Arquitectónico* and several environmental protection associations.

The main projects are [1,2,11,17]:

- Mining Museum of S. Pedro da Cova Coal Mines;
- Mining Museum of S. Domingos Mines;
- Mining Museum of Aljustrel Copper Mines;
- Iron Museum of Moncorvo region;
- Mining Park of Covas dos Mouros;
- Lousal Mining Museum;

In most of these projects there is also the involvement of the regional authorities as indispensable partners.

GEOCONSERVATION

The conservation of the geological heritage (geoconservation) is of great importance for society for three main reasons [3,4,5,6,7,8,20]: i) geosites with scientific importance are essential for the advancement of the Geosciences; ii) geosites of educational significance are very important for promotion of the teaching/learning of geosciences in different contexts; iii) geosites with geotouristic relevance are the support for significant economic activities.

The Aveleira mine case study

The Aveleira Mine is an old wolfram mine (fig.7), belonging to the Monastery of St Martin of Tibães, near Braga, in the North of Portugal. It was the mother house of the Benedictine order in Portugal. By the initiative of the Tibães Monastery (actually *Direcção Regional de Cultura do Norte*) this mine will probably reconverted, partially, in a geomining museum.

Fig. 7. Aveleira wolfram Mine, St Martin of Tibães.

However, before decide which actions to implement, it was necessary to define the conservation grade and the possibility of a geotechnical recovery of the mine [9,13]. Therefore, a multidisciplinary LABCARGA (Laboratory of Cartography and Applied Geology) team took the responsibility of this part of the study. The project aim was to present a methodological approach, in a geoconservation point of view, allowing an ulterior partially recovering and stabilization of the ancient mine. Therefore, the initial studies that were carried out involved a compilation of documentation, as well as cartographic, geomorphologic, geotectonic and hydrogeological surveys. In addition, several geologic, geotechnical and geomechanical mining studies were performed. The main goal of this work to feasibly general public visits with both cultural and scientific purposes.

ACKNOWLEDGEMENTS

This paper is a LABCARGA contribution. This study was performed within the scope of the "*HidroUrban - Hidrogeologia, geomecânica e geoconservação de antigas minas de água: contribuição para a gestão dos recursos hídricos subterrâneos em áreas urbanas e peri-urbanas"* supported by the IPP|PADInv'2007 and the LABCARGA R&D Project *"Mosteiro de Tibães: "Minas das Aveleiras: elaboração do estudo geológico-geotécnico e projecto da estrutura de reforço e de protecção".*

References

[1] Barroqueiro, M.L., *O Projecto Rio e o Património Geomineiro das Minas da Panasqueira*, 3º Simpósio Sobre Mineração e Metalurgia Históricas no Sudoeste Europeu, Porto, 2005.
[2] Brandão, J. M. (Ed.), *Actas do Congresso Internacional sobre Património Geológico e Mineiro*. IGM/SEDPGYM/FCT. Instituto Politécnico de Beja. 2002.
[3] Brilha J., Andrade C., Azeredo A., Barriga F.J.A.S., Cachão M., Couto H., Cunha P.P., Crispim J.A., Dantas P., Duarte L.V.,. Freitas M.C, Granja M.H., Henriques M.H., Henriques P., Lopes L., Madeira J., Matos J.M.X., Noronha F., Pais J., Piçarra J., Ramalho M.M., Relvas J.M.R.S., Ribeiro A., Santos A., Santos V. & Terrinha P., *Definition of the Portuguese frameworks with international relevance as an input for the European geological heritage characterisation*. Episodes, volume 28 (3), 2005.
[4] Brilha, J., *A general overview of geoconservation in Portugal*. IV Int. Symp. ProGeo, Braga, 2005.
[5] Brilha, J.B., *Geoconservation and protected areas*, Environmental Conservation, volume 29 (3), 2002.
[6] Brilha, J.B., *Património geológico e geoconservação: a conservação da natureza na sua vertente geológica*. Palimage Editores, Viseu, 2005.
[7] Dowling R. & Newsome D., *Geotourism*. Elsevier, 2005.
[8] Gray, M. *Geodiversity: valuing and conserving abiotic nature*. John Wiley and Sons, Chichester, 2004.
[9] Lopes, M.E, in prep. Geodiversidade e Geoconservação do património geológico-mineiro: os casos dos subterrâneos do Porto e da mina das Aveleiras (Braga). Universidade de Coimbra. (PhD Thesis, in preparation).
[10] Martinez, C.R., Lacalle, A.B., *Optimización del Patrimonio Minero Español*, 3º Simpósio Sobre Mineração e Metalurgia Históricas no Sudoeste Europeu, Porto, 2005.
[11] Matos, J.X., Rodrigues, S., *Contribuição Para a Valorização Patrimonial e Geoambiental da Mina de Cobre de Aparis, Barrancos, Alentejo*, 3º Simpósio Sobre Mineração e Metalurgia Históricas no Sudoeste Europeu, Porto, 2005.
[12] Nero, J.M.G., *A situação portuguesa relativamente à reabilitação ambiental de minas abandonadas recuperação ambiental de áreas mineiras abandonadas*. In: Workshop Reabilitação Ambiental das Áreas Mineiras Abandonadas, 2004.
[13] Neto, E.P., *Estudo Geológico e Geomecânico em Antigas Explorações Mineiras: O Caso da Mina das Aveleiras*, Tese de Mestrado, Universidade de Aveiro, Departamento de Geociências, Aveiro, 2007.
[14] Orche, E., *La Funcion Multidisciplinar de Los Parques Geomineros*, V Reunión Nacional de la Cómision de Património Geológico, Murcia, 2001.
[15] Orche, E., *Pueste en el Valor del Património Geológico-Minero: El Processo de Adaptación de Explotaciones Mineras a Parques Temáticos*, Universidade de Vigo, Vigo, 2002.
[16] Peña, J.L., Garcia, E., *Metodologia Para La Transformacion de Labores Mineras em Parques Temáticos*, Universidade de Vigo, 2002.
[17] Santos, M.L:, Tinoco, A.A., *A Practical Case of Conservation and Reuse of Industrial Heritage: The Lousal Mine – Grândola, Portugal*, II Latin American Conference on Rescue, Preservation and Reuse of the Industrial Heritage, 1999.
[18] SEDPGYM – Sociedad Española para la defensa del Património Geológico y Minero, *Actas da mineração e metalurgia históricas no Sudoeste Europeu*. SEDPGYM / IPPAR /FCT. Faculdade de Engenharia do Porto, 2006.
[19] Theodossiou-Drandaki, I. *No conservation without education*. In: Geological Heritage: Its Conservation and Management. Barettino, D., Wimbledon, W.A.P., Gallego, E. (Eds), ITGE, Madrid, España, 2000.
[20] Wilson, C. [ed.], Earth heritage conservation. The Open University, Milton Keynes, 1994.
[21] Wolkersdorfer, C. & Bowell, R. [eds.], Contemporary Reviews of Mine Water Studies in Europe. Mine Water and the Environment, volume 24, 2005.
[22] http://www.namho.org/
[23] http://www.ncm.org.uk/
[24] http://www.scottishminingmuseum.com/
[25] http://www.deutsches-museum.de/en/exhibitions/werkstoffe-produktion/

ON TURBULENT ENVIRONMENT AND ADAPTIVE BEHAVIOUR

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Abstract: We conjecture the human species is permanently and exclusively occupied in two tasks, the creation of knowledge and the construction of society. Our aim is to translate it mathematically. We begin by listing a sample of fifteen types of environment turbulence and the adaptive countermeasures mankind has opposed to them till today. Then we state certain general modelling conditions and we are able to fit the model and to synthesize the theoretical support. As model testing we discuss several topics.

Keywords: Adaptive_system, engineering, heuristics, knowledge creation, society.

1. INTRODUCTION

We have been working for some time in a theory of human behaviour, that we have called “the theory of the double task”. It conjectures that the human species is permanently and exclusively occupied in two tasks, the creation of knowledge and the construction of society.

This conjecture was inspired by the work of two authors, Norbert Wiener and Pierre Bourdieu and particularly by two books: *Cybernetics or control and communication in the animal and the machine* [16] and *Science de la science et réflexivité* [17] .

The present work appears as a fair opportunity to find a very general approach to the problem of business sustainability in turbulent environments, on one hand, and on the other hand, to provide a test of applicability of our theory.

We begin by listing a sample of fifteen types of environment turbulence (2) that we believe are representative and the adaptive countermeasures mankind has opposed to them till today.

Then we state certain general modelling conditions (3) and we are able to fit the model (4).

In (5) we synthesize the theoretical support of the model.

As Model Testing (6) in (6.1) we discuss sustainability; in (6.2) we discuss the interest of the model for business management; in (6.3) we establish a parallel between business management paradigms and the origins of the model; in (6.4) we look at technology as the development of creation of knowledge; in (6.5) we see learning as proper creation of knowledge; in (6.6) we ask if the model is valid for People and its environment.

As conclusions (7) we argue that the model is a general one i.e. that it is valid for different epochs; that it is a forecasting one i.e. that it admits extrapolation in future time; that it is an accurate one i.e. that it does not introduce any calculation errors.

2. ENVIRONMENT TURBULENCE AND ADAPTIVE COUNTERMEASURES

We believe that the sample of types $(\mathbf{t_{ij}^{k}})$ we have chosen is representative and that the opposing sets of countermeasures $\mathbf{A_k(\ )}$sum up to the present situation. Types $(\mathbf{t_{ij}^{k}})$ have a rank **i**, corresponding to its nature, an order **j** corresponding to its location and an epoch **k** corresponding to the time of its observation. Countermeasure $\mathbf{A_k(\ )}$ corresponds to an epoch **k** (time of intervention = time of observation). Only for **k** ≥ 4 the observers are capable of intervention ($\mathbf{A_k} \neq 0$). And it is a consequence of the chain of determinations (⟶) for a certain epoch, see below:

$$\mathbf{k} \longrightarrow \mathbf{S}_{\mathbf{k},\,(3^{k-4}+1)/2} \longrightarrow \mathcal{C}^{\mathbf{k}} \longrightarrow \mathbf{M_k} \longrightarrow \mathbf{A_k}$$

for **k**≥ 4

Epoch → Root of tree → Tree → Heuristic of discovery → Methodology of intervention to be made clear in sections **3.** and **4.**

2.1 Types of Environment Turbulence

1. Earthquakes $(\mathbf{t_{1j}^{k}})$
2. Tsunamis $(\mathbf{t_{2j}^{k}})$
3. Volcanoes $(\mathbf{t_{3j}^{k}})$
4. River floods $(\mathbf{t_{4j}^{k}})$
5. Landslides $(\mathbf{t_{5j}^{k}})$
6. Meteorological phenomena $(\mathbf{t_{6j}^{k}})$
7. Droughts $(\mathbf{t_{7j}^{k}})$

8. Epidemics **(t_{8j}^{k})**

9. Wars **(t_{9j}^{k})**

10. Stock exchange collapses **($t_{10,j}^{k}$)**

11. Starvation **($t_{11,j}^{k}$)**

12. Deforestation **($t_{12,j}^{k}$)**

13. Species extinction **($t_{13,j}^{k}$)**

14. Energy shortage **($t_{14,j}^{k}$)**

15. Pollution **($t_{15,j}^{k}$)**

2.2 Sets of Adaptive Countermeasures

1. Early warning nets
Proper building
International cooperation
$A_4(t_{1j}^{4})$, $A_5(t_{1j}^{5})$, $A_6(t_{1j}^{6})$, $A_7(t_{1j}^{7})$, $A_8(t_{1j}^{8})$

2. Early warning nets
International cooperation
$A_4(t_{2j}^{4})$, $A_5(t_{2j}^{5})$, $A_6(t_{2j}^{6})$, $A_7(t_{2j}^{7})$, $A_8(t_{2j}^{8})$

3. Monitoring stations
Conditioning of settlement
$A_4(t_{3j}^{4})$, $A_5(t_{3j}^{5})$, $A_6(t_{3j}^{6})$, $A_7(t_{3j}^{7})$, $A_8(t_{3j}^{8})$

4. Dikes, Dams
Monitoring of river floods
International cooperation
$A_4(t_{4j}^{4})$, $A_5(t_{4j}^{5})$, $A_6(t_{4j}^{6})$, $A_7(t_{4j}^{7})$, $A_8(t_{4j}^{8})$

5. Slopes civil engineering
Conditioning of settlement
$A_4(t_{5j}^{4})$, $A_5(t_{5j}^{5})$, $A_6(t_{5j}^{6})$, $A_7(t_{5j}^{7})$, $A_8(t_{5j}^{8})$

6. Weather monitoring and forecasting
International cooperation
$A_4(t_{6j}^{4})$, $A_5(t_{6j}^{5})$, $A_6(t_{6j}^{6})$, $A_7(t_{6j}^{7})$, $A_8(t_{6j}^{8})$

7. Dams, river basin exploitation
Desalination of sea water
Artesian holes
International cooperation
$A_4(t_{7j}^{4})$, $A_5(t_{7j}^{5})$, $A_6(t_{7j}^{6})$, $A_7(t_{7j}^{7})$, $A_8(t_{7j}^{8})$

8. Improved sanitary conditions
Vaccines, antibiotics, antiviruses
Monitoring and early warning
World Health Organization
$A_4(t_{8j}^{4})$, $A_5(t_{8j}^{5})$, $A_6(t_{8j}^{6})$, $A_7(t_{8j}^{7})$, $A_8(t_{8j}^{8})$

9. International mediation
Moderating regional organizations
United Nations
$A_4(t_{9j}^{4})$, $A_5(t_{9j}^{5})$, $A_6(t_{9j}^{6})$, $A_7(t_{9j}^{7})$, $A_8(t_{9j}^{8})$

10. Rigorous and strict regulations
both national and international
$A_4(t_{10,j}^{4})$, $A_5(t_{10,j}^{5})$, $A_6(t_{10,j}^{6})$, $A_7(t_{10,j}^{7})$, $A_8(t_{10,j}^{8})$

11. Prevention
Help from non-affected countries
$A_4(t_{11,j}^{4})$, $A_5(t_{11,j}^{5})$, $A_6(t_{11,j}^{6})$, $A_7(t_{11,j}^{7})$, $A_8(t_{11,j}^{8})$

12. Protection of woodlands
$A_4(t_{12,j}^{4})$, $A_5(t_{12,j}^{5})$, $A_6(t_{12,j}^{6})$, $A_7(t_{12,j}^{7})$, $A_8(t_{12,j}^{8})$,

13. Protection of endangered species
$A_4(t_{13,j}^{4})$, $A_5(t_{13,j}^{5})$, $A_6(t_{13,j}^{6})$, $A_7(t_{13,j}^{7})$, $A_8(t_{13,j}^{8})$,

14. Rational use
Search of renewable sources
International cooperation
$A_4(t_{14,j}^{4})$, $A_5(t_{14,j}^{5})$, $A_6(t_{14,j}^{6})$, $A_7(t_{14,j}^{7})$, $A_8(t_{14,j}^{8})$,

15. Recycling
Rational waste disposal
International agreements on upper
ceilings or bans
$A_4(t_{15,j}^{4})$, $A_5(t_{15,j}^{5})$, $A_6(t_{15,j}^{6})$, $A_7(t_{15,j}^{7})$, $A_8(t_{15,j}^{8})$

Admitting that **$A_4(E)$, $A_5(E)$,…, $A_k(E)$** is the adaptive response to the environment, we believe (see **3.2**) that the actual approximation is **$A_4(E)$, $A_5(E)$, …, $A_8(E)$** depending on the most recent reaction to the environment.

Likewise to an environment turbulence type t_{ij}^{k} we attribute an adaptive response $A_4(t_{ij}^{4})$ $A_5(t_{ij}^{5})$ $A_6(t_{ij}^{6})$ $A_7(t_{ij}^{7})$… $A_k(t_{ij}^{k})$ to obtain $A_4(t_{1j}^{4})$, $A_5(t_{1j}^{5})$, $A_6(t_{1j}^{6})$, $A_7(t_{1j}^{7})$, $A_8(t_{1j}^{8})$; $A_4(t_{2j}^{4})$, $A_5(t_{2j}^{5})$,

$A_6(t_{2j}{}^6)$, $A_7(t_{2j}{}^7)$, $A_8(t_{2j}{}^8)$; …; $A_4(t_{15,j}{}^4)$, $A_5(t_{15,j}{}^5)$, $A_6(t_{15,j}{}^6)$, $A_7(t_{15,j}{}^7)$, $A_8(t_{15,j}{}^8)$.

3. CONSIDERATIONS ABOUT MODELLING CONDITIONS

3.1 Double Task Process

We consider a "double task process", that is to say creation of knowledge and construction of society and the only and permanent occupation of the human species.

In terms of model it amounts to assign to the creation of knowledge a particular succession:

$$A_4, A_5, \ldots, A_k$$

of successions $\mathbf{A_k}$:$\mathbf{M_1, M_2, \ldots, M_k}$ of mental heuristics and to assign to the construction of society a special succession of trees,

$\mathcal{C}^4{}_1, \mathcal{C}^5{}_2, \ldots \mathcal{C}^k{}_j$, of roots, social heuristics

S_{kj} with $j = (3^{k-4} + 1) / 2$.

3.2 Creation of Knowledge

$$\underbrace{M_1, M_2, M_3, M_4}_{A_4};\ \underbrace{M_1, M_2, M_3, M_4, M_5}_{A_5};\ \ldots;\ \underbrace{M_1, M_2 \ldots M_k}_{A_k}$$

Methodologies in the creation of knowledge

By studying and comparing the methodologies of various branches of knowledge we have found $\mathbf{A_8}$ [1] (see 5.2):

$\mathbf{M_1}$ = Observation of reality signals

$\mathbf{M_2}$ = Association of data

$\mathbf{M_3}$ = Search of regularities

$\mathbf{M_4}$ = Formulation of hypothesis

$\mathbf{M_5}$ = Codification of symbols

$\mathbf{M_6}$ = Formalization of structures

$\mathbf{M_7}$ = Concretization of theories

$\mathbf{M_8}$ = Construction of practices

and five multiplicity rules that mental heuristics must follow:

(1.) D = **ABC**

(2.) A is a part of **C**

(3.) B is a part of **C**

(4.) To one element of **A** corresponds zero or more elements of **B**.

(5.) To one element of **B** corresponds one or more elements of **A**.

3.3 Construction of Society

By studying the theories of enterprise science [2] [3] [4] [5] [6] [7], ethology [8] [9] [10] and evolutive biology [11] [12] we have succeeded in building tree $\mathcal{C}^7{}_{14}$ (see Appendix).

Appendix is a representation of tree $\mathcal{C}^8{}_{41}$ and of trees $\mathcal{C}^7{}_{14}$, $\mathcal{C}^6{}_5$, $\mathcal{C}^5{}_2$ and $\mathcal{C}^4{}_1$.

As an example of $\mathcal{C}^7{}_{14}$ construction we have:

C B A

Organization **(1.)''(2.)(3.)(4.)(5.)** ↑

C B A

Production **(1.)'(2.)(3.)(4.)(5.)** ↑

C B A

Society **(1.)(2.)(3.)(4.)(5.)** ↑

Applying the multiplicity rules (see 3.2)

(1.) Society = **ABC** and

(1.)' Production = **ABC** and

(1.)'' Organization = **ABC** and

(2.)

(3.)

(4.)

(5.)

Recursive operations leading in three stages to the construction of $\mathcal{C}^7{}_{14}$.

4. SKETCH OF A DESCRIBING MODEL

Now we consider the successive constructions (trees) of social reality (construction of society):

$$\mathcal{C}^4{}_1, \mathcal{C}^5{}_2, \ldots, \mathcal{C}^k{}_{(3^{k-4}+1)/2}$$

of nodes

$$S_{i,[3^{i-4}(2n-1)+1]/2}$$

with $4 \le i \le k$, and $1 \le n \le 3^{k-i}$

to whom respond successive adaptive countermeasures (creation of knowledge)

$\mathbf{M_4, M_5, \ldots, M_i}$ (see 5.2)

obeying to the formula

$$M_i = \; 3^{\,i-r} \quad [3^{r-4}(2n-1)+1] \;/\; 2$$

with $\mathbf{4 \le r \le i,\ 4 \le i \le k}$ and $\mathbf{1 \le n \le 3^{i-r}}$

where $\mathbf{M_i}$ is a mental heuristic or manifestation of genetic configurations in the central nervous systems of the human species and

$$S_{r,\,[3^{r-4}\,[(2n-1)+1]\,/\,2}$$

is a social heuristic or collective manifestation of the human species (see 5.3).

And now we state the initial conditions of the model: $\mathbf{M_1} = e^{1}$; $\mathbf{M_2} = e^{2}$; $\mathbf{M_3} = e^{3}$.

Besides we can conclude that mental heuristic $\mathbf{M_i}$ is the sum of all the nodes of tree $e^{i}_{(3^{i-4}+1)/2}$.

We have succeeded in building e^{8}_{41} (see Appendix) and finding $\mathbf{M_8}$ (see 3.2).

We are convinced that it is the solution for the present problem.

So we can describe our solution as:

. a social tree e^{8}_{41} **and**

. an adaptive response $\mathbf{M_8}$

5. TENSOR REPRESENTATION AND LAWS OF FORMATION

5.1 Formalization

We have found a way to the formalization of our model.

It supposes the tensor representation [15] and the recognition of laws of formation of mental heuristics and social heuristics.

This is the theoretical support of our model.

5.2 Law of Formation in A_k

In the creation of knowledge the paradigm for the law of formation is the relation (in propositional calculus) among the first four mental heuristics (see 3.2):

Formulation of hypothesis

=

Observation of reality signals

Λ

Association of data

Λ

Search of regularities

$$M_4 = M_1 \wedge M_2 \wedge M_3$$

Likewise for each succession $\mathbf{A_k}$ and for every mental heuristic with $\mathbf{k \ge 4}$

$$M_k = M_{k-3}\, M_{k-2}\, M_{k-1}$$

Tensor representation not only provides generality but it also provides easy handling.

5.3 Law of Formation in $e^{k}_{(3^{k-4}+1)/2}$

In the construction of society the paradigm for the law of formation is in the relation (in propositional calculus) in tree e^{5}_{2} (see Appendix) in wich

Organization = Task Λ Activity Λ Goal

$$S_{52} = S_{41} \wedge S_{42} \wedge S_{43}$$

Likewise for each tree $e^{k}_{(3^{k-4}+1)/2}$ and for every social heuristic

with $\mathbf{5 \le i \le k}$, $\mathbf{j = [3^{i-4}(2n-1)+1] / 2,\ \ 1 \le n \le 3^{k-i}}$

$$S_{ij} = S_{i-1,\,j-3^{i-5}}\; S_{i-1,\,j}\; S_{i-1,\,j+3^{i-5}}$$

Tensor representation provides the desired generality and allows easy handling.

5.4 Tensor Representation

Tensor representation is more than just a complement to the model, it is a necessary and in-built condition and without it the model does not make sense.

Indeed the model is a reality representation only if the mental heuristics and the social heuristics are represented as tensors as anyone can verify beginning with the initial values of the two laws of formation.

6. MODEL TESTING

6.1 Sustainability

Until now we have considered "sustainability" ≡ "adaptive behaviour" .

Enterprise [3] has the actual role as the social dominant form.

On those conditions "enterprise sustainability" is the cultural paradigm of "human species sustainability".

Contrary to that current opinion our model points to human species adaptive behaviour creating knowledge (**A_4, A_5, …, A_8)** and constructing society ($\mathcal{C}^4_1$, $\mathcal{C}^5_2$, ... $\mathcal{C}^8_{41}$**)**. It is a new paradigm.

6.2 Interest for Business Management

The succession of trees $\mathcal{C}^4_1$, $\mathcal{C}^5_2$, $\mathcal{C}^6_5$, $\mathcal{C}^7_{14}$, develops an analysis capacity decisively increased by $\mathcal{C}^4_1$, $\mathcal{C}^5_2$, ..., $\mathcal{C}^8_{41}$, ($\mathcal{C}^7_{14}$ has 40 nodes, $\mathcal{C}^8_{41}$ has 121 nodes).

The succession of methodologies **A_4, A_5, A_6, A_7** develops an intervention capacity greatly increased by **A_4, A_5, …, A_8** (**M_7** is a tensor of order 37, **M_8** is a tensor of order 68).

Analysis capacity and intervention capacity of undeniable interest, namely in business management.

6.3 Management Paradigms/ Origin of Model

The parallel between enterprise management paradigms and the origin of our model goes even further:

. Questions of method / creation of knowledge [1];

What is new is the parallel with the development of physical science. And the entire new world it opens.

. Productivity/ enterprise science [2] [3] [4] [5] [6] [7];

Production is an obligatory issue in every work on enterprise science and stays as a root concept of our model.

. Behaviour / ethology [8] [9] [10];

Much to learn with the lessons of the founding fathers of ethology.

. Competitiveness / evolutive biology [11] [12].

Better in the original [11]. Eliminates some old doubts [11].

6.4. Technology

Technology in its usual acceptation is reflected by the development of the creation of knowledge.

Or in other words techniques as the cumulative effects of successions of mental heuristics:

$$\mathbf{A_4}$$

$$\mathbf{A_4, A_5}$$

$$\mathbf{A_4, A_5 \ldots, A_k}$$

6.5 Learning

Learning as the process of acquiring knowledge is immediately captured by the modelling conditions:

$$\underbrace{M_1, M_2, M_3, M_4}_{A_4};\ \underbrace{M_1, M_2, M_3, M_4, M_5}_{A_5};\ \ldots;\ \underbrace{M_1, M_2 \ldots M_k}_{A_k}$$

Methodologies in the creation of knowledge

Mental heuristics

M_1 = Observation of reality signals

M_2 = Association of data

M_3 = Search of regularities

M_4 = Formulation of hypothesis

M_5 = Codification of symbols

M_6 = Formalization of structures

M_7 = Concretization of theories

M_8 = Construction of practices

6.6 People and Its Environment

Is the solution $\mathcal{C}^8_{41}$, **M_8** valid for People and its environment?

By its own construction the model is oriented to People ("the only and permanent occupation of the human species") and the two tasks, creation of knowledge and construction of society, are turned to its environment (human environment).

6.7 Comment

This is a reduced sample of model responses to several types of demand.

Owing to its conception and general foundation [13] [14] the model aims to respond to a number of questions on the border of various disciplines while staying firmly on the ground of engineering.

7. CONCLUSIONS

7.1. The model Is general

It is valid for different epochs.

The existence of the tree $\boldsymbol{e}^{8}_{41}$, supposes the existence of $\boldsymbol{e}^{4}_{1}$, $\boldsymbol{e}^{5}_{2}$, $\boldsymbol{e}^{6}_{5}$ and $\boldsymbol{e}^{7}_{14}$.

The existence of the heuristic $\mathbf{M_8}$ supposes the existence of the succession $\mathbf{M_1, M_2 \ldots, M_7}$.

The solution coexists with the preceding solutions.

So, the model is general.

7.2 The model is forecasting

It admits extrapolation in future time.

Admitting that the model is valid there is no formal reason not to accept a computable prevision

$\boldsymbol{e}^{9}_{122}$, $\mathbf{M_9}$

So, the model is a forecasting one.

7.3 The model is accurate

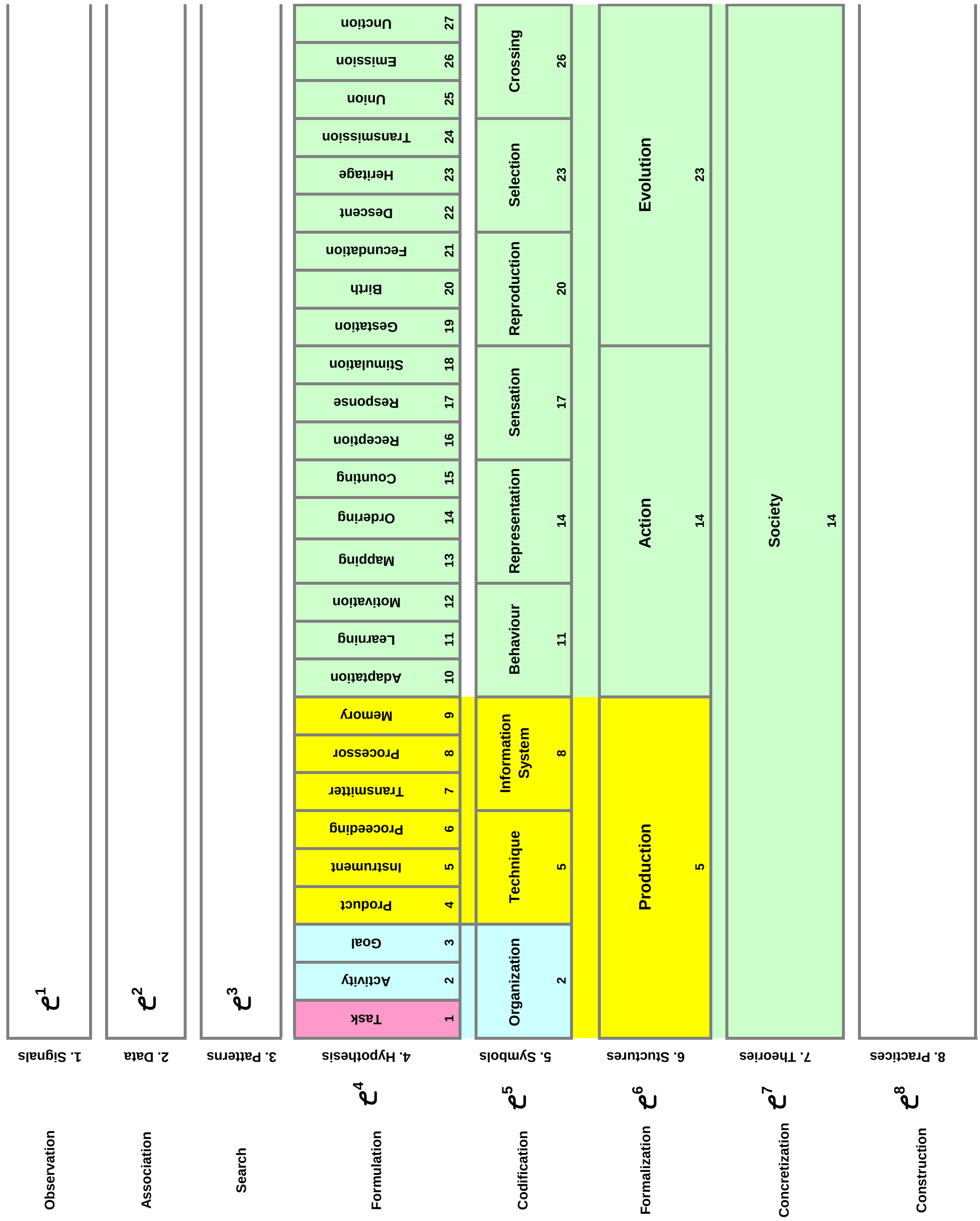
By its particular kind of definition the model does not introduce any calculation errors.

So, the model is accurate.

References

[1] Dolling, L. M., Gianelli A. F., Statile G. N. (ed.), The Test of Time. Readings in the Development of Physical Theory. 2003, Princeton University Press.
[2] Vernadat, F.B., Enterprise Modeling and Integration: principles and applications.1996, Chapman and Hall.
[3] IFIP – IFAC Task Force, GERAM - Generalised Enterprise Reference Architecture and Methodology, Version 1.6.2. 1998.
[4] AMICE (ESPRIT Consortium) CIMOSA: Open System Architecture for CIM. Eds.1991, Springer-Verlag
[5] Bernus, P., Nemes, L., Williams, T. J. eds, Architectures for Enterprise Integration. 1996, Chapman and Hall.
[6] Scheer, A.-W. , Business Process Modeling. 1999, Springer – Verlag.
[7] Checkland, P., Systems Thinking, Systems Practice. 1981, John Wiley & Sons Ltd.
[8] Tinbergen, N., The Study of Instinct.1989, Oxford University Press.
[9] Lorenz, K., L´Homme dans le Fleuve du Vivant.1981, Flammarion.
[10] Hinde, R. A., Ethology, Its nature and relations with other sciences. 1986, Fontana Press.
[11] Darwin, C., The Origin of Species.1956, Oxford University Press.
[12] Moore, J. A. (Ed.), Ideas in Modern Biology, Proceedings Vol. 6. XVI International Congress of Zoology. 1965, The Natural History Press. New York.
[13] Klüver, J., The Dynamics and Evolution of Social Systems: New Foundations of a Mathematical Sociology. 2000, Kluwer Academic Publishers.
[14] Klüver, J., An Essay Concerning Sociocultural Evolution: Theoretical Principles and Mathematical Models. 2002, Kluwer Academic Publishers.
[15] Spain, B.,Tensor Calculus, A Concise Course. 2003, Dover.
[16] Wiener, N. Cybernetics or control and communication in the animal and the machine.1958 Hermann.
[17] Bourdieu, P. Science de la science et réflexivité. 2001, Éditions Raisons d'Agi.

Appendix


Observation
Association
Search
Formulation
Codification
Formalization
Concretization
Construction
e^1 1. Signals
e^2 2. Data
e^3 3. Patterns
e^4 4. Hypothesis
e^5 5. Symbols
e^6 6. Stuctures
e^7 7. Theories
e^8 8. Practices
1 Task
2 Activity
3 Goal
4 Product
5 Instrument
6 Proceeding
7 Transmitter
8 Processor
9 Memory
10 Adaptation
11 Learning
12 Motivation
13 Mapping
14 Ordering
15 Counting
16 Reception
17 Response
18 Stimulation
19 Gestation
20 Birth
21 Fecundation
22 Descent
23 Heritage
24 Transmission
25 Union
26 Emission
27 Unction
Organization 2
Technique 5
Information System 8
Behaviour 11
Representation 14
Sensation 17
Reproduction 20
Selection 23
Crossing 26
Production 5
Action 14
Evolution 23
Society 14

28	Work	Method	29	Engineering	32	Culture	41	Globalization	41
29	Construction								
30	Project								
31	Innovation	Knowhow	32						
32	Operation								
33	Process								
34	Hardware	Informatics	35						
35	Firmware								
36	Software								
37	Practice	Research	38	Science	41				
38	Analogy								
39	Curiosity								
40	Geometry	Modeling	41						
41	Logic								
42	Number Theory								
43	Recipient	Sampling	44						
44	Answer								
45	Interrogation								
46	Incubation	Genesis	47	Art	50				
47	Origin								
48	Conception								
49	Inheritance	Choice	50						
50	Descending								
51	Transition								
52	Day	Rise	53						
53	Dawn								
54	Dusk								

Observation	Association	Search	Formulation		Codfication		Formalization		Concretizatior		Construction
			Wave	81							
			Amplifying	80	Ascent	80					
			Scanning	79							
			Shifting	78							
			Legacy	77	Sorting	77	Biology	77			
			Descendant	76							
			Fertilization	75							
			Derivation	74	Replication	74					
			Hatching	73							
			Signal	72							
			Reflexion	71	Observing	71					
			Receiver	70							
			Numbers	69							
			Sequences	68	Representing	68	Politics	68	Life	68	
			Maps	67							
			Power	66							
			Democracy	65	Acting	65					
			People	64							
			Gathering	63							
			Analysing	62	Statistics	62					
			Inferring	61							
			Progress	60							
			Step	59	Theory	59	Economics	59			
			Novelty	58							
			Sustainability	57							
			Development	56	System	56					
			Prosperity	55							

HUMAN LIMITATIONS ON WASTE DETECTION: AN EXPERIMENT

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ABSTRACT: Waste, or in other words, the search to its elimination, has been the target on most important production philosophies. Mass production success was based on the drastic cost reduction caused by elimination of many forms of waste. Lean production went even deeper on pursuing the elimination of more forms of waste. Waste elimination plays a key role in production performance and this paper intends to be a contribution to the deeper understanding of waste as well as on the natural human limitation on detecting it. Waste detection can be performed from two different angles, either from the search for non-value adding activities, or from the focus on value adding activities. Aligned with what some experts say and from the experiment presented on this paper we tend to believe that when we focus our attention on value adding activities and eliminate everything else the results are better. This paper also shows that people are normally "contaminated" from existing production practices and therefore their ability to detecting waste is conditioned.

INTRODUCTION

The impact of Lean Production in world's economy during the end of the twentieth century can be easily compared with the impact obtained from Mass Production during the beginning of the same century. Both lean production and mass production are, without any shadow of doubt, the major milestones in the history of industrial management. Both concepts were created in the car industry; the mass production associated with the assembly line concept was developed in the Ford Company while lean production was developed by Toyota Motor Company. The concept of lean production was originally developed by Taichi Ohno during the decade of 1950 under the name of Toyota Production System [1]. This way of organizing and managing production was later coined as Lean Production by a research group from the Massachusetts Institute of Technology [2]. This research group was involved in a 5 million dollars and 5 years project studying the car industry throughout the world during the 1980s.

Lean production can be seen as an evolution of mass production and one of the similarities is the focus on waste reduction. Lean manufacturing puts its main focus on clarifying the difference between activities contributing to adding value to the product and activities that do not add value to the product. Any effort, time our resource used in activities that does not add value to the product is considered waste ("Muda" in Japanese). The continuous identification of waste and its elimination is the mechanism for continuous improvement, being a key factor in lean production environments. The idea is that any waste that is eliminated results in production performance improvements and therefore a step towards higher competitiveness.

Factories as well as offices are fulfilled with waste everywhere but not always easy to be identified or eliminated. Many forms of waste are not identified as waste for everybody and to make things even more complicated, some authors and experts classify some waste as "necessary waste". People with different experiences, backgrounds, and production culture, do not always agree on labeling some activities as waste and also is true that some waste would never be identified at all for some people just because they wouldn't see it. Even the same person, looking at the same production problem in different angles would identify different forms of waste.

This paper intends to show that the same people when analyzing the same production problem with different information would identify different forms of waste. Another interesting feature shown is that different results are obtained when we focus our attention on non-adding value activities or on value adding activities.

WASTE

Waste is typically defined as anything that does not add value to the product, in other words, anything that adds cost to the product but your customer will not pay for. The value of a product can then only be defined by the ultimate customer [3]. Waste is therefore intimately connected to value and a good way of identifying waste is though the recognition of which part of the process is actually adding value to the products.

Another way of understanding waste is through the nature of the operations that are preformed in production systems. Anything that is performed on a product that does not result in any physical our chemical changes can be considered waste. Any operation that does not change anything on the product is not adding value (Some may not agree but under this definition inspection is waste). On the other hand some operations resulting in real changes on the product may not add value to the product and therefore being waste.

The forms of waste are classically classified in seven types [1]: waste of overproduction, waste of time on hand (waiting), waste of transportation, waste of processing it self (over-processing), waste of stock on hand (inventory), waste of movement, and waste of making defective products. It is important to point out that the waste of overproduction plays a key role in waste since it leads to all those other types of waste [4].

All these forms of waste are in some degree presented in general industries and offices. Only about 5% of the time that products spend in a production system is actually used in operations that are adding value to the products [5] but in offices that percentage decreases to about 1% [6]. Most time products are doing operations that are not increasing their value or waiting for something.

When I try to make people understand waste a list of typical questions normally arise: “how can I consider transport as waste if I really need to move the products from one machine to the next or from the warehouse to the assembly line?”; “how come the time I spend on setting up the machine is waste?”; “when I inspect the quality of the product I am actually adding value to the product since that product is declared as good, how can that work be waste?”. Apart form this type of questions there are other problems even more complicated. The idea of production in batches is difficult to be identified as waste since producing in batches is so natural and obvious that most people would never look at it as waste.

All forms of waste can be divided in two types: necessary waste and non-necessary waste [6]. According to the authors, the difference is that the not necessary waste is the one that is possible to remove under present circumstances while the necessary waste cannot be removed unless the existing supply process is radically changed. Although I understand the reason for that distinction, many managers feel comfortable when most of their waste is considered as necessary, I do not think it is necessary and I am quite confident that it does not make things easier.

The important issue in this paper is, since waste is everywhere in the factory, from where should we start? How can we be effective in identifying and reducing waste? We can say that there are two main approaches: (1) approaches centered of non-value adding activities detection and (2) approaches centered on value adding activities.

The approaches centered on non-value adding activities put all effort on identifying, on the shop floor, activities that do not add value to products. One straight forward way of doing so is going around the factory or around the office trying to find forms of waste and then trying to eliminate it. This is not a very effective way to go lean. A more systematic and effective technique for waste identification is the technique known as “Treasure map” [4]. This technique uses the principles of work sampling studies to identify the areas on the shop floor where more waste occurs. The first area to be focused to waste reduction actions would be the area where more waste was identified. Detecting areas with large quantities of waste is like finding treasures because of the money you can save once that waste is eliminated.

The approaches centered on value adding activities go around the problem from a complete different angle. Instead of trying to find waste and eliminating it, what is proposed by many experts is that you should identify the necessary adding value operation for a product or family of products and then eliminate all the remaining operations. A technique that can be successfully used for that purpose is the Value Stream Mapping [7]. This technique although with some limitation, makes a clear distinction between adding value and not-adding value operation as well as the time spent on each one of them throughout the production system.

We can say that the improvements on waste reduction go through three steps: (1) understanding the concept of waste; (2) identifying forms of waste on the shop floor; and (3) eliminating or reducing waste. The identification of waste can be sometimes complicated but even more complicated is frequently its elimination. In some cases, the way of eliminating the waste is known but its financial viability is not clear.

This paper intends to shown that people can easily be conditioned by the existing practices on the shop floor and therefore being unable to see several forms of waste. On the experience reported here, we can also see the two approaches for waste identification: (1) the approach centered of non-value adding activities detection and (2) the approach centered on value adding activities.

THE EXPERIMENT

The ability of a person in perceiving production waste is strongly dependent on which production culture the person is involved with as well as on how the person is informed or experienced on the concept of waste. Workers, supervisors and managers in traditional production environments are so used to their production practices that they loose the ability to see many forms of waste present everyday around them.

The experience presented here is the result of an interesting finding occurred during de introduction of Lean Production principles to engineering students at School of Engineering of Minho University. A common behavior pattern has being perceived during a production game that is taking place every semester for the last 5 years. These finding made me understand some of our limitation on understanding production waste as well as understanding how much we are conditioned by our own intuition.

Description of the production game

One of the first lecturers on lean production a basic production system is set up in the class room showing two alternative production approaches for the same production problem: the traditional mass production approach and the lean production approach. We start with the traditional mass production approach (see figure 1), setting up the warehouses, workplaces, buffers, and so on and make the students participate actively in the operations of that almost real production environment during some time to feel its dynamics. The students are then asked to measure the performance of the system, identify forms of waste, and to propose improvements. The production system is then modified into a lean production form and once again students are involved in the operations for the same amount of time they did before so they can fell the differences in both approaches.

Most of the times, because I normally have more students than the students needed to run this "factory" some students are just observing the production run while some others are being really involved: two acting as suppliers, six as workers, one as quality controller, one as production manager, and a last one acting as customer.

In this production system, four different types of products can be assembled and a Takt Time of 20 seconds is assumed for market demand. Once the production is set, the person acting as customer places an order every 20 seconds. The order can be on one of the available four types of products chosen randomly. If that product exists already assembled it is considered to be on time, otherwise it is considered a late delivery. We normally perform a production run for 5 minutes which is the same as saying that the customer actually places 15 orders. The production is managed based on production orders, using batches of 5 products in a push production manner. The "factory" is full of inventory everywhere and everybody is quite busy. At least one workplace is clearly identified as bottleneck and sometimes the student acting as production manager puts somebody or himself helping that "worker".

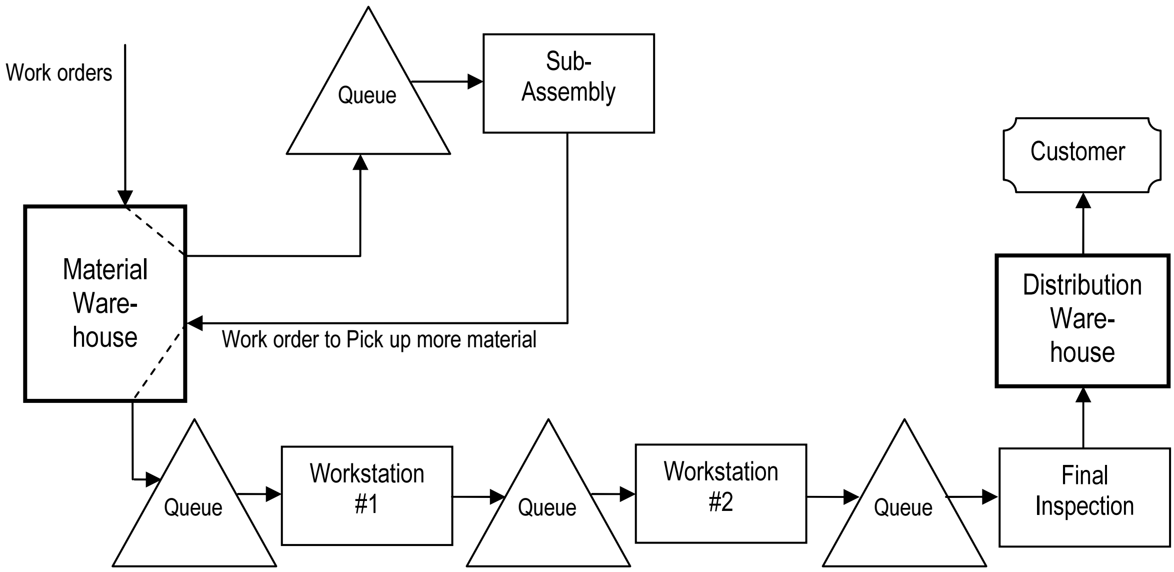

Fig. 1. Production Systems Flow Overview.

Then the students are asked to stop anything they were doing and asked to measure the performance of the existing system. The performance indicators are: Productivity, Labor Utilization, WIP, throughput time, number of tables utilized, as well as others. The students are then asked to identify waste and propose improvements. They identify some forms of waste such as transport, inventory, and waiting. As solutions they vary from class to class but a typical proposal is to put more workers under the idea that the worker on the bottleneck is not able to deal with queue that is piling up just before its workplace. I explain that this solution is not a good solution because it only makes performance to get even worse.

After some discussion I divide the class in groups of 4 or 5 students and I give them the task of proposing improvements to the existing production system and come up with a proposal with less waste. Once they finish their proposals, each group runs the system and we measure its performance. Most groups end up with some improvements on production performance typically solutions such as improving the layout, reducing transport, and reducing one or two workers. Curiously students normally do not recognize that:

- Batches may not be necessary,
- Quality controllers may not be necessary,
- Overproduction is avoidable,
- Most transportation can be eliminated,
- The supervisor may not be necessary,
- The production may be pulled by demand requests,
- And so on.

The students were just looking at the problem as anybody else, as most workers in our traditional factories and offices.

The production system is then modified into a lean production oriented approach where we can see many lean production practices applied: one piece-flow, pull production with kanban, milk run, cellular production, new relationship with suppliers, etc. The students are also involved in a 15 customer order production cycle and at the end they are also asked to measure its performance and compare with the performance obtained on the previous production approach. With this approach we only use 3 workers and the WIP and Throughput time is drastically reduced.

The Interesting finding

In one of lectures, because the number of students was quite large (a bit more than 60 students) and because I know that if there are too many students just observing they get a bit noise and distracted, I decide to do something different. I divided the class into two groups in two separate class rooms. With one of the groups (lets call them as group A) I performed the production game as described earlier in this article, but with the other group (lets call them as group B) I just gave them the type of products they had to assemble and the type of demand as in the game. The job of students from group B, working in teams of 5 or 6 members, was to build from scratch a production system able to respond to the Takt Time of 20 seconds with random customer orders as in the game. They had to test different ways of assembling the products, they had to measure assembly operation times, assume inventory policies, number of workstations, batch sizes, etc. in order to meet customer demand, and present a solution to be tested in the class room.

Group A (the group that was involved in the production run of the traditional factory) as in previous experiments came up with the same type of comments and solutions. Very little performance improvements were achieved with their proposals. Although detecting several forms of waste, solutions to eliminate it were in most cases not achieved. We consider that the student teams from this group actually approached the problem form the identification of waste angle, focusing their attention on non-value adding activities and trying to find solution to eliminate it.

Amazingly the teams from group B came up with solutions a lot more efficient than the solutions developed by teams from group A. Since they were not “contaminated” by any existing production practice, they had their focus on value adding activities and the result of their production system design was a lot less messy and with a lo less waste than the solution of the group A teams.

Table 1 shows the production performance values obtained from the traditional factory production run compared with the solutions typically achieved by teams from Group A and Group B production runs. We believe that the students that were not exposed to any existing production solution would concentrate on value adding activities resulting in better solutions. The students exposed to an existing production solution became conditioned by it and therefore tending to focus the improvements on non-value adding activities, resulting in poorer solutions.

Tab. 1. Comparison of production performance results.

Perform. Indicators	Tradit. Factory	Group A (Typical values)	Group B (Typical values)
Production time	5 min	5 min	5 min
Products sold	15	15	15
Cycle time	20 sec	20 sec	20 sec
People involved	8	6	3
Throughput (p/h)	180	180	180
Productivity (p/man.h)	22	30	60
WIP	90	35	10
Throughput time	30 min	11.6 min	3.3 min

Legend:
(p/h) – products per hour;
(p/man.h) – products per person per hour;
WIP – (Work In Process) – Number of products being processed.

CONCLUSIONS

Improving production performance through waste reduction or elimination can be done either with focus on value adding or with focus on non-value adding activities. If we are improving an existing production solution we tend to be conditioned by the existing practices and some forms of waste cannot be detected. Even when some forms of waste are detected, solutions to its elimination are harder to be found since we are conditioned by existing practices. In these cases we tend to focus our attention on non-value adding activities. On the other hand, if we are not exposed to any existing production solution we tend to focus our attention on value adding activities and achieve better production performance. This paper shows an experiment where some teams of students were exposed to an existing production solution while some other groups were not. All teams had the task of developing the best solution in terms of production performance. The teams not exposed to existing solution performed a lot better than the other ones. In my believe the reason for these results is that the teams exposed to existing solution focused their attention on non-value adding activities while the other teams put their focus on value adding activities.

References

[1] Ohno, T. Toyota Production System: Beyond Large-Scale Production, 1998, Portand, Productivity Press.
[2] Womack, J., D. Jones and D. Ross, The machine that changed de world. 1990, New York, Harper-Collins
[3] Womack, J. P. and D. T. Jones. Lean Thinking. 2003, New York, Free Press
[4] Kobayashi, I. 20 Keys to Workplace Improvement, 1995, Productivity press.
[5] Productivity Press Development Team, Just In Time for Operators, 1998, Portland, Productivity Press.
[6] Hines, P. and D. Taylor, Going Lean: A guide to implementation, 2000, Cardiff Business School, Lean Enterprise Research Centre.
[7] Jones, D. T. and J. P. Womack, Seeing the Whole: Mapping the Extended Value Stream, 2002, Lean Enterprise Institute.

THE ORGANIZATIONAL MATURITY AS A CONDUCIVE FIELD FOR GERMINATING BUSINESS SUSTAINABILITY

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Abstract: The organizational growth, the sensibility towards the concepts of eco-efficiency (environment), social contribution and economical galvanisation are critical factors for gaining a more active role towards the society revitalization. This organizational awareness shows a high degree of organizational maturity, where the concepts of business sustainability are not only attainable or tangible, but acquire also a conscious maturation of their capital knowledge and the definition of a clear strategy, in the direction of differentiation. In this context, we want to address our beliefs and expectations in the concepts of project maturity and organizational maturity as crucial factors for attaining the business sustainability

Keywords: business_excellence; sustainable_growth; organization(s); organizational_performance; project_management_skills; business(es); project management maturity; mature organizations;

INTRODUCTION

The term "***maturity***", usually expresses a state of fulfilment, achievement and perfect development. Nevertheless, common sense and life experience suggest that there is an endless way to attain perfection, and so it is always something that escapes us. Despite that, this concept is very important to characterise a state of development or even to measure the level of improvement and performance.

The term maturity has a clear sense of introspection, and as such a mature organisation tends to reflect, on a constant basis, about all the metrics that influence its results. Thus, it is intimately related to learning and knowledgeable organisations. [1][2]

The Concept of Maturity

Reference [3, p.617] defines "mature" as being ripe or having reached the state of full natural or maximum development. Accordingly, a "mature" organisation can be seen as possessing the proper state of development to achieve all its established objectives. Project Management Maturity can be assessed by its level of sophistication that indicates organization's current Project Management practices, processes and performance. [4]

The analogy between ripe and mature, intends to encapsulate the meaning of the latter in all the underlying concepts to this reality of organizational maturation. Therefore, an organizational maturity picture has to be as most detailed and complete as possible, in order to express all factors that contribute to the achievement of that state of organizational maturity. Some project management maturity papers, such as Ibbs and Kwak [4] and OPM3 [5], focus on what organisations and project people are *doing operationally,* but to Andersen and Jessen [6], this perspective seems to be a minor form of interpreting the meaning and content of maturity.

According to reference [7], only with a *certain* maturity stage, an organisation can capitalize its assets, in order to understand, develop, and sustain its organisational strategies to attain a clear competitive advantage and continuous improvement and growth. Assets can be tangible (concrete and physical) or intangible (tacit, unspoken but understood; e.g., knowledge-based assets)

The corporation strategic assets that contribute to competitive advantage involve explicit and tacit knowledge [8] that is embedded in a company's unique internal skills, knowledge, resources and practices. [9]

PROJECT MATURITY

Nowadays, investments are time, cost, and resource intensive, so firms are willing to take only a critical interest in those projects that will improve their competitive positions.

The *maturity models,* seen as an evaluation technique, have the 'ambition' of measuring the organizational performance, or characterizing the organizational position in the market, based on different elements considered important to the organizational performance. As stated by reference [6, p.457], "The term *project maturity* might be used as an indication of or a measurement of the organisation's ability to use projects for different purposes".

Reference [10]'s author believes in a framework where competence and maturity are joined together with the purpose of increasing project success. Competence is considered to be a keen combination of knowledge, skills, and attitudes which influence the organizational performance.

The ladder construction is used in several maturity models, namely the Software Engineering Institute Capability Maturity Model for Software and the PMI's OMP3.

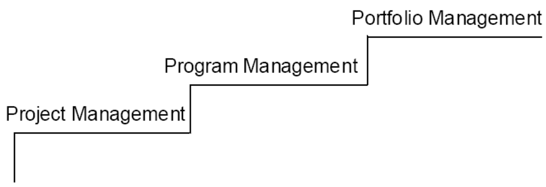

Fig. 1. The Ladder of Project Maturity

Source: Andersen and Jessen (2002)

The relation established between maturity models and project management, in the ladder of Project Maturity, is related with the rigour and experience demanded for each type of approach.

According to reference [6, p.459], "The basic "layer", or level, is *Project Management*, or the management of individual projects. At this level, project managers concentrate on individual team efforts in order to achieve predefined project goals with predetermined time and resources' constraints". The next level is *Program Management*. The most common and convincing definition is that a program is a collection of projects related to some extent to a common objective [11]. At the highest level, *Portfolio Management* is the management of several projects and programs with different multiple objectives but, which are carried out simultaneously, and concurring to the firm's strategic objectives.

The three different *plateau* suggested in the maturity ladder are strongly correlated, and the lower level (*Project Management*) will still be very relevant to the higher stage (*Portfolio Management*). So, it is very important to improve the way of measuring the organizational maturity in order to obtain a sharper distinction between the levels presented in Fig.1. A more effective diagnosis and strategic plan will help increasing the organizational maturity and so contributing to climb the ladder.

ORGANIZATIONAL MATURITY

The transition between the adoption of the project management standards, policies and good practices towards the achievement of the organizational maturity is not instantaneous, although these remarks will, undoubtedly, increase the organizational maturity. Other authors, [12][13][14], claim that organizational maturity is extremely related with the organizational performance, and with the process according to which all the organizational resources are managed to fulfil the strategic objectives.

Another well known representation of the organizational maturity development is the ***Resource Pyramid of Value Creation***, [15]. It stratifies the different phases of the organizational maturity development, starting with the *generic resources* (supplies and materials), at the basis of the pyramid. Those once combined with other organizational resources, create capabilities that improve a firm's ability to deploy resources. *Capabilities* are a mixture of proprietary resources, knowledge, and skills that become a part of the firm's operating routines and tacit knowledge. [15]

Further than core competencies, *capabilities* are indispensable requisites for doing better then rivals and so, for obtaining a good firm's performance. The combination of some specialized *core competencies* creates what is known as strategic assets. The *unique advantages* take place only when these assets are valuable, rare, inimitable, and non-substitutable.

BUSINESS SUSTAINABILITY

Business, being one of the three pillars of society [16], has an important role and responsibility towards the active incorporation of sustainability concepts in the organizational strategy of the whole society. [17]

The pressure is therefore mounting for businesses to align operational processes and to introduce the concepts of sustainability into business practices, with the objective of achieving sustainable development. [18][19]

The International Institute for Sustainable Development (IISD) has suggested that businesses can gain a competitive edge, increase their market share, and boost shareholder value by adopting and implementing sustainable practices. This can be done by companies "*adopting* business *strategies and activities that meet the needs of the enterprise and its stakeholders today, while protecting, sustaining and enhancing the human and natural resources that will be needed in the future"*. [20][21]

Business sustainability seeks to create a long-term shareholder value by developing a balanced and integrated approach to ponder and manage the risks that result from meeting its economic, environmental, and social responsibilities to its stakeholders. In doing so, it allows a more resilient organization to emerge and be sustained for the long term. [22]

In order to accomplish this goal, organizations' top management must have a vision which incorporates the well crafted and well-understood strategies of the organization. [23]

However, according to reference [24], there is still a tension between the two different perspectives and approaches that continuously hinder the sustainability concepts. The first perspective derives from economic theory and argues that the only mission of the organization is to maximize profits and thus increase the shareholder value. The second perspective argues that there are profit gains to be made by adopting a corporate social agenda. [25]

ORGANIZATIONAL MATURITY AS A FAVOURABLE MEAN FOR DEVELOPING BUSINESS SUSTAINABILITY

As pointed previously, there are at least two different perspectives towards the mission of the organization, and similarly, its integration with the concepts of business sustainability. Some authors argue that applying those concepts will not always create value to the organization. In fact, some organizations that apply those concepts without the required organizational infrastructure and maturity, suffer in their economical performance, while losing ground for the main competitors. [24][25]

So, it is very important to be prepared to these new challenges, and create an organizational culture of sustainability and green consciousness. As pointed by reference [26], from a business perspective, it makes no sense to pay to create waste, and then pay again to dispose of it. Hence, almost by definition, a company cannot be fully competitive unless it is also green. [25]

Thus we believe that there is a long way to be pursued in order to effectively implement the concepts of sustainable growth in the organization, and attain the maximum profit of those concepts. We consider the assimilation and integration of the following concepts a key process for the attainment of business sustainability:

- The ladder of project maturity [6];
- The resource pyramid of value creation and the VRIO framework [15][27];
- The development of critical organizational areas such as: Strategy, Decision Support Systems and Organizational Learning [28]; and
- Business Sustainability framework [22].

As such, this paper intends to present the following framework (figure 2), which compiles several developments that, in our opinion, should be combined. The aim is that the introduction of the business sustainability concepts will then have a significant if not maximum impact, and thus reveal the degree of development and differentiation of the organization. The merger between the concepts of project maturity, organizational maturity, value creation and the development of nuclear areas in the organization will contribute to develop an organizational culture focused on the efficiency, performance and excellence, placing it in an ideal position to effectively implement the concepts of business sustainability.

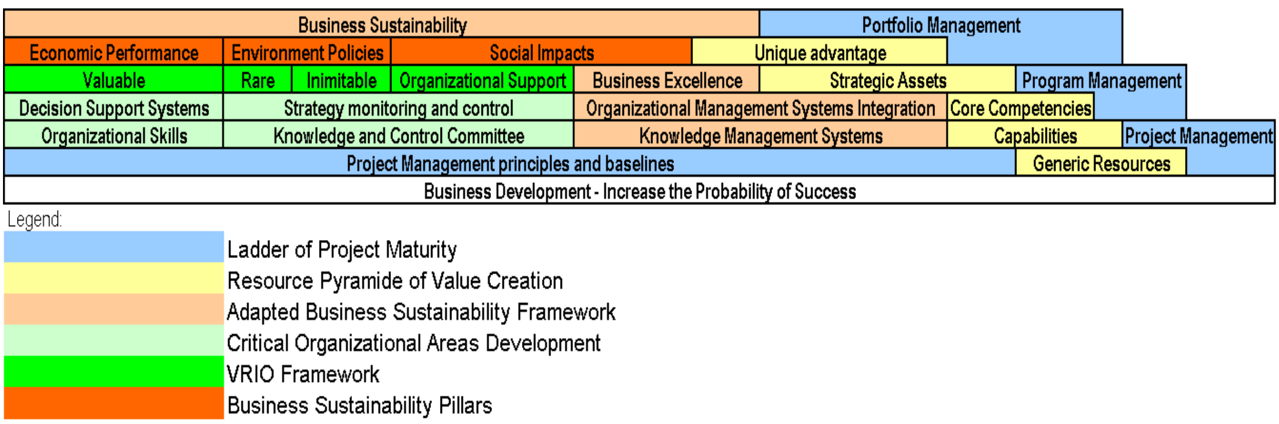

Fig. 2. Framework for Organizational Maturity and Business Sustainability

The introduction and integration of all these concepts and developments is not simple or immediate. The structure of the Framework aims to demonstrate and characterize the several steps which need to be developed and incorporated in order to achieve the level of business sustainability.

The introduction of the concepts of project management is not innocent, to the extent that authors like [29] and [30] indicate the necessity of developing project management methodologies for internalising social and environmental impacts.

The strategy definition of all the areas mentioned in the Framework for Organizational Maturity and Business Sustainability is the one with primary importance. Despite not being mentioned in the first step of the framework, strategy is already present in the Project Management principles and baselines, and directly or indirectly, in several other steps. Therefore it is seen as a critical area, because it describes what an organization stands for, what it intends to do and who it intends to serve. [25]

The most difficult stage in strategic management is not how organizations formulate strategy but how they implement it. [31][32]

The simple awareness of the interrelations between the different steps and levels of the structure above will make top managers more sensitive to important sustainability concepts and socio and cultural differences.

CONCLUSION

The establishment of an organization based on the business sustainability principles and sustainable growth have progressively more importance in the development of business and management models. The awareness of the social, environmental and economic impacts and consequences of the organization behaviour can not be neglected or disregarded.

However, the business sustainable growth can not ignore the economic and financial performance of the organization, as well as the present business maturity. Before applying social principles we must estimate their effective contribution to the excellence of the organization and to the creation of *uniqueness*, which contribute decisively to society progress in general.

The framework for Organizational Maturity and Business Sustainability establishes a conjunction of steps which support and assist the sustainable growth of the organization, and allows an organic and structured development. The different areas, concepts and approaches mentioned will contribute to achieve the right conditions and properly benefit from the application of the business sustainability principles.

FURTHER DEVELOPMENTS

Research is being carried in order to develop a model for the diagnosis and evaluation of organizational maturity. This tool will characterize the organization's maturity state. The expectation is that, using the information assessed, it will also support the strategic decisions towards the incorporation of the framework's principles and concepts to attain an increased organizational maturity and business sustainability.

References

[1] Kerzner, H. Applied Project Management: Best Practices on Implementation, Wiley: New York; 2000.
[2] Williams, T. Learning from projects. Journal of Operations Research Society, 2003; 54, 443-451.
[3] Webster. The new lexicon Webster's dictionary of the English language 1988 Edition. NY: Lexicon Publications; 1988.
[4] Ibbs, C.W., Kwak, Y.H. Assessing project management maturity. Project Management Journal, 2000; 31(1): 32–43.
[5] Project Management Institute (PMI). Organizational project management maturity model (OPM3) Available from: http://opm3.pmi.org/models.htm, 2002b.
[6] Andersen, E.S., Jessen, S.A. Project maturity in organisations. International Journal of Project Management, 2003; 21, 457-461.
[7] Teece, D.J., Pisano, G., Shuen, A. Dynamic capabilities and strategic management. Strategic Management Journal, 1997; 18 (7): 509–33.
[8] Kaplan, S., Schenkel, A., Von Krogh, G., Weber, C. Knowledge-based theories of the firm in strategic management: a review and extension. MIT Sloan, 2001; working paper 4216-01
[9] Rumelt, R.P., Schendel, D.E., and Teece, D.J. Fundamental issues in strategy. 1994, Cambridge, MA: Harvard Business Scholl Press.
[10] Skulmoski, G. Project maturity and competence interface. Cost Engineering, 2001; 43(6): 11–18.
[11] Association for Project Management (APM). The body of knowledge. Buckinghamshire, UK: Association for Project Management, 2000.
[12] Barney, J.B. Gaining and sustaining competitive advantage. 2nd Ed. Uppler Sandle River, NJ: Prentice-Hall, Inc. 2002.
[13] Rumelt, R.P., Schendel, D.E., and Teece, D.J. Fundamental issues in strategy: A research agenda. Cambridge MA: Harvard Business Scholl Press. 1994.
[14] Jonker, J. Organisations as responsible contributions to society, Linking quality,

sustainability and accountability. Total Quality Management, 11 (4-6), S741-S748, 2000.
[15] Jugdev, K., Thomas, J. Project management maturity models: The silver bullets of competitive advantage. Project Management Journal, 2002; 33(4): 4-14.
[16] Wartick, S.L., Wood, D.J., International business and society, Malden: Blackwell, 1998.
[17] Holliday, C.O., Schmidheiny, S. and Watts, P. Walking the talk: The business case for sustainable development. Sheffield Greenleaf Publishing, 2002.
[18] Keeble, J.J., Topiol, S. and Berkeley, S. "Using indicators to measure sustainability performance at a corporate and project level". Journal of Business Ethics, 2003; 44: 149-158.
[19] Goede, F. The Future of SH&E in the process industry with the focus on products,2003; Sasol Group Presentation, Department of Engineering and Technology Management, University of Pretoria, South Africa.
[20] International Institute for Sustainable Development, Deloitte & Touche and the World Business Council for Sustainable Development. Business Strategies for Sustainable Development: Leadership and Accountability for the 90's. Retrieved from: http://www.iisd.org/publications/publication.asp?pno=242; 2003 [accessed on 2 April].
[21] Brent, A. C., Labuschange, C. Sustainable life cycle management: indicators to assess the sustainability of engineering projects and technologies. In Proc. IEEE International Engineering Management Conference, Singapore, 2004; 1: 99 -103.
[22] Pojasek, R.B. A framework for business sustainability. Environmental Quality Management, 2007; 17(2): 81-88.
[23] Schermerhorn, JR. Management. 7th ed. 2002, New York: Wiley.
[24] Margolis, J., Walsh, J., "Misery loves companies; rethinking social initiatives by business". Administrative Science Quarterly, 2003; 48: 268-305.
[25] Walton, S.V., Galea, C.E., Some considerations for applying business sustainability practices to campus environmental challenges. International Journal of Sustainability in Higher Education, 2005; 6: 147-160.
[26] Porter, M.E., Van der Linde, C., Toward a New Conception of the Environment-Competitiveness Relationship. Journal of Economic Perspectives, 1995; 9 (4): 97-118.
[27] Jugdev, K., Mathur, G. and Fung, T.S., Project management assets and their relationship with the project management capability of the firm. International Journal of Project Management, 2007; 25(6): 560-568.
[28] Amaral, A., Araújo, M., (2007). Organizational Strategy within Project Management Framework, INFORMS – Annual Meeting, Seattle (U.S.), 4-7 November.
[29] Visser, W., Sunter, C., Beyond reasonable greed: why sustainable business is a much better idea!. 2002, Cape town: Human & Rousseau Tafelberg.
[30] Labuschagne, C., Brent, A.C. Sustainable Project Life Cycle Management: the need to integrate life cycles in the manufacturing sector. International Journal of Project Management, 2005; 23(2): 159-168.
[31] Hitt, M.A., Ireland, R.E., and Hoskisson, R.E., Strategic management: competitiveness and globalization. 2001, Cincinnati, OH: South-Western College Publishing.
[32] Kaplan, R.S., Norton, D.P., The strategy-focused organization: how balanced scorecard companies thrive in the new business environment. 2001,Boston, MA: Harvard Business School Press.

MATURITY EVALUATION IN HEALTH AND SAFETY MANAGEMENT SYSTEMS: A PROPOSAL MODEL TOWARDS THE ADOPTION OF SUSTAINABLE PRACTICES

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Principal Keywords: Management

Object/Function Keywords: assessment; auditing; benchmarking; continuous improvements; evaluation process(es); human factors; models performance management systems; safety performance

Application Area Keywords: general systems management.

INTRODUCTION

The implementation of management systems, such as those related with Quality, Environment and Health and Safety (H&S), assumes that such an implementation will allow for a sustainable continuous improvement in a specific operational management domain. Furthermore, in the specific case of H&S management systems, this improvement could be carried out by involving the organizations' high management levels, as well as other organization levels, to attain a joint goal, which is the improvement of the working conditions.

Despite that, it is possible to verify that a few organisations has progressed enough in involving all the organization levels in this process, but at the same time, some companies were not able to do it. Therefore, it seems that there is a need for establishing a model that could be able to "measure" the maturity of this process and feedback companies about their performance.

Companies have available several techniques developed for improving their performance. Some of those techniques are exclusively dedicated to the management of Occupational Health and Safety (OHS) [12]. Despite that, it is possible to find some models that propose the adoption of some actions at any organizational level, such as the SOBANE strategy (Screening, OBservation, ANalysis, Expertise) [14], the INDICATE (Identifying Needed Defences In The Civil Aviation Transport Environment) [1], [10] the ASSET (Automated Security Self-Evaluation Tool) model [18] and the OHSAS 18001 [4], which is the most disseminated model amongst the mentioned resources. However, even in the case of the most widespread models, it is possible to detect some difficulties in establishing a level of heterogeneity in measuring the performance of the management process. This heterogeneity is needed, in particular when comparing very different types of organizations, such as the companies with different sizes, certifications, activity sectors, OHS services, etc.

The lack of an internal and external reliable reference, have led to the emergence of new resources dedicated to the evaluation of OHS management systems [6]. As a consequence, it is now possible to find a wide range of possibilities for measuring organizations' performance in this area. Amongst these available resources, maturity evaluation as been each time more, and it is already been used very often in other management areas, such as project management, and software development. Currently, it is also possible to find some models that were developed for the specific OHS management, for example, the Safety and Security Extensions for CMMI [13], the SCMM (Safety Culture Maturity Model) [11], the MINEX [3], [15] or the +SAFE [17].

Despite the broad application cases found, in the some models, like the CMMI, the way these models are structured may originate some problems when applied to the OHS management. Those models are often very extensive and complex, requiring a significant effort for their application. Due to the fact that these models were initially developed for software projects management, their application to the OHS domain may require significant adaptations. Furthermore, in these models there is a lack of mechanisms that could be used to differentiate companies with different profiles. Accordingly, this shows the relevance of the present work, considering that it will try to define which are the more appropriate criteria for evaluating the maturity of a management systems implementation in a specific organization, as well as in identifying the main factors that could play an important role in the hypothetical results' inconsistency.

The main aim of this work is to present a proposal model to evaluate and classify the OHS management system maturity, as well as to present some preliminary obtained results.

METHODOLOGICAL PROCEDURES

In order to accomplish the proposed aims, an exploratory research was adopted. Despite this kind of research could not be totally conclusive in some analysis aspects, it will provide some information that could be very useful for future applications, in particular for the development of the proposed model [2].

In the first stage, a literature review about maturity evaluation models was carried out. This review as involved the use of the main scientific journals database in this domain, as well as institutional websites related with maturity evaluation. All the identified models were sorted, using as criteria, in this order, (a) their relation with the OHS domain, (b) the number of citations, (c) the covered type of applications and (d) the number of referred applications.

After that, the key-areas defined in the maturity models analysed were associated with the key-areas of a typical OHS management model. This association was implemented in a matrix. Those key-areas with a great association with OHS management system were examined thoroughly and all the specific goals and practices were also analysed. All these goals and practices were adapted in order to be used as a criterion to indentify the maturity of any organization, in what regards the OHS management.

The matrix was filled having in mind two aspects: *i*) the need to ensure that the specific goals and practices adopted were related with a typical model of OHS management; *ii*) the need to supply data for establishing a balance in the number of practice for each specific goal.

In the following stage, a survey was developed and applied. The mains goal of the survey was to define which were the most relevant criteria for the maturity evaluation, and in which maturity level it should be considered. In the same survey, it was also requested the definition of which are the companies' characteristics that could interfere in the differentiation regarding OHS management performance, considering similar companies. This survey was sent to OHS experts, both from academia and from professional and technical organizations. The main questions underlying this survey were:

1. “Which companies' characteristics will allow to distinguish different performances between companies with similar OHS management systems?”
2. “Which are the most relevant practices that should be considered in the maturity evaluation of the OHS management?”

In order to answer these questions, it was necessary to obtain a list of the companies' characteristics that may interfere in the company OHS management system maturity. It was also needed to obtain a list of several key-practices (in the domain of OHS) and their corresponding maturity level. Each research question has generated one different survey dimension, the first one regarding the organization profile, and the second regarding the most relevant practices for the evaluation of OHS management system maturity.

Concerning the intended information to be obtained by the application of this survey, it should be emphasized that the applied survey represents a cross sectional study, which will have a specific targeted sample [2]. It was determined that all the survey's respondents should be experts, researchers or consultants that work, or have a particular familiarity, with the subject of organizational management, OHS and maturity evaluation. As this choice imposes some limitations to the sample's size, it was decided to include also some respondents that were not Ergonomists or Safety Engineers, but who can have a value opinion regarding organization management and maturity evaluation. The selected sample was composed by 64 invited respondents, from which 48 were Portuguese and 16 Brazilian.

The survey was applied using a website platform, which was developed to this specific purpose and has implied the need to use some computational programming.

The obtained results from the first survey were used to guide and help the construction of a second survey that will be applied to companies in order to evaluate their organizational profile and maturity level. Some of the proposed procedures to be adopted in the construction of the second survey are also presented in this paper.

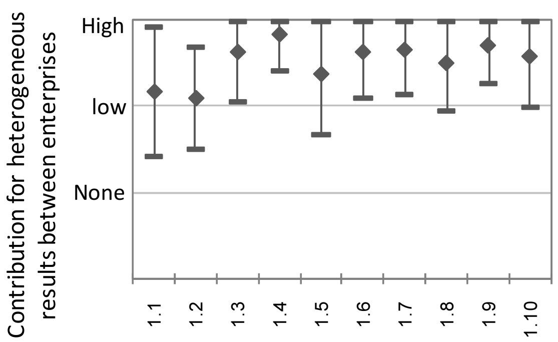
RESULTS

The main maturity evaluation models that were selected and that were considered to have an important contribute to the present study were the CMMI-DEV V1.2 [5], the MINEX [3], [15], the SCMM [11] and the +SAFE [17]. After their analysis, it was concluded that there are no significant variability amongst the evaluation mechanism used by these models. All the main models proposed five different maturity levels, similarly to what Crosby's [7] has proposed in his first applications. An exception occurs with the case of MINEX, this model also considers the maturity concept but it makes no distinctions between maturity levels, and the maturity is defined in a continuous scale ranging from 0 to 1000 points.

Amongst the selected models, the CMMI-DEV v1.2 was the one who have influenced more the present work. However, some of the proposed areas in the models SCMM and +SAFE were also used for analysis of the relationship between maturity evaluation models and OHS management systems. In the same way, the key-areas were also used to propose a new evaluation criterion. Those areas were later divided in specific goals and key-practices, having in mind the similarity between the used items from the original models and the balance between the number of practices in each key-area.

In this first survey, the obtained response rate was 61%. In Portugal, this rate was 56%, while in Brazil was significantly higher, 75%. Considering the mentioned response rates, the final number of respondents corresponds to 69% from Portuguese respondents and 31% from Brazil.

In Fig. 1, it is possible to observe the answers' behaviour regarding the organizational profile dimension. The great majority of the respondents (59%) have agreed on the suggested criteria that might play a high contribution for obtaining heterogeneous results, regarding OHS performance, between similar companies. The existence of internal of an OHS service, as suggested by 87% of the answers is the main factor regarding this contribution. The factor that has obtained the lowest score was the companies' annual sales, with only 64% of the answers. The number of workers is the factor that has generated a higher disagreement amongst the respondents, with the higher standard deviation, 0.75 points.



1.1 Number of workers
1.2 Annual sales
1.3 Activity sector
1.4 OHS internal service existence
1.5 OHS management system certification seniority
1.6 Existence of other management systems certifications
1.7 Physical work environment characteristics
1.8 Type of company (micro, SME or large)
1.9 Workers' average education level
1.10 Utilization level of sub-contracted services

Fig. 1. Results obtained for the organizational profile dimension.

Regarding the second dimension of the survey, the key-practices for the OHS management, it was verified that, in average, the respondents have agreed that the suggested key-practices should be included in the highest maturity levels, namely between levels L3 and L4 (Fig. 2). The mean obtained score was 3.51 points, in a scale ranging between 1 and 5. If respondents consider that a key-practice is not appropriate for maturity evaluation, then they can opt for answer in the "not applicable" category.

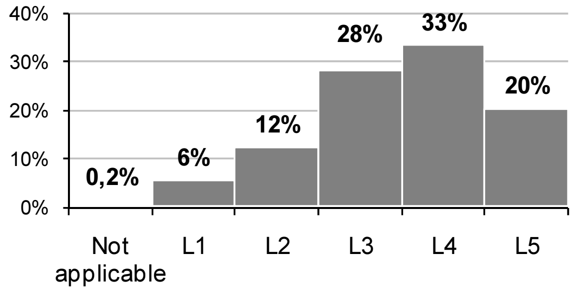


Fig. 2. Key practices distribution according to the maturity level.

Comparing the obtained answers between Portugal and Brazil, it is possible to verify that there is significant differences in almost a half of the total key-practices (24 items), as well as in 3 items in the organization profile dimension. In all of these identified differences, the Brazilian answers have indicated a higher maturity level for the considered key-practices.

Amongst the differences in key-practices it was possible to identify four different groups, namely those regarding the levels L2, L3, L4 and L5. Level L1, according to the results, have not been indicated as containing any of the suggested key-practices. All the key-practices were considered by the respondents as belonging to, at least, one of the mentioned maturity levels. The distribution amongst the different levels was as following:

L1 = 0;

L2 = 3 key practices;

L3 = 13 key practices;

L4 = 28 key practices;

L5 = 4 key practices.

After the analysis of the results, the suggested key-practices were complemented by a few additional key-practices that were not included in the survey. The main criterion for the selection of these complementary practices was the need to balance the number of practices allocated to each maturity level. The selection was also oriented by the number of citations that each of the considered key-practices have in the reviewed bibliographic references within the domain of OHS. The new added practices were allocated to the levels L1, L2 and L5 and, therefore, we have obtained a new survey that includes almost 80 key-practices. The distribution of the key-practices by each level remains like this:

L1 = 13 key practices;

L2 = 13 key practices;

L3 = 13 key practices;

L4 = 28 key practices;

L5 = 13 key practices.

Maturity Level Computation

In what concerns the analysis of the organizational profile characteristics, it was decided that each characteristic will receive a different weight, which should be based on the experts' opinion. In accordance, those characteristics with higher score will have a higher weight. The main idea was to differentiate organizations, and at the same time relate their characteristics to the needed effort for increase their maturity level. For example, if we consider two different companies, for instance, both from the chemical sector and with their quality and OHS management systems certified. The first one has 10 workers, no internal OHS service and annual sales lower than the other. The second company has 500 workers and an internal OHS service. Using their profile characteristics, it is expected that the needed effort to advance in the maturity of the OHS management system should be substantially different. In fact, it is expected that the first company will achieve a lower score on the organization profile dimension and, consequently, will have less difficult (it means less accomplish less key-practices) to advance to higher maturity level.

The Organizational Profile Score (S_{OP}) is obtained by the sum of the weights, regarding each organizational characteristic. Generically, the higher the company scored in the S_{PO}, the lower will be the requirements for a maturity level increase, and vice-versa. The required effort for the company will be distinct, according to his organizational profile. This effort will be represented by an Inertia Index ($I_{inertia}$), which will be used jointly with the key-practices accomplishment percentage, for the different maturity levels. The $I_{inertia}$ is obtained as indicated in the Equation 1.

$$\textbf{Eq. 1.}\quad I_{inertia} = \left(\frac{S_{OP}}{280}\right) - \left(\frac{1}{7}\right)$$

By its turn, each key-practice does not have any associated weights. Each practice may, or not, be accomplished. This is verified if the company have adopted a specific practice in a period less, or equal, to the suggested period, then the answer will be "yes", otherwise it will be "no". A positive answer will score 1 point, and a negative answer will score 0 point. Using this scoring scheme, it was possible to obtain the key-practices accomplishment percentage ($\%_{ac}$). This percentage was obtained by the sum of all scores, divided by the numbers of existent practices in each level. Equation 2 represents the mathematical procedures used to determine the accomplishment percentage in each maturity level, where L_i is the level i, M is the number of practices in the level i, and S is the score for each practice (m).

$$\textbf{Eq. 2.}\quad \%_{ac} = \left(\sum_{m=1}^{M} S_m\right) \Big/ M_{Li}$$

With the obtained value of $\%_{ac}$ and the $I_{inertia}$ it was possible to obtain the adjusted accomplishment percentage ($\%_{ac\_adj}$) for the maturity levels L2, L3, L4 and L5. For L1 the percentage $\%_{ac\_adj}$ will be equal to $\%_{ac}$. This adjusted percentage avoids that a company achieved an accomplishment value, in a specific maturity level, higher than the same percentage in a lower maturity level. Equation 3 shows how the adjusted percentage is computed.

$$\textbf{Eq. 3.}\quad \%_{ac\_adj_{Li}} = \%_{acLi} \times \left(\%_{acL(i-1)}\right)^{I_{inertia}}$$

where Li is the maturity level, and L(i-1) is the maturity level immediately before level i.

The maturity level classification criteria for a apsecific company will be defined using a criterion involving the $\%_{ac\_adj}$, i.e., if a company accomplishes 80%, or more, in a specific maturity levels key-practices, then that level will be the maturity level of the company's OHS management system.

Companies' maturity level assessment

Using the previous described results, a second survey was developed and applied. This survey was designed considering the need to obtain a high response rate. As the number of questions will be inevitably larger than the first one used in the first stage, it was necessary to use some usability guidelines and principles to improve the easiness and atractiveness of the survey fulfillment. One of the underlying ideas was to give respondents the sensation that it is worthy to answer the survey and to spend some time doing that.

Similar to the first survey, this second stage will also use a website platform. Through this platform, it will be easy to reach companies, both in Brazil and Portugal. The use of internet is quite common amongst Portuguese and Brazilian companies. Moreover, this type of interface will allow an interaction that will not be possible if a printed questionnaire was applied.

The survey will be divided in five different WebPages, namely:

- Introduction;
- Organizational profile questions;
- Organizational profile results presentation;
- Key-practices questions;
- Final results on the company's maturity level, regarding OHS management system.

In the introduction webpage it will be presented two access possibilities, one option if the user is not registered and another option if the user has already a login name and password. In the first access option, the respondent should compulsory go through all the questions regarding the organizational profile, which probably will take about 6 to 8 minutes to fulfil. After completing this phase, the respondent will be able to access the next page, where he can see all the information about his company organizational profile and the profile of the entire sample of companies that have answered the survey. In the next step, the respondent will have to answer to all the questions regarding the adopted key-practices. This survey's phase will take approximately 15 minutes. At the end of the survey, the maturity level of the company will be computed and presented to the respondent, considering the organizational profile and the key-practices referred.

During the results presentation, the respondent will also have the possibility to return later on to consult the survey's results and the position of his company regarding the other respondents of the sample. When the respondents return to the survey, a login name and password will be requested. As soon as the respondent is identified by the system, he will be able to access directly to the overall results.

The first call for participation will be sent to companies through e-mail, in which will be included a description of the survey, some instructions for fulfilling the questionnaire, as well as a direct link to the survey's webpage.

CONCLUSIONS

The aim of this study was to present the current development of a proposal model for maturity evaluation concerning the OHS management systems, as well as in presenting some of the preliminary obtained results.

From the literature review, it was possible to observe that some of the procedures used by other maturity evaluation models are somehow ambiguous, and are dedicated to other management systems and, therefore, with a need for adaptation to the specific area of OHS. Moreover, those models are excessively long and complex, as is the case of the CMMI-DEV v1.2, which requires a specific type of audits.

Concerning the results of the survey applied to OHS experts, it was possible to verify that there is a long list of key-practices that could be considered for maturity evaluation of a specific organization. Most of these practices represent a sustainable approach in what regards the organization engagement with the OHS area.

Furthermore, the obtained results seem to demonstrate that there is a tendency to classify most of the key-practices as belonging to higher maturity levels. Additionally, it was also possible to verify that the key-practices were not identically distributed by all the maturity levels.

Both Portuguese and Brazilian OHS experts have considered that the existence of internal OHS service is the most important factor for OHS performance concerning the differentiation between similar companies. Although there is an agreement in the majority of the analysed points, in approximately one third of the suggested factors the experts from the two countries presented significant different opinions.

It was also possible to conclude that there is a significant agreement in what regards the key-practices classification. When there was some disagreement it was possible to note that Brazilian experts tend to classify key-practices with a higher level.

Finally, it is important to refer that this study is part of an ongoing project, therefore it is hoped that further results can be obtained and the preliminary conclusions presented here can be updated and/or validated.

References

[1] ATSB, (2001). The INDICATE safety program: implementation guide. ASTB – Australian Transport Safety Bureau, v 2.0.

[2] Babbie, E.R., (1999). Survey research methods. Belmont, CA: Wadsworth Publishing Company. 2 ed.

[3] Barreiros, D., (2002). Gestão da segurança e saúde no trabalho: estudo de um modelo sistêmico para as organizações do setor mineral. PhD Thesis, Polytechnic Scholl of São Paulo University. Mine and Petroleum Engineering Department – USP.

[4] British Standards Institution, 1999. OHSAS 18001: occupational health and safety management systems – specification. British Standards Institution, London.

[5] Carnegie Mellon University, (2006). CMMI for Development, Version 1.2, CMMI-DEV, V1.2, CMU/SEI-2006-TR-008 ESC-TR-2006-008.

[6] Costella, M.F., (2008). Método de avaliação de sistemas de gestão de segurança e saúde no trabalho (MASST) com enfoque na engenharia de resiliência. PhD Thesis, Product Engineering. Federal University of Rio Grande do Sul - UFRGS, Porto Alegre-BR.

[7] Crosby, P.B., (1979). Quality is free: the art of making quality certain. McGraw-Hill.

[8] Deming, W.E., (1986). Out of the Crisis. Massachusetts: Mit Caes, 7 ed.

[9] Dillman, D.A., (2000) Mail and Internet Surveys: The Tailored Design Method. New York: John Wiley & Sons, 2. ed.

[10] Edkins, G.D., (1998). The Indicate safety program: evaluation of a method to proactively improve airline safety performance. Safety science, n 30, p 275-295.

[11] Fleming, M., (2001). Safety culture maturity model – otr 2000/049. The Keil Centre for the Health and Safety Executive, Norwish.

[12] Franz, L.A, Amaral, F.G., Arezes, P.M., (2008). Uma revisão sobre as principais características e práticas existentes na gestão da segurança e saúde no trabalho. In: SHO 2008 - Colóquio Internacional sobre Segurança e Higiene Ocupacionais, 2008, Guimarães. (SPOSHO), v. 1, p. 139-146.

[13] Ibrahim, L., Jarzombek, J., Ashford, M., Bate, R., Croll, P., Horn, M., Labruyere, L., Wells, C., (2004). Safety and Security Extensions for Integrated Capability Maturity Models. United States Federal Aviation Administration.

[14] Malchaire, J., (2002) Diagnóstico participativo dos riscos de uma situação de trabalho: método Déparis. Available on: <http://www.sobane.be/>.

[15] MCA, (2007). MINEX 2007: Minerals industry safety and health excellence awards.

[16] Paulk, M.C., Curtis, B., Chrissis, M.B., Weber, C.V., (1993). Capability Maturity Model for Software, Version 1.1. Software Engineering Institute. Carnegie Mellon University. Pennsylvania. USA.

[17] SEI Administrative Agent. +SAFE, V1.2 A Safety Extension to CMMI-DEV, V1.2. Defence Materiel Organisation, Australian Department of Defence. Mar 2007.

[18] Swanson, M., Stevens, M., Jimenez, I., Korolev, V., (2004). Automated Security Self-Evaluation Tool User Manual. National Institute of Standards and Technology. Available on: <http://csrc.nist.gov/archive/asset/Version2/ASSET_User_Manual_2004ED.pdf>.

THE EFFECT OF CONSUMER SATISFACTION ON THE ENVIRONMENT

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Keywords: Environment, Consumer, Technology, Satisfaction, Waste, Mass-customisation

BACKGROUND

The idea of this paper arose during discussions of the Production Organisation and Management (POM) and the Intelligent Design Technologies (IDT) clusters of the EU-funded Innovative Production Machines and Systems (I*PROMS) network of excellence, of which the authors are core members. The discussions of the paper are based on the results of surveys that were published in the deliverables of the project. In the framework of the project, a large-scale Delphi study was carried out to forecast the future of European manufacturing by the year 2020. Leading experts from many EU companies provided their views, and the results were statistically analysed. Other deliverables included roadmaps for the future of manufacturing and grand challenges that manufacturing companies will have to face. While most of the questions were aimed at ensuring the success and prosperity of European manufacturers, a growing concern about what this success might mean for the environment gave way. This paper will try to consider these concerns. Since the network is manufacturing and technology oriented, the consumers in this paper are consumers of manufacturing companies.

INTRODUCTION

Companies generally claim that their aim (or mission) is customer satisfaction. Although this sounds encouraging from a customer's perspective, this is not exactly correct as customer (consumer) satisfaction is not their aim but the means to reach their real aim: profit. But even if the first claim was true, is customer satisfaction a good thing? Is a happy customer all a goods producer needs to care about? Or are there higher-order issues that can not and should not be passed by.

Although discussions about the environment and the effect people have on it have been around for many years, it is really the last couple of years that these discussions have gained space and have entered the general domain. This is partially due to some high-profile advocates (like Al Gore), but also to recent fast changes in the environment that can not any more go unnoticed.

Nowadays, most people agree that there is far too much damage being made to our environment than the Earth can comfortably cope with, and that there have to be major changes introduced. However, the huge differences in level of economy, culture, religion and lifestyle of different peoples make a general solution extremely difficult. The majority of scientists now agree that technological development does cause climate change (although many still argue that this has nothing to do with technology, that climate change happened before, too, and the current climate change is simply a result of changes hundreds of thousand of years ago). On the other side, some scientists suggest that the damage that has been done is far too big and the process of climate change is irreversible, although it can be slowed down if acted immediately. Discussions about the environment are widespread, new buzzwords like 'carbon footprint' have emerged, and more and more people have started to worried about the environment (to different extent). However, even if one is concerned about the environment and its future, not many are ready to sacrifice their well-being, satisfaction and usual lifestyle. But what is the cost of this satisfaction? And who will pay the price of it? Who should make the steps to changes; the manufacturer, the consumer, or if none of them is willing to can they be forced to change?

MAIN CAUSES OF ENVIRONMENTAL DAMAGE

There are many causes of environmental change and damage, but not all are directly related to technology, engineering and manufacturing. An example is introducing new species of animals in wildlife, which is not fuelled by technological developments, although it is normally the case that those animals were introduced for the satisfaction of customers.

Similarly, many of the natural disasters are not directly technology-related but may have roots to it. Landslides, for example, are often caused by deforestation. However, technology-related causes have a major role in changing the local and global environment.

Habitat Destruction

In an attempt to produce low-cost products, many industrial companies nowadays outsource their production (while keeping research and development at home) to developing countries. Weaker legislation in those countries allow to destroy rainforests and other natural environment in order to build factories, roads, railways, and also to use and sell the mineral resources. This inevitably leads to the disappearance of wildlife and to the reduction of the Earth's capability to recycle itself.

Overpopulation

Although at first it seems it has nothing to do with technology and industry, this is not the case.

It is widely accepted nowadays that despite having large areas that are virtually untouched, the Earth in general is overpopulated: with a current population of around 6.5 billion and 9 billion forecasted by 2050, it is becoming evident that such a huge population is not sustainable any more. According to some estimation, with the current Western lifestyle (expanded globally) the Earth could comfortably support only around one billion people [1]. Western lifestyle (a car for every adult person, low rate of using public transport, multiple household appliances, increased long-distance travel, fast changeover of products, overconsuming in general) is not sustainable for the whole population. The level of current consumption in Western countries is only possible because of the huge disbalance between the economies of Western and developing countries. In a sense, poorer countries have to pay the price for the well-being of developed ones. Shockingly cheap products in the West are a result of the extremely cheap labour in many Asian and African countries.

As a general tendency, developed countries have a lower birth rate. Some of the reasons may be that with higher income the desire to more fully enjoy life (travel, sports, leisure, entertainment) increases. High birth rate does not facilitate this. This means that technological advancements have two opposite effects on the environment: higher development creates more environmental damage due to pollution, but at the same time it reduces the size of the population, thus reducing the environmental impact. However, at least at this stage, it seems that the negative effect of technological developments on the environment outweighs the positive one.

Pollution

Pollution is probably the biggest contributor to destroying the environment. And there is a big contradiction that the richest economies pollute the environment mostly, but it is the poorest countries that are affected by the environmental changes mostly. Making products as cheap as possible is the primary driving force behind pollution. Dumping into rivers, oceans and landfills in many cases is cheaper than recycling. However, the environmental impact is immense. Using fossil and other fuels as energy sources is now considered to be one of the main contributors to climate change.

Overexploitation

Some aspects of overexploitation of natural resources (like overfishing, overhunting) do not have a direct link to technological development (although modern technology does underpin them). However, the extreme use of mineral resources is mainly dictated by the attempt to make products cheaper, more attractive and more competitive.

Even if it does not cause direct environmental change in terms of disasters, the vanish of mineral resources means that in the future our choice of materials to be used in products might be limited. Some of the mineral resources are now at their final stage of exploitation.

So what could manufacturing companies and consumers do in order to reduce the environmental damage?

STRATEGY FOR ADDRESSING CHALLENGES FACING MANUFACTURING

In order to tackle the major challenges to the manufacturing industry and technological advancements in general, research in the following strategic areas is needed:

Products and technologies that use less energy

No matter how much of the energy used in manufacturing processes and during the exploitation of the finished products is from renewable resources, those energy resources still cost money to produce and maintain. This is why the primary focus needs to be on eliminating the problem at source, that is reducing the energy consumption.

Products and technologies that use renewable energy resources

Even if a product is produced from fully recyclable materials using renewable energy sources (which is currently not possible), its production still requires resources, so it still has an environmental impact. Extensive use of any energy source will influence the environment. However, this impact is much less than when using fossil fuels. In many cases the direct impact of using renewable energy on the environment is not obvious. Using hydroenergy, for example, seems relatively harmless (apart form the damage it does by introducing a new building site), but it inevitably leads to taking away water from wildlife areas, thus depriving wild animal and nature of water.

Using renewable energy (the word 'renewable' used in the conventional way) is not necessarily a good thing. A typical example is biofuels like palm oil. Oil-palm grows in an environment similar to that for rainforests and the widespread use of palm oil in an attempt to reduce cost leads to deforestation. So far the most widespread use of palm oil is in the food and makeup industry and is still sustainable. However, if the energy market (in an attempt to replace fossil fuel) starts to rely on it, it would have a large negative environmental effect.

The biggest problem that a company would face in an attempt to use renewable energy sources is that sustainable technologies cost a lot of money, and if this is not a general practice accepted by all competitors, the pioneers have to pay extra and may not be able to compete on the global market. Higher level protection is needed (tax relief, protective import duties).

Reusable energy sources: although they seem to be 'free' resources, they still cost a lot to build and maintain and they also have huge negative environmental impact. Building wind generators and dams, for example, not only costs a lot of money but may themselves destroy the environment.

According to the US Energy Information Administration (Fig. 1), in 2005 about 87% of the total energy sources came from burning fossil fuels (liquid petroleum, natural gas, coal).

The survey in [3] forecasts a decrease to 45% by the year 2020, but given the increasing total amount of energy used, the volume of emission from fossil fuels will most likely exceed the current values. Given that even at current rates natural processes (like oceans, forests) can only absorb less than half the amount of the carbon dioxide emission, the possible effects on the environment are alarming.

Energy source	Usage, %
Fossil fuels	86.8
Hydroelectric	6.3
Nuclear	6.0
Other (geothermal, solar, wind, wood, waste)	0.9

Fig. 1. Energy sources in 2005

Even according to the most optimistic forecasts (assuming that oil consumption rate remains at current levels and all reserves can be recovered) predicts that oil reserves will diminish within 50 years. Many vital areas then, like the production of medicines, will be deprived of elementary supplies. The satisfaction of our current generation will have to be paid by generations in the near future.

Using Recyclable Materials

The major dilemma a manufacturing company would face in order to decide whether or not to use recyclable materials is that in many cases recycling costs more than dumping and exploiting mineral resources. Waste management strategies of many companies are only affected by its cost rather than its environmental impact. Unless they are forced to consider the environment (due to legislation, special taxes, quota on resources) they do not tend to. Until such a time that there is a real shortage of materials, the natural driving force behind recycling is not obvious. In the interest of fast profit manufacturers tend to forget that mineral resources require an extremely long time to develop and future generations will most like be deprived of many of the currently available raw materials. Fig. 2 shows some EU countries' recycling rate [2]. Official government figures are slightly higher, but the current rate in many countries is extremely low. Although quite a bit of change has happened over the last decade, the level of recycling of materials still has not reached its full potential and much more research is needed in this area. According to the forecast in [3], the average EU recycling rate by the year 2020 will be around 50-55%, which still would not make manufacturing environmentally friendly.

Another problem that affects smaller countries is that they may not generate sufficient waste in total to have their own recycling plants for each type of waste. In this case the only option is to transport the waste to another country, which not only increases recycling cost but also has a significant environmental effect. Denmark, for example, regularly send their batteries and waste form electrical and electronic products abroad for recycling.

Country	Recycling rate
Netherlands	59%
Austria	58%
Germany	53%
Belgium	39%
Sweden	39%
Luxembourg	36%
Denmark	32%
Spain	28%
Finland	25%
France	25%
Italy	24%
Ireland	13%
United Kingdom	17%
Greece	9%
Portugal	4%

Fig. 2. Current EU recycling rates

Standards

One of the reasons products change so fast on the market (thus leading to increased use of materials and energy) is that industrial standards change rapidly. This is partially dictated by the technological advancements and is a natural phenomena. However, it is often caused by individual companies not co-operating between themselves, thus creating short-term local standards that make products obsolete very quickly. Typical examples are the Betamax v/s VHS battle, or the current many different standards in digital media. Supporting obsolete standards is an expensive business, and consumers are rather forced to discard their purchases in order to by a newer one. Although it is impossible to eliminate the problem totally (that is to design products that will only be discarded once their useful life is exhausted), standards with long-term view, developed by international organisations, can slow down the process.

Introducing a new standard makes other products obsolete almost instantly. An example is the introduction of the high definition (HD) video standard that leads to fast obsoletion of ‘old’ equipment. The whole world will now have to discard TV sets, DVDs, videos, computer graphic cards (and computers with them).

Cultural change

Cultural change, required to reduce environmental impact, does not primarily seem to be an engineering issue. However, engineering can influence it. Examples of cultural changes that are required to reduce environmental damage include the habit of recycling, conscious purchase of products (checking the origin of products and conditions of production, avoiding buying products that do not conform to the standards of sustainable technologies).

Lifestyle change

Unless a separation of poor developing countries and rich, developed countries is to be maintained (which can not and should not be the aim of any society), there has to be a significant lifestyle change in developed countries in order to achieve sustainability. Overconsuming leads to increased use of materials and energy, and overconsuming food in addition leads to the need for more hospital equipment and building, training equipment, drugs, which yet again requires increased use of materials and energy, thus damaging the environment. Any improvement in the life in developing countries will inevitably lead to increased consuming, which means that in order to maintain sustainability with the predicted population people in the developed countries will have to change lifestyle. Manufacturing companies can help in doing this by making products for public transport, sports, recreation more desirable.

Integrate consumer satisfaction with overall well being

Consumer satisfaction does not necessarily mean general satisfaction. In the Western and developed world consumer satisfaction normally means satisfaction of people living in those countries, and satisfaction caused by a product is limited to those buying the product only. However, this satisfaction comes with the price that others in developing countries have to pay.

Modern manufacturing paradigms like consumer-based design, consumer-driven design, mass customisation, reconfigurable manufacturing systems, time to market compression, rapid manufacturing, concurrent engineering all focus on increasing the success of the companies by selling as many products as possible. This consumer-focused production naturally leads to very fast turnover of products. People tend to discard products much faster than their useful lifetime. Without incentives or penalties, currently it might be cheaper to discard a product than to recycle it, to buy a new product instead of repair a broken one. Products returned to customer service will most likely not be considered for repair at all. Instead, they are automatically discarded. People in poorer countries are much more likely to exploit products to their full extent. Companies are not interested in long-lasting products because they reduce their profit. According to the predictions published in [3], by the year of 2020 the average product life cycle (that includes production, introduction of the product, growth, maturity, decline and withdrawal of the product) will shorten by over 50%. Even currently it is quite usual that products are designed to last no longer than the minimum warranty period of the sale, which for an average product is one year. Companies tend to anticipate that after that period the customer will replace the product anyway.

The effect of fashion trends is that consumers are 'forced' to buy new products more frequently than necessary. This is underpinned by aggressive advertising campaigns of large companies. The authors believe that advertisements should be banned or at least moderated because they act against the free will of people. Although it seems that people are free to make their own decisions, aggressive advertisement mobilising a whole arsenal (including mass media) in fact capitalise on human nature and deprive people of free choice. Even the most conscious people make unconscious decisions influenced by advertisements.

Fashion and trends and aggressive advertising may unnecessarily increase production volume: you may not need the product but you do not want to be left outside a large group. A typical example is the iPOD: not all who bought it actually need it, not necessarily with the specifications provided. It is, in fact, a psychological warfare to try to sell more products than needed.

Rapidly changing new products make existing ones obsolete very quickly. This means increased waste of material and energy, increased recycling costs, increased environmental damage.

The biggest contradiction in the producer-consumer relationship is that both the consumer and producer (meaning the owner of the business) are satisfied by quick changeover of products without realising (or not paying attention) what damage this does to the environment.

One of the controversial issues is mass unification when by exploiting people's desire to belong to a group, major manufacturers make all efforts to have a large number of people having the same product without any variety. Typical examples are blue jeans and i-pods. Mass unification (as opposed to mass customisation) enables cheap mass production. Although it may be somewhat limiting from a cultural point of view, it can be good from an environmental point of view if products are long-lasting.

Apart from consumer satisfaction, fast-changing products can have a positive side: they can implement new technological developments to reduce environmental impact. very changeover For example newer cars generally have lower emission levels, but producing and recycling them still has a high environmental impact. However, most products have little or no effect on the environment with ageing.

CONCLUSIONS

- In order to increase profit by satisfying consumers, companies employing modern manufacturing paradigms contribute to faster changeover of products which cause negative environmental impact.
- Without cultural and lifestyle changes of people in developed countries the price of their satisfaction has to be paid by people in developing countries and by future generations.

ACKNOWLEDGEMENTS

Dublin City University and the University of Minho are partners of the EU-funded FP6 Innovative production Machines and Systems (I*PROMS) Network of Excellence (www.iproms.org).

References

[1] Porritt, J., Planet Earth: The Future. 2006: BBC Books.
[2] Friends of the Earth, [online], http://www.foe.co.uk (Accessed 10 March 2008).
[3] Report on the Delphi study on ‘The future of European Manufacturing’ of the I*PROMS Network of Excellence, 2008.
[4] Energy Information Administration, [online], www.eia.doe.gov (Accessed 8 February 2008).

ACQUISITION AND DATA ANALYSIS OF THE ECO-EFFICIENCY FOR THE ESTABLISHMENT OF INDICATORS PARAMETERS FOR INDUSTRIAL ENVIRONMENTAL SUSTAINABILITY

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Keywords: Eco-efficiency, sustainable development, residues; environmental remediation, metallurgical industry; metal-workshop industry

ABSTRACT

The industrial activity is inevitably associated with a certain degradation of the environmental quality, because is not possible to guarantee that a manufacturing process can be totally innocuous.

The eco-efficiency concept is globally accepted as a philosophy of enterprise management, that encourages the companies to become more competitive, innovative and environmentally responsible by promoting the link between its companies objectives for excellence and its objectives of environmental excellence issues. This link imposes the creation of an organizational methodology where the performance of the company is concordant with the sustainable development.

The main propose of this project is to apply the concept of eco-efficiency to the particular case of the metallurgical and metal workshop Industries through the development of the particular indicators needed and to produce a manual of procedures for implementation of the accurate solution.

THE ECO-EFICIENCY PROCESS

The eco-efficiency concept was formulated for the first time by the World Business Council for Sustainable Development (WBCSD) in 1992.

The eco-efficiency is reached by means of the supply of products and services at competitive prices that satisfy the human being needs and bring life quality, at the same time as it gradually reduces both the environmental impact and the consumption of resources throughout the life cycle, to a level, at the minimum, equivalent to the capacity of sustentation esteem for the Earth.

This concept suggests a significant link between efficiency of the resources and environment responsibility. Therefore, eco-efficiency is considered as the most efficient use of materials and energy, in order to reduce the economical costs and the ambient impacts.

It can also be said that eco-efficiency consists of knowing how to combine economical and environmental performances by reducing ambient impacts; by using raw materials and energy on a more rationally way; by reducing the risks of accidents and by improving the relation of the organization (industry) with the related partners (stakeholders).

Elements of eco-efficiency

With the application of the eco-efficiency concept it is intended:

- To reduce the consumption of materials associated with products and services;
- To reduce the consumption of energy associated with products and services;
- To reduce the toxic substance dispersion;
- To intensify the recycling of materials;
- To maximize the sustainable use of resources renewed;
- To intensify the products durability;
- To add value to the products and services.

Benefits of the eco-efficiency

The benefits related with the eco-efficiency are the following:

- Costs reduction by the optimization of the resources and capital allocated to the infrastructure;
- Minimization of the environmental damage by reducing the risks and the responsibilities associated to that;
- Improvement of the security conditions and occupational health;
- Improvement of the efficiency and competitiveness, by favoring the innovation;
- Improvement of the company image and increase of the confidence of the partners (stakeholders);
- Improvement of the relationship between the environment agencies, the connecting community and *the media*.

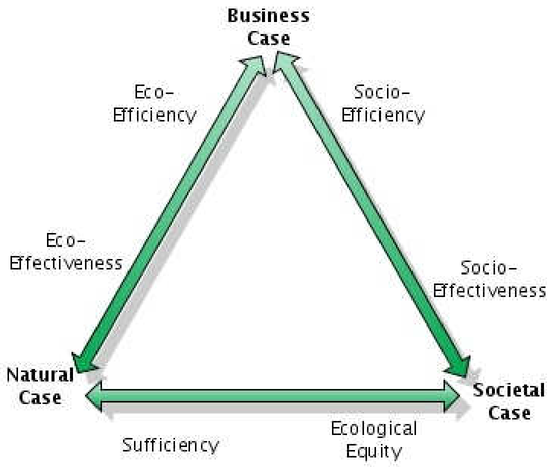

Fig.1 – Links in the eco-efficiency process [Dyllick, 2002]

THE ECO-METAL PROJECT

The relation between the industrial sector and the environment has not always been easy. Indeed, the industrial activity is inevitably associated to a certain degradation of the environment quality, because it's not possible to ensure that a manufacturing process can be totally innocuous.

Actually, there are several pressures applied on the industry with the main objective of increasing its environmental conscience and to stimulate its reaction. Consumers, investors, local communities and legislators demand a new attitude about the environment and, consequently, with the associated costs of the pollution control, residues and effluent elimination. More recently, banks, insurance companies and other service companies also made efforts in order to reduce its costs associated with the pollution control.

The eco-efficiency concept is globally accepted as a philosophy of enterprise management, which encourages the companies to become more competitive, more innovative and more environmental responsible by promoting the link between its industrial excellence objectives and its environmental excellence objectives. This link estimates the creation of an organizational methodology where the performance of the company is concordant with the sustainable development.

In the particular case of the metal workshops and metallurgic industries, the eco-efficiency concept is not yet enough explored. In this context, the challenge to pass from the conceptual plan to the operational one, that is, the translation of the sustainable development in actions, in this area of activity is, without a doubt, interesting and opportune.

Characterization of the industrial company

The company in focus has started its activity in 1981, as a cast iron and high alloy steels foundry. It is a small/medium company with a very interesting link with the University and I&D Units, that likes to innovate permanently, trying to satisfy always its customers. Its installations are located in the North of Portugal, which have most of its soil in earthen floor. Company's target is the production of small and medium dimensions parts, in small or medium series, under order and in several kinds of ferrous alloys.

The moulds used in the foundry process are based essentially on resin-bonded sand, which uses resins and catalysts to keep the degree of aggregation required during the further storage, manipulation, pouring and knock-out processes. Although the sands can be re-used, its cycle of life finishes at the end of a small number of castings. Furthermore, these products also use coatings and painting processes in order to improve the sand aggregation and minimize the moulds superficial roughness. Adding to this, the finishing product operations promotes a large number of abrasive material projections, whose destination is not exactly known. The company acquires iron scrap and ingots/ore of pure metal as raw material, and sands and respective binders for the accomplishment of the moulds.

The raw material is casting in induction furnaces (generating gaseous effluents), leaked to a teapot ladle (with ceramic coating, generating solid residues) and then leaked inside of the sand moulds, where it cools until a room temperature, in a wind tunnel (generating gaseous effluents). The next step is the knock-out process, where the moulds are broken in a vibratory machine (generating solid residues). The sand is taken for re-use (with correction additions), while the pre-finished part is led to the finishing section. The operations of cut and cleanness by shot blasting processes (generating solids residues), as well as grinding operations (generating solids residues), confer to the parts the desirable aspect pretended by the customers. So far, this Company does not have a solid description and tradition in the effluent and residues treatment.

Project objectives

With this project is intended to do an analysis of the possibility of consumption reduction of natural resources, changing the process in order to increase the productivity and minimize its environmental impact, in particular:

1. Company initial situation survey and analysis, in terms of industrial process:

a) Identification and quantification of used raw materials.

b) Identification and quantification of the manufactured products and its respective production processes.

c) Identification and quantification of substances (residues) produced in the industrial process and its emissions.

2. Company initial situation analysis, in terms of environmental impact:

a) Characterization of the solid residues produced.

b) Characterization of the degree of soil contamination and effluent contamination.

c) Evaluation of the dilution capacity of the residues (solid, liquid and gaseous) to acceptable levels

3. Proposal and study of technological remediation solutions, economically interesting, to implement in order to reduce/eliminate the negatives environmental impacts

4. Analysis of the achieved solution sustainability

5. Development of the eco-efficiency parameters in order to apply on a particular situation

6. Procedure manuals embossing, in order to implement the achieved solution.

Methodology

The methodology to be used in the analysis of the manufacturing process will consist on a specific inventory of all the input and output variables associated with the production of cast iron and steel parts. The accomplishment of this inventory will imply that the productive process is divided into individual operations. The analysis of the individual operations will consider the determination of associated flows and consumptions of materials and energy in the process, as raw materials and components, auxiliary materials, intermediate products, finished products, etc. The emission of liquids, gaseous effluents and residues will be also considered.

The environmental impacts caused by the productive process will be analyzed by a survey of the activity effluents, for further characterization and identification of its danger degree. In this case, manufacturing processes and sub-processes, as well as the quality control and cleanness auxiliary activities with repercussions on the environment will be considered.

The methodology to be use for the eco-efficiency indicators development will be based in the rules defined by the WBCSD and ISO 14031:1999 standard for this type of analysis. For such achievement, it will be used a multi-attribute decision methodology associated with a critical data analysis, in order to identify the global and specific indicators that can represent the Company's eco-efficiency profile, based on those results.

Repercussions

This project is based on the simple principle that the private sector can contribute for the sustainable development through the rational and eco-efficient use of the natural resources and environment, when providing products and services that satisfy the needs of the actual generations, without compromising the future generations.

An immediate effect that must be considered is the adequacy of the Company to the recommendations, in order to apply clean technologies in the productive process, as well as to implement a centered methodology in the "eco-efficiency" paradigm.

References

[1] Atinkson, G.; Hamilton, K. Accounting for Progress: Indicator for Sustainable Development. Environment, Setember 1996.

[2] Braga, J.; Morgado E. Guia do Ambiente – Empresas competitividade e Desenvolvimento Sustentável. Monitor. 2007
[3] Boog, E. G.; Bizzo, W. A. Utilização de indicadores ambientais como instrumento para gestão de desempenho ambiental em empresas certificadas com a ISO 14001. In: X SIMPÓSIO DE ENGENHARIA DA PRODUÇÃO – SIMPEP, 2003, Bauru. Anais do X SIMPEP – Simpósio de Engenharia da Produção, 2003.
[4] Ditz, D.; Ranganathan, J. Measuring Up: Toward a Common Framework for Tracking Corporate Environmental Performance. Washington, DC: World Resources Institute, July 1997.
[5] Feem, A. M.; Mattei, F. E. E. Environmental Indicators in EMAS Environmental Statements. Milano, Italy, 1998.
[6] Hammond, A. et al. Environmental indicators: a systematic approach to measuring and reporting on environmental policy performance in the context of sustainable development. Baltimore: World Resources Institute Publications, 1995. 302p.
[7] IMD - Managing the Industrial and Business Environment: Environmental Performance Indicators. Lausanne, International Institute for Management Development, IMD – MIBE Working Paper, 1996.
[8] Mitchell, G. Problems and Fundamentals of sustainable development indicators.
[9] Spangenberg, J. H., Bonniot, O. Sustainability Indicators - A Compass on the Road Towards Sustainability. Wuppertal Institute for Climate, Environment, Energy, Wuppertal Paper No 81, February 1998.
[10] Tyteca, D., Van Den Berghe, S.; Callens, I. et al. Indicators of Environmental Performance and Sustainable Development. Louvain-La-Neuve: Université Catholique de Louvain, Working Paper, 1997.
[11] http://www.wbcsd.org
[12] Dyllick, T., Hockerts, K. Business Strategy and the Environment, 11, 130–141, 2002

INTELLECTUAL PROPERTY MANAGEMENT FOR SUSTAINABILITY: PROBLEMSFACED BY SMALL INNOVATIVE COMPANIES

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Abstract: To sustain a competitive advantage and survive in the competitive market, it is necessary for firm to innovate. Intellectual Property Rights such as patents, trademarks, design registration, and copyrights are becoming an essential feature of an innovative economy; as it protects innovation for certain time period and helps innovator in earning monetary benefits for their efforts; on other hand it diffuses the knowledge and technology which helps in further invention and economic development. Small sized Enterprises are dynamic and flexible in operation, and hence are more innovative and quick in adapting new technologies, as compared to big companies. And these days small firms are realising the importance of intellectual property rights and do know how to manage their intellectual assets, and trend of formal intellectual practice is increasing within small size firms. But small firms don't have resources as good as large firms to practice intellectual property management efficiently, and hence they find it difficult to manage intellectual property. This research presents the problems faced by small-scale innovative enterprises for managing their intellectual property; and the measures adopted by them in overcoming them.

Keywords: innovation, sustainability, technology policy, intellectual property rights.

INTRODUCTION

With the increasing competition and globalisation, the core concern for any enterprise is to prove its existence by growing constantly [1]. In addition, these firms need to improve the quality and simultaneously reduce the cost of production or services in comparison with its competitors. According to Burrone [2] and Masurel [1] firm must 'innovate' by introducing enhanced or innovative products and services in the market. Innovation has a direct relationship with demand and knowledge. Before introducing any new product or service in the market, companies should communicate effectively with the consumers and identify the need and knowledge required for introducing new and/or original ideas. Either this required knowledge can be created in-house by its own employees or it can be outsourced through licensing or collaboration

Small and medium sized firms are regarded as important innovators; and in this knowledge economy, they add and exchange substantial knowledge within environment [3]. These small firms possess some intellectual property; their skills, capabilities, creative efforts and knowledge. The protection of Intellectual Property Rights (IPRs) and their impact on competition and innovation is growing [4].

Knowledge is rapidly diffused around the world and applied in products and processes; and products are easily duplicated or cloned. Therefore, it is also important to protect intellectual property and knowledge of small firms, such that they can gain competitive advantage as well as monetary benefits from their innovation, and sustain themselves for longer period. Successful management of such knowledge for business purpose is provided by the 'modern intellectual property system', which is based on intellectual property rights (IPR), such as patents, copy rights, contractual agreements and trade secrets [2]. At small firm level for gaining benefits from invention and innovation; similar to large scale companies, small firm should engage in efficient management of intellectual property.

Small size innovative enterprise and their problems of intellectual property management

Global Entrepreneurship Monitor [5] (page 5-6) identified positive relationship between economic growth and business start-ups, and it says that small firms are important for economic development. Small enterprises will continue innovation and economic growth, if they earn benefits from their innovation; and this is possible through protection of knowledge and intellectual property of small firms-

Furthermore, many academic researches are being conducted on innovation management and intellectual property protection for corporate sector, where as researches on IP management and enterprises size are limited. 'The Intellectual

Property Research Programme' [6] conducted by Economic and Social Research Council in 1996-1999 focused to learn the prevalence of the working of intellectual property protection for small and medium-size enterprises (SMEs). However, Blackburn [5] in his research on innovation management in small size enterprises, tried to bridge the gap between small firms, their innovation management activities and intellectual property protection. These researches resulted into findings that SMEs have realised the importance of intellectual property rights and how to manage their resources, but how ever these small enterprises makes little use of formal methods of protection and don't earn enough benefits from their innovation.

However these studies done on IP management within small and medium size enterprises still lacks focus on the problems faces by small firms for intellectual property management and ways of solving them. Also World Intellectual Property Organisation (WIPO) is increasing the awareness and importance of intellectual property protection for small and medium-size firms through different activities. Thus, this research is an attempt to discover the intellectual property management problems faced by small innovative firms and the steps taken by them to overcome the problems. The outcome of this research may enhance the IP management studies related to small firms, which may help in designing more effective IP management practice for small firms and encourage them in effectively managing their intellectual property through formal methods like patents, trademarks etc., which will ensure them benefits for their efforts and innovation.

RELATED WORK

In order to understand the intellectual property management problems in small size innovative firms, it is important to recognise work done by others in the area of innovation and intellectual property management; and their relationship with small firms.

Innovation and its need

'Innovation' is defined in many different ways; Myers and Marquis [7] (page 11) define innovation as "..Not a single action but a total process of interrelated sub processes. It is not just the conception of a new idea, nor the invention of a new device, nor the development of a new market. The process is all these things acting in an integrated fashion", where as Jorde and Teece [8] defines it as "The search for, and discovery, development, improvement, adoption and commercialisation, of new processes, products, organisational structures and procedures". From the above definitions, it can be inferred that innovation consists of all processes right from the generation of idea, manufacturing, or setup process, technological advancement, marketing, and sales of product or service. In other words, we can say innovation as commercial exploitation of new idea or product.

After knowing what innovation is, question comes up "Why Innovate?" We can answer this question by following the Schumpeterian hypothesis of 'economic development' [9], which states that, "The prospect of attaining a market position in which monopolistic practices can be used against (potential) competitors positively affects a firm's willingness to innovate". [10]

"Innovations increase welfare in the long run; to the extent that monopolistic practices are an attribute of competition through innovation ". [10]

"When compared to competition among firms with similar products and technologies, the competition that counts comes from a new commodity, technology, or source of supply, and is so much more effective than other forms of competition that it becomes a matter of comparative indifference whether competition in an ordinary sense functions more or less promptly." [10]

These hypotheses say that innovation can help company in sustaining a competitive advantage, and survive in the competitive market.

As mentioned above that innovation management is a process, and looking at all five generation process models of innovations [11], all the models has sub processes like idea generation, research and development, technology acquisition, industrial design, production start up and finally the marketing and sale of product/service in the market. These processes or phases might incorporate interaction involving market and scientific or technological knowledge [12]. However Lundvall [13] defines innovation process according to the present 'knowledge economy' as "elements and relationships that interact in the production, diffusion and use of new and economically useful knowledge". Lundvall narrates that a firm generates new idea and transform these ideas in to new product or services, entering a new market or changing the working procedure; it is a knowledge that a firm gains from interactive learning as well as from institutions and says that such knowledge is asset to an organisation. Based on this we can say that such a capability of a firm to acquire such knowledge and knowledge gained by a firm are its resources.

According to Barneys' resource based theory, "sustained competitive advantage is not achieved through an analysis of its external market position but through a careful analysis of the firm's skills and capabilities; characteristics which competitors find themselves unable to imitate" [14]. Whereas Porter [15], argues that a firm can gain a competitive advantage through differentiation on product, price, or combination of the both of them. Innovative firm can sustain in the market by combining the above-mentioned theories. Firm should produce new product, services, or new process. Knowledge, skills, and other intangible assets like creative efforts and firms image, which the firm converts into usable resources to generate a competitive advantage, are called as 'Intellectual Capital'. In addition, as the processes of commercialisation of new products are risky, complicated, and expensive techniques [8], firms should prevent its competitors doing same thing by protecting its intellectual capital by gaining Intellectual Property Rights (IPR).

Intellectual Property Management

Intellectual property (IP), allows people to own their creativity and innovation in the same way that they can own physical property (www.intellectualproperty.gov.uk). Intellectual property can be defined as "the legal rights, existing under national and international law, which can be asserted in respect of intellectual capital and its products and which entail legal sanctions for their infringement" [5] (page 16-17). To gain such rights a firm required formal registration with the relevant national or international authorities.

Once intellectual property rights are gained by the firm, the law offers protection from the misuse of intellectual property; in the case of theft, imitation, or modification of firms' intellectual capital. Different types of intellectual capital can be protected in different ways as showed in table1. Troll [7] and Pearson & Miller [16] say that Patents are largely used for intellectual property protection than other form of protection as many patents are recorded everyday and much literature on patents and innovation is available.

To obtain the maximum benefits from the intellectual capital (assets), Intellectual Property must be managed efficiently i.e. "The use of IP, either alone or in combination with other resources of the firm, to achieve the firm's strategic objectives" [17].

Protection type	Intellectual capital protected	Time period of protection
Patents	Claimed for new product or process, improvements in existing product or process	20 years monopoly
Registered design	Protects outward appearance like design, shape or colour	Initially 5 years Can be renewed for 15 years
Copy rights	Protection of creativity, literature or computer programs No formal registration is required	Lifetime of author or artist, plus 70 years
Registered trademarks	Protection of identification symbol which is used for differentiation from imitators or competitors	Registration lasts 7 years Can be renewed indefinitely
Confidentiality agreements	Mechanism for one company to disclose confidential information to another It protects the ownership and use	Depends on the terms and conditions agreed in agreement

Table 1: Different IP rights (summarised from[18] page 293, [7] page 375 and [5] page 6-7)

Managing an enterprise's IP assets is more than just acquiring the formal IP rights through the national or international IP office. Matthews et al. [19] and Burrone [2] stated that irrespective of the size of innovative firms, IP management should include the following sub tasks:

IP Identification

According to Matthews et al. [19], the first task in IP management or developing IP strategy is to identify the firms' intellectual property. Moreover, auditing is the best way of identifying intellectual property, which consists of two main sub tasks; IP Valuation, i.e. determining the likely monetary value of IP; and second is IP

Evaluation, which consists of determining worth value of IP [20]. Audits allows firms to find out what IP they own, how much will the IP portfolio maintenance cost, which helps in deciding which intellectual capital should be protected and selecting best mechanism to be used for protection.

IP Acquisition

There are different types of IP rights (table 1) and a single product or service may be protected by various forms of IP rights covering different aspects of that product or service. Burrone [2] suggest that firms must consider the best protection package based on the result of IP audit, and all the formal rights should be acquired as early as possible, to prevent from copying of idea or imitation of product. Firms should also create an IP portfolio, if possible, which may be a considerable investment. Somaya [21] stated that "the greater the number of in-citations by the patentee to patents in its rival's portfolio, the more likely is settlement of the patent suit", i.e. if the IP portfolio of any firm is of commercial interest for the other firm (being sued), then a firm can force suit settlement through mutual bargaining. Similarly, Lanjouw and Schankerman [22] discovered that the probability of litigation sharply declines with increasing portfolio size. They found in their survey that Firms having larger patent portfolios gives them both experience and the ability to settle disputes by pooling or trading intellectual property, before suits are filed. This depicts that by acquisition of intellectual property and having a good IP portfolio increases the value of the firm, its bargaining power, and reducing the litigation cost.

IP Exploitation

Gaining intellectual property rights is of no use until and unless a firm make use of it. Pearson and Miller [16], Burrone [2] and IPR-UK [23] identified different uses of intellectual property rights and making benefits out of it.

- Firm can keep the secrets within the firm and gain competitive advantage by being a first mover in the market and if some one infringes the intellectual property, firm can go for legal actions against them.
- If some firm does not have, capability to fulfil the market demands or fight against infringers, firm can commercialise IP-protected products and services, even franchise or license the use of intellectual property to others and earn monetary benefits.
- Intellectual property like any other property can be sold to some one else, but in this case innovator looses its ownership of intellectual property.
- In order to take least possible risk and capital expenditure, firm can use other people's intellectual property, i.e. by buying it, licensing it or by becoming distributor.

IP Monitoring and enforcement

It is important for innovative firm that it keeps regular touch with the technical developments and new technologies, Burrone [2] suggest that this is possible by regularly consulting patent and trademark databases. With such continuous IP monitoring, firm can identify new licensing partners or suppliers, new market opportunities and it is possible to monitor activities of competitors. To earn benefits from innovation, it is as well important to monitor and identify possible infringers. It is equally important to avoid infringing others rights. All these can be achieved with regular monitoring of national and international IP authorities databases. In case of infringement of IP rights, firm must be ready to take legal actions and solve the IP disputes.

Innovation and Intellectual PropertyManagement

Blackburn [5] relates intellectual property management to innovation as "intellectual property is protection justified on the grounds of innovation, raising productivity and for the dissemination of information". This has been proved by other researches conducted in this field.

Greenhalgh [24] when successful new products are introduced in the market, and it reflexes into imitation of products which erodes the profit. This may reduce the incentives to innovate. Moreover, intellectual property protection prevents competitor in imitating the innovativeness and helps in taking legal action against infringement. Boldrin and Levin [25] stated if innovator possesses such intellectual monopoly then they can earn more revenue from innovation, which is compensation for successful innovation in some manner. Intellectual property provides a competitive advantage by shielding the innovator from competition [24]. In addition, the competitive advantage and benefits earned from the intellectual property protection, motivates innovator for further innovation. So we can say that arguments of Boldrin and Levin on intellectual property like "patent or copyright system will result in more innovation than its absence" and Szogs [26] that IP "are often seen as providing incentives for innovation, as they are considered as essential mechanisms for securing economic returns on certain kinds of innovation" are valid.

There are some different benefits of intellectual property on innovation encountered by World Intellectual Property Organisation (WIPO, [27] [28] that IP adds value at every stage of value chain for innovation, rights from creative or innovative idea to introducing a new, better, and cheaper, product/service in the market.

Small firm innovations and IPR

Economist Schumpeter cited in Jensen and Webster [29], in his theory of economic development, argued that large firms are more innovative than small and medium-sized firms, since they have the retained earnings and capabilities to re-invest in risky innovative activities. However, contrary arguments from the researches like Christiansen [30] are that, new start-up small firms, better innovate involving new technologies, as they take risk and often succeed with innovation, where as large firms are too committed to the existing technologies, depicts something different to Schumpeterian approach, that SMEs are more innovative than large firms.

Andreassi [31] identified that most of the innovation in small businesses is in the activities concerned to production line, adaptation of new technologies, small and minor improvements, and not in major research and developments. Rothwell cited in Andreassi [31] said that there are many strengths within small firms, as small firms have flat structure and is less bureaucratic, which makes decision making faster and also makes it flexible to adapt to changes in short time as compared to large companies. Roger [32] also states that small firms have less inertia than large firms have and are therefore able to recognise market niches and take advantage of it. As a result, small companies are highly involved in technological advancement than large companies in the early stage of technology, and invent or innovate in greater amount than large companies. Andreassi supported this conclusion by identifying that the number of patents filed by small organisations is higher than that of large companies.

The research done by Masurel [1] and Kitching & Blackburn [3] on intellectual property management in small and medium sized firms reveals that though small firm does lot of innovation, the patents filed by them are very less as compared to the rate of innovation. This is because they are uncertain about the patentability of their innovations [1] and has limited knowledge regarding patents and unclear procedures; also, they consider patenting as a time consuming and expensive process.

Kitching and Blackburn [3] also identified that small organisation managers find patenting and handling infringers as complex and unaffordable process. Moreover, this is important reason why small firms are making little use of formal methods of protection. They also found in their survey that most small firm managers prefer informal protection methods for intellectual property protection, like maintaining lead-time advantage in bringing new product or services in the market. Small firms also preferred to stay ahead of their competition by out reaching its customers, and operating in niche markets [33] [6] [34] after conducting research on finding suitable appropriation practice within innovative firm concluded that higher percentage of small firm rate secrecy as more valuable than legal IP protection. Small firms develop high trust within firm to keep organisational knowledge and skills as a business secret [3]. Small firms prefer informal methods for protecting their IP, because these methods are successful, cheaper and within control of the company. In addition, small firms consider themselves less vulnerable to loss or unauthorised use of their intellectual property.

Blackburn cited in Coleman and Fishlock [6], concludes that Small firms have realised the importance of intellectual property rights and do know how to manage their assets. Small firms are also aware that their traditional faith in negotiation and trust is no longer enough protection. In addition, for practicing formal intellectual property protection, some of the innovative small firms are urging government to make the protection of IP quicker and cheaper to obtain and to maintain. Coleman and Fishlock [6] and Masurel [1], identified some small innovative firms who use formal IP protection. They discovered very unusual practice, that their interest in patent lies just in protection and not in technology transfer or monitoring and enforcement of IP.

RESEARCH FINDINGS

The main concern to carry out research was to identify small firms who are into innovations, i.e. producing new product or services in the market, and most important who practice intellectual property management. Three different innovative companies were identified. These small companies were having pending patents for their invention(s); and possess registered design or copyrights, at the time of the research. All the firms selected for research were operating in different industries, which gave broader understanding of business processes in different industries.

Research aim was to investigate the IP management problems in the small innovative firms and issues related to solving such problems. Innovations of these small firms, their intellectual property management practice were studied, which includes their current business practices, experiences in intellectual property management, their strategic choices for intellectual property protections and actions they undertake.

Moreover, the interview data demonstrated how these small companies have identified the value of intellectual capital and their attempt to manage their intellectual property. Analysis of the cases of three companies highlighted a range of problems that these small firms face in managing their intellectual property. These problems are:

- Incomplete knowledge of intellectual property rights
- High cost of gaining and managing intellectual property ;
- Time-consuming process
- Difficulties in communication with patent attorneys
- Lack of resources to handle legal disputes
- Difficulties in getting appropriate advice and access to reliable people
- Irrelevant laws

a) Incomplete knowledge of intellectual property rights

One of the three business owners considers incomplete knowledge of intellectual property rights as a problem and barrier towards managing intellectual property. The manager (owner) of the company had no idea about intellectual property management at the time of starting a new business. Someone suggested owner to file for a patent before exposing the invention to public, so with limited knowledge, the owner filed an inappropriate patent, which cost money, efforts, and time.

"I initially filed patent myself; drafted the specification myself, learnt all about it, did all that, and then further down the line realised actually what I filed wasn't worth anything because I applied for a UK patent, instead of European patent, which cost me money and time." (owner of company producing innovative recycled product)

b) High cost of gaining and managing intellectual property

All three business owners interviewed considered the cost of obtaining, maintaining, and enforcing intellectual property rights very high as compared to the investment made in the business. The costs include patent searching and monitoring, along with application and renewal fees.

"Even though if we would like to patent our software, it could be really expensive, as we have to go to states to get it patented. One such software company who patented their software, it cost them approximately £35000, and £10000-15000 every year, apart from that if patent is infringed then extra litigation cost" (owner of company having innovative software product)

"Cost is a huge barrier... I mean, as being a small company I don't have funds to throw up for intellectual property to speed up the process, where as large companies do have such resources." (owner of company producing innovative recycled product)

"I did file a patent and had a UK patent pending, which cost me £7000, which was a wrong investment, actually I dropped it as I was not sure, whether I would be able to manage patent maintenance,." (owner of company producing innovative paper folded table product)

c) Time-consuming process

Two business owners indicated that intellectual property management was a time consuming process, which also hindered their other business activities.

"Patenting is lot more complex and time consuming process, so I find it very frustrating... I filed for patent in 2001, and at current stage it has not yet been granted, and I am waiting to get it finalised and draw up some really good licensing contracts" (owner of company producing innovative recycled product)

"When you start up new business, its time to take business off the ground, concentrate on sales and rest of it, but anything like intellectual property protection or patents takes up your time" (owner of company producing innovative paper folded table product)

d) Difficulties in communication with patent attorneys

Two owners experienced difficulties in communicating with patent attorneys; they do not understand what patent attorneys says, and consider patenting as complex process. This reduced the motivation of innovator and often led to a decision of not filing for a patent or dropping out the patent.

"It's a different world; they (attorneys) speak in another language. And when talking to patent attorneys, they do not seem to appreciate my lack of knowledge and I some time feel ignorant, in meeting with them" (owner of company producing innovative recycled product)

"I found very difficult to deal with lawyers, I do not know what they are talking about" (owner of company producing innovative paper folded table product)

e) Lack of resources and capabilities to handle legal disputes

Majority of interviewees though being innovative and having intellectual property rights, felt that they had insufficient resources to defend intellectual property and pursue litigation against infringers, particularly, when any large organisation infringes the intellectual property.

"Unfortunately, all my resources were put into patent at very early stage of business, and now when my idea is being copied, I cannot really do anything, I am not capable enough to take a legal action against them, but apart from that they will blow me out of water' (owner of company producing innovative recycled product)

"we haven't taken any legal action against them, not at this stage, it will be very difficult, we don't have resources to look that at this stage, I mean time to put together, the information needed, the cost of solicitors and legal team to deal with it" (owner of company having innovative software product)

f) Difficulties in getting appropriate advice and access to reliable people

One interesting point discovered is that, one of the owner found difficulties in accessing reliable people and get appropriate advice; legal advisers (attorneys) were not able to provide proper advice on which intellectual property rights to be gained for innovation.

"it is terribly difficult to get decent advice... I ran out of time for design registration, I wasn't told that I had to apply for design registration in Europe and in States within the certain time frame from the legal person I was going through, and I missed that, which has affected my business as a result. Today I haven't got a design registration in States. I could have sold rights into States for lot more money than I have been able to" (owner of company producing innovative paper folded table product)

Irrelevant laws

In one case the firm found the law to be irrelevant to their innovation. The firm developed innovative software, and law provides them copyright protection, as the software are written and written work always gets copy right protection, such rights prevents unauthorised used of the software, but it does not prevent from getting innovative ideas copied

"...particularly patenting of software is not possible in UK and EU, so it has to go to the States to get patent protected... Legally software patent is not allowed in UK and EU, if we would have written the software in completely different programming language that no one has ever invented before, we could patent it because that would be new, and we have written it in a normal programming code, so its not new enough to patent it" (owner of company having innovative software product)

Small firms' efforts in solving intellectual property management problems

Though having similar kind of problems, these small firms' owners, have different perception toward solving them. Some of the problems like higher cost of system, time-consuming process, and irrelevancy of laws were not in their hands so these problems were insolvable by them. However, to overcome other problems like insufficient knowledge; difficulties in communication with patent attorneys; lack of resources to handle legal disputes; and to get appropriate advice and right people for right work, small firms took number of steps.

To avoid same mistake; i.e. filing inappropriate patent (different form previous one) one owner, did sufficient research and attained good knowledge of intellectual property management by reading about it and attaining seminars; contacted different design agency and Prince's Trust (a charity organisation) for free guide lines and information; and then sought professional advice from patent attorneys and filed right patent.

After getting improper advice on patent and then realising patent as worthless, one owner dropped out pending patent. Then moved to other option of registering a design for protecting it from getting copied. Again, after missing out design registration in EU and US because of limited guidance by legal adviser, owner contacted an attorney who had similar prior profession (who properly studied the product) and on attorney's suggestion, owner registered for ACiD (Anti Copying in Design) and copy watch scheme. These are membership insurance schemes where organisations monitor through the world for protecting the members design, and on identifying the design being copied, covers litigation cost to a certain limit.

One of the owners on finding patenting as impossible option as a reason of high cost; and having insufficient resources for litigation, opted for avoiding legal form of protecting their intellectual property, and preferred informal protection of its intellectual capital. These practices are staying ahead of competition, continuing the innovation process and creating product portfolio.

CONCLUSION

The empirical data collected from interview clearly leads to the following conclusion:

1. An intellectual property rights are an important issue for small firms. Small firms do identify the value of intellectual capital and try to manage their intellectual property.
2. Small firms do face problems over intellectual property rights, and these problems are as follows:

a) Lack a/knowledge on intellectual property rights

Small firms do not have sufficient knowledge about intellectual property rights and their benefits, as so are not able to make any kind decisions related to availing intellectual property rights, protecting intellectual property, or execution of intellectual property rights. And small firms do not understand what attorneys say, so they consider intellectual property protection as a complex process and lack of understanding it as a barrier towards efficient intellectual property management

b) Small firms find intellectual property management as time consuming and costly process

Small firm owners considers intellectual property management as time- consuming process, right from searching database prior registering till intellectual property rights are granted, and they consider such long time hindering other business activities. In addition to that, Small firm owners find the cost of gaining and managing intellectual property very high, as compared to their other business investments.

c) Lack of resources, especially for litigation

Small firm owners find it difficult to handle legal disputes due to limited resources and funds.

d) Inappropriate advice

Small firms' owners often find difficulties in accessing reliable people and get appropriate advice, as they have no experience in dealing with legal professionals at all; and also legal advisers (attorneys) have fewer clues about the innovations done by small firms.

3. Small firms do not stop back, but try to solve their problems. Some of the steps taken for solving intellectual property management problems are as follows:

a) Small firms increased their awareness of intellectual property rights by contacting, and attending seminars conducted by, organisations like Prince's Trust who provide information and guidance free of charge. In addition to this small firms also approached local attorneys for professional guidance.

b) To overcome the problem of lack of resources, these small firms became the member of organisation like Copy watch, and ACiD who provides insurance for litigation up to certain cost.

c) Small firms, to avoid litigation process, often adopt informal methods of intellectual property management like being first mover and having lead- time in innovating as compared to competitors.

References

[1] Masurel, E., 2002. Patenting Behaviour By Smes.International Journal of Entrepreneurship and Innovation Management, 2(6), 574-583.
[2] Burrone, E., 2001. Why Intellectual Property Matters: The Importance of Intellectual Property For Small and Medium-Sized Enterprises. World Intellectual Property Organisation, Available At: http://www.wipo.int/sme/en/documents/pdf/ipmatt er s.pdf
[3] Kitching, J., and Blackburn, R., 1998. Intellectual Property Management In The Small and Medium Enterprise (Sme). Journal of Small Business and Enterprise Development, 5(4), 372-335.
[4] Lall, *S.,* 2003. Indicators of The Relative Importance of Iprs In Developing Countries. *Research Policy*, 32, 657-1680.
[5] Blackburn, R., 2003. Intellectual Property and Innovation Management In Small Firms. London: Routledge
[6] Coleman, R., and Fishlock, D., 2000. *Background and Overview of the Intellectual Property Initiatives*. Economic and Social Research Council funded Intellectual Property Research Programme.
[7] Trott, P., 2002. *Innovation Management and New Product Development.* 2nd Ed. Harlow: Prentice Hall.

[8] Jorde, T., and Teece, D., 1990. Innovation and Cooperation: Implications for Competition and Antitrust. *Journal of Economic Perspective*. 4(3), 75-96.
[9] Witt, U., 2002. How Evolutionary Is Schumpeter's Theory of Economic Development. *Industry and Innovation*. 9(1/2), 7-22.
[10] Schumpeter, J., 1954. *Capitalism, Socialism and Democracy.* 4th Ed. London: Allen & Unwin [11] Rothwell, R., 1994. Towards The Fifth-Generation Innovation Process. *International Marketing Review*. 11(1), 7-31.
[12] Deakins, D. and Freel, M., 2003. *Entrepreneurship and Small Firms.* 3rd Ed, London: Mcgraw Hill Education.
[13] Lundvall, B., 1992. *National Systems of Innovation. Towards A Theory of Innovation and Interactive Learning.* London: Pinter Publishers.
[14] Barney, J., 1991. Firm Resources and Sustained Competitive Advantage. *Journal of Management*. 17, 99-120.
[15] Porter, M., 2001. Strategy and Internet. *Harvard Business Review*. 62-78.
[16] Pearson, H., and Miller, C., 1990. Commercial Exploitation of Intellectual Property. London: Blackstone Press Limited. [17] Pitkethly, R., 2001. Intellectual Property Strategy In Japanese and UK Companies: Patent Licensing Decisions and Learning Opportunities. Research Policy. 30, 425-442.
[18] Bellon, B., and Whitting, G., 1996. *Competing Through Innovation.* Dublin: Oak Tree Press
[19] Matthews, D., Pickering, F., and Kirkland, F., 2003. A Strategic Approach to Managing Intellectual Property. *In:* Blackburn, R., Ed., *Intellectual Property and Innovation Management in Small Firms.* London: Routledge, 2003, Pp. 35-54.
[20] Partnersip Uk, 2002. Intellectual Property Management Strategy: Technical, Personnel and Implementation Issues. Available At: http://www.partnershipsuk.org.uk/widermarkets/guidance/2003_5_ip. pdf
[21] Somaya, D., 2002. Theoretical Perspectives on Patenting Strategy. College Park: University of Maryland. Available At: http://www.rhsmith.umd.edu/faculty/dsomaya/Papers/
[22] Lanjouw, J., and Schankerman, M., 2004. Protecting Intellectual Property Rights: Are Small Firms Handicapped? *Journal of Law and Economics,* 47 (1). pp. 45-74.
[23] www.intellectual-property.gov.uk
[24] Dixon, P., and Greenhalgh, C., 2002. *The Economics of Intellectual Property: A Review to Identify Themes for Future Research*. Economics Series Working Papers 135, University of Oxford, Department of Economics. Available At: http://www.economics.ox.ac.uk/Research/wp/pdf/paper135.pdf
[25] Boldrin, M., and Levine, D., 2003. *The Case Against Intellectual Monopoly*, Available At: Http://Www.Dklevine.Com/Papers/Klein-Paper.Pdf
[26] Szogs, A., 2004. Intellectual Property Rights: Necessary but Insufficient Incentives to encourage R&D in the Biopharmaceutical Industry: The Case of Neglected Diseases. *Druid Summer Conference 2004* on Industrial Dynamics, Innovation and Development. Elsinor, Denmark, June 14-16
[27] World Intellectual Property Organisation (WIPO), 2003. Intellectual Property for Businesses. Available At: http://www.wipo.int/export/sites/www/sme/en/ip_business/pdf/ip_business.pdf
[28] World Intellectual Property Organisation (WIPO), 2003. Fundamentals of Intellectual Property (IP) Management by Small and Medium-Sized Enterprises (SMEs). Available At: http://www.wipo.int/sme/en/documents/pdf/poland.pdf
[29] Jensen, P., and Webster, E., 2004. *SMEs and their use of Intellectual Property Rights in Australia* Melbourne Institute Working Paper Series wp2004n17, Melbourne Institute of Applied Economic and Social Research, The University of Melbourne. Available At: http://melbourneinstitute.com/wp/wp2004n17.pdf
[30] Christiansen, C., 1997. *The Innovators Dilemma.* Cambridge: Harvard Business School Press.
[31] Andreassi, T., 2003. Innovation in Small and Medium Sized Enterprise, *International Journal of Entrepreneurship and Innovation Management.* 3(1/2), 99-106.
[32] Roggers, M., 2004. Networks, Firms Size and Innovation, *Small Business Economics.* 22, 141-153.
[33] Kitching, J., and Blackburn, R., 2003. Innovation, Intellectual Property and Informality. *In:* Blackburn, R., Ed., *Intellectual Property and Innovation Management In Small Firms.* London: Routledge, 2003, Pp. 16-34
[34] Arundel, A., 2001. The Relative Effectiveness of Patents and Secrecy for Appropriation. *Research Policy*. 30, 611-624.

WHY ANTHROPOCENTRIC ORGANIZATION MODELS DON’T SUCCEED IN PORTUGAL? A CULTURAL PERSPECTIVE USING HOFSTEDE’S CULTURAL DIMENSIONS

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Keywords: Management; Culture_dimensions; Innovation; New_organization_models.

INTRODUCTION

The question introduced by this paper title is arguable, in so far that it states a fact – anthropocentric organization models don’t succeed in Portugal. It is arguable because, one might say, it’s not exactly like this; or, because it can be valid for some sectors or companies but not for others; finally, the factors which lead to this lack of success are not the same nowadays, at least when compared with Fast-Monitor 1990’s reports.

In Europe, anthropocentric organization models – an updated version of the socio-technique approach – had their maximum expression in the Swedish model, which came to be known as “uddevalism” or “volvoism”. Several factors were presented as conditioners of this success [1], and some critical factors to the success of that organization models were pointed out for the special case of LIMS (Less Industrialized Member States), such as Portugal. Furthermore, there is some evidence [2] [3] that stress the lack of success of anthropocentric models in Portugal. However, in any case, it wasn’t paid much attention to the importance of culture as a booster of the introduction of new organization models.

The purpose of this paper is to assess the viability of the general and exploratory hypothesis that national culture is an important factor to consider in the success of new organization models. Considering that the example which best expresses the anthropocentric approach came from Sweden, this assessment will be based on the confrontation of Portuguese and Swedish cultural characteristics using Hofstede’s cultural dimensions.

This paper starts by framing the different organization models, describing in more detail the Swedish model, which inspired anthropocentric organization models. The description of cultural dimensions is followed by a discussion of the dimensions’ results for both cultures. Some concluding remarks are made, namely that the cultural environment on which the Swedish model emerged is very different from the Portuguese one, which can help to explain the lack of success of anthropocentric models in Portugal. It should be noted, however, that this is an exploratory study and doesn’t intend by no means to jump to final conclusions.

ORGANIZATION MODELS AND NATIONAL CULTURES

Between Technocentrism and Anthropocentrism

Organization models can be classified in numerous ways. However, for the purpose of this paper, it will be used a perspective presented by Kovacs [4].

Technocentric perspective	Anthropocentric perspective
Introduction of new technologies in order to concentrate the potential control over production	Introduction of new technologies in order to obtain functional and organizational flexibility
Rigid working practices	Flexible working practices
Centralization and specialization	Decentralization and polyvalence
Vertical and horizontal division of work, strong hierarchical and professional divisions	Vertical and horizontal integration of work, unclear division between workers’ tasks
Centralized technical solutions	Decentralized technical solutions

Fig. 1. Two perspectives of organization models (adapted from Kovacs, 1998)

Technocentric perspective assumes that the solution for the challenges presented by the new economic context is on the use of high technology, which is believed to guarantee competitiveness offering quality and flexibility. High technology will allow a higher centralization and automation of mechanisms and processes and, at the same time, allows production diversification. Software can incorporate human knowledge and skills in a formalized and regular fashion.

The organizational model that better illustrates or represents this perspective is known as neo-fordism or neo-taylorism, which can be defined as an update of Taylor's classic work organization model with the incorporation of high technology. The principles of Taylor's work organization model are well known. The introduction of high technology allows expanding these principles reinforcing its rigid, centralised and controlling approach. The presence control strategies are substituted by absent control strategies [5].

On a different angle, anthropocentric perspective argues that the best way to face a segmented and demanding market is in the ability to quickly change and adapt. In this way, high technology is not sufficient to guarantee that competitive advantage. It should be followed by flexible human resources and organization models.

Taking the opposite approach of technocentrism, anthropocentric perspective stresses the importance of human resources to promote a flexible organization capable of change and adapt to market contingencies. This perspective can be seen on the adoption of participation, decentralization of the decision process and information, cooperation among workers through the implementation of working teams.

Technology in this scenario looses its deterministic status and becomes an important backup of human skills, allowing individual and collective creativity. This principle inverts the classic thinking, because it becomes necessary the development of technological systems capable of adapt to people and not the opposite. This frame is the basis of the development of anthropocentric technological systems, built on information, decision and control transparency and with user friendly interfaces, able to facilitate learning [6].

A Northern European Experience

The example that better illustrates the anthropocentric perspective is the model popularized by the experiences of Volvo car manufacturer, especially its Uddevalla factory in Sweden. Formerly, Volvo has developed a first attempt in Kalmar factory, the first to eliminate the traditional assembly line.

The development of this model in Sweden didn't occur by mere chance. The favourable social environment combined with Volvo's strategy created the necessary context to the development of this new production concept. Moreover, the product and labour markets' pressure were decisive to the development of work models centred in the human factor [7].

Uddevalla's experience was the result of a process of intense cooperation between Volvo engineers and managers, unions and researchers. Out of this cooperation came out some decisions regarding the work organization principles, namely the importance of long working cycles, product quality, flexibility and working life quality. However, there are some resemblances with Japanese model, lean production, regarding customer orientation, reduced delivery schedules and workers involvement. The main contrast with lean production is on the concept of "reflexive production system", i.e. the development of new production techniques using workers knowledge and learning capacity [7].

On the base of these principles, Uddevalla 700 workers assembly line was transformed in 8 workers teams who assembled the vehicle. From this point on, teamwork became the main characteristic of Uddevalla model.

Working teams allow its members to take control over vehicles assembly and the pace of work. Workers' control and the reduction of repeated tasks only were possible due to the introduction of long working cycles. On the other hand, teams had to develop other tasks such as breaks and holydays planning, communication, recruiting, maintenance and training. Vertical and horizontal integration of tasks was the key element [8].

Teams were integrated in a flat structure with only three hierarchical levels, which facilitated the information flux in any direction. On the other hand, recruiting strategy was embedded on teamwork philosophy. The main goal was to recruit workers from different gender and ages, guaranteeing a heterogeneous team constitution, allowing a better internal equilibrium [8].

Other characteristics supported the team work design: technology was developed on the basis of workers' needs and characteristics, without much heavy machinery; ergonomics was studied in order to promote more comfortable conditions, which contributed to more efficiency, quality and productivity [6]; logistics was also developed according the workers' natural learning processes [9].

Hofstede's Cultural Dimensions

The use of culture to study how national characteristics can help explain the success of different organization models needs an approach that presents some particular characteristics, namely: (1) it should be able to allow comparisons between countries, (2) a typology well tested and suited to organizations' context, and finally (3) it should present characteristics allowing comparison with the organization models. Hofstede's Cultural Dimensions [10] fulfil these requisites in so far that his model offers solid standards which had been used to understand cultures of many countries. Furthermore it was born from the study of organizational context.

Hofstede's interest for cultural phenomenon goes back to the 1970's when he started the study of cultural differences using IBM workers from over 50 countries as an empirical ground. He starts from the definition of culture, which can be seen as collective mental programming that distinguishes members of a group [11]. This computer metaphor doesn't mean that there is no room for creativity; on the contrary, individuals can adapt their "software" in order to adjust to different contexts and goals. Another important point about culture is that it allows individuals and groups to solve problems and, thus, facing the same problem, individuals from different cultures can present different solutions.

The theoretic model is made up of dimensions. In Hofstede's terms, this means that (1) they are independent of each other, (2) it's possible to combine them in different ways, and (3) they operate with two opposite extremes along a continuum. The theoretic model presented initially four dimensions [12]:

(i) Power Distance (PDI)

Defines how people deal with inequalities. These inequalities can be measured in terms of power and wealth. The power distance index gives us a clue on the social and individual level of tolerance of those differences. A high score on power distance index means that the society has a fairly high acceptance of differences in power and wealth distribution, both at the top and bottom of social hierarchy. According to Hofstede, this situation can remain so because there is a high level of dependence of the less powerful and wealthier.

This dimension seems to be correlated with collectivism: in countries where collectivism scores high, there's also a tendency to score high on power distance. However, the results are not so clear to the relation of individualism and power distance.

(ii) Individualism (IDV)

This dimension is about the relation between an individual and other individuals. At one end is individualism which is translated in very losing ties. At the other end is collectivism which, on the opposite, is traduced by very strong ties. In individualist societies is supposed that the individuals take care of their self-interests and perhaps of their near family. Individual freedom is a very import value. On the other hand, the concern with groups of belonging in collectivist societies is very important and, in exchange, the group functions as a shield against external threats.

This dimension seems to be correlated with national wealth: more individualist societies tend to be wealthier.

(iii) Masculinity (MAS)

Masculinity accounts for the (social) division of roles between sexes. Traditionally, men take more assertive and dominant roles, when women are devoted to more service-oriented and caring roles. When a society is mainly "masculine" it means that masculine values spread out all society, including women, such as performing, achieving and materialism. The opposite, "feminine" societies, are more concerned with relationships, quality of life and the preservation of the environment. A high score means a "masculine" society; a low score means a "feminine" society.

(iv) Uncertainty Avoidance (UAI)

Uncertainty avoidance refers to the way societies deal with the unknown, an unchangeable characteristic of the future. Societies that score low on uncertainty avoidance tend to prepare their members to accept with ease the uncertainty, taking risks more easily. Another characteristic of low uncertainty avoidance societies is the high level of tolerance regarding others' opinions and behaviour. High score societies on uncertainty avoidance tend to develop strategies to control the future making it more predictable, which can be reflected on the creation of institutions specially devoted to diminish risk and create security. This can be done on three levels: technology, law and religion.

A fifth dimension was added after a study developed by Chinese scholars [12]:

(v) Long/short term orientation

It deals with what as been called Virtue and Truth, which is found in the thinking of Confucious. The former is associated with thrift and perseverance; the latter emphasises tradition and the fulfilling of social obligations.

Although Hofstede's Cultural Dimensions are a comprehensive model which allows the study of national cultures and the comparison between cultures it's not immune to criticism. One of its more tough opponents is McSweeney [13] that criticizes the entire model, from the basis (the notion of culture) to the methodology approach.

It's not our goal to go through, step by step, the arguments of McSweeney, and the answer to his critics was already given by Hofstede himself elsewhere [14]. Although the model is far from being perfect and to cover all the aspects of such a complex concept as culture, it should be considered the wide applicability of its principles in areas such as organizations, consumption, tourism, marketing and others. Furthermore every theoretic development should be under scrutiny, but it should be made on a construction and not a destruction basis. In other words, the criticisms should be followed by new enlightening proposals which were not the case.

WHAT CULTURE HAS TO DO WITH IT

Swedish and Portuguese Cultural Dimensions

We now turn to the description of Portuguese and Swedish cultural dimensions' results. As was stated before, the choice of the latter is based on the fact that the most successful experiences regarding the application of anthropocentric organization models came from Sweden.

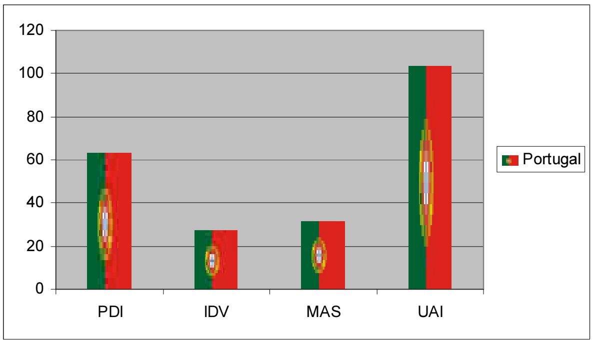

Fig. 2. Portuguese Cultural Dimensions (source: http://www.geert-hofstede.com)

Two dimensions reveal a strong presence in the Portuguese culture: power distance (PDI) and uncertainty avoidance (UAI). On the other hand, masculinity (MAS) has a weak presence, revealing that Portuguese culture is more feminine. In the same way, the score for individualism (IDV) shows that Portuguese culture has a strong presence of collectivism.

Sweden presents a more balanced result. The strongest dimension is IDV; the weakest dimension is MAS, meaning a greater presence of femininity. PDI and UAI also have low scores when compared with other dimensions and with Portugal's results for these two dimensions.

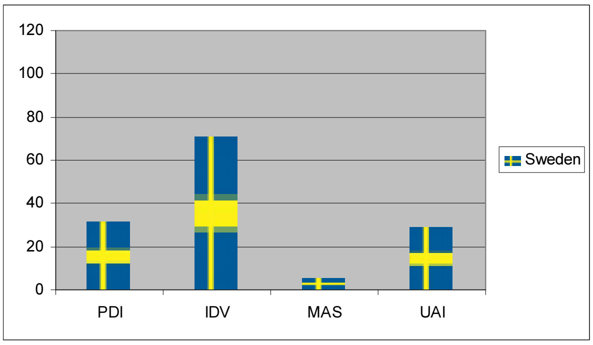

Fig. 3. Swedish Cultural Dimensions (source: http://www.geert-hofstede.com)

When compared, cultural differences between these two countries are well visible. Portugal clearly has a more power distant culture, meaning that inequalities are more persistent and accepted in Portugal than in Sweden. But the major difference is in the UAI. Portugal as a score three times superior when compared with Sweden. This means that Portuguese culture is less open to changes, to deal with the unknown and to cope with it. On the opposite, Swedish culture is a more open minded culture, which accepts fairly well the unknown.

This is a very important characteristic when the subject is change, because a high UAI can be a predictor of strong resistances to change. Moreover, this high score can lead a society to create and impose a very formal and standardized approach to change.

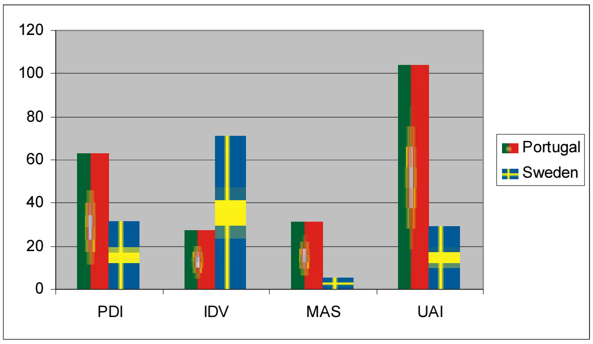

Fig. 4. Portuguese and Swedish Cultural Dimensions Comparison (source: http://www.geert-hofstede.com)

On the other hand, Portugal has a low score on MAS, but Sweden score is even lesser. This means that we are facing two societies that value harmony. This is consistent with Portugal results for IDV (or collectivism), because these two dimensions reveal the value of relationships for Portuguese culture.

However, the explanation for the low score of Sweden must be found somewhere else, because it scores the double of Portugal for IDV. The reason for this may be on the scores for PDI and UAI. The low scores for these two dimensions mean that Swedish culture has a looser control over uncertainty – coping better with change – and doesn't value differences and inequalities, which in turn can be argued to give them more security to turn to and fulfil there own personal goals.

Is there cultural context for anthropocentric models in Portugal?

Organization models have their own characteristics which can be said to suit better or worse depending on the context on which they are implemented. In other words, context factors are of utter importance if we want to understand the success or failure of an organization model implementation.

This also the case; anthropocentric models, namely the example that came from Sweden, uddevalism, as some characteristics that imply a certain cultural environmental context. For example, the high level of autonomy, appeals to the capacity of workers to discuss problems and find their own solutions without being told how and what. This implies a capacity to manage conflicts and deal with new problems. It can be argued that this calls for a low UAI.

Another example is the flat structure promoted by this model. With only three levels of hierarchy, the bottom and top are closer presenting less power differences. This type of structure appeals for a low PDI score in order to cope with shorter inequalities among different (few) hierarchical levels.

	PDI	IDV	MAS	UAI
Autonomy	Low			Low
Horizontal and vertical integration of tasks				Low
Flat hierarchical structure	Low			Low
Teamwork		Low	Low	

Fig. 5. Combination of anthropocentric main characteristics and cultural dimensions

A final example is teamwork, which comes with autonomy. In this kind of context, workers are part of a small team which has to do all the tasks related to the working process. Obviously, this means more qualifications and skills. However it also means that workers have to cope with horizontal and vertical integration of tasks, have a more flexible approach, and manage constant changes in their day-to-day functions. This description suits with a less individualist and masculine culture.

According to Hofstede's model Portuguese cultural characteristics don't seem to present the appropriated context for anthropocentric organization models.

The most inappropriate dimensions are PDI and UAI. In fact, Portuguese culture score high on these two dimensions and to be successful anthropocentric organization models need a low UAI and a lesser PDI score in order to be easier the introduction of flat structures and a more flexible approach to work processes.

However, Portuguese scores for IDV and MAS allow arguing that there are some favourable characteristics. The low score for IDV points out the importance of groups and tight relationships which is a very important factor in the implementation of teamwork. Also, low scores on MAS dimension anticipate a strong possibility of success for anthropocentric models due to the emphasis on harmony and quality of life.

CONCLUDING REMARKS

The main goal of this paper was to explore the viability of culture as a factor to take into account when explaining the success of new organization models. Hofstede's cultural dimensions model was used as an instrument to frame and compare two cultural contexts, one as the birth of the most successful anthropocentric model and Portugal as a host culture.

This paper presents an exploratory study, which needs more empirical research in order to present more solid conclusions. However, it can be said that the approach and analyses presented opens a solid topic of research, meaning that there is sufficient ground for the study of culture as an influencing factor for the introduction of new organization models.

As an empirical instrument Hofstede's cultural dimensions seems to have capacity to explain the importance of culture in this context. Moreover, and although Hofstede's cultural dimensions may have its limitations, it stresses the problem of management in a global environment, namely the simple transposition of models from one culture to another.

Regarding the evidence presented in this paper, UAI and PDI dimensions seem to be the main cultural threats to the implementation of anthropocentric organization models in Portugal; on the other hand, IDV and MAS dimensions represent the main opportunity. However, it should be noted that the strong presence of UAI and PDI may be a strong conditioner.

FAST-Monitor reports already have stated this problem, classifying Portugal as a Less Industrialized Member Sate (LIMS), which represented greater difficulties on the adoption of new organization models, such an anthropocentric model [2 [15].

Three sets of limitations can be pointed out to this exploratory study. First, a methodological one, and already stated, is the fact that it is an exploratory study. The second set of limitations can be found on the critics to Hofstede's cultural dimensions model. Finally, the methodological approach should be refined in order to develop a more broad and accurate picture of the subject.

Regarding this last limitation, our attention should be focused on other topics for further research, namely (1) the development of more country case studies, (2) establish comparisons between different countries, and finally (3) look for regional and sector differences combined for the results of cultural dimensions and the success of new organization models.

References

[1] Durand, J.P., Questions sur une brisure, in *La fin du modèle suédois*, J.P. Durand, Editor. 1994, Paris: Syros. pp. 12-39.

[2] Kovács, Ilona; Moniz, A.B.; Mateus, Augusto, *Introduction of Anthropocentric Automated Systems in Portugal: problems and trends*, 1990. APS Research Papers, CEC/FAST, vol. 16, FOP 260, Bruxelles: CEC

[3] Ferreira, Pedro, *Condições de Implementação dos Sistemas Antropocêntricos de Produção: estudo de caso no sector da metalomecânica*, 2001. Lisboa: ISEG/UTL (Master's dissertation, not published)

[4] Kovács, Ilona, Sistemas Antropocêntricos de Produção. Uma alternativa para a Europa?, in *Novos Modelos de Produção. Trabalho e pessoas* Ilona Kovács e Juan José Castillo. 1998. Oeiras: Celta Editora, pp. 93-114.

[5] Kovács, Ilona; Ferreira, J.M Carvalho; Santos, M. João, *Mudança Tecnológica e Organizacional: análise de tendências na indústria*. SOCIUS Working Papers, n.º 2/94. 1994. Lisboa: UTL.

[6] Wobbe, Werner, *Anthropocentric Production Systems: a strategig issue for Europe*, APS Research Papers, CEC/FAST, vol. 1, FOP 245, 1991. Bruxelles: CEC.

[7] Sandberg, Ake, The Uddevalla experience in perspective, in *Enriching Production. Perspectives on Volvo's Uddevalla plant as an alternative to lean production*. Ake Sandberg, Editor. 1995. Aldershot: Avebury, pp. 1-32

[8] Ellegard, Kajsa, The creation of a new production system at the Volvo automobile assembly plant in Uddevalla, Sweden, in *Enriching Production. Perspectives on Volvo's Uddevalla plant as an alternative to lean production.* Ake Sandberg. Editor. 1995. Aldershot: Avebury, pp. 37-59

[9] Nilsson, Lennart, The Uddevalla plant: why did it succeed with a holistic approach and why did it come to an end?, in *Enriching Production. Perspectives on Volvo's Uddevalla plant as an alternative to lean production*, Ake Sandberg. Editor. 1995. Aldershot: Avebury, pp.

[10] Hofstede, Geert, *Culture's Consequences*. 1980. Beverly Hills CA: Sage

[11] Hofstede, Geert. *Culturas e Organizações. Compreender a nossa programação mental*. 1997. Lisboa: Edições Sílabo

[12] Hofstede, Geert, The cultural relativity of organizational practices and theories, *Journal of International Business Studies*. 1983. 14, pp. 75-89

[13] McSweeney, Brendan, Hofstede's model of national cultural differences and their consequences: a triumph of faith – a failure of analysis, *Human Relations*. 2002. 55 (1), pp. 89-118

[14] Hofstede, Geert, Dimensions do not exist. A reply to Brendan McSweeney. *Human Relations*. 2002. 55 (11) pp. 1355-1361

[15] O'Siochrù, Sean, *Propects for APS in Less Industrialised Member States – Synthesis Report*, 1990. APS Research Papers, CEC/FAST, vol. 6, FOP 250, Bruxelles: CEC

THE HUMAN RESOURCES MANAGEMENT NIPPON AND THE ENTERPRISES COMPETITION IN PORTUGAL

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Keywords: Economical Competition, Technological Progress, Human Research, Management Tactics, Marketing.

1. INTRODUCTION

The Japanese islands are part of four main islands – Honshu (where is located Tóquio), Hokkaido, Kiu-shu e Shikoku (from the bigger to the smallest) and about 1042 smaller islands.

The Nippon population is of 127 millions of inhabitants, that live in less than 10% of the territory, being concentrated 11 million in the capital, Tokyo.

Talking about religion (or *shinto*), the most f Japanese are Introits and Buddhists. In the Rising Sun Country there is a parliament monarchy, being nowadays the imperator (or *tennô*) the symbol on State and unity of the people, in the second world war, he possessed the title of divine an untouchable.

Portugal benefits, in relation to Japan, a very positive factor that the others countries don't have: a historical image very favourable that left in the Japanese a collective memory of the country we were in the pass.

In 23 of September 1543, Japan lived the age of wars (to be more exact: *sengoku-jidai*), when a group of Portuguese sailors, travelling in a not strong raft, where carried by a storm that reach the island of Tanegashima at Nixumura-Coúra beach.

The first news about Japan that reach European ears where the ones of Marco

Polo. Cimpangu, as Pólo was named, was described by him as "a great island, of white people, good manners and beauty".

When Cristóvão Colombo arrived in Haiti, in 1492, he was convinced that those lands were the lands of the unknown Cimpangu of Marco Pólo.

Time differentiated the geographic positions and Cimpangu was replaced by the name it has today, Japan or Nippon, that means " Country Origin by the Sun" .

It is proved that were António Mota, Francisco Zeimoto e António Peixoto, that gave the knowledge and show gun powder and fire weapons like the mosquitoes (or *têppo*).

Other Portuguese were notables in Japan, like Luís de Almeida that, taking part of the Jesus Brotherhood, helped healing a great number of leprous and with is own money, raised up and run in 1557, one hospital in Funai (nowadays called Oita).

The Portuguese Jesuits had a big importance in teaching, numerous Portuguese words are found nowadays in the Nippon language, such as: *Botan* (bottom), *shabon* (soup), *pan*(bread), *Koppu* (glass), among others.

The Portuguese knowledge in the scientific areas, such as medicine and mats left the Japanese astounded.

It was with the arrival of the Portuguese that Japans stopped being an isolated territory and feudal, becoming latter in a centralized estate open to the world.

Although there is a cultural diversity in the Orient region of Asia, there is a preponderance of the Confucius cultural matrix.

One of the basic principles of Confucius philosophy (their religion that is preponderant in Japan), it's the importance posed in the collective aspect of social order in deterioration of the individual action and in consequence, the importance of the Harmony and Congress that are the base of the two enterprise cultures.

A fount of the Nippon Harmony it's the production of rice that requires the cooperation and coordination between all the farmers to plant and collect the production.

One of the existent Contents is having consideration the people as the more important natural resource and an example is the elaboration of a scholar system that offers to all the population a high educational level (after world war one school was by obligation till nine years old and free).

The Nippon's learned that social concentration environment origin an increase of production in work and an increase in work rotation.

While in the national enterprises the management is participative and has defined responsibilities, after discussion of the several arguments and intervenient, the power is given to a decider.

In the Rising Sun Empire, the management method is based in consensus, because everything is discuses until there is an agreement among everyone and only this way the final decision is taken. This origins a big motivation to increase the production, an agreement between the group and individual objectives and a involvement in all areas, being a slow process.

But time has a different meaning to the Nippon's, I verify that myself when I was in Japan, the way they like going around subjects and thinking about them it is really difficult to obtain a final decision in the first meeting. The serenity and patience are some much admired virtues.

This article has as main purpose research the result of the work of the matrix in the Nippon's enterprise management system in the auto and electric sectors, with and without japanese capital, that work in Portugal.

The study search the answer to the question connect to the research "what is the relation between the nippon management system and the economic production and technological progress indicators, in the enterprises that work in Portugal?".

2. EPIRIC WORKS

In this research model, I used economic nature indicators adjusted to the observed data, in the enterprises in question.

The management system and its evolving context were explained, in an analytic model, through a conceptual tool composed by tree independents variables (in terms of quality): Managing Tactics (TG) Human Resources (RH), and Marketing (MK). And the dependent variables (Qualitative): Economic Competition (CE) and Technological Progress.

I selected this qualitative variables do to all the literature revision, and the preoccupation in adequate the research to the characteristics of the enterprises being studied.

The same ones secure a covertures detailed of the main managing areas and allows the analyzes of its comportment possibilities a global vision about the way as the enterprise organizes their management tactics in relation to the results it want to obtain.

The enterprises panel was built starting in a selection of the enterprises in the auto and electric sectors that had the economic data of common knowledge, along the period from 2002 to 2006 and that make part of the Dun&Bradtreer/the bigger 500.

The method approach deals with the work of enterprises production in two perspectives that are the fallowing:

Economic Production Perspective.

In this perspective the work effect of production is evaluated as a reduction factor of the operation costs. The economic competition (g) translated in the percentage of the economic production variant (r) with the variation tax of operational costs "per capita"(m), have the fallowing expression:

$$g = \left(\frac{1+r}{1+m} - 1\right) \times 100$$

$$r = \frac{(VAB / T)n - (VAB / T)o}{(VAB/T)o}$$

$$m = \frac{(CO/T)n - (CO/T)o}{(CO/T)o}$$

VAB - brut additional value

CO - Operandi costs

T - Labour posts

n - year of competition evaluation

o - Base year to evaluate the competition

The brut additional value (VAB) corresponds to the difference between the business volume and the middle costumes (material, and external services and indirect taxes).

The operandi costs are the addition of the costs of material, external services and costs with personnel and amortizations.

Technologic Perspective of Production

This perspective evaluates the technologic progress tax (Pt). This indicator measures the efficiency that is combined with the capital and work factors, based in the fallowing expression:

Pt = gVAB – gT.c – g.K (1-c))

gVAB - variation tax (g) of the auditioned value

gT - Tax of variation (g) in the labour posts (T)

gK - Tax of variation (g) of the capital immobilized evaluated by the cantabiles data of the amortizing.

c - Main factor of the capital and work translated by the honoraries indicator (s/VAB).

Based in this model, there were calculate the indicators of competition and technological progress, by enterprise and year (from 1998 to 2002) with the respective taxes of inflation, ending, it was made the alf of each one of the enterprise indicators.

The next step in the methodologies was translated in the construction of the independent variables, trough the elaboration of a questionnaire in a way to evaluate the level of qualitative work in the specific practices of nippon management and traditional management practices.

And it was brought to the enterprises panel previous selected, in a way to obtain a data base that contains information about the nippon management practices and the traditional practices more relevant in the enterprises, without and with nippon's capital working in Portugal.

The questionnaire allowed the mode interpretation, processes and relative factors in the system transposition, model and enterprises Japanese culture to the enterprises.

For this, it was calculated the gap work-importance of the questions putted on the questionnaire, in a numeric scale of 1 to 6 points (20 attributes to the specific Nippon's management practices - 7 of TG, 7 of RH, 6 of MK and 20 attributes of the traditional management practices. – 7 of TG, 7 of RH, 6 of MK).

The answers to the questionnaire, reveal that the enterprises with nippon capital show a superior gap of the enterprises without nippon capital, in the group of questions E1- Nippon enterprises managing principles: Human Resources and E2 – Nippon enterprises managing principles: Strategies of Marketing.

The first board shows the syntheses of the gap calculation in work- importance (the level percentage of the importance dividing by the work level), of the posed questions in the questionnaire.

Board 1

Syntheses of the average in the work and importance levels in the questionnaire

	Enterprises with nippon capital			Enterprises without nippon capital		
Questions	Importance	Work	*Gap*	Importance	Work	*Gap*
E1	4.66	3.66	78.54	3.66	2.16	59.01
E2	4.16	3.66	87.98	4.33	2.66	61.43
E3	5.08	2.66	52.36	4.74	4	84.38

Source: Reis, Felipa (2006).

Note:
E1 - Nippon enterprises management principles: Human Resources

E2 - Nippon enterprises management principles: Marketing Tactics

E3 - Nippon enterprises management principles: Management Tactics

Gap is the percentage of the division of the work level by the level of importance.

From the answers of the questionnaires I got two indices of quality work, one corresponds to the attributes vector of the specific practices of nippon management and the other to the vector of attributes of the traditional practices of management, in the enterprises with and without nippon capital.

In regard to the statistic treatment there were used correlation coefficient tactics (r of *Pearson*) and the determination coefficient, that allowed determine the association straight between the two variables.

Allowing this way, the analyzes of the casual mechanisms between the quality work level of the specific practices of Nippon management an the traditional management practices and the quantities work of enterprises competition, trough the economics competition and the technologic progress.

The hypotheses that were tested in the evaluation of the causal relations between the dependent variables and the independent variables, in a way to respond to the main objective and to the question of the research, are the fallowing:

Hypotheses 1: The matrix of the Nippon management system in relation to the traditional management system leads to the improvement of the economic production.

Hypotheses 2: The matrix of the Nippon management system in relation to the traditional management system leads to the improvement of the technological progress.

3. MAIN ASSERTIONS

After collecting and treating all the data, it was calculated the correlation between the qualitative variables (TG, MK, RH) and that quantitative variables (CE, PT), in the enterprises with and without Nippon capital, of booth management practices that are presented in the Boards 2 and 3.

Board 2

Matrix of correlation between the traditional management practices and the enterprises competition indicators

		Enterprises with nippon capital	Enterprises without nippon capital
RH	CE	0.45	0.46
	PT	0.45	0.48
OM	CE	0.40	0.41
	PT	0.40	0.44
MK	CE	0.41	0.49
	PT	0.43	0.48

Board 3

Matrix of correlation between the specific practices of nippon management and the enterprises competition indicators

		Enterprises with nippon capital	Enterprises without nippon capital
RH	CE	0.46	0.44
	PT	0.47	0.42
TG	CE	0.39	0.46
	PT	0.43	0.36
MK	CE	0.45	0.48
	PT	0.46	0.44

The Boards 4 and 5 present the correlations average between bough management practices, by enterprises competition indicator, economic competition and technological progress, in the enterprises with and without Nippon capital.

In the Board 4 is presented the relations of causality between the traditional management practices and the enterprises competition performance.

The associations between the traditional management practices an the economic competition and the technologic progress, are the strongest in the enterprises without Japanese capital, den in the enterprises with Nippon capital, that means that the traditional management practices induce to the improve of the economic competition.

Board 4

Average of correlation between the traditional management practices and the enterprises competition indicators

	Enterprises with nippon capital	Enterprises without nippon capital
Economic competition	0.42	0.49
Technological progress	0.45	0.48

The Board 5 shows the relations of causality between the specific practices of Nippon management an the performance of enterprise competition.

The association between specific practices of Nippon management and the economic competition is stronger in the enterprises without Japanese capital dam in the enterprises with Nippon capital.

And the association between the same practices of management and the indicator of technologic progress is stronger in the enterprises with Nippon capital.

Board 5

Average of correlation between the specific practices of nippon management and the enterprises competition indicators

	Enterprises with nippon capital	Enterprises without nippon capital
Economic competition	0.45	0.47
Technological progress	0.45	0.41

The main assertions are the following:

Hypotheses 1 was not verify because there is a casualty relation between the specific practices of Nippon management and the enterprises with Japanese capital. These enterprises don't use competitive strategies based on the costs.

Hypotheses 2 was verify because there is a relation of causality between the specific practices of Nippon management and the enterprises with Japanese capital. That means that these enterprises adopt competitive strategies based in the technologies.

The study assures substantial evidences upon the specific Nippon practices do a effective influence in the enterprises competition, in the enterprises with and without Nippon capital, that work I Portugal.

In conclusion, the enterprises competition with Nippon capital is induce mainly by the adopted technologies (technologic progress)

4. FINAL CONCLUSIONS

This research shows some conclusions upon the idea that the individual use of the Nippon management methods (discipline and control, management practices by total quality, recruitment and selection, collective relation, among others), not insert in the system and Nippon management culture, have one limited efficiency upon the work of the enterprises and their results.

In reality it does not exists a Japanese management, one nihontekikeia, with rules and methods that are different from the ones that are in Portugal. What is really original in the Nippon management is the conjunction of the several elements as structures organized more integrated and more efficient.

In the rising sun country, there is a solid base, that doesn't happen in other countries of Asia. The straight with quality in work of the Nippon people, being more conscious , more instructed and dedicated.

A group of values that where introduced in the enterprises by the ancient samurais(military), that took domain of the big enterprises, after the Meiji revolution , as the respect by the hierarchy, team work, duty and loyalty, devotion to the enterprise, among others.

It is extremely difficult export the model f the Japanese management system to other cultures because the cultural factors and the specificity of the Japanese history are aspects of difficulty to the occident cultures.

One elucidative example of the Nippon culture is the respect and devotion to the roads and buds temples and introits sanctuaries, the same Japanese of computer lives the gods and ancestors like 1000years ago.

The mental and educational construction is very different from the occident. The complexity and integrity in the values of supreme help to understand the behaviour at several levels of the business man, the intellectual, the technologic.

The Japanese gave to the world organizational models in relation with the surround and cultural evolving, making a fusion of methods in management, many of them extracted from the occident, with their same cultural values adapting the west technologies to the Nippon culture and tradition.

The Nippon management methods are so solid that when taken from the Japanese management system and culture have a limited efficiency over the work of the enterprises and their results.

In the same way that the west technologies where adapted to japans culture and traditions, also the Portuguese society may continue to identify the key elements of the Japanese management tactics to adapt to the personal characteristics of the Portuguese executives.

In regard, the specific of each organization conditioned the adoption of the Nippon management principles.

The answers to the questionnaire demonstrate that many enterprises that work in Portugal adopted part f the model and system of the Nippon management that represents a start of recognizing of their merit in the creation of value.

The study of the application of the methods of Nippon management in Portugal is desirable by many reasons, such as, the fast recovering of crises, that is the best prove of efficiency of the Nippon management methods.

A country that managed emerge from the devastation of world war two and in 1968 was already the second world powerful country livered for a decade in the world competition.

References

Benson, John; Yusa, Masal (2007), "The prospect for gender diversity in japanese employment", International Journal of Human Resource Management, 18, pp.890-907.

Delbridge, Rick; Whitfield, Keith (2007), "More than mere fragments? The use of the workplace employment relations survey data in HRM

research", International Journal of Human Resource Management, 18, pp. 2166-2181.
Dolan, Simon; Cabrera Ramon; Jackson, Susan; Schuler, Randall (2007), La Gestión De Los Recursos Humanos, McGraw-Hill.
Grzybowska, Katarzyna (2007), "The social aspect of introducing changes to the organisation", International Journal of Human Resources Development and Management, 7, no.1, pp.67-82.
Hirono, Ryokichi (2007), "Japan's Environmental Cooperation with China During the Last Two Decades", Asia pacific Review, 14, no. 2, pp. 1-16.
Miah, Khasro; Bird, Allan (2007), "The impact of culture on HRM styles and firm performance: evidence from japanese parent, japanese subsdiaries/joint ventures and south asian local companies", International Journal of Human Resource Management, 18, pp.908-923.
Paul, Anantharaman (2003), "Impact of people management practices on organizational performance. Analysis of a causal model", International Journal of Human Resources Management, 14(7), pp.1246-1266.
Reis, Felipa (2008), "Las Claves del Éxito de la Competitividad del Sistema Empresarial Japonés", Empresa Y Humanismo, pp. 156-187.
Reis, Felipa (2008), Perspectiva Empresarial em Portugal com os Modelos Típicos de Gestão Nipónica", Tese de Doutoramento, Universidade Lusíada.
Suda, Toshiba (2007), "Converging or still diverging? A comparison of pay systems in the UK and Japan", International Journal of Human Resources Management, 18, pp.2166-2181.
Takeda, Margaret; Helms, Marilyn (2007), "The influence of human resources management identy on strategic intent in the multinational enterprise", International Journal of Human Resources Development and Management, 7, no.2, pp.139-160.
Youshikawa, Eiji (2006), Musash, Editora Estação Liberdade.

THE NIPONIC MANAGEMENT OF INNOVATION SYSTEM IN THE IBERIAN PENINSULA

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Keywords: Economic Productivity, "Workonomic Index", Technological Progress, Japanese Management.

1. INTRODUCTION

The technological capacity of niponic businesses constitutes one of their main sources of competitive advantage in the market. From oil tankers to watches, from industrial robots to microwaves, from semiconductors to compact discs, Japanese competitors have reached primacy by introducing a succession of innovative products of higher quality and at lower cost, promoting the rapid expansion of markets and sales and the results of companies in particular.

When the base industry is in recession, niponic companies seek to identify other growing industries that may constitute good business ventures in the future. The creative usage of new business technology may benefit the base activity of the corporation. Kanebo (textiles) entered the cosmetic business in the 60's based on their knowledge of chemical components. In the 90's, the company's new clothing lines included pieces with exotic fragrances, an intelligent combination of their diversified technological base.

The history of modern science and technology in Japan dates to the late XIXth Century, when the country's recently open borders began actively studying the knowledge that Europe had to offer. The Land of the Rising Sun was poor in natural resources and the only way in which it could progress in both social and economic fields was through technological breakthroughs obtained by its people, its only resource.

The great strategic flexibility of niponic companies originated a rapid ascension of those very same. Japanese industries earned positions in international markets introducing new products of better quality and at lower prices.

Sony was able to reinforce its competitive positions in all segments of the audiovisual industry, being one of the most successful companies in Japan, in terms of business strategy. It was initially a domestic business specialized in audiovisual equipment and it bought Columbia Pictures, complementing audiovisual equipment production with thousands of films. When CD (Compact Disc) technology replaced video cassettes, Sony was already positioned to determine the standard of CD-Video.

The Japanese have traditionally placed education and science on top of their national concerns and the Meiji era was a period devoted to catching up with the West.

Investment in robotics and automation have allowed niponic industry to overcome the lack of manpower without destroying the social harmony and avoiding, as other industrialized countries do, having to resort to foreign workforces.

Niponic industrial productivity continues to grow and Nissan is an illustrative example, when it doubled its automobile factories in Tokyo utilizing a highly sophisticated assembly method utilizing automation, needing only to fully equip the assembly line of an automobile model a quarter of the time and a third of the cost.

The usage of robots in niponic businesses represents an extension of the machine automation process and the liberation of the workforce. And they advantageously replace human labour, in determined processes the productivity of a robot is at least 50% higher than that of a human worker. The usage of robots is getting increasingly advantageous due to the reduction of their prices and that of computer, and the constant increase in salary costs.

Robots and computerized production systems promote automation. Their introduction must therefore be set in an environment prepared to make use of its benefits without loss of human control. Many of the great niponic businesses have adapted to the appreciation of the Yen, introducing new technologies, adding value to products and constant restriction to their manpower. This approach explains why Japanese installations placed in markets outside the Land of the Rising Sun may equally apply adaptive approaches to exports of foreign markets. An example of that is environmental technology. In the 70's, Japan was a pollutant industrial country, absent from regulatory rules and with its economic growth in expense of its natural environment. After only a decade, it's a potential world leader in the application of technology aimed at environmental problems, due to the change of values in its society. And thus, develops exportable products and services.

The engines of technology are the private sector companies, very competitive in global markets. Furthermore the land of the Rising Sun has the weight of Asia, the enormous growing markets of the Southeast Asia (the so-called Asian Dragons) and China.

Although the United States began computerization earlier, Japan advanced faster in replacing factory technologies. Sophisticated assembly methods, much dependant on computers and information, produced assets whose quality could hardly be matched in the global market.

Management of Research and Development (R&D) assumes a strategic role in corporate development due to the constant introduction of new products in the markets it constitutes, the principal source of sales growth and profits for Japanese companies. With the impossibility of importing foreign goods in large scale in the post-war period, several domestic businesses developed their own technologies and products.

The R&D cycle in niponic companies is composed of three phases: copying initiatives from more advanced competitors, through the licensing of their technologies or mere reproduction of their products, services or processes. The second phase is the upgrading of acquired technologies, adopted processes and characteristics of commercialized products and services. And the innovation phase, where new technologies are designed and new products, services and processes are created. Throughout this whole process, there is a constant concern in integrating basic investigation with applied research, so as to maintain an elevated rhythm of introduction of innovations into the market and reinforcing the company's competitiveness.

In rich countries, buyers looking for the best quality-price ratio became very demanding and have, more often, greater tendency to place the emphasis on the quality factor. Other factors contributed to this evolution: thus, the elevated price of repairs in countries of high salary level reinforces the need for products that need as few repairs as possible; the increase of pollution (crucial problem in Japan) and the growing awareness on environmental issues are also part of those factors.

Quality for the Japanese does not correspond only to a demand by the buyers and a reduction of cost, it's also an internal demand of the company, almost like a religion; it places an emphasis on greater efficiency, even regarding points that have no apparent relation with customer demand, like workplace cleanliness, where customers will never go, neat accounting books, good equipment maintenance. The expression *miryoku-teki hinshitsu* ("seductive quality"), last metamorphosis of quality, clearly expresses the ideal to which it's aspired.

The successive development of new products at an increased rate, is one of the secrets for success *made in Japan.* The developed technique of quality function (*quality function deployment),* is a good example. It works in two stages: the first is to choose a rival brand of reference (benchmarking), in relation to which the company asks its users what they do and do not like. The second is the inversion of this process. The engineers try to associate to their developing product the characteristics customers appreciated in the performance of the rival brand.

The Japanese have always had a great concern in involving all the company in solving quality problems and have long since believed that the strategy leading to improved product quality is most important and promising of success. The production of high quality goods at a reduced cost has become the key to their success relative to international competition and businesses have systematically mobilized their physical and human resources to reach that goal. In this fashion they have introduced, on the one hand, new technological and management *Know-how,* and on the other hand, proceeded to undertake large investments to rationalize production.

Technical boards (engineers, managers) have been sent from Europe and the USA to familiarize themselves with the new techniques. To quote only a few examples of technological transfer we can remembers the cases of General Electric to Toshiba, of Austin to Nissan and of Philips to Matsushita.

Techniques learnt in other countries, on their own, have not helped to improve production: it's also important how well these techniques are applied. Car builders, for example, developed a unique supply system of parts and materials, globalizing external suppliers and internal departments, so as to reduce stocks to a minimum. The system works according to the principal of *Just-in-Time* (stock minimization) which has as its symbol the production methods of Toyota. The basic principal of stock minimization isn't just about a new production management technique. Japanese car manufacturers have edified a very complex social and technical system, involving sub-contracted companies for parts supplies and several internal departments, according to management practices that consider the characteristics of local conditions.

And it was the success of the Japanese automobile industry that came to have a very special impact in the USA. Until then many Americans acknowledged that the Japanese knew how to make good watches, good radios, good television sets and good cameras. But their cars being competitive and produced in greater number than American cars came as a shock.

2. OBJECTIVES

The object of this investigation focused on the performance of niponic innovation management in companies operating in the Iberian Peninsula, in the 5-year span 2002-2006. The central objective was to seek to evaluate the results of corporate competitiveness in these companies, when they utilize the niponic innovation management system.

The hypothesis that were tested in the study and which sought to establish a relationship between the characteristics of the niponic innovation management system and the results of corporate competitiveness, are as follows:

Hypothesis 1: The niponic innovation management system relatively to the traditional management system leads to an improved corporate competitiveness induced by economic productivity.

Hypothesis 2: The niponic innovation management system relatively to the traditional management system leads to an improved corporate competitiveness induced by salary productivity of the human factor.

Hypothesis 3: The niponic innovation management system relatively to the traditional management system leads to an improved corporate competitiveness induced by technological progress.

These hypotheses were tested in the evaluation of casual relations between the variable dependents: Economic Competitive (CE), "*Workonomic Index*" (WI), Technological Progress (PT), and the independent variable Research & Development (RD).

3. METHODOLOGY

In this investigation, I used a proper model, with indicators of economic nature adjusted to the observed data.

The management system and its enveloping context were explained, in an analytical model, though a conceptual tool composed by an independent variable (qualitative) – Research Development. And three dependant variables (quantitative) – Economic Competitive, *"Workonomic Index"* and Technological Progress.

The first step in methodology was the selection of companies from the electronic and automobile sectors whose economical data were in the public domain, in the period ranging from 2002 to 2006, from the information treated processing and divulged by Dun&Braadstreet/Exame.

The second step was the elaboration of an integrated model of evaluating competitive business which served as a support to the dependant variables of the model. In these variables, the methodological approach treats the performance of business productivity in three perspectives, which are as follows:

- Economic Production Perspective.

In this perspective the work effect of production is evaluated as a reduction factor of the operation costs. The economic competition (g) translated in the percentage of the economic production variant (r) with the variation tax of operational costs "per capita"(m), have the fallowing expression:

$$g = \left(\frac{1+r}{1+m} - 1\right) \times 100$$

$$r = \frac{(VAB / T)n - (VAB / T)o}{(VAB/T)o}$$

$$m = \frac{(CO/T)n - (CO/T)o}{(CO/T)o}$$

VAB - brut additional value

CO - Operandi costs

T - Labour posts

n - year of competition evaluation

o - Base year to evaluate the competition

The brut additional value (VAB) corresponds to the difference between the business volume and the middle costumes(material, and external services and indirect taxes).

The operandi costs are the addition of the costs of material, external services and costs with personnel and amortizations.

- The Cost Perspective of Production

The production costs is translated in the sufficient of the gross Value in addition (VAB)

IN the used perspective in the developed research, the costs of production is evaluated having as base in the factor “workonomic índex” (WI) that avail the percentage of the value auditioning made in the business, that remains free to remunerate the capital factors that intervene in the creation of VAB.

- Technologic Perspective of Production

This perspective evaluates the technologic progress tax (Pt). This indicator measures the efficiency that is combined with the capital and work factors, based in the fallowing expression:

$$Pt = gVAB – gT.c – g.K (1-c))$$

gVAB - variation tax (g) of the auditioned value

gT - Tax of variation (g) in the labour posts (T)

gK - Tax of variation (g) of the capital immobilized evaluated by the cantabiles data of the amortizing.

c - Main factor of the capital and work translated by the honoraries indicator (s/VAB).

Lastly, we established an average of each of the indicators of corporate competitiveness by company, in the period ranging from 2002 through 2006, which are the final results of corporate competitiveness.

The third step was the construction of the independent variable, through the elaboration of a questionnaire, so as to evaluate the qualitative level of performance of the niponic innovation management system. And it was submitted to the previously selected panel of companies, so as to obtain a database containing information regarding the most relevant innovation management system practices in the companies operating in the Iberian Peninsula.

For that effect, we calculated the performance-importance *gap* (percentage of the division of the performance level by the importance level) of the questions posed in the questionnaire, on a numerical scale of 1 through 6 points. And it was measured through an index composed of six items referent to the niponic innovation management system and six items referring to the traditional innovation management system, which sought to reveal the intensity of usage by the company of different tools of this nature.

Of the answers in the questionnaires I obtained two qualitative performance indexes, one corresponding to the niponic innovation management system and the other to the traditional innovation management system, in companies with and without niponic capital.

After gathering and treating all this data we utilized the statistical technique of the correlation coefficient R from *Pearson*, which allows us to determine the associating strength between two variables. Thus allowing the analysis of causality mechanisms between the qualitative level of performance of the niponic innovation management system (resulting from the questionnaire), and the quantitative performance of corporate competitiveness (resulting from the integrated model of evaluating corporate competitiveness), in companies with and without niponic capital operating in the Iberian Peninsula.

Chart 1 presents the causality relations between the niponic innovation management system and corporate competitiveness performance. The association between the niponic innovation management system and corporate economic competitiveness is stronger in companies without Japanese capital. And the association between the same management system and the “workonomic index” indicators and technological progress is stronger in companies with niponic capital.

Chart 1

Average of the correlation between the niponic innovation management system and the indicators of economic competitiveness

	Companies with japanese capital	Companies without japanese capital
CE	.40	.41
WI	.42	.40
PT	.42	.39

Source: Reis, Felipa (2007).

4. CONCLUSIONS

This study ensures substantial evidence according to which the niponic innovation management system exerts an effective influence over corporate competitiveness, in companies with and without niponic capital.

Principal conclusions are as follows:

Hypothesis 1 was not verified because there is no causality relation between the niponic innovation management system and companies with niponic capital. Meaning, companies with Japanese capital do not compete utilizing competitive strategies based on cost.

Hypothesis 2 was verified because there is a causality relation between the niponic innovation management system and companies with niponic capital. Meaning, companies with niponic capital compete utilizing competitive strategies based on the qualification of human resources (workonomic index).

Hypothesis 3 was verified because there is a causality relation between the niponic innovation management system and companies with niponic capital. Meaning, companies with niponic capital compete using competitive strategies based on technologies (technological progress).

The three phases of the R&D cycle in Japanese companies do not necessarily follow the copy-upgrade-innovate sequence. In most cases, technological innovation requires a parallel licensing of the complementary external *know-how*. In equal fashion, after the introduction of an innovative product, successive models are released, more functional, of higher quality and at lower prices.

The R&D cycle in Japan is extremely dynamic supporting the constant introduction of innovations in the market. The satisfaction of consumer needs is undertaken as a challenge to the company's creativity, an imperative to discover new technological solutions. Commercial success is mostly the consequence of introducing the right product at the right time before competitors do.

Typically the Japanese company develops new ideas or perfects concepts under the expectation that they will please their target segment. Machines that regularly feed house pets while the owners are on vacation. Shirts made out of a fabric that never wrinkles, hairstyle simulation monitors in hair salons, eggs enriched with vitamins, antibacterial sanitation ceramics for hospitals and public spaces or electric guitars with built-in cassette recorder constitute some examples of products or services released in the niponic market that later proved well successful.

The management of R&D is crucial for the success of niponic companies in global competition. The constant introduction of new products or services expands their commercial presence and speeds up the restructure of industries. From robots to videogames, from semiconductors to cameras, from automobiles to fax machines, Japanese manufacturers ascended to highly regarded positions by continuously innovating and improving not only the products but also the productive processes. The integration of R&D management with production management in Japan constitutes the vehicle of simultaneous consolidation of technological leadership and costs.

References

Benson, John; Yusa, Masal (2007). The prospect for gender diversity in japanese employment. International Journal of Human Resource Management, 18, pp.890-907.

Brillman, Jean (2000). As melhores Práticas de Gestão – No Centro do Desempenho.Lisboa, Edições Silabo.

Carvalho, J. Eduardo (2004). Produtividade: o que é. Lisboa, Quimera Editora.

Caetano, António, Vala (2006). Gestão de Recursos Humanos Contexto. Editora RH.

Ceitil, Mário (2006). Gestão de Recursos Humanos Para o Século XXI. Edições Sílabo.

Dolan, Simon; Cabrera Ramon; Jackson, Susan; Schuler, Randall (2007). La Gestión De Los Recursos Humanos. McGraw-Hill.

Gordon, Gary (2006). A Batalha do Japão. Edições Vida e Aventura.

Hearn, Lafcadio (2006). O Japão-uma antologia de escritos sobre os agentes. Livros Cotovia.

Maricourt, Renaud (1995). Les Samourais du Management. Lisboa: Edições Silabo.

Marishima, Michio (1992). Porque Triunfou o Japão. Lisboa: Gradiva.

Miah, Khasro; Bird, Allan (2007). The impact of culture on HRM styles and firm performance: evidence from japanese parent, japanese subsdiaries/joint ventures and south asian local companies. International Journal of Human Resource Management, 18, pp.908-923.

Moura, Estêvão de (2002). Gestão de Recursos Humanos – Influências e Determinantes do Desempenho. Lisboa: Edições Silabo.

Ozaki, Robert (1991). O Sistema empresarial Japonês. Publicações Europa-América.

Paul, Anantharaman (2003). Impact of people management practices on organizational performance. Analysis of a causal model. International Journal of Human Resources Management, 14(7), pp.1246-1266.

Reis, Felipa (2006). Modelos Típicos de Gestão Nipónica: Perspectivas de desenvolvimento em Portugal. Revista Economia & Empresa, Lusíada, Nº7, pp.129-143.

Reis, Felipa (2008). Las claves del éxito de la competitividad del sistema empresarial japonés. Revista Empresa Y Humanismo, Universidad de Navarra, pp.157-186.

Takeda, Margaret; Helms, Marilyn (2007). The influence of human resources management identy on strategic intent in the multinational enterprise. International Journal of Human Resources Development and Management, 7, no.2, pp.139-160.

Westbrook, Oscar Ratti (1999). Segredos dos Samurais: As artes marciais do Japão feudal .Editora: Madras.

Y Youshikawa, Eiji, (2006). Musash. Editora Estação Liberdade

SUSTAINABILITY AND SOCIAL RESPONSIBILITY BALANCED SCORECARD

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Keywords: organisation; strategy; sustainability; social responsibility, balanced scorecard

1. INTRODUCTION

Humanity faces today problems of unique dimension and complexity:

- In the year 2000, world population reached 6.1 billion people and continues to growth at an annual rate of 1.2% (approximately, 80 millions people per year), which means world population can increase 50% in the next 50 years reaching 9 billion people;
- In 2050, 85% of human beings will live in development countries;
- Poverty remains the major challenge for development countries. The 25% richest control 75% of world wealth, while the 20% poorest control only 2%;
- According to the United Nations Human Development Report (2007/2008) in the long run, climate change remains the biggest treat to human development. Climate change affects all (Earth atmosphere doesn't distinguishes the greenhouse effect gases by country) and if all countries in the world had the same greenhouse gases emissions than development countries, we would need 9 planets Earth;
- The climate change effects will be harder for the poorest countries: less agriculture outputs, lack of water supplies, increase of the ocean levels, impacts on biodiversity and negative effects on human health.

In order to overcome these problems there is a must for a development model that takes into account economic, social and environmental perspectives. It is also required an active involvement of all economic actors, governments, public and private institutions and citizens in this process.

This paper tries to analyse how Kaplan and Norton's (1997) Balanced Scorecard concept [1] can be applied to incorporate and integrate sustainable development and social responsibility in organizations strategy.

2. SUSTAINABILITY AND SOCIAL RESPONSIBILITY

As a working definition for this paper, we will use the Brundtland Commission's report [2] definition of sustainable development: "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987).

Sustainability implies the simultaneous search of profitable economic development, social progress and equity and respect for the environment, to create value for shareholders, customers, workers and society at large:

- Economic Dimension is concerned with the interaction between an organisation and the other interested parties (Stakeholders), as seen in profit & loss balances, profitability analysis and also in the implications of the organisation in Customers, Supply Chain, Workers, Local Communities, Non Governmental Organizations, Local and Central Governments;
- Environmental Dimension is related to the impacts of organisation activities in living and non living systems, including eco systems, air, water and soil;
- Social Dimension, addressees the respect for Human Rights, the fight against inequalities, the responsibilities to future generations and the acknowledgement of valuable human diversity.

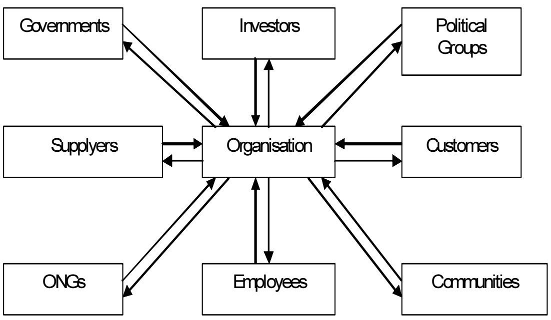
According to Elkington (1997), in order to achieve business sustainability there is a need to act in a balanced way within the three perspectives, economic, environmental and social, because all are interconnected and have multiple interactions [3]. Sustainable development should be regarded as a continuous and gradual process (a continuous journey) and not a goal to attain at a certain point in time (a destiny).

Complementing and interconnecting with the Sustainability concept, we also have the concept of Social Responsibility. Although there is not yet a universal accepted definition of this concept, most interpretations of Social Responsibility include an economic, a social and an environmental dimension.

For the purpose of this paper, we will adopt the definition proposed in ISO 26000 (WD3, 2007, www.iso.org): Social Responsibility is the responsibility of an organisation for the impacts of its decisions and activities on society and the environment, trough transparent and ethical behaviour that:

- Is consistent with sustainable development and the welfare of society;
- Takes into account the expectations of stakeholders;
- Is in compliance with applicable law and consistent with international norms of behaviours; and
- Is integrated through the organisation.

Theoretically, the concepts of Sustainable Development (SD) and Social Responsibility (SR) are supported by "Stakeholder Theory" (Freeman, 1984,[4]). According to this theory, to be successful, an organisation should identify, take into consideration and systematically manage the interests of multiple stakeholders (individual or group of individuals with interests that may either affect, or be affected by, an organisation):



Source: Adapted from Donaldson and Preston [5].

This approach can lead to mutual beneficial outcomes for a wide range of stakeholders:

- Higher value (profits) for stakeholders (e.g., due to process improvements, innovation and learning, better brand reputation and talent retention);
- Improved quality for Customers;
- Better working conditions for Employees;
- Fairs practices with Suppliers;
- Joint Programmes with Communities.

The Competitive Advantage Theories suggest that for an organisation to have success, it must have access to unique and valuable resources and competences that will translate into competitive advantages that can in turn generate operational results and generate sustainable value. But in order to achieve sustainable competitive advantage, an organisation must assure the satisfaction of all relevant stakeholders.

However, there might be some situations were it could be difficult to achieve mutual beneficial outcomes, when there are conflicts of interests between different groups of stakeholders (e.g., disagreements on environmental impacts). Also questions about the legitimacy and power of different stakeholders might arise.

Another issue that must be considered, concerns the SR and SD maturity level of each organisation. According to Vilanova, Arenas and Lozano (ESADE/Stanford University, CSR Executive Training, 2008,[6]) the following maturity levels can be considered (building on Zadek, 2001,[7]):

SR/SD Maturity Level	Characterization
1. Defensive	Comply with market and legal frameworks
2. Reactive	Reacts to external threats as cost of doing business
3.Functional	Includes SR and SD as a management issue
4.Integrated	Integrates SR and SD issues in strategy and culture
5."Civil"	Integrates role in collaborative governance as part of strategy

It is the attempt of this paper to propose the use of a Sustainability Balanced Scorecard to help organisations presently at stages 1 or 2, to proceed to levels 3 or above, looking forward its long term success by integrating SD and SR into their strategy and culture.

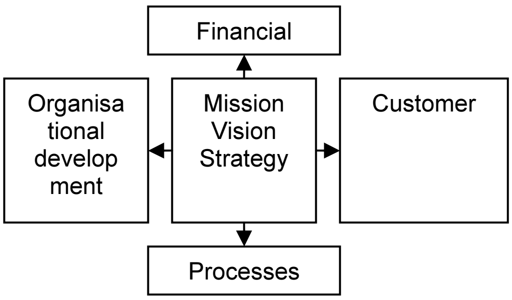
3. THE BALANCED SCORECARD

One of the major challenges that organisations face is how to integrate and deploy a vision, mission and strategy into strategic well defined objectives, action plans and performance and result measurements systems.

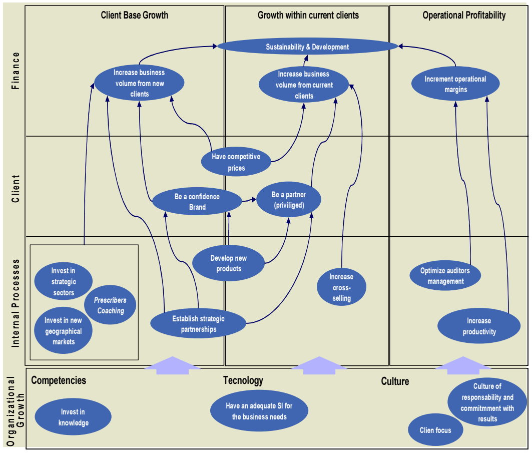
It is not enough to define objectives like “to be the best in our sector”, actions must be defined, responsibilities assigned, time tables established and further follow-up of indicators and results is a must to assure success.

The “Balanced Scorecard” (BSC) is an information and measurement instrument that evaluates in real time and in a prospective way, the implementation of the organisational strategy, maximizing the likelihood of continuous improvement and innovation while reinforcing the critical success factors of the organisation.

The concept was developed by Kaplan and Norton (6) and takes into account that an organisation in addition to the management of traditional financial indicators (lagging indicators, backwards looking), must also attend to the intangible aspects and non financial factors (leading indicators), like the capacity to successfully implement previous defined strategies, have a credible management team, be able to innovate and learn and to retain human talent:



According to the authors, this approach is most effective to manage organisations in a prospective way, both in short and long term, through a set of balanced and coherent aligned actions and measurements with the overall objectives. In this way, organisations can control and monitor the activities and key actions that it performs today, and will affect future results. It is a tool for organisations to manage the demands and expectations of their relevant stakeholders. BSC can foster both short/ long term and internal/external equilibrium and provide enablers that will generate results. The final visual picture of a BSC should look like:



Kaplan and Norton [8] recommend the integration of BSC into the existing management system of companies, providing an interesting opportunity to integrate sustainability and social responsibility in the organisation vision, mission and strategy. An application of BSC is presented in Fonseca (2003, [9]).

4. CONTRIBUTIONS FOR A SUSTAINABILITY AND SOCIAL RESPONSIBILITY BALANCED SCORECARD

According to Bieker et al. [10] the research on the implementation of social and environmental strategies into the BSC is very recent and only few publications exist on the topic (e.g. Epstein and Wisner, 2001, Figge et al., 2001, Hockerts, 2001, Zingales et al., 2001). The authors suggest that there might be different approaches for organisations to implement Sustainability BSC including a Partial BSC, by incorporation a few sustainability indicators in some perspectives of the BSC, or a Transversal BSC, by including environmental and social indicators in all the four perspectives of BSC.

To incorporate and integrate Sustainable Development and Social Responsibility in organizations strategy, the Integrated (Transversal approach) should be the preferred one. This is supported by the works of Vilanova, Arenas and Lozano [6] and Zadek [7] concerning the SR and SD maturity level of organisations.

While the particular BSC for each organisation would depend on its mission, vision, strategy, culture, processes and structure model, some general propositions can be put forward as contributions for the development of a Sustainability Balanced Scorecard:

Perspective	Key issues
Financial: Value creation	Growth Profitability Investments Risk Social and Environmental Impact
Customer	Product/Markets selection Segments How to differentiate from competitors
Processes	How to manage business processes (R-D-I, Production, Logistics, Sales and After Sales) minimizing negative Social and Environmental negative impacts and maximizing the positive impacts
Organisational Development	How to develop key Competences People Management and Talent Retention Key Networks and Alliances

Specifically concerning some Social and Environmental related indicators, the following ones can be proposed:

Perspective	Indicators to measure impact of Social responsibility and Sustainability strategies and check model assumptions
Financial: Value creation	FR: financial results (e.g. Net Profit) R: revenues (+ R leads to + Net Profit) C: Costs (- C leads to + Net Profit) R: business risks (less R leads to more Value Creation) VC: value creation (e.g. Net Profit & Stock Value)
Customer	CL: customer loyalty (+ CL leads to + Revenues) Q: quality (+ Q leads to + Customer Loyalty) BI: + brand image (+BI leads to + Customer Loyalty) NB: new business (e.g. ethical consumers)
Processes	RC: resource consumptions (-RC leads to – Costs) PP: process performance (both productivity and quality)
Organisational Development	M: employees motivation (+M leads to – Costs and + Talent Retention) C: competences (+C leads to + Innovation & Learning) I&L: innovation & learning (+ I&L leads to + Process Performance)

It should be remarked that the above table assumes some specific relationships. Literature review indicates that the search for relationship between Social Responsibility and Sustainable Development with Value Creation has been focused on possible positive relationship between SR and SD and financial and stakeholder satisfaction results.

Results concerning the relationship between and financial performance have shown a positive relationship, (McWillams, Siegel and Wright 2006, [11]; Margolis and Walsh 2001, [12]) but these results must be analyzed with precaution due to methodological concerns in some of the studies.

Concerning the impact of SR and SD development on stakeholder relations, according to Money and Hillenbrand (2007, [13]) it is possible to come to the following conclusions:

- Positive effect of SR in Employee Studies (Brammer, Millington and Rayton 2005; Ahmad, O´Reagn and Ghobadian 2003);
- Positive effect of SR in Customer Studies (Folkes and Kramins 1999; Maigan et al. 1999; Creyer and Ross 1997).

According to Money and Hillenbrand (2007, [13] the validity of these approaches is confirmed by studies that shown a positive correlation between positive Stakeholder attitudes and intentions with long term organisational success (Colins and Porras, 1994), competitive advantages (Barone, Miyazaki and Taylor 2000) and reputational risk minimization (Fombrun and vanRiel 2004).

5. CONCLUSION

In summary, considering the present and future challenges that affect Humanity, it is worth for organisations to consider the use of the BSC to foster integration of Sustainable Development and Social Responsibility in theirs vision, mission and strategy and culture, looking forward its sustainable success, while contributing to the Human Development and respecting the Environment.

After all, in a world without Human Beings, what would be the purpose of Human (?) Managed Organisations?

References

[1] Kaplan, R.S., Norton, D.P., Balanced Scorecard – Measures that Drive Performance, Harvard Business Review, 1992, Jan-Feb.
[2] World Commission on Environment and Development, 1987, Our Common Future.
[3] Elkington, J., Cannibals with Forks. The Triple Bottom Line of 21st Century Business, 1997, Oxford: Capstone Publishing.
[4] Freeman, R.E., Strategic Management: A Stakeholder Approach, 1984, Pitman, Boston.
[5] Donaldson, T., Preston, L.E.,, The Stakeholder Theory of the Corporation: Concepts, Evidence, and Implications, Academy of Management Review, 1995, 20/1, 65-91.
[6] Vilanova M, Lozano J.P., Arenas D., Responsible Competitiveness: CSR and Core Business Processes, 2007, Sixth Annual Colloquium of EABIS.
[7] Zadek S., The Civil Corporation: the New Economy of Corporate Citizenship, 2001, Earthscan, London.
[8] Kaplan, R.S., Norton, D.P., Using the Balanced Scorecard as Strategic Management System, Harvard Business Review, 1996, Jan-Feb.
[9] Fonseca, L., Avaliação Qualidade e Melhoria Contínua, Forum Interno IPP, 2003.
[10] Bieker T., Dyllick T., Gminder C-U., Hockerts H., Towards a Sustainability Balanced Scorecard, forschungsmethodische Grundlagen und erste konzepte, IWO-Diskussionsbeitrag Nr. 94, St. Gallen 2001.
[11] MacWilliams A., Siegel D., Corporate Social Responsibility: A Theory of the Firm Perspective, The Academy of Management Review, 2001, 26(1), 117-127.
[12] Margolis, J. D, Walsh, J. P., Misery Loves Companies: Rethinking Social Initiatives by Business, Administrative Science Quarterly, 2003, 48 Issue 2, p268, 38p.
[13] Money, K., Hillenbrand C., Towards a framework for using Corporate Responsibility in the governance of organisations, 2007, Sixth Annual Colloquium of EABIS.

ON THE DESIGN OF A SUSTAINABLE PERFORMANCE MEASUREMENT SYSTEM (PMS) IN A TURBULENT ENVIRONMENT

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Keywords: Performance measurement systems, turbulent environments, Business Excellence Models, customers' data and organization's flexibility.

INTRODUCTION

In order to achieve and maintain a competitive edge in the world marketplace, companies must produce high quality products at low cost with increasing variety, over shorter lead times [1]. To achieve these objectives many companies are adopting the recently developed management, production, and quality philosophies such as TQM, just-in-time, computer integrated manufacturing, optimised production technology, global supply chain [2], rapid product realisation, and are adopting new information technologies [3] and automation. To assess organisation's success when adopting these philosophies, that is to assess organisational performance, companies use measures. The problem is not only to find the best set of performance measures (PMs) to use, and how, where, when, by whom, etc. but also to develop a PMS congruent with business excellence.

Performance measurement systems (PMSs) are receiving increasing attention from academics and practitioners particularly after the development of the Balanced Scorecard (BSC) [4], and many PMSs are available nowadays [5]. Nevertheless, this subject is not new and, for example, quality gurus such as Crosby, Feigenbaum, or Deming recognized the importance of performance measurement as an activity within quality control, quality improvement or quality management. Recently, there are many publications on the design of PMSs, (developed for industries, services, SMEs, public services, non-for profit organizations) and about their implementation and use, however there is a lack of investigation on PMSs specifically adequate for organizations operating on turbulent environments.

According to Verweire and Berghe [6] integrated performance measurement needs both strategic and maturity alignment. The performance measurement system (PMS) should not be static but should be frequently questioned or reviewed. Its purpose is to contribute to both the goals and the sustainability of the organisation.

The development of an integrated framework for performance measurement recognises that performance appraisal encompasses a multitude of processes and tools, requiring a systems view that may not be managed through a single framework focused solely on performance measurement. However, it can be achieved through an open system that recognises dynamic flows between various organisational levels, in which both micro and macro views are addressed ranging from control models to broader evaluation perspectives appropriate to stakeholder requirements and organisations' purposes [7]. This open system would provide flexibility to allow organisations to survive and prosper in turbulent and unpredictable environments.

This work starts from Business Excellence Models (BEMs) and PMSs to identify factors to take in consideration when designing a PMS in turbulent environments. It is part of ongoing research, which is being carried out on world-class organisations and subsequently will study these factors through longitudinal case studies to ascertain their validity (even if the generalisation of the findings is not possible, it will suggest research directions on the design of PMSs in turbulent environments).

Motivation

The motivation for this work was twofold. The first was the recent developments in performance measurement mainly due to the use of benchmarking, balanced scorecards, the ISO 9001:2000 quality standard and the ISO 9004 guidelines, which are now closer to excellence models. The second was that the dynamic nature of the environment in which organisations operate is changing faster than ever.

Many of the principles behind models of excellence put emphasis on the performance measurement of key indicators of an organisation. The hypothesis is that organisations on turbulent environment need to reflect the uncertainty of their PMs in the PMS that is used to support decisions.

The objective which compels an organisation to adopt change in its normal operations may be internal or external. An organisation will benefit from the adoption of a PMS if its contribution to achieve its objectives is positive, i.e. its costs (often hard to identify and consequently hard to measure) are less significant than the benefits. Overall, a strategy for designing PMS based on TQM principles and tailored to organizations on turbulent environments will be proposed.

LITERATURE REVIEW

Background on TQM principles and Business Excellence

There is a plethora of quality improvement paradigms to help organisations improve their products or services [8]. Based on the principles of TQM models, implementation guidelines can be grouped into three types [9]:

1. prescriptive teachings from quality experts or practitioners such as Juran, Deming and Crosby - have proposed a number of different implementation models, each based on their own knowledge and interests resulting in a diversity of philosophies, principles and methods. The gurus commonly declare their interest in managing people in their philosophies, but offer few tangible principles and virtually no usable methods. According to a survey carried out by Claver and Tarí [10], the human aspects were those least implemented. If the success claimed by these quality experts is a result of implementing their methodologies, then it confirms the idea that there is not one best solution but a set of solutions that will improve organisational performance.

2. quality certifications from international organisations such as the ISO 9000 series of standards and quality awards, such as the Deming Prize in Japan, the Malcolm Baldrige Quality Award in the USA and the EFQM in Europe - provide recognition of the adoption of quality practices, and are based on TQM principles. Self-assessments against these models are widely considered to be more advantageous in respect of the actual value added for clients and businesses in general [11]. Overall, business excellence is replacing the narrow objective of meeting customer specifications; the focus is on the performance of the whole system, and not just the outputs.

3. scholarly academic research that strives to conceptually and empirically extract the components of quality management and their linkages to performance, such as the balanced scorecard [4], the performance prism [12] and Kanji's business excellence model [13] - focus on two main areas, the technical needs of quality control and the human dimension of quality management. Technical needs of prediction and control are catered for largely by statistical and quantitative methods.

Prajogo and Sohal [14] strongly argue that despite the decline in TQM popularity, it will remain an essential part of developing and maintaining a competitive advantage for organisations. TQM, excellence models, and quality awards have highlighted the importance of performance measurement in achieving business excellence.

Performance measurement systems

Juran and Godfrey [15] argue that "the choice of what to measure and the analysis, synthesis, and presentation of the information are just as important as the act of measurement itself" and emphasise the system to which the measurement process belongs (Figure 1). The measurement process consists of steps needed to collect data and present results. The larger measurement systems also embrace the decisions that are made and the framework in which the process operates.

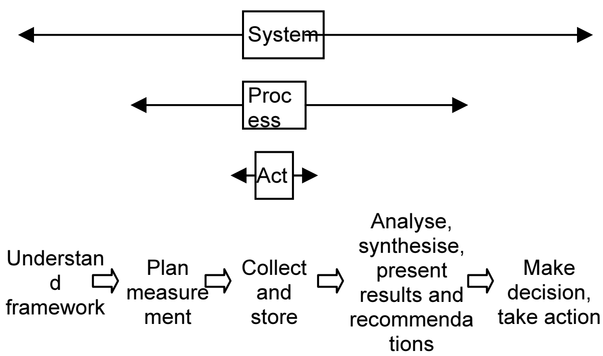

Fig. 1. The act of measurement is but one step in a large system. Source: adapted from Juran and Godfrey [15].

The first step in defining a PMS is to understand who will make the decisions (and how) and who will take actions (Figure 1) [15], i.e. the purpose of each PM must be clear [16], and must promote a company's strategy [17]. It can be concluded that there are no bad PMs, only the bad use of them [18]. Before determining what to measure and how to measure it, the overall framework in which the PMS operates (see Figure 1) should be understood [15]. This involves the analysis of stakeholders' goals [12] and the range of possible decisions and actions. Assuming that what is measured gets managed and improved, organisations must measure only those areas that will help them better manage and make accurate decisions [19]. According to Macpherson [18] there are two approaches to identifying PMs: top-down and bottom-up. Using the first approach, the search for PMs is based on the mission and vision of the organisation. The latter, on the other hand, is determined by what data is currently available [18] and has the advantage of being cost effective by only focusing on visible data [18]. The bottom-up has the advantage of being cost effective by only focusing on visible data [18]. A third approach is [20] outside (or customer) - inside (or internal processes), endorsing the argument about the importance of looking at the organisation from the customer's viewpoint. The focus of managers will be to improve services as seen by the customer instead of increasing conformance to a model, because employees will perform exactly as the measures tell them to, regardless of their original intent [21].

According to literature, PMs should be clear, credible, balanced, tied to desired results, precise, quantifiable, clearly specified, reliable, valid, sensitive to important changes, relevant to each managerial level, flexible, able to be changed as the need arises [22] and support day-to-day operations with information that is both timely and relevant [22], [23]. Effective performance management requires reliable data [18], [23]. Potential data quality elements are discussed in [24] and [25]. To contribute to the planning phase of the PMS, Appendix 1 presents Critical success factors to improve PMSs [17].

Overall, PMs should be based upon data that can be collected and analysed at a reasonable cost and with minimal effort. The focus of measurement should be in situations where improvement can be achieved by those directly involved, through defined approaches. Several frameworks have been proposed to develop and use PMSs in organisations, a sample of which will be presented in the next section.

Performance Measurement Frameworks

In recognition of the need for more relevant, better structured and integrated PMSs, a number of frameworks and models have been developed [26]. These will be called performance measurement frameworks (PMFs) as they provide specific guidelines to contribute to the definition of such PMSs.

Given the extensive number of frameworks found in the literature, the author will review only a sample based on their impact on the academic community, the introduction of new concepts or the simplicity of implementation.

There are two basic types of PM in any organisation – those related to results (competitiveness, financial performance), and those that focus on the determinants of the results (quality, flexibility resource utilisation and innovation) [27]. This suggests that it should be possible to build a PMF around the concepts of results and determinants. The EFQM also supports this concept.

The "strategic measurement analysis and reporting technique" (SMART) as cited by [22], consists of a four level pyramid of objectives and measures, which attempts to integrate corporate objectives with operational PMs. However, it does not provide any mechanism for identifying key PMs, nor does it explicitly integrate the concept of continuous improvement. The performance measurement matrix presented by Keegan et al. and reported by [27] seeks to integrate different dimensions of performance, and employs the generic terms "internal", "external", "cost" and "non-cost" to enhance its flexibility.

Perhaps the best know PMF is Kaplan and Norton's BSC [4] [27]; it seems to be the most influential and dominant concept in the field. The authors of the BSC suggested [28] the definition of strategy maps to describe the cause-and-effect relationships between the identified measures, but according to Wilcox and Bourne [29] these relationships are outdated. According to Brown [19], though the principles behind the BSC are simple, applying them is exceedingly difficult. The collaborative culture of the integrated supply chain has triggered the emergence of new measures, especially in five areas [16]: external focus, power to consumer, value-based competition, network performance, and intellectual capital.

Bititci et al. [26] developed a model for an integrated and dynamic PMS. They investigated the use of IT tools as a self-auditing dynamic PMS, which would ensure that an organisation's PMS remained integrated, efficient and effective at all times. A dynamic PMS should have: an external and internal monitoring system, a review system, and an internal deployment system. The model [26] also extends the notion of performance measurement into a control loop to include corrective action.

Basu [16] argued that the PMs should be more externally focused for the total network, there should be a shift from "measurement" to "management", and a formal senior management review process with two-way communication to all partners was essential to success.

Karapetrovic and Willborn [11] maintained that integrative approaches to performance evaluation, including auditing, self-assessments, benchmarking, and performance measurements are still required. Performance measurement is a methodology that complements the self-audit, since it focusses on identifying metrics related to business results, and on evaluating the actual performance with reference to developed metrics. Self-assessment against quality award models has gained prominence in exactly areas where quality audits were lacking, most importantly in performance improvement [11]. The EFQM believes that the process of self-assessment is a catalyst for driving business improvement, and so could act as an initiative to start a business excellence initiative [16].

Kanji and Sá [30] started with the BSC and improved it by integrating TQM principles and CSFs resulting in a model which focussed on measuring how an organisation is performing from an outside perspective. According to its authors, achievements in each of the four areas of Kanji's business scorecard need to feed into each other to form a cycle of continuous improvement so that:

- delighting the stakeholders helps to generate revenues and satisfactory returns to the investor;
- increased revenues help to fund investments in processes and learning; and
- better processes and learning help people to delight the stakeholders and create business excellence.

The above concepts start with organisational values to derive a business scorecard index (see Part B in Figure 2). This extension to the BSC taken from an external perspective complements Kanji's Business Excellence Model [13], which is mainly an internal assessment framework (see Part A in Figure 2), and together they form a single and complementary view of organisational performance. Each concept represents a latent variable that is measured through a set of variables that represent that concept, and altogether constitute a structural equation model. Kanji and Sá [30] argue that it is a means of overcoming one of the problems of the BSC associated with the causal relationships assumed.

The assessment against this measurement model results in a number and makes comparisons between different organisations possible. Lower scores in different criteria indicate areas in which the organisation should put more emphasis on improvement. This model was named Global Excellence Measurement System (GEMS) [31].

The Performance Prism [12] focusses on stakeholder satisfaction to integrate and align strategies, processes and capabilities. In addition, it refers to the importance of identifying stakeholders' contributions, as they are part of a reciprocal relationship with the organisation. All these suggest that organisational values, process excellence, organisational learning and delighting the stakeholders are the fundamental dimensions to be managed and monitored. The Performance Prism's authors argue that it is necessary to move away from thinking about measurement in the traditional sense – the process of quantification – and start to think about measurement as the process of gathering management intelligence.

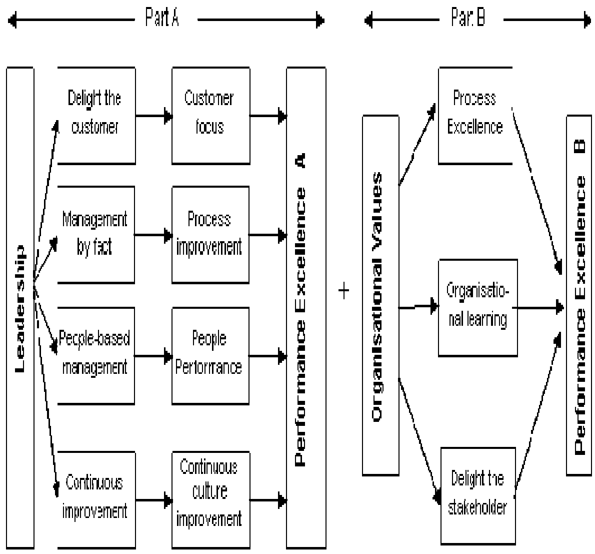

Fig. 2. Kanji's Business Excellence Measurement System (source: [173]).

Having reviewed performance measurement and its systems, the next section will address the characteristics of turbulent environments that may limit or facilitate their introduction.

Turbulent environments

To cope with turbulent environments organisations change to become flexible and the PMS must include information about the wider environment. As a result the PMS interacts with the organisation and with the external environment which is unique in each case, but some generalities may be described.

Factors affecting the development and use of the PMS can be grouped as (Figure 3):

Inputs - The knowledge, identification of requirements and resources that will be required to develop a PMS. As organisations depend on many stakeholders, the PMS should include information related to them.

External environment - It is dynamic and may enhance or limit the adoption of the PMS by changing its priority. Each organisation exists within an environment. The first difficulty associated with performance measurement is its justification. One source of variation of the external environment arises from the variety of customers, and products that may dictate rearrangements within the organizations for example: changes in layout, in people's responsibilities and tasks, but also may require rearrangements with partners and suppliers. External environment consists of market (including competitors), legal, technological, socio-cultural, and international factors [32]. The competitor performance can be monitored through benchmarking. Instead of considering strategy as the basis of a PMS, one must start by looking at stakeholders, which are not all within the organisation. It is commonly recognised that the external and internal environment of an organisation is not static but is constantly changing.

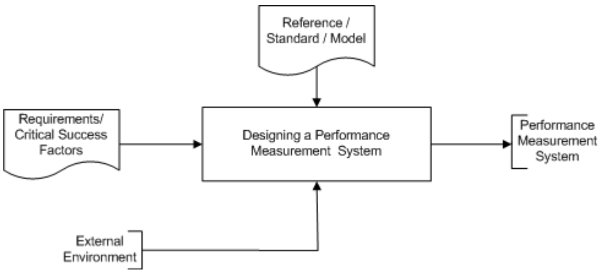

Fig. 3. Factors affecting the development of a PMS

Reference / Standard / Model - The reference or standard or model is either externally imposed or is related to what the organisation expects from the PMS. It may contribute to the definition of the level or target for the identified measures. The nature of the industry, the company culture, and its immediate, medium, and long-term goals; the adoption of quality tools and techniques; and the views of senior management toward award models and TQM philosophy are unique in each case.

The design of the PMS is also affected by the internal environment. Internal environment factors considered are: corporate planning, role of top management leadership, customer focus, human resource focus, process focus, quality focus, and information and analysis [32]. Neegaard [33] formulated five different contextual definitions and identified some factors that seem to explain the choice of each organisation's configuration. The choice of configuration is contingent on a number of contextual factors, such as the organisation's size, technology, strategy, organisational structure, culture, management style and uncertainty in the external environment.

Finally, the PMS will provide information about the system, but unless some action is taken, no improvement will be expected. It will produce results if integrated into a process-based change.

METHODOLOGY

Performance measurement in turbulent environments is at the centre of this on-going research. The research methodology to design a PMS in a turbulent environment will comprise both deductive and inductive stages. It starts with a literature review on the field of performance measurement to develop through deductive logic a conceptual and theoretical structure. This part of the research presents the findings of this deductive research which will later be tested through case studies, to allow another step of inductive research to support, change or refute the proposed elements of the PMS.

CRITICAL SUCCESS FACTORS ON THE DESIGN OF PMSs IN A TURBULENT ENVIRONMENT

Two key critical factors will be discussed Customer Performance Measures (CPMs) and organisation flexibility, as flexibility is a means to adapt to turbulent environment and customer focus is still one the principles that managers can not neglect. The following analysis reveals the importance of these two critical elements in a PMS that are implicit or explicit the renowned PMSs: Balanced Scorecard, Global Excellence Measurement System and Performance Prism, as they represent the current best practices on the design of PMSs and are accepted by practitioners and academics.

Customers

Assumptions - each organization has internal and external customers and the PMS must include customers' information. This is a vital component of any balanced scorecard and can serve different objectives:

- if customers are "unhappy", means that competitors are doing relatively better or that their expectations are not being met.
- if customer satisfaction is associated with customer retention that indicator can be used as a predictor of future sales and thus can be considered as an indicator of future performance or sustainability of sales.
- customers' requirements are always changing and organisations may have products/services for different customer segments, and sell to different regions and cultures.
- most methods to assess customer satisfaction find hard to quantify lost sales or the cost of opportunity.

- information about the experience of each customer of the organization must be used and be available in future contacts with the same customer.

Potential Problems - according to the Kano Model customer needs are continuously evolving. How to know exactly what each customer wants and what he does not want and why?

The needs, opinions and expectations of the customers are usually expressed through natural language, using linguistics terms.

There are studies that argue that only a small fraction of (un)satisfied customers will actually express formally such situation to the organization, for example, through customer feedback boxes or by email. How to design reliable and flexible (CPMs) at low cost?

In the traditional formulation of a PMS, most systems variables are affected by imprecision and vagueness but they are represented using numerical crisp values. A good decision-making model needs to tolerate vagueness and imprecision because these types of the non-probabilistic uncertainty are common in decision-making problems [34].

Measuring customer performance will not improve business unless action is taken over the system. How can CPMs contribute to identify problems and aid decision making? If the uncertainty (fuzziness) of human decision-making is not taken into account, the results can be misleading [35].

Proposed Solutions - There is not one method alone to study customers exempt from limitations and thus more than one method must be used.

The organisation must provide, by all means of contact with the customer the ability for him to make a complaint/suggestion and must record that information in a simple, economic and reliable way. Additionally, it must ask simple questions such as: are you satisfied with our organization? What would you like us to do for you?

The responses to these and other questions are given normally in natural language, using linguistic terms such as: “very good”, “probably so”, “not very clear” or “acceptable”. These terms have associated vagueness and fuzziness, being much natural to refer to their values using a linguistic label instead a crisp numerical value as frequently is done [36].

Fuzzy Set Theory and Fuzzy Logic have proved to be a successful in handling imprecise and vague knowledge that characterise this kind of problems, and it has been applied in a variety of fields in the last decades.

The understanding of customers’ (present and future) needs and the evolution of society is a means of predicting future trends in the near future. So the task of studying Customers and transforming their needs into organizational requirements and contracts must be one vital process of any organization that adds value to the next product/service offered (at least in the design phase).

Flexibility

Assumptions: flexibility is the “firm’s capacity to adjust to change and/or exploit opportunities resulting from environmental changes” [37]. A flexible organization may have frequently new processes, new process owners, new suppliers, new partnerships, new subcontractors, new collaborators, etc. In this context is not valid the assumption underlying in most performance measurement studies that it is known the structure of the system and the dependence relations between parts.

All the workers and more in general customers and some stakeholders are potential owners of PMs or contribute with data to some PMs that are used in the PMS.

Potential Problems: all the above actors may have a different culture, knowledge or experience resulting data from a multitude of sources that is non-reliable and/or non-valid. Data quality [25] is the first metric that is fundamental to successful performance management deployments. The problem is how to overcome this situation or how to deal with this uncertainty of data.

Proposed solutions:

1. A colour scheme to represent the quality of each PM.
2. To use Fuzzy Set Theory for capturing vagueness and fuzziness of the input variables, the explicit representation of data semantics, the subjectivity of human perception and assessment, and the non-deterministic behaviour of the users.
3. To develop adequate methods to propagate the uncertainty of the parameters or input variables throughout the PMS.
4. To allow stakeholders of the organization to provide their opinion (greater than or smaller than) about existing PMs. Afterwards, each one that was correct about the evolution of a PM will increase the credit of their prediction while others will decrease or maintain that credit. This would be a basis to provide a level of “believability” to each PM.

References

[1] Ghalayini, A., J. Noble, and T. Crowe, An integrated dynamic performance measurement system for improving manufacturing competitiveness. Int. Journal of Production Economics, 1997. 48: pp. 207-225.

[2] Gonzalez-Benito, J. and B. Dale, Supplier quality and reliability assurance practices in the Spanish auto components industry: a study of implementation issues. European Journal of Purchasing & Supply Management, 2001. 7: pp. 187-196.

[3] Dewhurst, F., A. Martínez-Lorente, and B. Dale, Total quality management and information technologies: an exploration of the issues. Int. Journal of Quality & Reliability Management, 1999. 16(4): pp. 392-405.

[4] Kaplan, R., & Norton, D. (1992). The balanced scorecard - measures that drive performance. Harvard Business Review (Jan-Feb.), 71-79.

[5] Bourne, M. (2004). Handbook of performance measurement (3rd ed.). London: Gee Publishing.

[6] Verweire, K., & Berghe, L. V. d. (2003). Integrated performance management: adding a new dimension. Management Decision, 41(8), 782-790.

[7] Marr, B., & Schiuma, G. (2003). Business performance measurement - past, present and future. Management Decision, 41(8), 680-687.

[8] Arneson, T., M. Rys, and C. McCahon. A guide to the selection of appropriate quality improvement tools. in Proceedings of the 1st Annual Int. Conference on Industrial Engineering Applications and Practice. 1996. Huston, Texas.

[9] Yusof, S.M. and E. Aspinwall, Total quality management implementation frameworks: comparison and review. Total Quality Management, 2000. 11(3): pp. 281-294.

[10] Claver, E. and J.J. Tarí, Levels of Quality Management in Certified Firms. TQM & Business Excellence, 2003. 14(9): pp. 981-998.

[11] Karapetrovic, S. and W. Willborn, Self-audit of process performance. Int. Journal of Quality & Reliability Management, 2002. 19(1): pp. 24-45.

[12] Neely, A., C. Adams, and M. Kennerley, The performance prism: the scorecard for measuring and managing business success. 2002: Financial Times Prentice Hall.

[13] Kanji, G., Forces of excellence in Kanji's business excellence model. Total Quality Management, 2001. 12(2): pp. 259-272.

[14] Prajogo, D.I. and A.S. Sohal, The Sustainability and Evolution of Quality Improvement Programmes-an Australian Case Study. Total Quality Management, 2004. 15(2): pp. 205-220.

[15] Juran, J.M. and A.B. Godfrey, Juran's Quality Handbook. 5th ed. 1999: McGraw-Hill.

[16] Basu, R., New criteria of performance management. Measuring Business Excellence, 2001. 5(4):pp. 7-12.

[17] Schalkwyk, J., Total quality management and the performance measurement barrier. The TQM Magazine, 1998. 10(2): pp. 124-131.

[18] Macpherson, M., Performance measurement in not-for-profit and public-sector organisations. Measuring Business Excellence, 2001. 5(2): pp. 13-17.

[19] Brown, M.G., Winning Score - how to design and implement organizational scorecards. 2000, Portland: Productivity Press.

[20]. Seddon, J. Changing Management Thinking. in Q2002 - A World Quality Congress - 46th EOQ Congress. 2002. UK.

[21] Tenner, A. and I. DeToro, Process Redesign. 1997, Harlow: Addison-Wesley.

[22]Ghalayini, A., J. Noble, and T. Crowe, An integrated dynamic performance measurement system for improving manufacturing competitiveness. Int. Journal of Production Economics, 1997. 48: pp. 207-225.

[23]. Franco, M. and M. Bourne, Factors that play a role in "managing through measures". Management Decision, 2003. 41(8): pp. 698-710.

[24] Divorski, S. and M. Scheirer, Improving data quality for performance measures: results from GAO study of verification and validation. Evaluation and Program Planning, 2001. 24: pp. 83-94.

[25] Prat, Nicolas & Stuart Madnick (2008) 'Measuring Data Believability: a Provenance Approach' MIT-Engineering Systems Division - Working Paper Series ESD-WP-2008-04.

[26] Bititci, U., T. Turner, and C. Begemann, Dynamics of performance measurement systems. Int. Journal of Operations & Production Management, 2000. 20(6): pp. 692-704.

[27] Neely, A., M. Gregory, and K. Platts, Performance measurement system design. Int. Journal of Operations & Production Management, 1995. 15(4): pp. 80-116.

[28] Kaplan, R.S. and D.P. Norton, The strategy-focused organization. 2001, Boston, Mass.: Harvard Business School Press.

[29] Wilcox, M. and M. Bourne, Predicting performance. Management Decision, 2003. 41(8): pp.806-816.

[30] Kanji, G. and P. Sá, Kanji's Business Scorecard. Total Quality Management, 2002. 13(1): pp. 13-27.

[31] Kanji, Gopal K. (2008) 'Architecture of business excellence in the public and service sectors', Total Quality Management & Business Excellence, 19:4, 399 – 415

[32] Brah, S.A., S.S.L. Tee, and B. Rao, Relationship between TQM and performance of Singapore companies. Int. Journal of Quality & Reliability Management, 2002. 19(4): p. 356-379.

[33].Neergaard, P., Configurations in quality management. Scandinavian Journal of Management, 2002. 18: p. 173-195.

[34] Yu, C.S., A GP-AHP method for solving group decision-making fuzzy AHP problems. Computers and Operations Research, 2002, 29: pp.1969-2001.

[35] Lee, A., W. Chen, and C. Chang, A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan. Expert Systems with Applications, 2008, 34: pp. 96-107.

[36] Tsaur, S. H., T. Y. Chang, and C. H. Yen, The evaluation of airline service quality by fuzzy MCDM. Tourism Managment, 2002, 23: pp. 107-115.

[37] Dreyer, Bent & Kjell Gronhaug (2004) 'Uncertainty, flexibility, and sustained competitive advantage' Journal of Business Research 57, 484– 494.

[38] Globerson, S., Issues in developing a performance criteria system for an organisation. Int. Journal of Production Research, 1985. 23(4): pp. 639-46.

APPENDIX 1 – CRITICAL SUCCESS FACTORS OF PERFORMANCE MEASUREMENT

Dimension	Critical success factors of performance measurement
Top management support	Management consensus concerning an organisation's objectives and the means at its disposal for attaining them [27]. PMs must be chosen from the company's objectives and strategy (Maskell, 1989) (cited by [27]). PMSs need to achieve alignment with strategic priorities 26], [27]. The PMS must place significant emphasis on the quality strategies of the company [17]. The departments and functions responsible for introducing performance information must be totally committed to their service responsibilities in the organisation [17]. The PMS must show a healthy apprehension for financial indicators and actively promote the use of non-financial indicators [17]. Achievement of an overall feeling of urgency and perpetual improvement [21].
Customer relationship	Performance criteria should be selected through discussions with customers [38]. The PMS must place a strong focus on performance information that directly measures customer satisfaction and responsiveness to customer requirements [17]. Visibility [21].
Workforce management	Performance criteria should be selected through discussions with employees [38]. PM must not be used as a weapon nor used to punish or blame [17]. Departmental goal-setting without creating inconsistencies in policy or excessive interdepartmental conflict [27]. There are measures to indicate performance of teams [27]. Long-, short- and medium-term goals [27]. Part-ownership of problems – so that a solution has to be found across functional boundaries and the escape route, "it's somebody else's fault", no longer has any meaning or validation [27].
Employee attitudes and behaviour	The measures should be designed so that they stimulate continuous improvement rather than simply monitor (Maskell, 1989) (cited by [27]). Involvement of all concerned [21]. Total commitment from all involved [27].
Process flow management	PMs should provide fast feedback (Maskell, 1989) (cited by [27]). PMs should encourage and enable employees to control and improve processes. They must not stimulate nor promote short-term manipulation of processes [17]. Straightforward measurement of what is important [21].
Quality data and reporting	Data collection and methods for calculating the PMs must be clearly defined [38]. Ratio-based performance criteria are preferred to absolute numbers [38]. Performance measurement information must be freely available at all levels in the organisation to encourage employee empowerment [17]. A thorough understanding of the existing measurement systems, both formal and informal, spoken and unspoken, as they are perceived [27]. Performance information must be relevant, user-friendly, reliable and frequent [17]. More extensive use should be made of subjective data [17]. Simplicity of presentation (few and understandable variables) [21].
Role of the quality dep.	It should be acknowledged that measures change as circumstances do (Maskell, 1989) (cited by [27]). Undistorted collection of primary information throughout the operations area [21].
Culture	It should be recognised that measures vary between locations (Maskell, 1989) (cited by [27]). The corporate culture [27].
Structure	Performance criteria should be under the control of the evaluated organisational unit [38]. The measures should be simple and easy to use (Maskell, 1989) (cited by [27]). An appropriate mix of integration and differentiation (i.e. goals set both horizontally and vertically within the framework of the organisational chart) [27].
Benchmarking	Benchmarking must be used consistently to ensure the appropriateness of internal standards and to vitalise the continuous improvement process [17]. Performance criteria must make possible the comparison of organisations which are in the same business [38].

Achieving Sustainable Business for Industrial Software Systems

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Object/Function Keywords: Business_process(es) and software_engineering for development of software for complex_systems; impact_of_change on quality_cost; organizational_change.

INTRODUCTION

Sustainable development of industrial software systems with controllable outcome in terms of cost, schedule and quality despite changes originating from new technology, stakeholders' concerns, organization, and business goals during long life-times is a challenge. Unruh [17] has argued that numerous barriers to sustainability arise because today's technological systems were designed and built for permanence and reliability, not change.

Sustainability is a characteristic of a process or state that can be maintained at a certain level indefinitely. The implied preference would be for systems to be productive indefinitely, to be "sustainable." For instance, "sustainable development" would be development of software systems that last indefinitely. Author Michael Pollan [13] has defined an unsustainable system simply as "a practice or process that can't go on indefinitely because it is destroying the very conditions on which it depends.

There are several factors obstructing the sustainability of the software development process:

- Competing concerns from various stakeholders affect the system and the winner among the concerns is not always the most logical. For a mature software system most probably political concerns will compete with functional concerns and affect the system.
- The system's software qualities are exposed to change, e.g. the introduction of faster multi-core processors might solve performance issues outside the scope of the architecture and therefore the focus and mission of the architecture shifts to other issues.
- The business goals of the system are exposed to change. This happens when the management shifts the focus from increase of quality to cost cut and thereby changes one important business goal for the system.
- The technical environment and organization structure change. A new platform or distributed development might be unavoidable and therefore puts requirement on change for the system.

If these factor where possible to control and a stable balance of cost, schedule, and quality outcome of the software system was achieved, the system would be a sustainable software system. The development of the software system would deliver required quality to the customers' satisfaction at the desired scheduled and cost indefinitely. However unrealistic this might seem it is truly the goal of sustainable software development. The cost is a very important measure since a long-lived system can be achieved at a high cost but this would lead to an unsustainable development process which would eventually collapse.

Since software development is an art involving people and people communicating a sustainable system model must include influences from people, architecture, hardware, software, communication and unpredictable changes in form of; stakeholders' concerns' changes, technology changes, business goal changes, and organizational changes. With all influences included in one model it would be desirable to be able to predict or at least reason about the outcome of the system; cost, schedule and quality.

The remaining of this paper is organized with a short overview of related work in the section "Related Research" and the issues important for sustainable industrial software systems is given in section "Issues for Sustainable Business". The paper is concluded in the section "Conclusions" followed by a short description of further work in section "Future Work".

RELATED RESEARCH

The importance of technical, business, and social influences on software architecture is discussed in [1] and the relationship among the technical, business, and social environments that subsequently influence future architecture is called the architecture business cycle (ABC). The ABC focuses on the creation of software architecture and the maintenance of the architecture and conformance of the system to the architecture, however, the ABC does not handle sustainable system issues where it's possible that the architecture has to change during the system's lifetime. An attempt to address sustainable systems can be found in [10] where the integration of established engineering methods with a development organization's life cycle is discussed. Here the Attribute Driven Design (ADD) method, [19], and the Cost Benefit Analyze Method (CBAM), [9], are suggested as means for the architect to design and chose appropriate architectural responses to the new challenges during the software development life cycle. The methods are preferably used in the development phase and the Architecture Trade-off Analysis Method (ATAM) used after the system is released and the stakeholders want to discover risks and sensitivity point in the architecture related to business goals.

For the change requests entering the system after its release the stakeholders have to take a decision if they are worth implementing or not. In an article from Boehm [4] it is argued that software engineers should look at proposed changes to software systems as investment possibilities and calculate on the value of investing in those changes with methods similar to the methods in the investment economics, e.g. option theory. Especially the value of the success-critical stakeholders concerns should be considered important. For the sustainable software system this would mean that the software engineers have to be updated on who is a success-critical stakeholder and how to calculate the value of his/hers concern's implementation. The calculation could also serve as guidance to what concerns should be allowed to enter the system as change requests. However calculating a correct development effort for a proposed change request is very difficult. Joergensen [8] has showed that software project cost estimation uncertainty assessments are frequently based on expert judgment, i.e., unaided, intuition-based processes and not on formal models. His guidelines suggest, among other things, that the most promising strategies are not based on formal models, but on supporting the expert processes.

The implementation of change requests also have to include support in the development process. The process has to support unpredictable change requests as well as support their fast realization. The Scrum [15] development process has gained a lot of supporters as it's a light-weight process with a strong connection to agile development methods. Scrum considers the software development process to be a chaotic empirical process which requires close watching and control, with frequent intervention. A scrum software project is controlled by establishing, maintaining, and monitoring key control parameters. The key control parameters are backlog, issues, risk, problems and changes - task level management is not used. However in [5] it is argued that agile development methods are not well suited to large development organizations such as those evolving sustainable software systems. Scrum identifies the most important stakeholders and these success-critical stakeholder's concerns are implemented at first. This is similar to Ruhe and Saliu [14] who describe the release planning approach based on the features' internal dependencies, the resource constraints and the stakeholders' importance.

In [20] the uncertainty principle of software engineering (UPSE) is stated as "Uncertainty is inherent and inevitable in software development processes and products". The software development is described as a complex human enterprise carried out in problem domains and under circumstance that are often uncertain, vague or otherwise incomplete. The principle of uncertainty is also valid for those changes entering the development organization which are considered unpredictable in time and consequence. The control of the sustainable software development despite the UPSE is what makes the sustainable software development challenging.

ISSUES FOR SUSTAINABLE BUSINESS

The system architecture provides a context for the software architecture and includes, beside software architecture, also hardware and people. System quality attributes and business goals influence the system architecture. The influencing factors which are factors affecting the architecture part of the stakeholder concerns [16] and include trends, technical environment, previous experiences, market demands etc.

The influencing factors change over time and hence the stakeholders' concerns change over time. The influencing factors impact and/or put requirements on system quality attributes and business goals. This leads to that the system quality attributes change as result as well as the business goals. Changing business goals can lead to changing enterprise architecture and changing development organization as business structures and business processes.

Since all these changes come from outside the software system they are uncontrollable and unforeseeable. When building software architecture from start it may be possible to build in support for foreseeable changes but not for an unforeseen change, e.g. a sudden organizational change.

Technology

What makes software especially difficult to develop for sustainable system is that software and hardware themselves are not sustainable. Software technologies, tools, architectures like the World Wide Web, languages like C and C# change the software engineering culture in which system builders operate and learn.

In many cases the demand from the customers on smooth updates preferably in a running plant regardless of what changes occur over time translates into a requirement on backward compatibility. Backward compatibility also concerns hardware, where the customer might run the system on hardware no more available on the market.

For long-lived systems typically the components from which the system is built, have shorter life-cycles than the complete systems. Many components in a large and complex software system are acquired from third-party developers. Consequently, a system provider has no or limited control over the complete system (e.g. no access to source-code). Hence, it is very important to continuously monitoring the sub-suppliers roadmaps and to have a tight and sound relation with them. By doing so, a company have the possibility to react well in time before a particular component or technology for which the development organization has no control over gets obsolete. The fact that software technologies and commercially available software components have shorter life-cycles than what is required for the system is something that needs to be considered when designing the architecture.

Typically the life-cycle of a software product can be divided into three phases: initial design (I), evolution (II), and end-of-life (III) (see Figure 1). During the initial design phase the requirements are usually well-known and the development of new functionality requires relatively little effort. In the evolutionary phase the requirements that were not known in (I) are introduced and the effort for developing and implementing these requirements require higher effort, since consideration must be taken to what already exists in the system. The architecture developed during initial design does to a large extent define what is possible in later phases from an economical point of view.

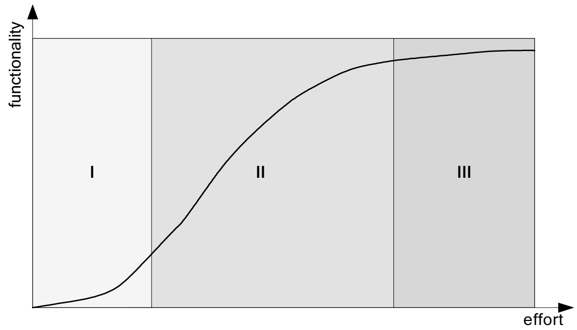

Fig. 1. Product life-cycle phases

It is important to find a balance between upfront investments in, e.g. software architectural design, and time-to-market for software development in sustainable complex industrial systems in the perspective of a product's life-cycle. By diagnosing a system's life-cycle phase in terms of trends in crucial organizational measurements we believe that it is possible to quantitatively motivate efforts in improving fundamental software qualities in order to prolong a system's productive life-time. A typical trend in an organizational measurement could be the increasing number of person-hours invested related to the decreasing number of function points delivered. This could be an indication of a system being in the end-of-life phase (III).

Even though technology evolves in a high pace, business specific logic does not. Operating systems and hardware change all the time but the basic principles for, e.g. the motion control of a robot, evolves slower. Another example is the paper production. The chemical process behind paper production will not change as it's defined by physical parameters and reactions. The control algorithms, which are part of the business logic, involved in controlling the pressure, strain and so on will continuously be refined but not experience major change. Usually there are great investments in the business logic and the investments are secured by intellectual property claims, so it is important to make as much as possible out of these investments. This is where we have the core competence, and the core business. Returning to the core business has proven to be successful for many companies where ABB is one of them. ABB returned its focus to automation and power distribution after some years with a broader scope. Isolating the business logic in a way that enables the technology around it to evolve with the least possible cost is crucial. E.g. researchers who have been using FORTRAN and now have the possibility of using C# just as efficiently for their algorithm code the question is; have they modelled the algorithms in a language independent fashion so that they can switch to C# effortlessly? What's the return of investment, the ROI, value of the change?

Organization

According to [1] there are three classes of organizational influences on software architecture;

- Immediate business: An organization may have an investment in certain assets, such as existing architectures and the products based on them.
- Long-term business: The architecture can form the core of the long-term infrastructure investment to meet the organization's strategic goals.
- Organizational structure: The organizational structure can shape the architecture such that the division of functionality aligns with existing units of expertise.

For sustainable systems there is a challenge in creating a sustainable architecture possible to implement under these three different organizational influences. There will be shifts in organization influence inside a development organization, e.g. if distributed development is introduced. In this case the distributed development could for instance put requirement on the architecture to support isolated module development. Another example is if the architecture suddenly has to support the migration of several products into one, as may be the case when a company acquires another company. For this case the shift in organizational structure goes from immediate business to long-term business. Development organizations often have to deal with drastic shifts like this without the customer noticing any major differences in actual system software quality.

Recognizing that change requests are something normal and that deviations from predictions will occur for a sustainable software system, the question is how to act upon them. Should a change in stakeholders' concerns toward more secure system always respond in that the system is optimized for security? Or will this be in conflict with business goals as e.g. making the system available over internet?

In traditional control theory [12], optimization theories have been developed to optimize the system parameters for stability. Something similar is needed for sustainable software systems in order to make the right system decisions in terms of economics, architecture, technology and people. There are many states that can be controlled and/or observed for a sustainable software system model:

- Software architecture – The design and the infrastructure of the system
- Software technology – The various technologies used as a technical base, such as programming environment, operating system and middleware.
- Software components – The various proprietary and commercial components used to realize the system, examples of components are user interface, user management and transaction managers.
- Hardware – The core of the system where the software is running
- Software communication – everything regarding communication including compatibility with other vendor products, communication hardware, communication stacks and redundancy concepts.
- People interaction – Most industrial systems have people that interact with them and how this is performed is one key to the operation of the whole system.
- Development processes – Processes influence the organization and the architecture and the opposite.

The two last states, people interaction and the development processes, might be the hardest to control since they include human psychology. In [3] programming accidents are examined, i.e., models, methods, artefacts, and tools, to determine that each has a step that programmers find very painful and consequently avoid or postpone. The avoidance or postponement disturbs the processes in a not controllable way and leads at the worst to uncontrollable cost, schedule, and quality outcome.

But before the change request reaches the development stage it has to be approved and there is various way of handling change requirements. In [7] a decision support theory in form of real options theory is suggested for guiding investment decisions regarding a change in the software. Typically the option theory calculations could serve as input to a change request board.

During the lifetime of a long-lived system there will be a turn-over of engineers. The engineers possess competence and know-how concerning the system. Typical examples of crucial know-how is the intention and rational behind certain architectural decisions. As engineers come and go through the organization there is a great risk that this knowledge is lost. As a consequence, poor design decision may be taken during a system's evolution which contributes to shorten the productive phase of the sustainable systems. A proper architectural documentation is one way to minimize the risk of competence drain due to turn-over of engineers. Yet again the human psychology aspect enters the field since software developers often find documentation a very painful step and avoid this as far as possible. When documenting software the people doing the documentation has to find it meaningful and ultimately, such documentation has to have some notion of intention, i.e. rationales for architectural decisions [21].

Market

It's not only customers' expectations that change over time. Also a company's business goals change, e.g. penetration of new markets. Every company has its own set of business goals and to achieve a common perception of the goals, it would be beneficiary to generalize them. One approach is presented by Bass and Kazmann where they have categorized the business goals from a number of ATAM evaluations [2]. Their five categories are; 1) "Reduce total cost of ownership", (2) "Improve capability/quality of system", (3) "Improve market position", (4) "Support improved business processes", and (5) "Improve confidence in and perception of the system".

Typically there will be a movement between quality focused business goals as (1), (2), and (3) and functionality focused business goals as (3) and (5). A "fresh" software system is typically more focused on "Improve market position" and "Improve confidence in and perception of the system". New functionality is then released to customers and feedback from the release in form of change requirements and trackers leads to yet more new functionality. When the software system has grown to a certain extent the focus might shift to quality focused goals as "Reduce total cost of ownership", and "Improve capability/quality of system".

The challenge lays in balancing the shift in business goals with their interpretation to software quality goals and functionality requirements. For example "Reduce total cost of ownership" can mean outsourcing parts of the development and this puts high requirements on the modifiability and testability quality and also on software development processes different to in-house development [11].

Another example is the conflict of the shift towards "Reduce total cost of ownership" including the tactics to use standard hardware. If the market differentiators for the product are high robustness and backward compatibility, it means the robustness issue has to be solved with standard hardware and the backward compatibility issue with non complex architecture in order not to implement expensive development. This is truly a challenge. The customer's perception of the system should be the same, only with updated software and hardware. Industrial systems have customers running legacy hardware which have no intention or motivation to shift hardware to the latest technology. For system developers the customer's hardware puts requirement on the software to be backward compatible with the legacy hardware as well as backward compatible with legacy software.

It is not uncommon for industrial software system to have a few dominating customers who demand certain system qualities. In this case the challenge lies in to what extent the system producer can tailor the system to please one dominant customer before the other customers object to not getting their requirements met or having to pay for qualities they don't require. We have seen examples where a few dominant customers have driven a system to be too costly compared to competitors offers. The reason is that the system provides a lot of functionality which are not specifically requested by the majority of customer categories, but requires more expensive hardware infrastructure which contributes to the cost. However there is also an advantage with a large dominant customer. They provide the means for the rework of one system to an extent not possible otherwise, which in the CelsiusTech case proved very successful. In the case of CelsiusTech [6], the unpredictable change in the form of the simultaneous awarding of two massive contracts (each of which was for a system beyond anything the company had ever attempted) led to a complete redesign of the system architecture based on the core assets. The new product-line architecture was the entry to new business areas not previously accessible.

CONCLUSIONS

This paper has described the challenges for the development of sustainable industrial software systems. The most important factor to recognize is the factor of time and its effect on system development since industrial software systems often have long lifetimes. The second factor to recognize is that change in organization, technology, and market over time is something inevitable and that the development has to calculate for this. The third factor to recognize is that changes are not always predictable or foreseeable and that a static system could have difficulties to host unpredictable and unforeseeable changes. The forth factor to recognize for industrial systems is that their customers most often don't want to experience any change since a change that requires knowledge update or process interruptions is costly. The last factor to recognize is that the producer can achieve the desired quality and cost despite unpredictable changes at an unreasonable cost, but this would lead to an unsustainable development process which would eventually collapse.

This leads us to the conclusion that the sustainable industrial software system has to control the cost, quality, and schedule outcome of the system despite unpredictable and predictable changes in organization, market, and technology affecting the system over time.

FUTURE WORK

Future work will include an attempt to establish a sustainable software system model, including measures for the key states important for the control of the outcome of a sustainable industrial software system. In this work software economics will be a key essence influencing the software engineering theory for the model.

References

[1] Bass, L., Clements, P., Kazman, R.: Software Architecture in Practice. Addison-Wesley (1998)

[2] Bass, L., Kazman, R.: Categorizing Business Goals for Software Architectures. In: SEI (ed.), Pittsburgh (2005)

[3] Berry, D.M.: The Inevitable Pain of Software Development: Why There Is No Silver Bullet. LNCS 2941. Springer Verlag (2004)

[4] Boehm, B.W., Sullivan, K.J.: Software economics: a roadmap. Proceedings of the Conference on The Future of Software Engineering. ACM, Limerick, Ireland (2000)

[5] Boehm, B.W.: A view of 20th and 21st century software engineering. Proceeding of the 28th international conference on Software engineering. ACM, Shanghai, China (2006)

[6] Clements, P., Northrop, L., Software Product Lines: Practices and Patterns, Addison-Wesley (2002)

[7] Erdogmus, H.: Valuation of Complex Options in Software Development. ICSE'99 Workshop on Economics Driven Software Engineering Research (EDSER1). ACM/IEEE, Los Angeles (1999)

[8] Joergensen, M.: Evidence-bases guidelines for assessment of software development cost uncertainty. IEEE transactions on software engineering 31 (2005)

[9] Kazman, R., Jai, A., Klein, M.: Quantifying the costs and benefits of architectural decisions. In: Jai, A. (ed.): Software Engineering, 2001. ICSE 2001. Proceedings of the 23rd International Conference on (2001) 297-306

[10] Kazman, R., Nord, R.L., Klein, M.: A life-cycle view of architecture analysis and design methods. In: SEI (ed.), Pittsburg (2003)

[11] Larsson, S., Wall, A., Wallin, P.: Assessing the Influence on Processes when Evolving the Software Architecture. Workshop, IWPSE'07, Dubrovnik, Croatia (2007)

[12] Ljung, L.: System Identification - Theory For the User. Prentice Hall, Upper Saddle River, N.Y. (1999)

[13] Pollan, P, Our Decrepit Food Factories, New York Times, 2007.

[14] Ruhe, G., Saliu, M.O.: The art and science of software release planning. Software, IEEE 22 (2005) 47-53

[15] Schwaber, K.: SCRUM Development Process. OOPSLA 95 Business Object Design and Implementation workshop (1995)

[16] Stoll, P., Wall, A., Norström, C.: Guiding Architectural Decisions with the Influencing Factors Method. WICSA. IEEE, Vancouver (2008)

[17] Unruh , G.C., Escaping carbon lock-in, Energy Policy, vol. 30, no. 4, 2002, pp. 317-325.

[18] Unruh, G.C., Understanding carbon lock-in, Energy Policy, vol. 28, no. 12, 2000, p. 817-830.

[19] Wojcik, R., Bachmann, F., Bass, L., Clements, P., Merson, P., Nord, R.L., Wood, B.: Attribute-Driven Design (ADD), Version 2.0. CMU/SEI, Pittsburg (2006)

[20] Ziv, H., Richardson, D.J.: The Uncertainty Principle in Software Engineering. 19th International Conference on Software Engineering (ICSE'97). ACM (1997)

[21] Leveson N. G, Intent Specifications: An Approach to Building, Human-Centered Specifications, IEEE Transections on Software Engineering, vol. 26, no. 1, 2000

CREATING VALUE WITH OPEN SOURCE SOFTWARE

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Keywords: business_model; technology_policy; implementation_methodology; organizational_culture; development model of software

INTRODUCTION

The concept of open source software isn't entirely consensual. To make clear the here-adopted view, we briefly present the notion of proprietary software, free software and open source software, and compare them.

During the last decades, most of the software companies have been used, all the legal means available to protect the intellectual property of their programs, with the purpose to hiding their programs' source codes from other competitor companies. They also used intellectual protection mechanisms, copyright laws and software patents, as far as they could This kind of software is called propriety software.

Generally, free or open source software refers to a program in which the source code is available to the general public for use and modification from its original design, free of the usual royalties. However, there are some nuances in the understanding of what exactly constitutes open source software. Two of the most reputed organizations concerning this type of software, differ in terminology and scope: the Free Software Foundation (FSF), recommends the use of the expression "free software" and insists on the obligatory publication of all source code derived from original free source code; and the Open Source Initiative (OSI), which prefers the expression "open source software", and is more liberal on the demand of derivative software publication. [4]

In this paper, we will mostly use the OSI view and the expression "open source software". For its protection, every piece of Open Source software must have a license that guarantees the freedom of use and modification. Its commercial use and how far the protection goes, justifies the existence of several types of licenses.

Another essential condition of the OSI view is the accessibility of the source code. Attending to this requirement, the term "Open Source" Software is most appropriate. One of the reasons that some people dislike the term "Free Software" is because it can easily be misunderstood: the word "free" does not have the meaning as in "free of charge", but as in free of secrets and free of use. Free and Open Source Software may or may not be free of charge, although this is a supplementary effect.

DEVELOPMENT MODEL

The basic idea behind Open Source software is very simple. When programmers can read, modify, and redistribute the software's source code, it evolves. Programmers all over the world can improve the program, adapt it to their personal needs and fix bugs. The experiences of the past years show that this can happen at a much faster speed, compared to the pace of traditional software development. People who are familiar with Open Source software have learned that this rapid evolutionary process produces better software than the conventional closed model, in which only the original programmers can see the source code and everybody else must use a so-called "black box" of bits. Because of the independent peer review and continuous evolutionary improvement and selection, Open Source software can reach levels of reliability, power and general maturity in short time frames that closed products will find hard to attain [1].

Several attempts have been made to explain this phenomenon. One of the first and most popular studies in this field was Eric Raymond's "Cathedral and the Bazaar" published in 1998. [5] Some of Raymond's ideas concerning the successful development of Open Source software will be presented here. The basis of Raymond's study is the assumption that two different categories of software development exist. One development category is called "Cathedral-like development". It is characterized by a centralized management and a strong control on design and implementation. Everything is well organized and planned in detail. This cathedral-like concept is typical of the development of proprietary software. The other development category, so-called "Bazaar-like development", is characterized by informal communication between programmers. Every programmer implements or improves parts of the code and offers it to the others. The programmers are in contact via private e-mail and other current electronic means, getting physically together very rarely. A mailing list and shared and synchronized information space (e.g. by CVS or SVN) for the core developers participating in a certain project are created. They discuss new features, bug fixes, user problems, developments in the Open Source community, etc. in an informal way. The code development takes place on the developer's local machines and new patches or improved source code is then posted to the mailing list and/or published on the appropriate webpage, or made freely available in global repositories. Everyone can then choose and pick the modules he wants, just like a bazaar.

Both cases can be considered as extremes in a continuum of software development models. While Open Source projects can be almost any model in that range, proprietary software project can hardly use models different from the cathedral-like. Whereas the openness of the Internet makes it possible for innovation to come from everywhere, big companies have difficulties gathering all necessary expertise on their teams. Furthermore, each company has only a limited number of software developers at its disposal and its goal is to make a profit with its results. Dividing the work just among its developers and in many cases not even sharing all of it among them, such a company thus cannot benefit from the advantages of the bazaar-like model. The important idea here is that Open Source software has allowed for the first time the introduction of successful alternative styles of software development that turned out to have a very positive influence on programmers' motivation and as a consequence on the quality of software products.

Another interesting point to look is about the driving forces that leads this community.

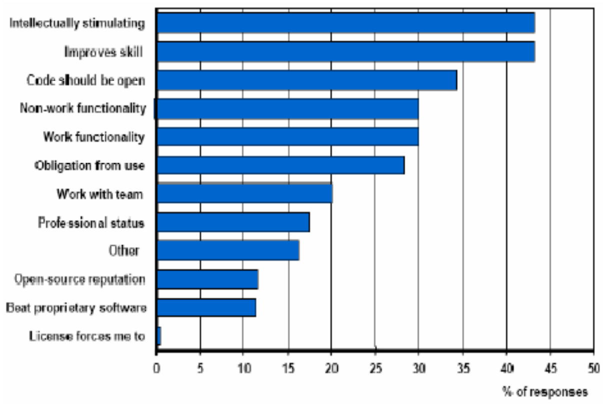

Fig. 1. Motivation to develop Open Source projects [2]

The study conducted by Boston Consulting Group (fig. 1) shows that learning is one of the driving forces that motivate developers to get involved in OSS projects because it provides the intrinsic satisfaction for OSS developers, and the role transformation in OSS communities that go along with learning offers the extrinsic motivation.

MAJOR CHARACTERISTICS

The Open Source projects have some common characteristics between them. These characteristics can also be mentioned as attributes of open source software. Some of these attributes contribute positively to the success of some open source initiatives, namely:

- Development and quality - the development of the software as well as the detection and correction of bugs takes place at a quick pace. The software is generally of very good quality because many excellent programmers are attracted by Open Source projects;
- Reliability and integrity – the code is of very high reliability and integrity because it can be reviewed and improved independently. This reduces the chances of so-called Trojan horse being hidden in the code;
- Stability – Open Source products have been proven to be much more stable than their proprietary counterparts, as was shown, for instance, by scientific analyses carried out by the Computer Science Department of the University of Wisconsin/Madison [2];
- Vendor independence and cost reduction – due to the availability of the source code and the freedom to redistribute the software, the user does not need to be bonded to a single software vendor and, as such, benefits from significant savings on licensing costs;
- Platform independence – the availability of the source code facilities portability to different hardware platforms and the potential to rapidly adapt to changing conditions;
- Support service – the support offered by mailing lists and newsgroups has been shown to be very fast and of high quality. For users who prefer the more traditional commercial support, there are many companies that offer complete solutions and supported distributions of the best-known Open Source products;
- Growing popularity – Open Source products are gaining a rising popularity among users, an increasing market for support services and customization and enjoy a growing attraction for software developers and consultants.

On the other hand, the Open Source concept also has negative aspects, which have to be considered:

- There is no guarantee that development will happen until the project reaches a kind of self-sustaining level. This problem of an initial gap might be solved or at least reduced by the strong backing of one or more big companies. On the other hand the involvement of big companies might keep away some of the idealistic Open Source programmers from joining the project because they only want to work for their ideals and ideologies and not for a big company, which is interested in making profit;

- The motivation for improving and developing an Open Source product might vanish or at least decrease if the product manages to replace proprietary software and gain a position as market leader. On the other hand, this can also have the opposite effect, i.e., the situation might persuade the proprietary software vendor to contribute the source code of some of his products to the Open Source movement;
- There may be significant problems concerning intellectual property rights and software patents because the availability of the source code simplifies the detection of patent infringements by patent holders.

Each company has to weigh up the positive and negative aspects of the use and/or the development of Open Source software in the long run. However, the rapid spread of Open Source in the past years does indicate that Open Source software will, at least in some areas, start to replace the currently common proprietary software products. More and more companies, such as *IBM*, *AT&T* and *Alcatel*, have adopted Open Source at different levels of commitments and have integrated the Open Source model into their business concept [4].

CULTURAL IMPACTS IN ORGANIZATIONS

The adoption of open source software by an organization brings some issues that we shall give a special attention, to be prepared to deal with them. Neus and Scherf asserted the following:

> "Based on our experience, we believe that very few challenges are the result of limits in technology, tools or process – rather, they are often the result of limits and boundaries in people's minds" [3].

The open source collaboration process is based on widespread access to source code and open collaboration - a meritocratic philosophy that invites feedback from everyone, regardless of official status or formal training, and frequent releases of interim versions to encourage testing, feedback, and quick evolution of solutions.

This open source paradigm is totally opposed to the traditional collaboration models, as we can see in Fig. 2.

Traditional Approach	Open Source Approach
Brooks' Law	Linus' Law
Hierarchy	Network
Experts	Peers
Teams	Communities
Cathedral	Bazaar
Perfection	Improvement
Construction	Evolution

Fig. 2. Traditional vs Open Source paradigms [3]

Based in Fig. 2, we can affirm that the traditional development approach is based on construction and the attempt at perfection. The software is designed once in a "top-down" mode, and then programmers execute the design. This paradigm assumes that only a small and select circle of designated experts should be allowed to design, create, and improve high-quality code or information, thus forcing the vast majority of practitioners into a passive or execution-oriented role, wherein they are expected to provide little or no feedback to improve the overall design.

The open-source paradigm, on the other hand, assumes that quality is the result of massive collaboration. The key of the success of the collaborative development model is based on the lower transaction cost for information, enabling the separation of the identification and solution components of quality problems and spreading these tasks over a much larger population than could sensibly be done in traditional hierarchical approaches.

A change in perspective from the traditional collaboration approach to an open-source approach requires a change in people's minds. The tools, processes, roles, and organizational charts for supporting multisite collaboration in an open-source method exist and are freely available in the Internet. However, these methods can't be directly transposed to an organization, without taking in consideration its own culture.

The visible organization, made up of the organization's formal tools, processes and roles is the tip of the organizational iceberg (Fig. 3). The organization's cultural identity lies "under the waterline". The following definition of culture was developed in the Complex Change Facilitation group and is useful when assessing or changing an organization's culture. Culture is a complex system of shared beliefs, values, language, customs, behaviors, and artifacts that members of a group use to cope with their environment and with one another [3].

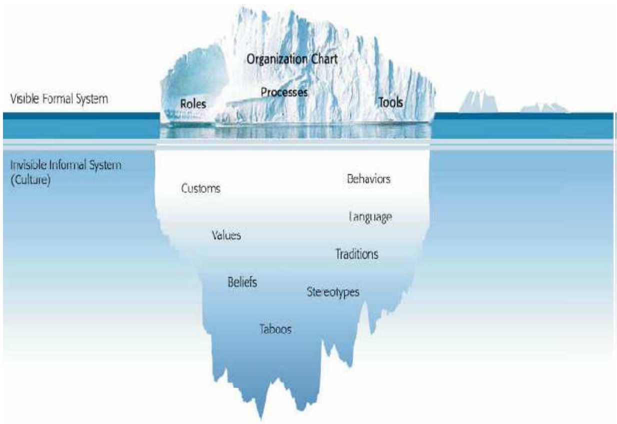

Fig. 3. Iceberg Model of an Organization [3]

OPEN SOURCE BUSINESS MODELS

During the last years several business models have been established with respect to Open Source software. In the following some of the most important models will be presented and related to companies that work according to these models. These examples show that Open Source and business are not in contrast to each other, as many people believe. It is possible to make business and earn money with Open Source. Even more, in the future it might be difficult, at least in the area of operating systems and server solutions, to have economic success with proprietary software. The fact that the European commission and many national governments, such as those of France, Germany, Italy, the USA and China, as well as some leading market research institutes have issued policy documents on the Open Source movement, is forcing software companies to think about business opportunities offered by the Open Source model [6]. Here we describe the most important and recent Open Source business models.

Support Service Provider Model

In this model, a company (effectively) gives away the software product, but earns money by selling distribution and offering support, after-sales services, course, etc.

One of the most popular companies in this field is *Red Hat*, which was founded in 1994 and floated on the stock market in 1999 (Nasdaq: RHAT). *Red Hat* is the leading provider of Open Source Internet infrastructure solutions, ranging from small-embedded devices to high availability clusters and web servicing. *Red Hat* shares all its software freely with the Open Source community under the GNU general public license (GPL).

Among other Open Source software products *Red Hat* sells various Linux distributions. The official Red Hat Linux OS and related services are available directly from the company or through its partner, distribution and reseller programs, which include top PC and server manufacturers such as *Compaq*, *Dell*, *Gateway*, *IBM*, *Hewlett-Packard* and *Silicon Graphics*. Each Red Hat Linux distribution includes special support packages, e.g., priority online access to software updates for a certain time (30 to 180 days, depending on the distribution) and telephone and/or email-based installation support for 30 to 90 days. They also sell a couple of further and more extensive support packages for their software distributions, which address different kinds of users. Furthermore Red Hat offers training and certification programs on Linux, Open Source software in general, diverse tools and programming languages.

In summary, it can be said that *Red Hat* is an exemplary company which has proven that the business model of a support seller works and that it is possible to have commercial success and make money with Open Source in that way.

Cost Reducers Model

Another business model related to Open Source software is characterized by the aim of reducing costs. In this model Open Source software is not used in order to make profit directly, but to reduce software related costs. For most of the proprietary software products the user has to pay high per-copy fees. Since he has to use the software as a black box, he completely depends on the company which produces this product exclusively. This usually leads to the fact that the user has to buy support from that software company which is, due to the lack of competition, not only expensive but also often very slow and of poor quality. Furthermore the user often has to buy another distribution for different hardware. Altogether the dependency from proprietary software produces huge costs and little comfort.

With Open Source software the situation is completely different. The charge for an Open Source software distribution is very low because there are competing providers. Furthermore there are no per-copy fees because it is permitted to duplicate the program as often as needed. Since the source code of the software is available, the user has several possibilities for getting support. He can either ask any person who is familiar with the software product, or he can get free support from one of the related newsgroups or he can buy the inexpensive and for the most part very quick and competent support from one of the above mentioned support service providers. Additionally, the availability of the source code also prevents the user from having to buy a new distribution if he wants to change his hardware. He can just adapt the existing software to the new conditions.

Motivated by the urgent necessity to reduce costs the European Commission and some national European governments namely the Germany, France and Italy, recently discovered Open Source software as a possible instrument for cutting down software expenses. The *Information Society Directorate General of the European Commission* recommends the promotion of Open Source software in several categories, e.g., in technical issues, organization and support, legal issues, etc. The European commission should take measures to accelerate the adoption process of Open Source software by European companies, organizations and individuals so that Europe does not miss this important development in the information society [5].

Proprietary Software Promotion Model

The Proprietary Software Promotion Model is another very interesting business model, which was recently introduced by *AT&T*. In this model, a company goes partially Open Source in order to promote their proprietary software products. The company releases a special distribution of a software product as Open Source. The special feature of this Open Source distribution is that some of the core modules and patches are replaced by older, worse or less efficient versions. For this purpose, the company has to use a special Open Source licence, which allows the company to use the same source code or parts of it in addition to their proprietary software.

The business strategy of this Open Source model is as follows. A company gives away those parts of their source code, which are no longer competitive because better solutions are already available. With these subtle tactics a company can reach three aims. First of all, it hopes to benefit from the Open Source community's ideas, improvements, bug fixing, etc. Secondly, this is the best possibility of establishing a certain software product as standard software. As a consequence the company can presume that a lot of their Open Source users will not be satisfied with the weaker Open Source product for the long run and buy the higher quality proprietary software product [5].

Developer License Model

Another very interesting business model is the Developer Licence Model which, for example, is used by Object Oriented Concepts, Inc. (OOC). OOC was founded in 1996 to provide CORBA compliant middleware. This software is commercialized under a novel licensing model.

For individual, non-commercial use the source code of the software is free of charge and distributed under the ORBacus Royalty Free Public license. This license allows the user to adopt the program to his personal use and to redistribute the original as well as the modified software if, and this is the decisive restriction, all these activities are non-commercial [6].

If the software is used in connection with the user's business, he has to buy either a run-time or a developer license. As the term implies, the run-time license only allows the license to run the program whereas the developer license also includes the right to modify the source code. However, the user is not allowed to redistribute the software. If he is interested in sharing his improvements with other users, he has to submit his modifications to OOC and ask them for insertion into the original source code. This shows clearly, that this developer license is not an Open Source license in the same of the OSI certification mark, but is a clever way of combining the distributions with per-copy fees (similar to conventional software companies) while at the same time having the possibility of benefiting from users' improvements and modifications.

Effective Advertising Model

This business model aims to improve the public reputation of a company. In this model, a company, the main business of which is not selling software, releases internally used software as Open Source. If the software is not competitively relevant, the company loses nothing by publishing its source code. However, since the current level of media attention for Open Source products is very high, releasing Open Source software seems to be an excellent opportunity for getting free publicity and for improving the company image.

An example of the technology promotion mentioned above, it was recently introduced into the telecommunications area by *Ericsson*. During the 1980s an internal project at the *Ericsson Computer Science Laboratory* aimed to find out which aspects of computer languages made it easier to program telecommunications systems. The programming language Erlang, the syntax of which is similar to Prolog, was the result of this project at the end of the 80s. Erlang was created by taking those features which made writing of telecommunication systems simpler and avoiding those which made them more complex or error prone. Erlang is particularly suitable for distributed soft real-time concurrent systems. It was designed especially for use in telecommunication applications, e.g., handling mobility in a mobile network or providing unified messaging.

Recently, *Ericsson* decided to publish the source code of Erlang. Since the core business of Ericsson relies on telecommunication products and not on selling software, they had nothing to loose. It was expected that the release of Erlang as Open Source would have a positive advertising effect. However, the advertising success has been marginal, because Erlang is not well known in the telecommunications area. Nevertheless, Ericsson have benefited from the Open Source release in other ways, because some programmers have started to fix bugs thus improving the quality of Erlang.

Start-up Company Promotion Model

Another model that is becoming very popular among start-up companies, usually associated with the so called "new economy", is to start and sponsor an Open Source project and to donate some initial code to it. Two very successful companies which have used this Start-up Company Promotion Model are *Vovida Networks*, which provide their Vovida Open Communication Applications Library (VOCAL) as Open Source, and Lutris, which was founded as an Open Source enterprise software and services company [7].

Usually, such companies develop complete solutions and commercial product packages (e.g., soft switches and application servers) based on the Open Source software provided by the community they sponsor. This model is a very good way of getting high quality products with reduced costs and in a short time. Additionally, the companies get free advertisement in the media and gain popularity in the rapidly expanding Open Source community, which is usually associated with the market where these companies operate.

CONCLUSION

Open source software such as the operating system Linux has created much attention as an alternative way to develop and distribute software. Open source is a movement, where communities of highly skilled developers collaborate deeply to create software, often of a quality that outperforms commercial proprietary software. The open source movement has also been said to provide important management lessons regarding the most effective ways to structure and implement innovation. The lessons of open source demonstrate the value of specialization through self-selection and how norms of meritocracy and peer recognition help ensure product quality. Attributes as quality, security, flexibility, reliability, time and cost savings are all benefits being generated by open source development model.

However, before following an open source development model a company must take in consideration not only the tools, processes and roles at the company, but also its organizational culture. The company must be ready to shift from a traditional paradigm of software development to a new paradigm where the massive collaboration is the center of all process.

There are already several business models that prove that it is possible to conduct a successful and profitable business based in Open Source software. We presented six business models and showed that they can be used by software companies.

References

[1] Kenwood, C., A Business Case Study of Open Source Software, 2001, MITRE Corporation.

[2] Kooths, S. and Langenfurth, M., Open-Source Software: An Economic Assessment, 2003, MICE Economic Research Studies, Vol. 4.

[3] Neus, A. and Scherf, P., Opening Minds: Cultural change with the introduction of open-source collaboration methods, 2005, IBM Systems Journal, Vol. 44, No. 2, p. 215-226.

[4] Feller, J., Fitzgerald, B., Hissam, S. and Lakhani, K., Perspectives on Free and Open Source Software, 2007, MIT Press, Vol. 3.

[5] Raymond, E., The Cathedral & the Bazaar, 2001, O'Reilly Editions.

[6] Woods, D., Guliani, G., Open Source for the Enterprise, 2005, O'Reilly Editions.

[7] http://www.openclovis.com – accessed on 11/03/2008.

[8] http://www.eu.conecta.it – accessed on 11/03/2008.

[9] http://www.omg.org – accessed on 14/03/2008.

[10] http://www.vovida.org – accessed on 17/03/2008

A P2P WEB DECISION SUPPORT SYSTEM FOR MANUFACTURING SCHEDULING

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Keywords: Manufacturing scheduling, web service, decision-support system, and P2P network.

INTRODUCTION

Good scheduling can have a great impact on companies' performance because it can ensure good use of manufacturing resources and good customer service dependent on order delivery times. Doing it well is important for the success and competitiveness of industrial companies.

Due to scheduling complexity when a company does not have access to good methods it usually draws upon simple and empirical procedures whose quality of scheduling solutions provided tends to be poor. This is a situation that can be avoided if companies have access to good scheduling methods or services.

By exploring the Internet facilities in a network of scheduling service providers, users can ensure better scheduling of their industrial operations. This is because a pool of knowledge on manufacturing scheduling that has been developed by academia and industry over the years can be made available to a much larger community of users. This idea is explored in this paper toward developing a web decision-support system for manufacturing scheduling, based on a P2P network of scheduling methods providers.

The paper is organized as follows. The next section briefly reviews the literature on scheduling solvers available trough the Internet. The nature of manufacturing scheduling and, in particular, the need for using a scheduling problem notation for problem definition and scheduling methods selection, is pointed out in section 3. Section 4 describes the scheduling web decision-support system and the web service put forward on this system, focusing on its P2P structure, components and prototype and shows, through some examples, how it can be useful for manufacturing scheduling decision making. In section 5 we present a conclusion.

REVIEWING SCHEDULING SYSTEMS

We encounter in the literature reference to a variety of scheduling solvers. Well known are the Lekin system, developed under the supervision of Pinedo [1], oriented to flexible job shop scheduling, and also the Lisa Library of scheduling algorithms [2].

Traditional scheduling applications, running locally on PCs have been gradually substituted by more dynamic and world wide available applications and systems running on the Internet. The NEOS Server, developed by the Northwestern University and the Argonne National Laboratory, is an example. It is a web system for solving optimization problems [3]. It accesses nearly 50 solvers, through several different interfaces, for remotely solving problems. Another novel application is the ForthMP, a mathematical programming system running on the web, developed by the Mitra's Group of the Brunel University [4]. The Test Bench Assistant, under development under the IMS-NoE umbrella is another example running on the Internet [5]. Other systems and applications can be accessed through sites such as [6, 7, 8]

Although useful and creative these scheduling applications and systems may be, in general, they tend to be centralized, based on a number of available methods and procedures provided for user access to solve problems. In this paper we explore a different approach, namely the development of dynamically upgradeable scheduling systems based on methods distributed globally and selectively chosen for solving scheduling problems.

SCHEDULING PROBLEMS

Manufacturing scheduling problems have a set of characteristics that need specification for problem identification. These characteristics can be organized into classes and represented through a classification nomenclature or notation. A variety of classification schemes and notations have been put forward by several authors [9, 10, 11]. One class of characteristics of problems, frequently referred as class α, specifies the manufacturing scheduling environment, essentially identifying production system requirements and structure and the number of machines or processors that can be available. Another, the β class deals mainly with characterization of jobs, production resources and processing requirements. Some important processing requirements that frequently have to be considered have to do with production resources. These, in addition to machines, may include operators, tools, handling devices and buffers. These are usually seen as auxiliary resources. The third, the γ class, specifies the optimization criteria. Typical examples of these are minimization of total or mean flow time, maximum completion time or makespan and maximum lateness of jobs. Sometimes measures based on multi criteria need do be specified.

In this work, the classification notation developed by Varela et al [12], which extends and merges ideas from other notations, is used for XML-based scheduling problems representation. It includes a wide range of problem classification parameters, which may be combined in different ways, for representing many different scheduling problems. For example, class fm/FP,m|n|Fmax, refers to the problem of processing n jobs on a pure flow shop (fm/FP), with m machines, with jobs simultaneously available for processing in the beginning of the production period. The optimization criterion consists on minimizing the total flow time of all jobs (Fmax). This notation is associated to methods, according to the class of problems that they can solve. This is important for easing the search process for methods to solve problems. This strategy is implemented in the work described in this paper. However, when problem instances have to be solved, all detailed problem data has to be specified. This is done based on the methods' signature, i.e. input data and formats required by the method to solve the problem. This signature has to be provided by every method which can be used for providing scheduling services.

P2P SCHEDULING NETWORK

We may define a P2P network as a network of several computers, i.e. peers, which do not have a permanent client or server nature but, instead, work dynamically as both, depending on a transaction or service being received from or supplied to the network [13, 14].

P2P technology enables distributing information in a network of peers by providing any user with direct or indirect access to peers in the network. The peers collaborate forming a virtual network for communication and data transfer and for solving problems in a collaborative manner.

In networked environments, distributed knowledge bases and intelligent brokers, for information retrieval from specialized servers and knowledge repositories distributed across the Internet, enable to establish high-quality problem solving, through knowledge and resource sharing. In this context, emerging peer-to-peer technology and appropriate networks suit well to the increasingly decentralized nature of modern companies and their industrial and business processes, whether it is a single enterprise or a group of companies. The P2P framework provides the capabilities that allow peers to directly interact with each other [13, 14].

Characteristics of P2P networks are explored for the design of a manufacturing scheduling web decision-support system, of which a simple prototype is described and illustrated through some examples in this paper. This design follows a P2P network development based on XML and related technologies [15, 16].

The web system described in this paper follows this P2P computing model, where a set of peers, contributing with a local knowledge base component, composes a DKB as a P2P network. The P2P network has the capability of allowing a direct-interaction between the peers, which turns the computing environment decentralized, namely in terms of storage, computations, messaging, security and distribution. One of the greatest benefits of this P2P network, in the context of this work, is to easily support the concept of community. Consequently, it is possible for users to organize themselves into groups that can collaborate with each other in order to achieve certain goals. One of the main goals aimed at in this work is the collaborative improvement of the resolution of manufacturing scheduling problems. This is possible through the DKB for manufacturing scheduling by easily accessing different scheduling approaches spread through a P2P network integrating several methods servers. This is achieved by providing a mechanism that allows the members of the P2P network to share their scheduling knowledge and scheduling methods.

Figure 1 shows a general outline of the P2P web system's architecture.

The system is able to quickly assign methods to problems that occur in real world manufacturing environments and solve them through the execution of one or more appropriate implemented methods that are local or remotely available and accessible through the Internet.

The selection of one or more specific scheduling methods for solving a given problem is made through a searching process on the distributed knowledge base.

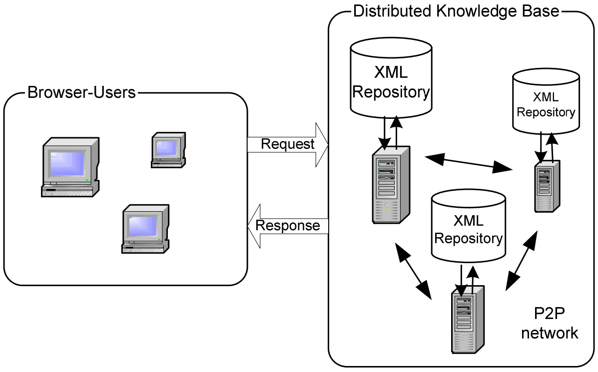

Fig. 1. P2P web system architecture

WEB SERVICE

The term web service has emerged as a general category for loosely coupled, dynamically connected web-based services and are a set of tools that let us build distributed applications on top of existing web infrastructures.

Many different scheduling methods, i.e. algorithms and procedures, for solving manufacturing scheduling problems are or can be made available through the Internet using web service technology.

For different methods and in some cases for the same method, different implementation approaches and instances may be used which may require input data, and/ or solution results, in different formats. When the need for solving a scheduling problem arises the use of a given Internet implementation requires problem data being provided in the right format and results conveniently supplied for user utilization and manipulation. To achieve this, a communication model is necessary for enabling data transferring between peers, for specifying problems needing solution and providing scheduling service by the peers, which solve the problems and send back the results. For this, we developed an XML structure, which is used in the communication process between the peers.

Knowledge usage in computer systems directly depends on knowledge representative schemes. The standardization of extensible markup language (http://www.w3.org/XML/) on the Internet gives new opportunities in such direction. XML provides general markup facilities that are useful for data interchange. The web system described in this paper is based on XML modeling and related technologies.

The web service use XML to encode both the message wrapper and the content of the message body. As a result, the integration is completely independent of operating system, language or other middleware product used by each component participating in the service. The only fundamental requirement is that each component has the ability to process XML documents and that each node or peer connected in the distributed system supports HTTP as a default transport layer [15, 16].

A web service is most commonly used to invoke remote applications or methods using a remote procedure call interaction (RPC) implemented using only XML messages [17].

The XML-RPC protocol is the sequence and structure of requests and responses required to invoke communications on a remote machine and consists on the communication protocol used on this work. Several other protocols that could also be used exist, namely SOAP (Simple Object Access Protocol), UDDI (Universal Description, Discovery, and Integration of business for the web), WSDL (Web Services Description Language), or other well known, like CORBA (Common Object Request Broker Architecture), RMI (Remote Method Invocation) or DCOM (Distributed Component Object Model). Nevertheless, XML-RPC is among the simplest and most foolproof web service approaches, and makes it easy for computers to call procedures on other computers [17]. The extensible markup language provides a vocabulary for describing remote procedure calls, which are then transmitted between computers using the HTTP protocol.

XML-RPC clients make procedure requests of XML-RPC servers, which return results to the XML-RPC clients. XML-RPC clients use the same HTTP facilities as web browser clients, and XML-RPC servers use the same HTTP facilities as web servers.

By using the XML-RPC protocol we are able to invoke scheduling methods implemented on different programming languages. Moreover, these methods, local or remotely available, may be running on different platforms.

This environment is heterogeneous as servers can use their own technology, i.e. use different implementation languages or/ and different operating systems.

More detailed information about the XML-RPC protocol can be obtained from http://www.xmlrpc.com.

SOME EXAMPLES

Manufacturing scheduling problems to be solved must initially be specified through XML documents. Each document has two different XML parts. The first is the heading of the document and the second contains data instantiating the problem class. This data could be directly input by the user in the XML document, but in this prototype this is done through a user interface. The interface was developed to ease the user task of inputting problem data. This input is used for automatically generating the XML problem data.

There is also other XML data that is necessary in the communication process, such as the IP of machines and data size of document etc., which are generated and managed by the web system.

Example 1

Let us consider a manufacturing scheduling problem example, where we have 4 jobs, which have to be processed on a pure flow shop system integrating 3 machines. The objective consists on minimizing the total flow time (Fmax). Table 1 shows the processing time for each job j on each machine i.

Table 1. Data for a fm/FP,3|4|Fmax problem

i \ j	J1	J2	J3	J4
M1	3	11	7	10
M2	4	1	9	12
M3	10	5	13	2

For solving this kind of problem, which belongs to class fm/FP,m|n|Fmax, with m equal to 3 and n equal to 4, we can select the Branch and Bound (B&B) method by Ignall and Schrage. This method was implemented in C++ under the XML-RPC protocol and Listing 1 shows an example that joins the headers and XML payload to form a complete XML-RPC request for solving the given problem instance.


```
POST /rpchandler HTTP/1.0
User-Agent: AcmeXMLRPC/1.0
Host:localhost:5001
Content-Type: text/xml
Content-Length: 832
<?xml version="1.0"?>
<methodCall>
<methodName>getExactBranchBound</methodName>
<params>
  <param><value><int>4</int></value></param>
  <param><value><int>3</int></value></param>
  <param><value>
    <array><data>
       <value><string>J1</string></value>
       <value><string>M1</string></value>
       <value><double>3</double></value>…
     </data></array>
</value></param></params></methodCall>
```


Listing 1. A complete XML-RPC request

Upon receiving an XML-RPC request, an XML-RPC methods server must deliver a response to the client. The response may take one of two forms: the result of processing the method for the given problem instance or a fault report, indicating that something has gone wrong in handling the request from the client. As with an XML-RPC request, the response consists of HTTP headers and an XML payload.

Listing 2 shows a complete response from an XML-RPC methods server, including both the HTTP headers and the XML payload.


```
HTTP/1.0 927 OK
Date: Fri, 25 Oct 2002 07:38:05 GMT
Server: MyCustomXMLRPCserver
Connection: close
Content-Type: text/xml
Content-Length: 868
<?xml version="1.0"?>
<methodResponse>
<params>
  <param><value><string>J1,J3,J4,J2</string></value>
  </param>
      <param><value><double>39</double></value>
</param>
  <param><value>
    <array><data>
       <value><string>J1</string></value>
       <value><string>M1</string></value>
       <value><double>0</double></value>
       <value><double>3</double></value>…
     </data></array>
</value></param></params></methodResponse>
```


Listing 2. A complete XML-RPC response

The response is provided to a call to the previously referred Branch and Bound (B&B) method getExactBranchBound, which returns a solution to the fm/FP,3|4|Fmax problem, which can be presented in several distinct formats to the user, namely through a table or a Gantt chart, indicating each job starting and finishing time on each machine of the pure flow shop system with three machines and the performance measure value, which in this case is the total flow time of the four jobs, with the minimum value of 39 time units for the J1, J3, J4, J2 optimal jobs sequence.

Example 2

Another problem that may arise in the context of manufacturing and which is largely considered in the arena of scheduling problems consists on processing a number of n jobs on a pure flow shop system integrating only two machines, maintaining the objective of minimizing total flow time of jobs, fm/FP,2|n|Fmax. Consider, for example, a problem instance with six jobs, with the processing times (pji) given in Table 2, for processing each job j on each machine i.

Table 2. Data for a fm/FP,2|6|Fmax problem

i / j	T1	T2	T3	T4	T5	T6
m1	2	3	2	6	2	5
m2	4	1	5	3	4	7

By applying the Johnson's method [18], which consists on a very simple method, based on the

SPT (shortest processing time) rule, it is possible to obtain an optimal solution for the fm/FP,2|6|Fmax problem.

Figure 2 shows the Gantt chart with the starting and finishing times of each job on each machine for the given problem. Moreover, we can realise that the optimal value for the total flow time of jobs is 26 time units and the optimal jobs processing order on the pure flow shop system is job5, job3, job1, job6, job4, job2.

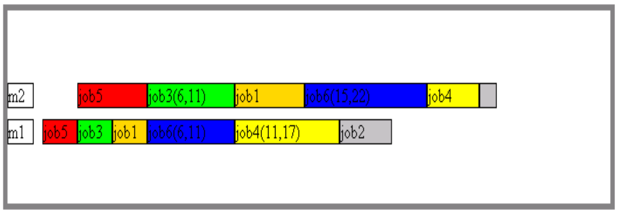

Fig. 2. Gantt chart for the fm/FP,2|6|Fmax problem

Example 3

Let us now consider another example about a problem that includes again six jobs, for which we want to minimize once more the total flow time (Fmax), but this time assuming that these jobs have to be processed on a pure job shop system with two machines (fm/JP,2). This problem belongs to problem class fm/JP,2|n|Fmax, and the corresponding processing times (pji) of each operation (1^{st} and/or 2^{nd}) of job j on each machine i (M_A and/ or M_B) are presented on Table 3.

Table 3. Data for a fm/JP,2| 6| Fmax problem

j	Job1	Job2	Job3	Job4	Job5	Job6
1^{st}	3|M_A	5|M_A	6|M B	6|M_B	2|M_A	5|M_B
2^{n}	4|M_B	---	---	3|M_A	4|M_B	7|M_A

Applying the Jackson's method [18] for solving this problem instance we obtain the results presented on the Gantt chart presented on Figure 3, where we again have the starting and the finishing times of each job on each machine A and B and the minimum value of the total flow time with 25 time units.

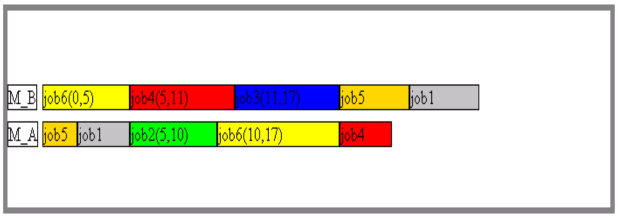

Fig. 3. Gantt chart for the fm/JP,2|6|Fmax problem

CONCLUSION

We can view the distributed knowledge available on computers as a very large knowledge base that can be accessed by users as long as adequate platforms and systems are developed and used.

In this paper this idea is explored through the concept of a P2P web-based decision-support scheduling system of manufacturing tasks, based on a network of computers. In this network each peer may supply and receive scheduling services. This system is based on scheduling methods that are available globally and accessed through the Internet.

A prototype of this system was designed and implemented with the support of XML-RPC technology and P2P networks and based on the use of XML and related technology.

Some application examples of use of the web system, to solve static pure flow shop and job shop problems for minimizing total flow time measure were presented.

References

[1]http://www.stern.nyu.edu/om/software/lekin/index.htm
[2] http://lisa.math.unimagdeburg.de/
[3] (http://www-neos.mcs.anl.gov/
[4] http://www.brunel.ac.uk/depts/ma/research/com
[5] http://www.ims-noe.org/BENCHMARK/TBA.asp
[6] http://vishnu.bbn.com
[7] http://www.ocea.li.univ-tours.fr/eocea/index.jsp
[8]http://riot.ieor.berkeley.edu/riot/Applications/Scheduling/index.html.
[9] Conway RW., Maxwell WL., Miller LW. Theory of Scheduling. Addison-Wesley Publishing Company Inc., England, 1967.
[10] Brucker P., "Scheduling Algorithms" Springer-Verlag, 1995.
[11]Blazewicz J., Ecker KH., Pesch E., Schmidt G., Weglarz J. "Scheduling Computer and Manufacturing Processes", Springer-Verlag, 1996.
[12]Varela MLR., Aparício JN., Silva SC. A Scheduling Web Service, In: Proceedings of the 1st International Conference on Scheduling: Theory and Applications, ICAPS'03, Nottingham, UK. ASAP, The University of Nottingham. 2003, pg. 540-551.
[13] Papazoglou MP., Krämer BJ., Yang J. Leveraging Web-Services and Peer-to-Peer Networks. In: Proceedings of Advanced Information Systems Engineering, 15th International Conference, CAiSE, Klagenfurt, Austria. June 16-18, 2003, pp 485-501.
[14] Terziyan V.; Zharko A. Semantic Web and Peer-to-Peer: Integration and Interoperability in Industry, Industrial Ontologies Group, MIT Department, University of Jyvaskyla,Finland (http://www.cs.jyu.fi/ai/vagan/papers.html).
[15] Ceponkus A, Hoodbhoy F, Applied XML. USA: Wiley Computer Publishing, 1999.

[16]Abiteboul S et al, Data on the web - from relations to semi structured data and XML. USA: Morgan Kaufmann Publishers, 2000.
[17] Laurent S, et al. Programming Web Services with XML-RPC. O'Reilly & Associates, Inc., 2001.
[18]Baker KR. Introduction to Sequencing and Scheduling. John Wiley & Sons, NY, 1974.

IMPROVING PROCESSES THROUGH THE EVOLUTION OF SOFTWARE: A CASE STUDY

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Keywords: processes, information management, technology, implementation, software engineering, agility

1. INTRODUCTION

The evolution of software constitutes sometimes opportunities to not only improve the conditions for using the software, but also a way of streamlining and improving the processes where it is used.

In a period of four months and a half (from end of October 2007 through middle of February of 2008), António Pedro Pinho (under the direction of João Pinho Ribeiro) carried out in ARSOPI's foundry the development of a software whose process of creation, the methodologies used and many of the main questions that arisen are described in this case study.

2. THE COMPANY ARSOPI

Established since 1942 the company ARSOPI - Indústrias Metalúrgicas Arlindo S. Pinho, S.A., is located in Vila Chã – Vale de Cambra.

ARSOPI's specialty is the construction of equipment with the following materials: Stainless steel, Carbon steel, Low alloy steel, Clad steel, Duplex steel, Special and refractory steel, Nickel and nickel alloys, Copper and cooper alloys, Aluminum, Titanium.

In a covered area of 30.000m2 ARSOPI has modern machines with great capacities and skilled professionals, ready to satisfy demands in the manufacturing of equipment for the various fields (dairy, wine and beverages, chemical and petrochemical and nuclear).

2.1 ARSOPI's foundry

ARSOPI's foundry (where the case study occurred) is prepared to produce different kinds of materials ranging from stainless steel to nickel alloys using self-drying sand process moulding (up to 600kg) or ceramic process up to box dimensions of 600 x 500 mm and weight of 25 kg.

Usually, ARSOPI's foundry supplies equipment manufacturers and engineering companies either directly or as sub-suppliers in the chemical and petrochemical areas, power production and waste treatment, and other areas like metallurgical furnaces, paper, cellulose and recycling, textile industries, food and dairy and naval construction.

2.2 The melting process of the foundry

The load ratio of a furnace is determined by the customers' specifications and the raw material that needs to be combined in certain proportions to meet the specifications of customers.

After calculated the quantities of raw materials, start up the process of melting. When the melting metal reaches a certain temperature, a sample is taken.

This sample is analyzed in a mass spectrometer, and it will result in a correction of the load in the furnace with the addition of several materials. Only after these steps are being made, the melting metal is casted into the moulds.

ARSOPI's foundry has internal specifications for the production of steel and nickel alloys [1]. These specifications are designed to combine in a single document, values specified in various standards.

2.3 The first software approach

The calculation of the load ratio of a furnace is determined by the client specifications and the combination of different raw materials. In the early years, this calculation was made manually by ARSOPI's engineers.

Since 1989, ARSOPI's foundry began to develop the initial software, called "CARG" and

"CORR", both developed in QuickBasic to the environment MS-Dos.

The “CARG” software allow the calculation of the quantities of raw materials for the base load’s and the “CORR” software allow the calculation of the quantities of materials needed to the correction of the melting material.

The algorithm used on the above software’s was based partly on the experience obtained over time by ARSOPI´s engineers and also with the possibility of obtaining the reading (through a spectrometer) of a sample of the melting material.

These two software’s (“CARG” and “CORR”) cover the needs of calculating the raw materials necessary for the base load and their corrections, but over time, arisen the need to integrate new features to accelerate the management of the melting process.

3. THE MELTING MANAGEMENT PROCESS SOFTWARE

3.1 Key objectives

The key objectives of the new software, denominated “Melting Management Process software” where the following:

- Improve "CARG98" and "CORR2000" (last evolution’s of “CARG” [2] and “CORR” [3]);
- Build a database that would make the management of all materials used in the melting process;
- Integrate the analysis (made by the mass spectrometer) of the samples from the melting materials with the new software in an automatic way.
- Create a more functional and user-friendly application,

3.2 Software platform

The first decision to make is to choose the software platform to use. The original program was written in QuickBasic and the first idea was adapting the algorithm to VB (Visual Basic) [4] .

Although was possible to implement a connection to a database (one of the objectives) from VB, the work effort involved was greater then using a rapid application development (RAD) with database functionality and programming capabilities.

By that reason, the Microsoft Access [5] was adapted as the software development platform.

3.3 Initial approach

The earlier questions that arise when creating the new software were mainly three:

- Were to begin?
- How to maximize the use of the experience gathered in the software “CARG” and CORR”?
- How to adapt and implement its algorithms in the new software platform?

Since “CARG” software was used in the start of the management of the melting process, was decided to begin to analyze that software and that the approached taken to translate the algorithm to the new platform will be also used in the translation of the “CORR” software.

The first step was the translation of the original coding in QuickBasic to Visual Basic for applications (the programming environment used in Microsoft Access). Another set of questions arise in this step:

- Is the syntax of Visual Basic for applications equal to the syntax of QuickBasic?
- All the commands used in QuickBasic are available in Visual Basic for applications?
- Because the interface of the “CARG” software was developed in an MS-Dos environment, which are the commands that where connected to this environment?

The answers for these questions were obtained after analyzing the code of “CARG”, which had about 1100 lines of code (NOTE: the “CORR” had about 2300 lines of code)-

Some commands connect with the MS-DOS environment like CLS, COLOR, LOCATE, PLAY and others were found in CARG code and where considered dispensable.

Other commands (like PRINT, GOTO, etc) where considered needed for the algorithm work, but must be “readdressed” / translated for equivalent commands / objects in Visual Basic / Access.

3.4 Translation of “CARG’s code

The translation of the code was made in four stages:

First stage: the entire code of “CARG” was imported into a module of VB inside Microsoft Access.

Second stage: Eliminate all commands that where dispensable (CLS, COLOR, etc.)

Third Stage: Substitute the commands that must be “readdressed” or translated. (By example, the PRINT command was readdressed in a first stage to the Debug.PRINT command in the VB programming environment.

Forth stage: The use of the Debug.PRINT command with the use of “immediate Window” in the VB programming environment allowed debugging and testing of the ported code.

This testing was made by checking the results of the ported coding with the results obtained from the “CARG” program.

3.5 Creation of the database structure

In the original “CARG” and “CORR” software the raw data needed to calculate the raw materials (to define the melting materials) was hardcoded inside the program, it’s internal database could only be updated by the program developer, which was starting to be a major setback.

Mainly by that reason, the new software should get its data from a database structure with the capability of being user-friendly.

The first step was to study the information needs, from two points of view:

- What is needed for running the algorithm that calculates the raw materials?
- What more information is necessary to kept to improving the management of the melting process?

The information and data needed in the context of the first point of view was discovered after the original algorithm was studied.

The data that support the calculation of the quantity of the raw material was in a set of arrays with the data of the different materials that could be used in the melting process and the respective weights.

The management of the melting process included a paper archive with information of all loads and the manual introduction of the loads data (base materials, correction materials and load characterization) in a database program, which consumed work time.

By analysing the whole set of information needs (calculation and record keeping), a first database structure was achieve. After various considerations (and further integrations and developments) this database evolved through his natural development cycle to the final relations diagram presented in figure 1.

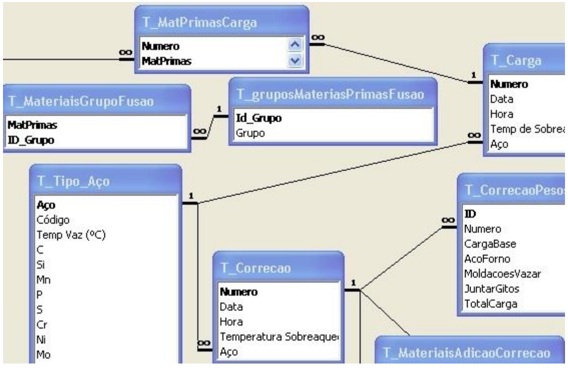

Fig. 1. Extract of the final relations diagram

3.6 Creation of the database interface

The database interface constituted the way to integrate the database structure, the calculation algorithm of the loads and of the algorithm of loads correction translated to Subroutines in VB modules.

The interface creation was driven by two main requisites:

- Process driven;
- User friendly, with good readability.

The interface should be “natural” to the employees that use it and reflect the process sequence that is needed to do to manage the melting process.

The interface it should be also user friendly and readable, since one of the problems of the “CORR” and “CARG” software is the repartition of information in several screens due to limitations in the MS-Dos environment in which was created as seen in figure 2.

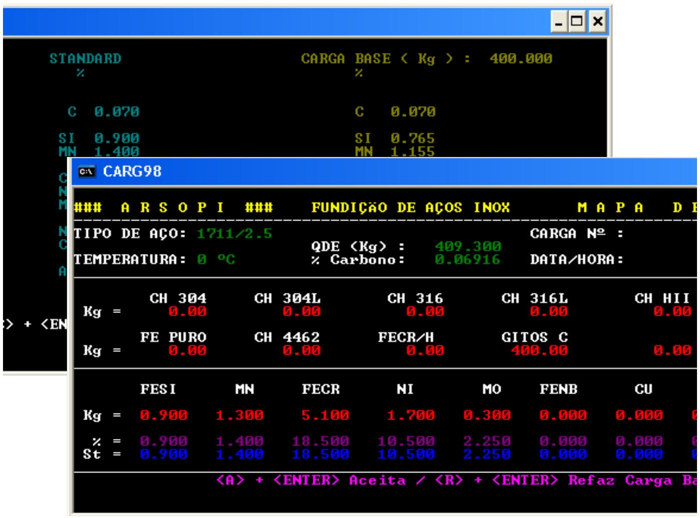

Fig. 2. Part of “CARG” software interface

After some iteration in the design of the interface, the final design achieved for the main form for the calculation of the base loads incorporated in one screen features like:

- easy raw material selection;
- easy chrome type selection;
- creation of new raw material and type of steel;
- calculation of the chemical composition of the melted steel
- warnings of possible deviation between the calculated composition and the clients specifications,
- Help system to enlighten the process calculation.

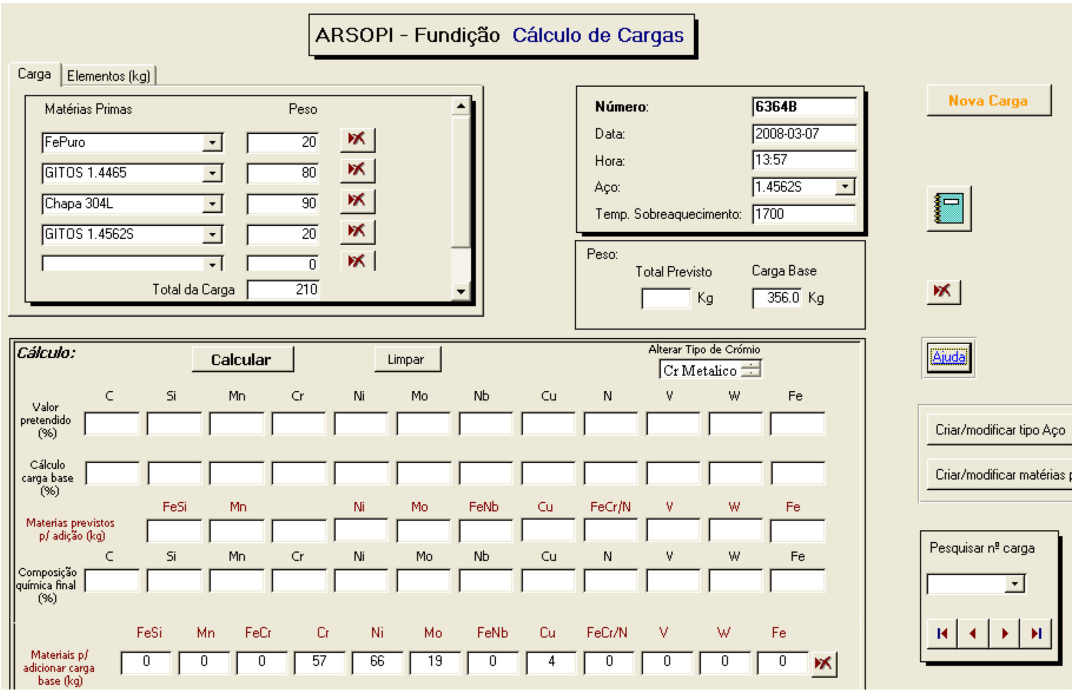

Fig. 3. Form interface to the calculation of base loads.

To use the data in the form as input for the calculation algorithm, several modifications were made in the implementation. The connection with the data was made by using Visual Basic, SQL instructions and several queries in Microsoft Access.

After calculating the quantities of raw materials, the calculation data is present in the form. To present the data in the form, a mix of Visual Basic, SQL instructions and queries were used.

3.6 Improvements incorporated

In the “Melting Management Process” software some improvements were incorporated in relation to the “CARG” and “CORR” software. The “CARG” software was used BEFORE the melting process started. The “CORR” software was used in the MIDDLE of the melting process, to calculate the corrections (if needed) to the melting metal.

The data needed to this correction is obtained from analysing a sample of the melting metal in a mass spectrometer and using that information as the basis of calculation. The mass spectrometer in ARSOPI’s foundry gives the information by writing a file.

In the “CORR” software the file with the information was printed and the values were introduced manually.

One of the improvements achieved was the automatic reading of the mass spectrometer into the new “Melting Management Process” software.

The steps taken to achieve this improvement were the following:

- Analysing several readings from the mass spectrometer and try to establish a pattern of information;
- If a pattern was found (and it was) mapping the information, i.e., capturing the type, positions and dimensions of the data;
- Importing the information to the “Melting Management Process” software and

connecting that information with the respective load.

Another improvement was the addition of three new chemical elements in the calculation algorithm addressed to nickel alloys, improving the base loads and minimizing corrections.

Another improvement was the connection made to the “FUSAO” database. The “FUSÂO” database manages all the materials used in the foundry. When “CARG” and “CORR” where used, the data was manually inputted.

The objective was, with a simple click store all data of the load in the “FUSAO” database. Because of its different nature, another data mapping between those applications (and another set of tables and procedures) was developed. This “one click data transfer connection” saves about 100 minutes each work week.

4. CONCLUSIONS

This software evolution from “CARG” and “CORR” to the “Melting Management Process” software brings process improvements in several areas.

The software usability which made possible several improvements and **greater agility in day to day management operations** like:

- Addition of the raw materials is easier and developer independent
- For the calculation of the base loads, data input is easier and faster
- The input from mass spectrometer is automated
- The calculation of the loads corrections is faster

Another area of **improvements is the traceability** of the raw-materials used in each load. In this software, the data that characterizes each load is kept in electronic record which is faster and efficient to retrieve by comparison with hardcopy print (NOTE: a hard copy in paper is also created by the software).

In the formation area, the creation of a help system (html based) ensures that **the knowledge to operate this software is available.**

This software evolution achieved also **savings in refractory lining of the furnace**, **extending its useful life**, since every step of the calculation of correction (procedure that is done with the furnace working) has been streamlined.

ACKNOWLEDGEMENTS

We want to thank for the opportunity given by ARSOPI’s foundry to implement this software which was created by the synergies developed between industry and academic institutions.

We wish also to thanks to Paulo Soares (Assistant Manager and Production responsible of ARSOPI’s foundry) and Manuel Bexiga (ARSOPI’s Quality Director).

References

[1] ARSOPI, Internal specifications for the production of steel and nickel alloys
[2] P. Soares, “CARG”- The load ratio of a furnace [computer software], 1998
[3] P. Soares, “CORR” - Melting load correction calculation software [computer software], 1998
[4] Microsoft, Integrated manual of VB development environment, 2000
[5] Microsoft, Integrated manual of Microsoft Access, 2000

INCREASING PRODUCTIVITY OF KNOWLEDGE WORKERS BY ONTOLOGICAL TRAINING

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Keywords: knowledge-driven organizations, productivity of knowledge workers, learning, thinking, analyst training.

1 INTRODUCTION

A central problem for supporting all phases of knowledge processing is still the productivity of the knowledge workers and usage of the special techniques and models for the integration of various knowledge patterns within and across enterprises. Knowledge work deals with structuring. New information age with huge information overload makes knowledge processing more and more sophisticated. Sophistication needs professionals.

How many professional knowledge engineers need the company targeted at busines sustainability? How to find them and to teach?

Knowledge Engineering traditionally emphasizes and developes a range of techniques and tools including knowledge acquisition, conceptual structuring and representation models [1], [2]. But for practitioners as enterprise analysts it is still a rather new, eclectic domain that draws upon areas like cognitive science. Accordingly, knowledge engineering has been, and still is, in danger from fragmentation, incoherence and superficiality. Still few universities deliver courses in practical knowledge engineering.

Many companies take decision to teach and train their IT-staff and developers. This paper describes recent experience in such training for some Russian subsidiaries of international companies (British-American Tobacco, Siemens Business Services, etc.). The total number of trainees that received certificates of knowledge analysts is more than 60.

Training for Knowledge Engineering (TKE) is based on university courses in intelligent-systems development, cognitive sciences, user modelling and human-computer interaction delivered by author in 1992-2005. TKE proposes information structuring multi-disciplinary methodology, including the principles, practices, issues, methods, techniques involved with the knowledge elicitation, structuring and formalizing. Emphasis is put not on technologies and tools, but in training of analytical skills. Ontological Engineering is further development of knowledge engineering towards ontology design and creating.

2 KNOWLEDGE ANALYSTS TRAINING OUTLINE

The future analysts gain an understanding the role of knowledge engineering and knowledge management in companies and organizations; in decision-making by members of an organization; in developing information framework. They study and are trained in practical methods mainly by doing.

Trainees are introduced to major issues in the field and to the role of the knowledge analyst in strategic information system development. Attention is given both to developing inter-personal information communication skills and analytical cognitive creative abilities. One group is not more than 8 persons.

The class features short lectures, discussions, tests, quizzes and exercises. Lectures are important but the emphasis is put on learning through discussions, simulation, special games, training and case studies. A good deal of the course focuses on auto-reflection and auto-formalizing of knowledge, training of analytical and communicative abilities, discovery, creativity, cognitive styles features, and gaining new insights.

TKE consists of 4 inter-connected modules:

- Getting Started in KE (12 hours),
- Practical KE in depth (12 hours),
- Ontological Engineering (12 hours),
- Business Processes Modelling (12 hours).

Different combination of sub-topics is possible. Fig.1 illustrates the structure of one variant chosen by Business Engineering Group Company.

The main difference of TKE to existing methodologies is cognitive (not technological) bias. The topics of exercises cover categorization, observation, laddering, lateral thinking and other problem solving cognitive methods. IT-managers often under-value the significance of psychological background of categorization, laddering and lateral thinking. But during training some of them feel "insight" and become very enthusiastic.

But only knowledge structuring exercises show the importance of obtained analytical skills in practice. Even simple tests from their professional domains are rather difficult at the first workshops.

The training is aimed on semantics not syntax of knowledge engineering. We suppose that systems and languages may be self-studied while general scope and knowledge-stressed approach should be trained thoroughly. Practical specialists often under-estimate the role of cognitive styles, verbal skills and logics in information processing. It is supposed to be guided common sense while it needs to be taught.

Since 2000 a major interest of researchers focuses on building customized tools that aid in the process of knowledge capture and structuring. This new generation of tools – such as Protégé, OntoEdit, and OilEd - is concerned with visual knowledge mapping that facilitates knowledge sharing and reuse [5], [6], [7]. The problem of iconic representation has been partially solved by developing knowledge repositories and ontology servers where reusable static domain knowledge is stored. Ontolingua, and Ontobroker are examples of such projects [8], [9].

But practitioners from companies need simple and constructive algorithms for their activity.

Ontology creating also faces the knowledge acquisition bottleneck problem. The ontology developer encounters the additional problem of

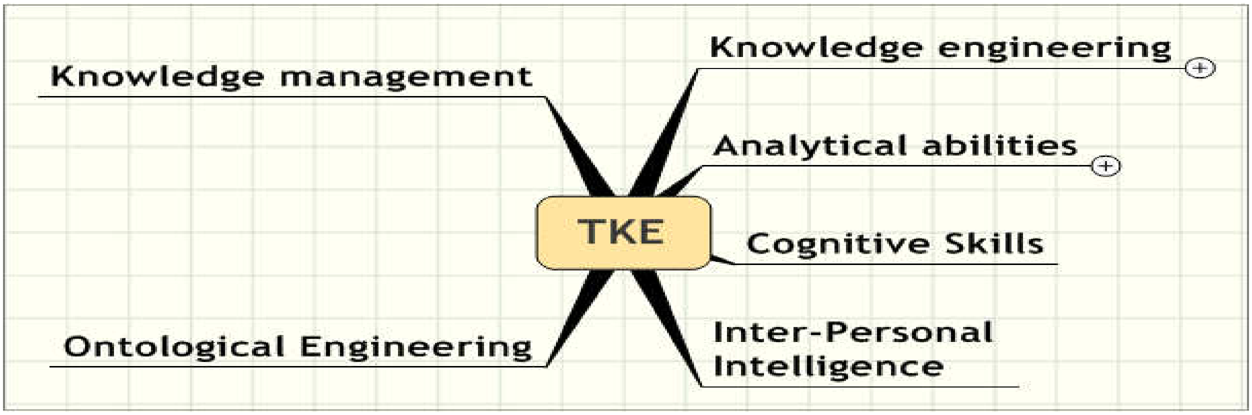

Fig. 1. Outline of training of knowledge engineering

We try to implement the ontological approach into the teaching style and strategy. Philosophers of science define ontologism by postulating existence of the systemic hierarchial conceptual specification of any complex object.

3 TEACHING ONTOLOGICAL THINKING AND DESIGN

Ontologies can be used to describe any business world. But our experience in training show that nobody can deal with ontologies without knowledge engineering practice. How to teach ontology design? The theory differs from practical needs…

There are numerous well-known definitions of this milestone term (Gruber , 1993; Guarino and Giaretta, 1998; Jasper and Uschold, 1999; Mizogushi and Bourdeau, 2000; Neches, 1991) but they may be generalized as "Ontology is a hierarchically structured set of terms for describing an arbitrary domain"[3]. In other words "ontologies are nothing but making knowledge explicit" [4].

not having sufficiently tested practical methodologies, which would recommend what activities to perform. An example of this can be seen when each development team usually follows their own set of principles, design criteria, and steps in the ontology development process. The lack of structured guidelines hinders the development of shared and consensual ontologies within and between the teams. Moreover, it makes the extension of a given ontology by others, its reuse in other ontologies, and final applications difficult [10].

Several effective methodological approaches have been reported for building ontologies [11]; [12], [13]. What they have in common is that they start from the identification of the purpose of the ontology and the needs for the domain knowledge acquisition. However, having acquired a significant amount of knowledge, major researchers propose a formal language expressing the idea as a set of intermediate representations and then generating the ontology using translators. These representations bridge the gap between how people see a domain and the languages in which ontologies are formalized. The conceptual models are implicit in the implementation codes. A re-engineering process is usually required to make the conceptual models explicit.

Fig. 2 presents our vision of the mainstream state-of-the-art categorization in ontological engineering [4], [14], [15] and may help the knowledge analyst to figure out what type of ontology he/she really needs. We use Mindmanager™ and Cmap as they proved to be powerful visual tools.

We try to simplify a bunch of different approaches, terms and notations for practical use and dare to propose a 5-steps recipe for practical ontology design.

3.1 Ontology Design Recipe

The existing methodologies describing ontology life cycle [15], [13], [3] deal with general phases and sometimes don't discover the design process in details. Five simple practical steps were proposed.

Step 2. **Laddering:** Having all the essential objects and concepts of the domain in hand, the next step is to define the main levels of abstraction. It is also important to elucidate the type of ontology according to Fig. 1 classification, such as taxonomy, partonomy, and genealogy.

This is being done at this step since it affects the next stages of the design. Consequently, the high level hierarchies among the concepts should be revealed and the hierarchy should be represented visually on the defined levels.

Step3. **Disintegration:** the main goal of this step is breaking high level concepts, built in the previous step, into a set of detailed ones where it is needed. This could be done via a top-down strategy trying to break the high level concept from the root of previously built hierarchy.

Step4. **Categorization:** At this stage, detailed concepts are revealed in a structured hierarchy and the main goal at this stage is generalization via bottom-up structuring strategy. This could be done by associating similar concepts to create

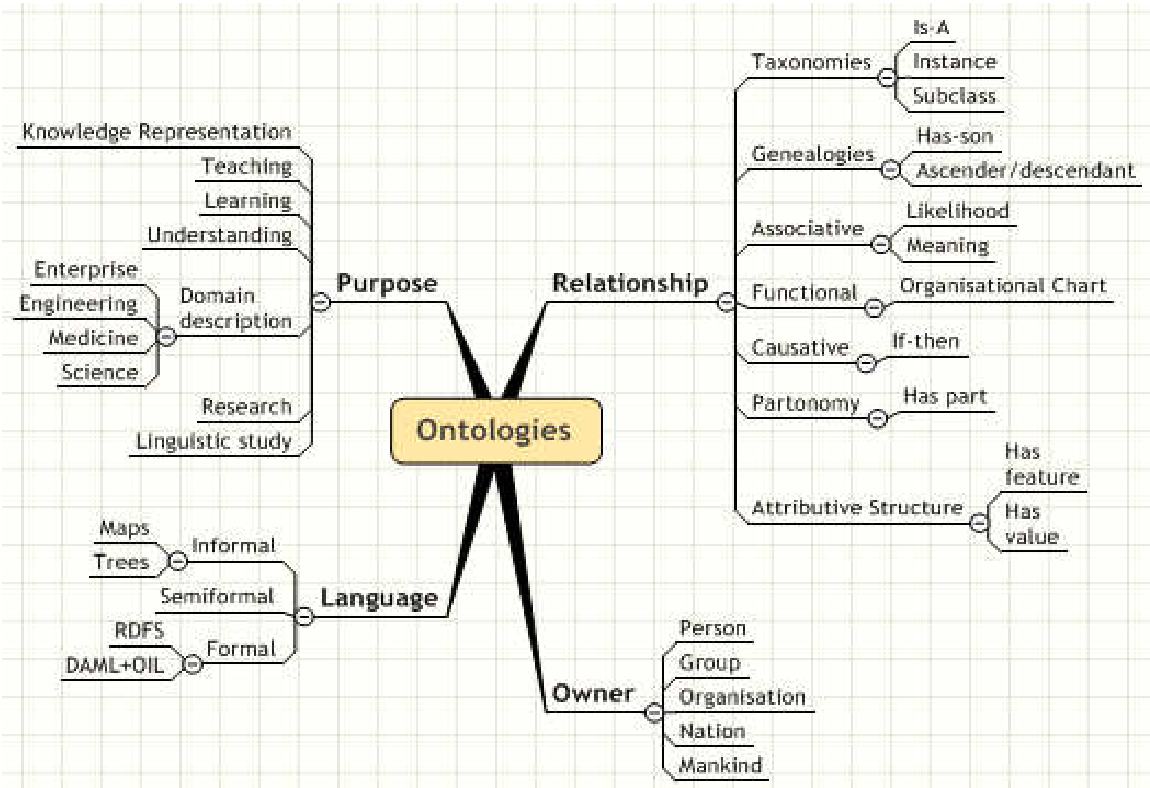

Fig. 2. Ontology mind map

Step 1. **Glossary development:** The first step should be devoted to gathering all the information relevant to the described domain. The main goal of this step is selecting and verbalizing all the essential objects and concepts in the domain.

meta-concepts from leaves of the aforementioned hierarchy.

Step 5. **Refinement**: The final step is devoted to updating the visual structure by excluding the excessiveness, synonymy, and contradictions. As mentioned before, the main goal of the final step is try to create a beautiful ontology. We believe what makes ontology beautiful is harmony.

Using these tips the trainees develop several huge company ontologies.

3.2 "Beatification" of Business Ontology

The idea of the good shape in modelling is rather common in science. Let's try to apply this approach to the ontology design. One of substantial impulse to it was given by German psychological school of M. Wertheimer. His idea of good Gestalt (image or pattern) may be transferred into ontological engineering. Some essential Gestalt principles of this school [16]:

- Law of Pragnanz (M. Wertheimer) - organization of any structure in nature or cognition will be as good (regular, complete, balanced, or symmetrical) as the prevailing conditions allow (law of good shape).
- Law of Proximity – objects or stimuli that are viewed being close together will tend to be perceived as a unit.
- Law of Similarity – things that appear to have the same attributes are usually perceived as being a whole.
- Law of Inclusiveness (W.Kohler) - there is a tending to perceive only the larger figure and not the smaller when it is embedded in a larger.
- Law of Parsimony – the simplest example is the best or known as Ockham's razor principle .(14-th century): ``entities should not be multiplied unnecessarily"

We suggest to use these laws for pursuing conceptual balance and clarity of corporate knowledge ontology.

3.2.1 Conceptual balance

A well-balanced ontological hierarchy equals a strong and comprehensible representation of the domain knowledge. However, it is a challenge to formulate the idea of a well-balanced tree. Here we offer some tips to help formulate the "harmony":

- Concepts of one level should be linked with the parent concept by one type of relationship such as is-a, or has part.
- The depth of the branches should be more or less equal (±2 nodes).
- The general outlay should be symmetrical
- Cross-links should be avoided as much as possible.

Fig.3 illustrates the idea of well-balanced (A) and ill-balanced (B) ontology design.

The maximal number of branches and the number of levels should follow Miller's magical number (7±2) [17]. Furthermore, the type of relationship should be clear and obvious if the name of the link is missed. .

Some practical tips to refine and illuminate the ontology's design layout stage can be proposed:

3.2.2 Clarity

Moreover, when building a comprehensible ontology it is important to pay attention to clarity. Clarity may be provided through number of concepts and type of the relationships among the concepts. Minimizing the number of concepts is the best tip according to Law of Parsimony .

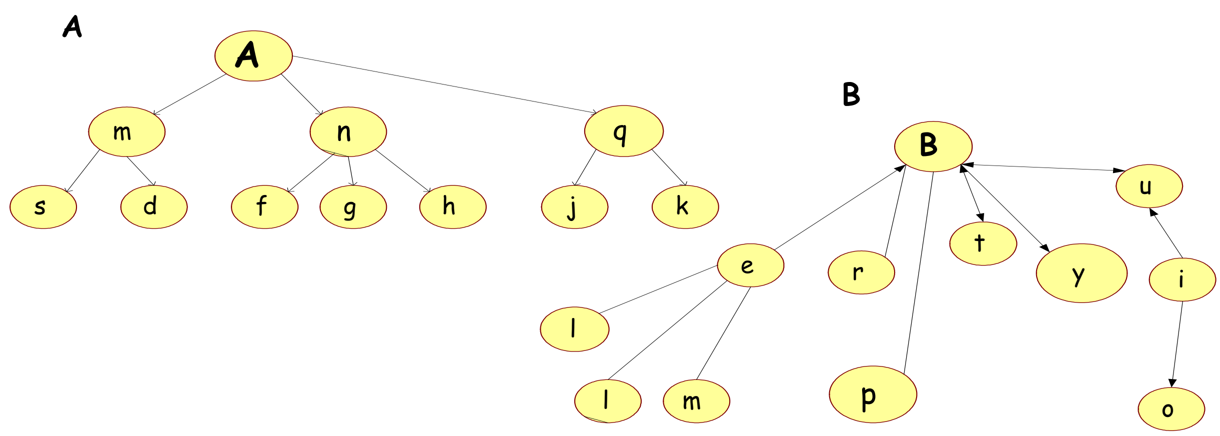

Fig. 3. Well-balanced" and "ill-balanced" ontologies

- Use different font sizes for different levels.
- Use different colours to distinguish particular subsets or branches.
- Use a vertical layout of the tree structure/diagram.
- If needed, use different shapes for different types of nodes.

At the first stages it is possible to use any of the available graphical editors to design ontology, e.g. PaintBrush, Visio, Inspiration. A nice layout can be reached by using mindmapping tools as MindManager™ or Visual Mind ™.

The trainees really enjoy the process of “beatification” of their ontologies during test exercises.

4 DISCUSSION

Business modelling needs business analysts. Analysts are super-knowledge workers, but even they enter “the world of ontologies” with some doubt. But in the training their interest grows and rather soon they begin to use ontologies in their practical work. Our experience in training of knowledge analysts in the period of 1999-2007 confirm the unique role of knowledge structuring for developing ontologies quickly, efficiently and effectively. We follow David Jonassen’s idea of мusing concept maps as a mind tool” [18]. The use of visual paradigm to represent and support the training process not only helps a professional trainer to concentrate on the problem rather than on details, but also enables students to process and understand greater volume of information.

The described approach is twice ontological as the development of educational knowledge structures in the form of ontologies provides training and learning support. Teaching ontologies used in the course scaffold and improve trainees’ understanding of the courseware and later help to realize substantive and syntactic company knowledge. As such, they can play a part in the overall pattern of learning, facilitating for example analysis, comparison, generalization and transferability of understanding to analogous problems.

Business is based on knowledge processing in the new information age. So skillfull knowledge workers really increase the productivity and sustainability of modern business practice.

References

[1] Adeli, H. (1994) Knowledge Engineering. McGraw-Hill, New-York.

[2] Scott, A., Clayton, J.E. & Gibson E.L. (1994) A Practical Guide to Knowledge Acquisition, Addison-Wesley.

[3] Gómez-Pérez, A., Fernández-López, M., Corcho, O. (2004) Ontological Engineering with examples from the areas of Knowledge Management, e-Commerce and the Semantic Web, Springer.

[4] Guarino, N., Welty, C. (2000) A Formal Ontology of Properties. In R. Dieng and O. Corby (eds.), Knowledge Engineering and Knowledge Management: Methods, Models and Tools. 12th International Conference, EKAW2000. Springer Verlag, pp. 97-112.

[5] OilEd (2004) Bechhofer, S. and Ng G. http://oiled.man.ac.uk/

[6] OntoEdit (2004) AIFB, University Karlsruhe Accessed from http://www.ontoknowledge.org/tools/ at December 07.

[7] Protégé, Stanford Medical Informatics. Accessed from http://protege.stanford.edu/ at December 07, 2004.

[8] OntoBroker (2004), Accessed from http://ontobroker.aifb.uni-karlsruhe.de.

[9] Ontolingua, Stanford University. Accessed from http:// www.ksl.stanford.edu/ software/ontolingua/ at December 7, 2004.

[10] Guarino, N. & Giaretta, P. (1998) Ontologies and Knowledge Bases: Towards a Terminological Clarification. // Towards Very Large Knowledge Bases: Knowledge Building & Knowledge Sharing, IOS Press, pp.25- 32.

[11] Fensel, D. (2001) Ontologies: A Silver Bullet foe Knowledge Management and Electronic Commerce. Springer.

[12] Swartout, B., Patil, R., Knight, K. & Russ, T. (1997) Toward Distributed Use of Large-Scale Ontologies. In Ontological Engineering, AAAI- 97 Spring Symposium Series, pp.138- 148.

[13] Mizogushi, R. and Bourdeau J. (2000), Using Ontological Engineering to Overcome Common AI-ED Problems. International Journal of Artificial Intelligence in Education, v. 11, pp.1-12.

[14] Jasper, R. and Uschold, M (1999). A Framework for Understanding and Classifying Ontology Applications. In 12th Workshop on Knowledge Acquisition Modeling and Management KAW'99.

[15] Uschold, M., Gruninger M (1996). "Ontologies: Principles Methods and Applications", Knowledge Engineering Review,vol1, N1.

[16] Werthheimer, M. (1959) Productive Thinking, HarperCollins.

[17] Miller, G. (1956) The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information // The Psychological Review, v. 63, pp. 81-97.

[18] Jonassen, D.H. (1998) Designing constructivist learning environments. In Instructional design models and strategies (Reigeluth, C.M. (Ed), 2nd ed., Lawrence Eribaum, Mahwah, NJ.

[19] Boose, J.H. (1990) Knowledge Acquisition Tools, Methods and Mediating Representations. In Knowledge Acquisition for Knowledge-Based

Systems (Motoda, H. et al., Eds), IOS Press, Ohinsha Ltd., Tokyo, pp.123-168.
[20] Eisenstadt, M., Domingue, J., Rajan, T. & Motta, E. (1990) Visual Knowledge Engineering. In IEEE Transactions on Software Engineering, Vol.16, No.10, pp.1164-1177.
[21] Gavrilova, T., Voinov, A. (1998) Work in Progress: Visual Specification of Knowledge Bases // Lecture Notes in Artificial Intelligence 1416 “Tasks and Methods in Applied Artificial Intelligence”, A.P.del Pobil, J.Mira, M.Ali (Eds), Springer, pp. 717-726.
[22] Gavrilova, T.A., Voinov, A., Vasilyeva E. (1999) Visual Knowledge Engineering as a Cognitive Tool / Proc. of Int. Conf. on Artificial and Natural Networks IWANN’99, Spain, Benicassim. - pp.123-128.
[23] Gavrilova, T. (2003) Teaching via Using Ontological Engineering // Proceedings of XI Int. Conf. “Powerful ICT for Teaching and Learning” PEG-2003, St.Petersburg, p. 23-26.
[24] Gavrilova, T., Kurochkin M., Veremiev V. (2004) Teaching Strategies and Ontologies for E-learning // Int. J. “Information Theories and Applications”, vol.11, N1, pp.35-42.
[25] Gruber, T. (1993) A translation approach to portable ontology specifications. Knowledge Acquisition , Vol. 5, pp.199- 220.
[26] Neches, et al (1991) Enabling Technology for Knowledge Sharing. AI Magazin, Winter, pp.36-56.
[27] Sowa, J. F. (1984) Conceptual Structures: Information Processing in Mind and Machine. Addison-Wesley, Reading, Massachusetts.
[28] The CIO’s Guide to Semantics (2004) Semantic Arts©, Inc. www.semantic-conference.com
[29] Tu, S., Eriksson, H., Gennari, J., Shahar, Y. & Musen M. (1995) Ontology-Based Configuration of Problem-Solving Methods and Generation of Knowledge-Acquisition Tools. In “Artificial Intelligence in Medicine”, N7, pp.257-289.
[30] Wielinga, B., Schreiber, G. & Breuker J. (1992) A Modelling Approach to Knowledge Engineering. In Knowledge Acquisition, 4 (1), Special Issue, pp.23-39.

AN ONTOLOGY FOR SELECTING MANUFACTURING SCHEDULING METHODS

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Keywords: Manufacturing scheduling problems, ontology, characteristics, classes, instances and relations

INTRODUCTION

The scheduling activity in an organization seeks to optimize the use of available production means or resources.

With this work we make a contribution for the better resolution process of manufacturing scheduling problems by means of a proposed ontology for characterization of manufacturing scheduling problems.

An ontology defines a set of representational primitives with which to model a domain of knowledge [1]. In this sense, the proposed ontology enables the specification and identification of manufacturing scheduling problems that may occur either in industry or in the academic and research context.

Work already done in several closely related domains, include general manufacturing ontology approaches like [1, 2, 3], and a more specific one, still under development, for manufacturing scheduling.]This is being carried out as a pilot study, by a research student at the Knowledge Media Institute [4]. The purpose is a generic task ontology for constructing scheduling applications.

The here proposed ontology is described in terms of basic objects, the scheduling problem attributes, in the form of problems characterization parameters, problem classes or types of scheduling problems, relations among problem classes and problem instances.

The problems are expressed through a nomenclature that integrates a set of parameters or attributes grouped into three main classes α, β and γ, respectively defining the manufacturing environment, the jobs and resource characteristics and the performance measure.

Each specified problem, expressed according to the proposed nomenclature can be solved by accessing to resolution methods, which are put forward for solving them, through a P2P web decision-support system, which includes several distinct scheduling methods for different types of manufacturing scheduling problem classes. These methods can either be local or remotely available and accessible through the web.

When there are different methods available for solving a given problem class then we can obtain alternative solutions for each problem, which can be evaluated against specified criteria or objectives to be reached. Thus, we are able to properly solve a problem or closely related problems, through the execution of one or more scheduling methods and, subsequently, by selecting the best solutions, better support our decision-making process regarding manufacturing scheduling problems solving.

The ontology proposed ultimately aims enabling sharing scheduling knowledge and methods, in a globally distributed context. It is based on a classification nomenclature designed to better enabling the resolution of manufacturing scheduling problems. This classification nomenclature is represented through XML (eXtended Markup Language) for allowing scheduling problems to be solved with the aid of a P2P web based decision-support system. The nomenclature enables scheduling problems specification and methods selection for their resolution. This is done through a web service [5, 6, 7, 8, 9, 10].

The paper is organized as follows. First a brief description of manufacturing scheduling is presented. Then the proposed ontology is described in terms of three fundamental attribute classes. Problems classes and relations are then discussed followed by problem instances. The problematic of problem solving through a P2P web system is discussed next. The paper finishes with some conclusions.

MANUFACTURING SCHEDULING

The manufacturing scheduling activity may be defined as the activity of allocating production resources to tasks or vice versa, during a certain time period. The result of this is usually expressed in a production schedule and a proper production schedule enables a company to make good use of available resources and efficiently achieving operational objectives [5, 6, 7, 11].

The process of scheduling problem solving is essentially concerned with finding the sequence for jobs execution. Sometimes, however, it may also be required to know in advance planned scheduled start and finishing times of every job operation on each machine or processor. This information completely defines the schedule for jobs' processing.

Good schedules strongly contribute to increase companies' success, ensuring short time to complete jobs and, in addition, to satisfy other important organization objectives. Thus, it can highly contribute to good service to customers and to high profitability of an organization. Among other ways, this is achieved through deadlines satisfaction for the accepted orders, low flow times, few ongoing jobs in the system, high resource utilization and low production costs. These objectives can be better satisfied through the execution of the most suitable scheduling methods available for solving each particular problem under consideration and for doing that we need to clearly specify the problem to be solved.

AN ONTOLOGY

Scheduling problems have a set of characteristics that need specification. Some important processing requirements that frequently have to be taken into account for processing jobs have to do with resources other than machines, i.e. operators, tools, handling devices buffers and others. This attributes can be expressed through an ontology based on a "$\alpha|\beta|\gamma$" nomenclature, which includes three major classes of attributes, related to the manufacturing environment (α), the jobs and resource characteristics (β), which, in turn, is divided in jobs and operations and machines and auxiliary resources attributes and finally the performance measure (γ). This nomenclature is based on some well known nomenclatures described in the scheduling domain [5, 11] and consists on an extended form that can be represented by "$\alpha1, \alpha2|\beta1, ..., \beta18|\ \gamma$".

The α class of parameters characterizes the manufacturing environment, i.e. the system and machines available and the β class the nature of jobs, resources and processing requirements. The γ classes specifies schedules evaluation criteria.

Manufacturing environment attributes

The α class of parameters, related to the manufacturing environment, includes subclass $\alpha1$, which specifies the system type and which has as default value "1", representing a simple single processor system, and $\alpha2$, expresses the number of machines in case of multi-processor systems and does not appear in the nomenclature when it is set with its default value "$\varnothing$".

Table 1 shows a resume of the $\alpha1$ class parameters, including $\alpha1$ and $\alpha2$ parameters.

Table 1. α class for environment attributes

Parameter designation	Value
Manufacturing system type ($\alpha1$):	1
General flexible system with multi-processor jobs	GFM
Single-stage, single-processor GFM	GFM/f1
Single-stage GFM with parallel processors	GFM/f1/P
Single-stage GFM with identical parallel processors	GFM/f1/PI
Single-stage GFM with uniform parallel processors	GFM/f1/PU
Single-stage GFM with unrelated parallel processors	GFM/f1/PN
Multiple-stage GFM	GFM/fm
Jobshop or pure jobshop GFM	GFM/fm/J or /JP
Flowshop or pure flowshop GFM	GFM/fm/F or /FP
Openshop or pure openshop GFM	GFM/fm/O or /OP
General flexible system	GF
Single-stage single processor GF	GF/f1
Single-stage parallel processors GF	GF/f1/P
Single-stage identical parallel processors GF	GF/f1/PI
Single-stage uniform parallel processors GF	GF/f1/PU
Single-stage unrelated parallel processors GF	GF/f1/PN
Multiple-stage GF	GF/fm
Jobshop or pure jobshop GF	GF/fm/J or /JP
Flowshop or pure flowshop GF	GF/fm/F or /FP
Openshop or pure openshop GF	GF/fm/O or /OP
General system with multi-processor jobs	GM
Single-stage, single-processor GM	GM/f1
Single-stage GM with parallel processors	GM/f1/P
Single-stage GM with identical parallel processors	GM/f1/PI
Single-stage GM with uniform parallel processors	GM/f1/PU
Single-stage GM with unrelated parallel processors	GM/f1/PN
Multiple-stage GM	GM/fm
Jobshop or pure jobshop GM	GM/fm/J or /JP
Flowshop or pure flowshop GM	GM/fm/F or /FP
Openshop or pure openshop GM	GM/fm/O or /OP
General system	G
Single-stage, single-processor G	G/f1
Single-stage G with parallel processors	G/f1/P
Single-stage G with identical parallel processors	G/f1/PI
Single-stage G with uniform parallel processors	G/f1/PU
Single-stage G with unrelated parallel processors	G/f1/PN
Multiple-stage G	G/fm
Jobshop or pure jobshop G	G/fm/J or /JP
Flowshop or pure flowshop G	G/fm/F or /FP
Openshop or pure openshop G	G/fm/O or /OP
Number of processors ($\alpha2$)	$\varnothing$, variable, *m*

The $\alpha1$ subclass includes three main characterizing factors. The factor expressed by "G", represents general manufacturing environments, characterized by tasks, which may be single operation jobs j (i.e., nj=1, $\forall$j: j=1, ..., n) or multi-operation jobs (nj $\geq$ 2 $\forall$j: j=1, ..., n,). Moreover, jobs or jobs' operations may or may not be restricted by precedence relations. "F" stands for flexible manufacturing environments, meaning that tasks may have two or more equivalent processors, identical or not, available for its processing. When tasks (jobs or operations) may require two or more processors simultaneously this is expressed by the multi-processor tasks factor "M".

A single stage system, where each system includes only one processor, for processing single-operation jobs, is represented by factor "f1" and a multi-stage manufacturing system, for processing multi-operation jobs is expressed by "fm" in our nomenclature.

A single stage system may include two or more parallel processors, and this is represented, generally, by "P". If there are parallel unrelated processors then the corresponding characterization factor is "PN", otherwise, in case of uniform processors this is represented by "PU" and identical processors are expressed by "PI".

This ontology is designed to represent also other classical manufacturing environments, like job shops ("J"); pure job shops ("JP"); flow shops ("F"); pure flow shops ("FP"); open shops ("O") and pure open shops ("OP"), which may or may not appear combined with the previously introduced factors "G", "F" and "M", forming a variety of manufacturing environments that may occur in several different scenarios arising in industry or in academic context. For example, a classical job shop is represented by fm/J, whereas a general job shop is expressed by G/fm/J, as presented above on Table 2.

Jobs and operations attributes

The attributes related to jobs and operations characteristics are grouped in eleven problems classification parameters, belonging to class β (β1 to β11), as illustrated on Table 2.

Table 2. β class for jobs and operations attributes

Parameter	Designation	Value	Default value
β1	Jobs preemptions	∅, pmtn, free-pmtn, comp-pmtn	∅
β2	Jobs precedences	∅, prec, tree: intree, outtree, chain, sp-graph	∅
β3	Jobs ready-times	∅, rj, rij, rjl, rijl	∅
β4	Jobs processing time restrictions	∅, pj=1, pij=1, pj=p, pij=p, pi(j)∈{a,b}, pmin≤pi(j)≤pmax,...	∅
β5	Jobs due dates	∅, dl, dj, dij, D	∅
β6	Batch processing	∅, batch	∅
β7	Families processing	∅, fam	∅
β8	Complex jogs processing	∅, compj	∅
β9	Jobs quantity	n, nj, nl	n
β10	Jobs priorities	∅, wj, wji, wjl	∅
β11	Multi-processor tasks	∅, mptj, mptij, mptjl	∅

For example, attribute β1 refers to the possibility of allowing jobs processing to be pre-empted, when this is possible then the corresponding value is put, for example, with value pmtn, witch means that is possible to interrupt processing of all jobs one or more times.

Machines and resources attributes

The attributes related to machines and auxiliary resources characteristics are grouped in seven problems classification parameters, belonging to class β (β12 to β18), as illustrated on Table 3.

Table 3. β class for machines and resources attributes

Parameter	Designation	Value	Default value
β12	Machines elegibility	∅, Mk	∅
β13	Machines availability	∅, availk	∅
β14	Auxiliary resources	∅, auxk	∅
β15	Critical resources	∅, crtk	∅
β16	Machines setup	∅, sjk, sijk, slk, sk	∅
β17	Intermediate buffers	∅, bufferk, no-wait	∅
β18	Multi-purpose machines	∅, mpmk	∅

For example, attribute β17= no-wait, expresses that there are no intermediate buffers among machines in the manufacturing system.

Performance measure

The performance measure or evaluation criterion is specified through the third class, γ, which specifies a single or complex combination of objectives to maximized and/ or minimized.

Typical examples of such measures are the total flow time (Fmax), the makespan (Cmax) and the mean and maximum lateness of jobs (Lmean, Lmax), among many others, namely: γ ∈{Fmax, Cmax, Σ Cj, Σ (wjCj), Lmean, Lmax, Σ Tj, Σ (wjTj), Σ Ej, Σ (wjEj), Σ NTj, Σ(wjNTj),...(*)}.

Moreover, regarding this problems attribute the proposed manufacturing classification nomenclature allows users to add their own domain specific performance measures to be considered on each particular case.

PROBLEM CLASSES AND RELATIONS

The problem characteristics previously described may be combined in different ways, resulting in many distinct scheduling problem classes. Let us consider the following specification of the α, β and γ classes of attributes: α: α1= manufacturing system type= G/fm/F, representing a general flow shop system. α2= number of machines= 2. β: β9= number of jobs= n and γ: performance measure= Cmax.

Once we specify these problems attributes on the developed P2P web scheduling decision-support system it presents the results shown in Table 4, about some closely related problem classes found on its distributed knowledge base, where the problems attributes are represented through XML.

Table 4. Problem classes examples

	Problem class	Problem characteristics	Observations
1	fm/FP,2|n|Fmax	Manuf. system= fm/FP Number machines= 2 Number jobs= n Perf. measure= Fmax	Maximal polynomially Solvable Without preemption
2	G/fm/F,2|n,rj|Cmax	Manuf. system =G/fm/F Number machines= 2 Number jobs= n Jobs arrivals= rj Perf. measure =Cmax	Minimal NP-hard Without preemption
3	G/fm/F,2|n,rj,no-wait |Cmax	Manuf. system =G/fm/F Number machines= 2 Number jobs= n Jobs arrivals= rj Machines Availability=no-wait Perf. measure =Cmax	Maximal polynomially solvable With no wait
4	G/fm/F,3|n,pmtn| Cmax	Manuf. system =G/fm/F Number machines= 3 Number jobs= n Jobs pre-emption=pmtn Perf. measure =Cmax	Maximal polynomially solvable With preemption
5	G/fm/F,m|n,pji=1, prec|Cmax	Manuf. system =G/fm/F Number machines= m Number jobs= n Processing times= pji Jobs precedences= prec Perf. measure =Cmax	Minimal NP-hard Without preemption
6	GM/F,m|n=3|Cmax	Manuf. system = G/fm/F Multi-processor operations= M Number machines= m Number jobs= 3 Perf. measure = Cmax	Minimal NP-hard With multi-processor jobs
7	GF/fm/F,m|n,rj,pji=1| Cmax	Manuf. system = GF/fm/F Number machines= m Number jobs= n Jobs arrivals= rj Processing times= pji Perf. measure = Cmax	Minimal NP-hard With flexible manufacturing environment

One example of use of this notation is problem class 1 “G/fm/F,2|n, rj|Cmax”, which reads as: “Scheduling of non-preemptable and independent jobs of arbitrary processing time lengths, arriving to the system at time rj, which is a general flow shop, with 2 machines, in order to minimize the maximum completion time of jobs or makespan.

Regarding the previously presented table we can also realize that the problems are related in terms of classes and subclasses. For example, class fm/FP,2|n|Fmax, consists on a subclass of the class G/fm/F,m|n,rj|Cmax, since the last one refers to a general flow shop including any number of machines and dynamic jobs arrivals, while the first one refers to a pure flow shop integrating only two machines, in a static manufacturing environment, where all jobs are ready for processing at time 0.

Moreover, the system also returns searching results about other closely related problem classes, namely the ones that include one or more of the following attributes: M (multi-processor tasks system), no-wait (no intermediate buffers in the system), pmtn (allowing jobs preemption), pji (processing times restrictions) and prec (existence of precedence relations among jobs).

The proposed ontology provides a general framework of scheduling problems and related concepts, and consequently a way of characterizing each particular problem enabling to easily associate each problem to appropriate solving methods and specifying problem instances to be solved.

PROBLEM INSTANCES

One of the most critical success factors for implementing shop floor scheduling systems is the possibility of dealing with various constraints on each kind of production process [5, 11].

In defining job release orders it is necessary to express a hierarchy of elements and attributes about the problems, such as job (j), quantity (n), due date (dj), processing time (pji), and so on, as previously described.

Therefore, in manufacturing scheduling problems a job represents an action that has certain time duration. During that time, the job changes status of inventories of corresponding items, occupying or loading some particular resources. The jobs need some resources and produce some outputs. Manufacturing resource means workstations, machines, equipments, tools, and auxiliary resources, namely transportation devices, and so on.

An example of a scheduling problem instance consists on processing a set of ten non-preemptable jobs, with unit processing time lengths, and precedence relations among them, arriving at time zero, on a general flow shop, with 5 machines, in order to minimize maximum completion time of all jobs, and this problem instance belongs to a previously presented problem class: G/fm/F,5|10,pji=1,prec|Cmax.

Problems are associated to methods by matching problem attributes, according to the proposed nomenclature, to scheduling methods inputs and additional information about given problem instances has to be specified for solving them when using the developed P2P web scheduling decision-support system [6, 7].

SOLVING METHODS

The manufacturing scheduling problem instances can be specified in an easy way by starting with de specification of a certain problem class or a set of closely related problem classes, that include a set of attributes, as described above. Table 5 presents a sample of problem classes and references about some well known methods for solving them.

Table 5. Problem classes and solving methods

	Problem class	Method reference
1	fm/F,2 | n | Fmax	Johnson (1954)
2	G/fm/F,2 | n, rj | Cmax	Lenstra et al (1977)
3	G/fm//F,2 | n, rj, no-wait | Cmax	Roeck (1984)
4	G/fm/F,3 | n, pmtn | Cmax	Gonzalez & Sahni (1978) Cho & Sahni (1981)
5	G/fm/F,m | n, pji=1, prec | Cmax	Leung et al (1984) Timkovsky (1998)
6	GM/F | n=3 | Cmax	Kraemer (1995)
7	GF/fm/F,m | rj, pji=1| Cmax	Brucker et al (1997)

The possibility of making a multiple choice about solving methods for closely related problem classes is an important feature of the P2P web decision-support system developed, specially when the user does not know exactly which class of problems he/ she wants to solve or even to enlarge the set of possible solving methods to be found by the system, for solving them.

Once a user specifies certain problem characterization attributes according to the proposed ontology and one or more closely related problem classes, the system presents a list of proposed methods for solving the selected class(es), as illustrated in Table 5. For example, for solving problem class fm/F,2|n|Fmax, we can use the Jonson's method [7].

Next, the user has to choose a method from the list of identified applicable methods and once a method is selected by the user the system automatically generates an interface for introducing the corresponding problem instance data, enabling it to be solved through that chosen method [5, 6, 7].

CONCLUSION

In manufacturing enterprises, it is important, as a competitive strategy, to explore and use software applications becoming available through the Internet. This paper proposes an ontology for selecting manufacturing scheduling methods for solving problems by using a P2P web based decision-support system developed based on this ontology.

The main importance of the proposed ontology consists on enabling representation and specification of main manufacturing scheduling problem characteristics to consider when we are interested in solving a given problem instance.

The ontology is codified using a nomenclature. This was developed partially integrating nomenclatures put forward by other authors. New important attributes are considered that allow a more comprehensive characterization of scheduling problems arising from several industrial environments.

Although, the proposed ontology may appear complex it seems very suitable for real world scheduling problem classes characterization and identification and consequently, after methods' selection, for problem solving.

References

[1] Zhou, J., Dieng-Kuntz, R., "Manufacturing Ontology Analysis and Design: Towards Excellent Manufacturing", IEEE, 2004.

[2] Frankovic, B., "The Role of Ontology in Building of Knowledge Systems for Industrial Applications", Institute of Informatics, Slovak Academy of Science, 2005.

[3] Borgo, S., et al., "Formal Ontology meets Industry", Editorial for the Special Issue FOMI'05, 2005.

[4] Rajpathak, D. G., "The Task Ontology Component of the Scheduling Library", The Open University, 2001.

[5] Varela, L. R.; Aparício, J. N.; Silva, C. S., An XML knowledge base system for scheduling problems, In: Proceedings of the Innovative Internet Computing System Conference, I2CS'02, Kuhlungsborn, Germany. Springer-Verlag in the Lecture Notes in Computer Science series, 2002; 61-70.

[6] Varela, M. L. R.; Aparício, J. N.; Silva, S. C., Developing a Web Scheduling System Based on XML Modeling, In: Knowledge and Technology Integration in Product and Services – Balancing Knowledge and Technology in Product and Service Life Cycle, BASYS'02, Cancun, Mexico. Kluwer Academic Publishers, 2002, pp. 61-70.

[7] Varela, M. L. R.; Aparício, J. N.; Silva, S. C., A Scheduling Web Service based on XML-RPC, In: Proceedings of the 1st Multidisciplinary International Conference on Scheduling: Theory and Applications, MISTA'03, Nottingham, UK. ASAP, The University of Nottingham. 2003, pg. 540-551.

[8] Papazoglou, M.P.; Krämer, B.J.; Yang, J.; Leveraging Web-Services and Peer-to-Peer Networks, In: Proceedings of Advanced Information Systems Engineering, 15th International Conference, CaiSE, Klagenfurt, Austria. June 16-18, 2003, pp. 485-501.

[9] Terziyan, V.; Zharko, A.; Semantic Web and Peer-to-Peer: Integration and Interoperability in Industry, Industrial Ontologies Group, MIT Department, University of Jyvaskyla, Finland (http://www.cs.jyu.fi/ai/vagan/papers.html).

[10] Wu, J.; Distributed System Design. New York: CRC Press, 1999.

[11] Conway, R. W.; Maxwell, W. L.; Miller, L. W., Theory of Scheduling. England: Addison-Wesley Publishing Company, Inc., 1967.

EXECUTING DISTRIBUTED AND INTERACTIVE PROCESSES MODELS USING SEMANTICS

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Abstract: Huge production systems and their processes quickly become too complex to be administered by a fixed, standard interface and using a client-server architecture. In addition, a high rate of adaptations and process changes lead to high costs for system changes, which are in some contexts even impossible due to enterprise-spanning systems and processes. On the other hand most of the status information is not relevant for production control. The research project INT-MANUS has developed a communication layer to integrate various machines into a peer-to-peer based decentralised network infrastructure. Using this network, machine data can be requested from each machine and be transferred over the network. This paper introduces an approach to interpret messages and recognize relevant information as a basis for adaptive interaction. Such relevant information can be assembled, aggregated and routed through the network. Processes are executed within the Smart Connected Control Platform (SCCP) using a semantic model for definition and interpretation of organisational structures and processes. A concept for message interpretation and routing as well as decentralized process execution is described. Also the join mechanism of peers into a decentralized system using a SuperNode concept is detailed.

Keywords: holonic_enterprise;information_technologies; integrated_process(es); mass_customization; order_fulfilment_networks_and_processes; virtual_enterprise; information_management; control_systems

FLEXIBILITY AND GENERICITY

The scientific community in the field of Human Machine Interaction has experienced a strong interest on automated, model-based and generative system in the 1990s. Model-based User Interface generators started to create an semi-automated or even automated bridge from analysis and design models as used in Software Engineering and Task Modeling to executable software or interpreted User Interface (UI) models.

While the Software Engineering community still discusses and the generator concepts for example in the frame of Model-Driven Architecture (MDA) and Domain Specific Languages (DSL), industry has only very rarely adopted automated and generative models from the field of HMI.

When targeting static systems, created and compiled only once for execution, the advantage of specific – often not fully integrated – software models are accompanied with drawbacks like the often missing synchronisation of models and final software version.

When it comes to the type of distributed processes described above, the frequency of changes is much higher. Talking about rapid reconfiguration of processes with a high frequency, for example in Mass Customization [14] and beyond, it is even impossible to rewrite or manually produce new software versions each time changes in the processes occur.

This issue leads directly to the use of models that can be adapted to changes and also allow for consistent adaptations of the User Interfaces that connect people and processes. This becomes even more important the more knowledge-intense and flexible the processes are.

While creative processes often do not follow a predefined process model, production processes and other highly defined processes have to be executed as they are described. Creating the same product each time with different processes will directly have an impact on control of the whole system and the quality of its products.

The implication here is that while processes need to be flexible to answer needs of reconfiguration and customization, they also have to be predefined and repeatable to ensure quality and control.

OBJECT-ORIENTED PROCESSES

A well-known concept in the Object-Orientation community is instanciation. An object is instantiated from a class, meaning it has the attributes and functionality defined by the class and shared by all other instances. Although the process and the attribute types are common, each instance has its own identity and state.

The process instances can be regarded as projects for example in the services domain or as the production workflow of a single product (item) in a production system.

Transferring the object-oriented concept of instanciation from programmed classes to processes [13], it becomes possible to execute processes in the form of process instances.

This means that process act as classes or “type-layer” descriptions. Every instance of a process then shares the same process type and has the same attributes in common with the other instances of the same process.

ADAPTATION

When reconfiguration or unforeseen change happens during runtime or even during the execution of a process instance, these changes have to be reflected in the process definition in order to maintain control over the process execution. This is also necessary to be able to provide the same workflow and context information to process instances created in the future.

Rinderle et al. [15] describe the possibility of adaptations of workflow definitions after deviations in single process instances have occurred. While this allows for flexible execution of process instances, the process definition becomes non-mandatory if deviations from the predefined processes become possible. Also, older instances can not be executed and interpreted anymore, because the old process scheme has been adapted.

For this reason, inheritance is a powerful mechanism to incorporate changes in a process model without touching the basic process definition.

By inheritance, it is possible to create variants as children of a standard process.

Each child inherits all properties, that is attributes, types and signatures, from the basic process. This means that an unchanged child process will be executed exactly the same way as the basic process, it is inheriting from.

Once changes are made to the child process, they overwrite the basic process in only the specific part changed – leaving all other parts unchanged and still executable.

The next step is to make execution of such flexible processes possible also in decentralized environments.

DENCENTRALIZED CONCEPTS

The rise of Service Oriented Architectures (SOA, [9][2]) in enterprise systems shows a trend towards a decentralization of system and business functions.

Why use decentralized architectures and processes? The first IT-systems in production were non-networked standalone systems. After networks were introduced, integration started and the concept of mainframes and server-based architectures yielded high benefits compared to standalone systems thanks to their integration.

For a long period of time, systems and especially process execution were centralized as much as possible. Centralization makes implementation and execution easier, because decisions are made at a central point, which is known to all stakeholders. Also all necessary data, including the full process context is available at a powerful central system.

But centralized systems also often introduce a bottle-neck into the system: The central coordinator. This “single point of failure” is the backbone and weakest point in a central system. With backup controllers and redundancy, companies seek to reduce the risk of a system breakdown. But today, this inherent technological risk is not the only issue.

When virtual enterprises are created by contract on the basis of orders or logistics chains are flexibly adapted, every stakeholder in the process aims at maintaining control over internal information and processes.

This implies that there is often no central process-owner with control over the whole process and all (context and management) information that is necessary to execute the process.

With a central system, correct execution can often be impossible or at least error-prone due to lack of control and information at each point of process execution.

In the view of reconfigurability and build-operate-transfer (BOT) concepts, already within the same factory or production system, ownership and control is distributed or changes.

This requires system concepts that can operate without central control over processes, models and data.

There fore, the introduction of a new system type, Decentralized Distributed Control (D2C) systems, could make it possible to cope with these requirements and still ensure proper execution of production processes.

RAPID RECONFIGURATION

Rapid reconfiguration is often described as a key factor for successful European production in the future. Rapidly changing market conditions as well as the need for higher individualization and smaller lot-sizes put pressure on existing production systems. Shorter development cycles and a broader range of products and variants even strengthen this demand. Markets still tend to demand more and more flexibility in production triggered by a trend towards mass customization [10].

The requested reconfigurability of machines, cells, production lines, whole factories and even complete logistic chains, can not be solved with traditional concepts of automation using pre-defined and central control mechanisms. While Manufacturing Executions Systems (MES) [11] integrate different aspects of production into one central system, still their concepts are fixed on a syntactic level of production system definitions.

Roadmaps [10] show that key enabling features for sustaining under current and expected future market conditions clearly go in the direction of flexibility and model-based systems to cope with change and complexity.

SEMANTIC MODELS AND COMMUNICATION

Already current scenarios of reconfiguration can not be accomplished using programmed routines. Therefore, flexibility has to be introduced by comprehensive models that can be adapted and modified according to process and infrastructure changes.

Introducing semantic models into the factory, enhanced descriptive models can be created that allow for a model-based reconfiguration rather than reprogramming the factory as described in [13]

More recently, Object-Orientation (OO) has been applied to defining and designing software components and lager systems to be integrated in automation [1].

A semantics-enabled communication system also needs a protocol that allows for the transmission of models, model fragments and classified items.

As transport protocol, SOAP is a good choice despite of its large overhead of metadata, since it supports self describing mechanisms and provides asynchronous message conversation. It also allows for security features like Secure Socket Layer (SSL) based transmission and has become a standard for web-service-based communication.

Above SOAP, an extensible, dedicated application protocol is being developed in INT-MANUS project [16]. It is based on XML structures that easily comply with SOAP and allow for transmission of structured data as needed in automated message interpretation. It is capable of transferring messages between different system components like data repositories, CNC machines and terminals. Messages consist of a message header and a message body.

The header is used to identify sender, recipient and other meta-information that is used to transmit, verify and route the message according to these specifications and its contents. Therefore, the header contains all information necessary for the message transport.

As in every distributed network environment, a synchronization of local clocks is necessary to decide on priorities and maintain cause-and-effect relation.

The service-oriented paradigm of separating interfaces from implementations is used in the Smart Connected Control Platform (SCCP) of INT-MANUS system. Especially in a decentralized peer-system like SCCP it is absolutely necessary to offer and maintain interfaces defined for the system’s infrastructure. As communication is decentralized, it can only take place relying on defined communication concepts and interfaces. Common semantic models ensure the correct interpretation in each peer integrated in to the system.

The message body contains a recursive data structure representing a serialization of the object-oriented, semantic model integrated in the INT-MANUS system.

It incorporates models, model fragments and single semantically defined items. Each element in the body is uniquely identified by an identifier called SCCPID that is present in the overall model.

This means that each command, each peer and each process step can be directly identified, recognized and interpreted at any peer that is part of the SCCP.

Recognition and interpretation are possible via the shared common semantic model that holds classifications and relations for each model item transferred over and interpreted in the SCCP. The partial model at each peer is updated by the model fragments transferred with each semantic message.

Furthermore, the data structure can contain all types of defined elements, including events and error codes that are useful for corrective action and the provision of intelligent system behaviour. The XML based application protocol and the ontology [12] are extensible at run-time, which is a core requirement since infrastructure changes, process adaptations and local shut downs of machines for maintenance are common in any production environment. These changes have to be reflected just-in-time in the model to ensure proper function when system changes occur.

DECENTRALIZATION

For the Smart Connected Control Platform (SCCP) in the European Research Project INT-MANUS [4], we use a decentralized concept. The SCCP connects machines, terminals, portable devices and other processor-based components through a semantic messaging framework.

The first step is the creation of a communication infrastructure that allows for information exchange in this kind of decentralized environments. A messaging infrastructure provides the foundation for message-based data transmission.

On top of this message-based infrastructure level a peer-to-peer infrastructure model can be driven by agents for connecting all system components in the factory based on Web-Services and exchanging model-based information.

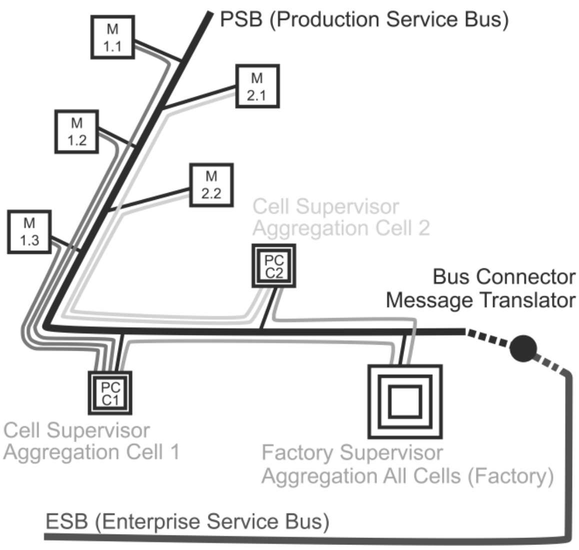

Fig. 1. The (Semantic) Production Service Bus (S)PSB

In analogy to the Enterprise Service Bus (ESB) in general Service Oriented Architecture (SOA, [9][2]), we call this production-oriented bus infrastructure Production Service Bus (PSB). When semantic models are used to route and interpret messages and calls, a Semantic Production Service Bus (SPSB) is created.

While on the basic level SPSB has many similarities with the Enterprise Service Bus, it requires not only advertisement of services and their connection on runtime in a syntactic way via WDSL. Much more, it is a message-based communication relying on a strong ontological classification model to route messages to the right recipient. The recipient is often identified by its address or ID but it is recognized by its capabilities and type. Using a classification concept to describe the recipient(s) of a message, the SPSB is able to find correct receiving peers even if they have been connected after the messages was sent.

This is possible, because the sender defines only the right type of recipient derived from the common ontology, for example all milling machines in a specified cell. If another milling machine is connected to the network, it may not already be known by the sender. But it receives the messages and will recognize that – as it is a milling machine – the message is intended for it.

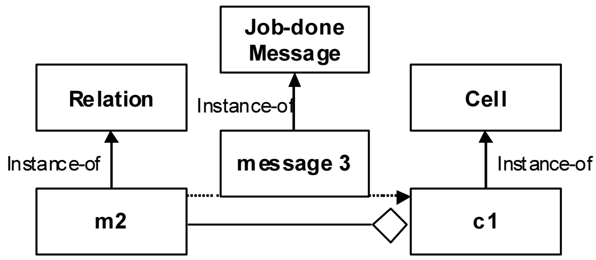

Fig. 2. Classification of messages, machines and cells as instances.

Therefore, besides the web-service infrastructure, each message contains partial models referring to the common model infrastructure. For example a "job done" event from machine m2 is classified as a notification kind of event. With machine m2 being an instance of milling machine type connected to cell instance c1, the system can conclude that the job of this machine (instance) is accomplished and a milling machine (type) is available for the next specific task. This will notify all peers waiting for a milling machine to become available.

SEMANTIC TECHNOLOGY IN INT-MANUS PLATFORM

Interpreting this model information, messages can be routed according to their type and classified destinations using the semantic message routing system as described above.

Classified sources and destinations can be identified by their attributes but also by contexts comparable to namespaces: machines integrate their sensors and parts, cells integrate machines and terminals to form a cluster or production line within the factory, which in turn aggregates cells and production lines to a bigger concept like factory or enterprise. In a further step it would be even possible to cluster factories or buildings to companies and these again to virtual enterprises connected to the market with its suppliers and customers.

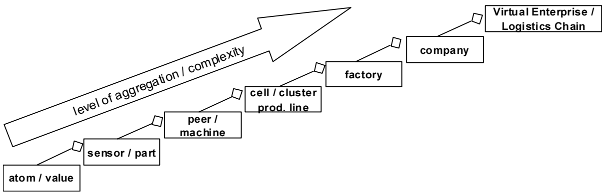

Fig. 3. Flexible aggregation levels in a semantic peer infrastructure system

The semantic model helps to classify each item within the system. Should changes occur that have an influence on the system structure, they can be applied to the system on runtime without having to shut down or reconfigure the system and its automation components.

A new machine is seamlessly integrated into the production system as well as Build-Operate-Transfer (BOT) suppliers are integrated into the network, even with special visibility rules. For example internal messages are kept away from the BOT supplier while process instances are routed to the supplier to keep him informed in real-time about the events and schedule that concern his work.

The message-based system allows for easy redundancy without reprogramming the system. A duplicate agent can subscribe to the same message types to share the same model or instantiate an update-listener at a secondary agent peer reading changes of the primary one to keep its model up-to-date. This partial and side-effect-free replication leads to more flexible and error-tolerant systems on the model and data layer.

Cascading data is another inherent approach for consistent redundancy. Machine agents interpret and aggregate data of their machines. Cell agents operate listeners for all machines belonging to the cell, while production lines and whole factories operate listeners to receive data from underlying cells.

In the case of a network split, messages can be stored until they are delivered or have expired. This way any network disconnection or partial drop-out can be handled as long as required model information is available redundantly within the disconnected cell.

Logical groups like cells can of course be defined intersecting each other, for example if one machine is used by more than one production line or capabilities of a machining centre relate it to multiple functional groups.

Different system components of the INT-MANUS platform are integrated using the distributed platform and common model.

MODEL REPOSITORY

A Distributed Model Repository (DMR) and Knowledge Repository is integrated into the platform for synchronizing the common model and all its components once parallel changes have occurred during a network split or communication problem – for example due to latency. Changes in the model can also trigger typed messages and events that help to update existing processes and execute additional workflows.

Each model repository is part of the DMR, synchronizing the model elements stored with others in the network. It is implemented as a peer to participate in the Smart Connected Control Platform (SCCP). The peer reviews each messages and decides whether or not it is part of the model segment stored in the peer. If it is a model update belonging to the model segment, the local model is updated.

The replication of the class layer is vital to the system, as all semantic interpretations of messages, processes and system structure rely on a common ontology that defines types and their meaning. Therefore, most of the class layer has to be replicated in each peer. Only if the partial semantic model necessary for interpretation of a message is always sent in conjunction with the message or if missing model-parts are requested from a model repository just-in-time, it is possible to run peers without the full class layer replicated.

Scheduling and planning is able to use type information to relate classes of parts and process steps to machines and capacities allowing for seamless transition to new variants produced with the existing or (partially) additional equipment. Learning modules can use the model information to draw conclusions from type-dependent actions also for similar components, situations etc. For the learning modules the semantic model and the messages provide the context for relating actions to a set of situational parameters.

Machine data is sent to the flat Knowledge Repository for storage, aggregation and interpretation. All values are model encoded before they are sent to the repository over the platform. This means that all data is also directly related to the common model and during transportation can be routed to all type-based listeners in the same manner as other semantic messages.

This data residing combined with its model information in the Knowledge Repository can be used to run Data Interpretation using statistical and semantic algorithms for drawing conclusions, for example extracting possible causes for machine failure and detecting patterns in system and user behaviour with an intelligent system.

SECURITY CONCEPTS

Although the system is decentralized, an Access Control Module is needed to control and grant access to the peer infrastructure.

This includes access control and security on two layers. Connection security represents the network layer while message routing security uses the semantic model for decisions and routing.

The connection security is based on the SuperNode concept. In every closed partition of the peer network – whether a separate system or disconnected from the other parts for example by a network split – there is a SuperNode existing or being elected.

Message routing security is implemented on the semantic layer above this networking and peer-based functionalities. A role-based authorization and message routing based on the classification of peers and using access and confidentiality levels depending on the type of peer and owner of the peer can be applied. This can be used to avoid intrusion and messages routed unnecessarily to peers that are no potential recipients, for example external suppliers.

Also platform user interfaces can profit greatly for the ontological definitions of users, roles, human-machine communication channels and environment. [5][7][8]

User interfaces could be generated according to these definitions as described for example in [6].

The connection of external systems like ERP to the peer infrastructure can be achieved through transformation of messages to fit the requirements of the external system.

A message translation gateway which transforms information contained in messages into the specific formats and actions of the ERP layer or other systems outside the platform is able to integrate ESB and (S)PSB into an enterprise spanning decentralized network.

As in Figure 1, a bus connector and message translator that shows a frontend to the ESB system as well as representing a peer to (S)PSB side allows for integrating both worlds with real-time messages.

SEMANTIC WORKFLOWS – DISTRIBUTED CONTROL

In the previous paragraph, the architectural concepts of the decentralized control platform have been presented. In particular, the components for semantic messaging and interpretation with the help of a semantic model.

The dynamic run-time behaviour of such a system relies strongly on the execution of processes. Central coordination of processes is not possible anymore in a decentralized peer system. In INT-MANUS the foremost task is the composition and co-ordination of workflows across the distributed SCCP via the Semantic Production Service Bus.

In order to get an execution framework for business process automation and automated production workflows, a run-time environment has to be provided that drives the business services attached to the ESB and triggers the production steps according to the component-spanning process descriptions, similar to semantic web-services concepts in automation [3].

In INT-MANUS, the processes are working procedures that contain all information and run-time behaviour of the production steps to be performed.

These processes are represented and stored in an abstract manner, since the binding to concrete service implementations is subject to the respective service busses and implementations. Hence, the INT-MANUS architecture allows the externalization of process descriptions and the modification thereof without touching the services wrapping sensors and actuators and their implementation.

Such chains of service invocations are performed by a run-time engine that processes the commands according to the description held in the process repository and is executed on each peer independently.

In some cases, a centralized execution of commands may be desirable, for instance in case of an emergency stop of a machine. For this purpose, dedicated message types are introduced that supersede any other messages held by the SPSB.

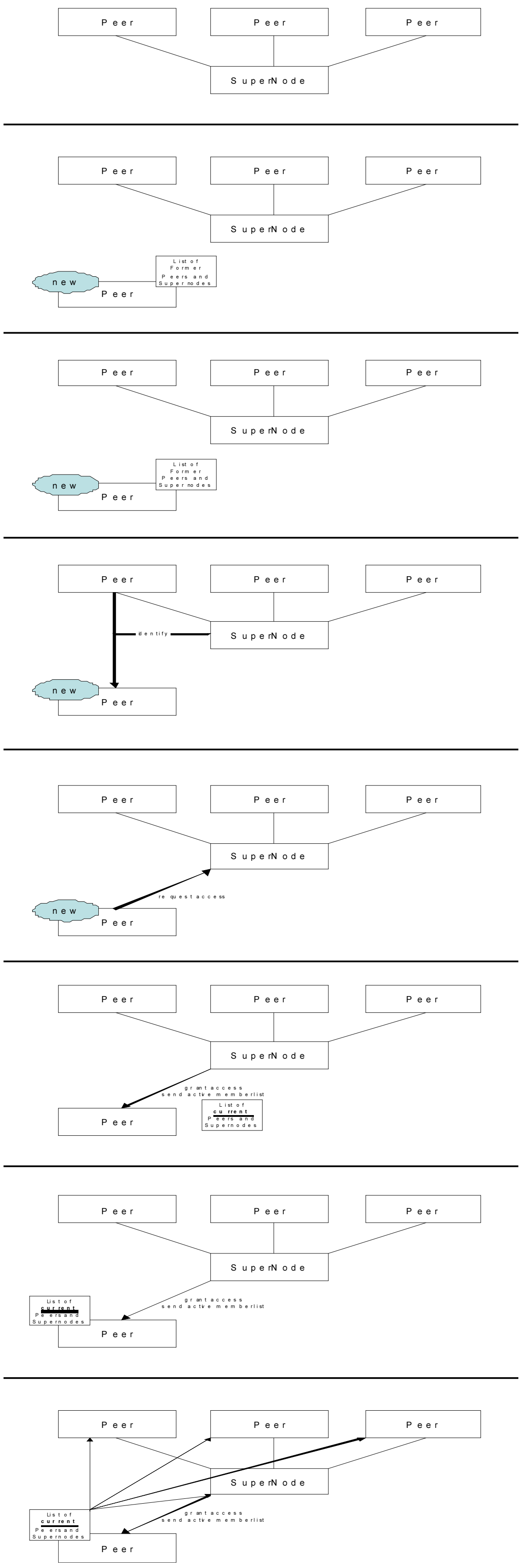

Fig. 4. Decentralized join and peer administration.

These system level messages are interpreted independent of higher level components like workflow instance interpretation to guarantee their execution with highest priority. These basic message types are part of the platform structure and active in every peer.

Processes are also described in the semantic model. A meta-model defines the types, relations and structures as framework for the definition of processes. Through the semantic model, coherent interpretation in each peer (that is the same interpretation in individual peers) is ensured.

Process instances are a special feature used in the system. While workflow systems often only copy the process, we use an object-oriented concept of process instanciation.

This enables process instances to be sent from peer to peer for execution. The instance carries the whole snapshot of process steps executed, task activation information and attribute values with it. This means that the whole process context of the executed process instance is available for interpretation and as input to the current execution.

It helps the peer in determining, if it is responsible and capable of executing the next step and offers the ability of semantic crosschecking for the status and parameters. Each process instance is an object-oriented instance of its process and each process step instance executed is the instance of a specific process step defined and typed at the class / process description level.

INT-MANUS DEMONSTRATOR

The INT-MANUS demonstrator presented at the Turin workshop already shows the peer concepts, including join mechanisms and SuperNode administration.

A web interface integrates the user into the system. It offers methods for starting and shutting down single peers or the whole system. Also messages are displayed and can be targeted to a specific recipient.

The most important capability of a decentralized production system platform like the SCCP is the integration of other parts of a production system into the platform. Monolithic solutions often do not offer the integration of external systems, which makes them incompatible to existing systems and often makes it impossible to implement it as the central component of a production system.

SCCP demonstrates the integration capabilities in the demonstrator connecting a robot and AGV (Automated Guided Vehicles) controller into the process environment. NC machine access is implemented through a web-service system that delivers all values into the SCCP and via the platform to a mobile control system. Mobile devices and web-browsers seamlessly integrate with the platform infrastructure and provide user access to the system.

CONCLUSIONS AND OUTLOOK

Production companies experience a high demand for rapid adaptation to new situations, conditions and requirements. Targeting rapid reconfiguration is a step into the future to achieve a high degree of flexibility for production systems within a short amount of time.

The approach and realisation presented shows how object-oriented, semantic concepts can advance production systems towards higher flexibility. The centralized integrative approach of Manufacturing Execution Systems (MES) already demonstrates the advantages of integration, connecting formerly separated data sources through common data structures, user interfaces and – partially – workflows. Also connecting the "upper" layer of Enterprise Resource Planning (ERP) and Production Planning Systems (PPS) to the "lower" shopfloor automation capabilities and real-time values is a key factor for intra- and inter-organisational integration.

Using object-orientation and a clearly decentralized approach provides the system with model-based reconfiguration and independency from a central system and process controller as well as scalability and high flexibility also regarding organisational structures.

Inherent redundancy and a powerful, message-based communication infrastructure allow for dynamic integration of new peers and partial systems to the Semantic Production Service Bus (SPSB). This bus system follows a semantic message-oriented paradigm, which enables a decentralized message interpretation and distributed execution of production processes.

An integrative ontology and system concept allows for handling the complete production in an object-oriented manner dynamically through model and service orientation. Agile, decentralized concepts based on a message-oriented, semantic communication and workflow infrastructure pave the ground for a new class of production systems avoiding centralized bottle-necks by applying an Internet-like concept.

The object-oriented production described above does not only target design and development of components in a production system. It integrates and enhances existing paradigms and technologies from other domains to converge to a new generation approach for production systems to make them flexible, dynamic and failsafe.

Runtime changes of a production system setup, organisation and its processes are made available using a decentralized, model-based structure.

These decentral execution of semantic process descriptions lays the foundation for close collaboration of personnel with systems. Interactive processes can be adapted using semantic model information to generate interactions with the user on the fly.

This way, next generation production system will become inherently interactive and adapt user interfaces automatically to processes and situations making production system more flexible and competitive.

Acknowledgements

INT-MANUS Project is funded by the European Commission and has emerged out of the European Network of Excellence I*PROMS, supported by its virtual Institute VIMation (www.VIMation.eu). – Fraunhofer IAO is a member of I*PROMS European Network of Excellence.

References

[1] V. V. Vyatkin, J. H. Christensen and J. L. Martinez Lastra: OOONEIDA: An Open, Object-Oriented Knowledge Economy for Intelligent Industrial Automation, IEEE Transactions on Industrial Informatics, Vol. 1, No. 1, February 2005: 4-17

[2] F. Jammes and H. Smit: Service-Oriented Paradigms in Industrial Automation, IEEE Transactions on Industrial Informatics, Vol. 1, No. 1, February 2005: 62-70

[3] J.L. Martinez Lastra and I.M. Delamer: Semantic Web Services in Factory Automation: Fundamental Insights and Research Roadmap, IEEE Transactions on Industrial Informatics, Vol. 2, No. 1, February 2006: 1-11

[4] T. Schlegel and K. Müller: Integrating human personnel, robots, and machines in manufacturing plants using ubiquitous augmented reality and smart agents. In: Intelligent Production Machines and Systems, 2005: 189-194

[5] W. Beinhauer and T. Schlegel: User Interface for Service Oriented Architectures. In: Intelligent Production Machines and Systems, 2005: 129-134

[6] T. Schlegel, A. Burst and T. Ertl: A flow centric interaction model for requirements specification and user interface generation, in: Proceedings of the 7th

international conference on WWCS, bridging diversity at work, CD-ROM, Damai Sciences, Kuala Lumpur: 2004

[7] W. Beinhauer and T. Schlegel: User interfaces for service oriented architectures, CD-ROM. Proceedings of HCI International 2005, Erlbaum: 2005

[8] Schlegel, T.: Integrating interaction and service workflow models by object-orientation, CD-ROM. Proceedings of HCI International 2005, Erlbaum: 2005

[9] T. Erl: Service-Oriented Architecture. Concepts, Technology, and Design, Prentice Hall, 2005

[10] I*PROMS POM Cluster: Deliverable D7.5: – Research roadmap covering all research areashttp://www.iproms.org/filestore2/download/633/iproms_D7.5_POM_roadmap_edited_2_06.pdf, 2005

[11] J. Kletti (Ed.): Manufacturing Execution System, Berlin, Heidelberg, New York: Springer 2006

[12] Gomez-Perez, M. Fernandez-Lopez, O. Corcho-Garcia: Ontological Engineering, Springer, 2004

[13] T. Schlegel, W. Beinhauer, F. Meo: Object-Orientation in Planning and Control of Decentralized Production Systems. In: VIMation Journal on Human-Machine Interaction and Models in Production, Issue 1/2008, 2008

[14] Anderson, D.M.: Build-to-Order & Mass Customization – The Ultimate Supply Chain Management and Lean Manufacturing Strategy for Low-Cost On-Demand Production without Forecasts or Inventory. Cambria: CIM Press, 2003

[15] Rinderle, S.B. and Bassil, S. and Reichert, M.U.: A Framework for Semantic Recovery Strategies in Case of Process Activity Failures. In: Proceedings of the Eighth International Conference on Enterprise Information Systems (ICEIS'06): Databases and Information Systems Integration, Setúbal: INSTICC Press, 2006, pp. 136-143

[16] Schlegel, T.; Müller, K.: Integrating human personnel, robots, and machines in manufacturing plants using ubiquitous augmented reality and smart agents. In: Intelligent Production Machines and Systems, 2005, pp. 189-194

COGNITIVE KNOWLEDGE MANAGEMENT SYSTEM FOR AUTOMATIC POPULATING ORGANISATION TAXONOMY WITH DOCUMENTS

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Abstract: Taxonomies have proved to be an integral part of any organization's Knowledge Management. Attaching documents in the taxonomy software is done manually in many cases. But when there is a huge mass of documents to be attached in the taxonomy structure, it is much beyond practical human efforts. Hence, the idea of automatic attaching documents to appropriate elements in the taxonomy appears. Presented paper is a report that offers a hybrid approach for text analysis and "understanding" the details in the documents in order to effectively populate taxonomy structure. This is an ongoing project, so no results are submitted in this abstract paper.

Keywords: Knowledge_Management, Text_Categorisation, Taxonomy, Text_Analysis, Cognitive_Agents, Natural_Language_Processing

INTRODUCTION

"Sharing Knowledge within the organization is as big a challenge in many ways as sharing it with a competitor". These words by Jordan Libit, vice president of FileNET Corporation, were quoted in an article by Delphi Group [1]. Of course, much has changed since that time in this rapidly growing dynamic information age, but the basic problems concerning Knowledge Management are still present, or on the contrary growing. As the production of information becomes easier and quicker, more challenges and problems arise for Knowledge Management practitioners. This is something of a "… is in the reverse proportional to …" kind of rule.

In a recent survey conducted by Delphi Research with over 300 companies, 59% of respondents indicated that locating and accessing the information needed to do their job has gotten simpler and more effective over the last 2 years. Yet, 68% went on to state that retrieval is still difficult and time consuming, with 62% expressing dissatisfaction with overall information retrieval efficiency [2]. Most organizations do not have centralized, strategically developed information architecture. According to the Delphi Research survey, 82% of respondents reported they do not have access to a centralized single point of search and management across information sources. In such situations it is easily convincing to have a centralized system which easily integrates, interrelates and structures all the knowledge so that it can be access at the right moment and in proper situation. Also, such an access should be quick and simple. Obviously, the idea of "taxonomy building" pops up in our mind. As the growing trend of Knowledge Management and other similar practices capture eyes of top level management in today's organizations, the demand for knowledge sharing and structuring also grows. And there are already many such systems available in the organizations world wide. Building taxonomies and managing them manually, are not a big problem now-a-days. Many state-of-the-art commercial software tools are already available for such kind of applications. Also, there are several different methods for text categorization, as works by [3], [4], [5], [6], among others.

Many of the existing systems for text categorisation offer an algorithm for "automated" systems, and some of these systems have proven to be more or less efficient and accurate according to their technical approaches, for e.g., hierarchical classifier approaches in [7] and [8], whereas in [9] they present a comparison between to learning algorithms. Also, there has been work on multi-lingual document classification [10] or even language independent text categorisation [11]. Yet, there has been a very little work on the document classification systems for documents written in Cyrillic scripts (Russian or Ukrainian language).

The presented paper talks about one system built for classification of Russian language documents by an organisation taxonomy. There is an ongoing project to build such a system. For the purpose of automatic text processing and classification, the concept of "cognitive agents" is applied. However, the detailed explanation of these agents is not in the scope of this paper. This paper discusses about the general architecture and the methodology of the system. In the following sections, we will see the architecture of the organisation information system which hosts the text categorisation module, brief explanation of stages for training and recognition and the scope for the future work.

EXISTING INFORMATION SYSTEMS ARCHITECTURE

Business Engineering Group [12], is a St. Petersburg (Russia) based consulting company, working in the field of Organizational Development and Business Process Re-engineering. They use own software for structuring data and creating and maintaining Knowledge Bases. But irrespective of the KM practices, these programs can be used for any organization's information structuring and retrieval systems. One such application is E-Master tool. The above discussed Automatic Document Classification and Indexing mechanism will be in addition to the E-Master.

E-Master Tool

This tool is mainly designed for structuring a collection of documents. The tool has facilities of designing and maintaining Business Content taxonomies. It can add, delete elements in the taxonomy or rearrange and change taxonomy structure by shifting element locations and modifying their relationships.

Apart from managing taxonomical structures, E-master has been aimed at several key functionalities which make it work as a server for the overall organizational data management. Figure 1 shows the general architecture of E-master. The core system is attached with Virtual File System, which can be the source for documents. Module for Importing/Exporting documents can be used to add documents to the taxonomy base and retrieve documents from the taxonomy on demand. The whole system works in network for facilitating multiple users at a time and to include documents from the whole network in the taxonomy.

The taxonomy structure is supposed to be created manually and pre-existing before the text classificatory system starts processing and attaching documents to it automatically. Such, manually created taxonomies are still believed to be more robust and appropriate than the automatically generated taxonomies. Also, to maintain the list of topics interesting to the organisation, manual taxonomy is more appropriate.

Fig. 1 shows the overall functional relations of the E-Master's server with different services.

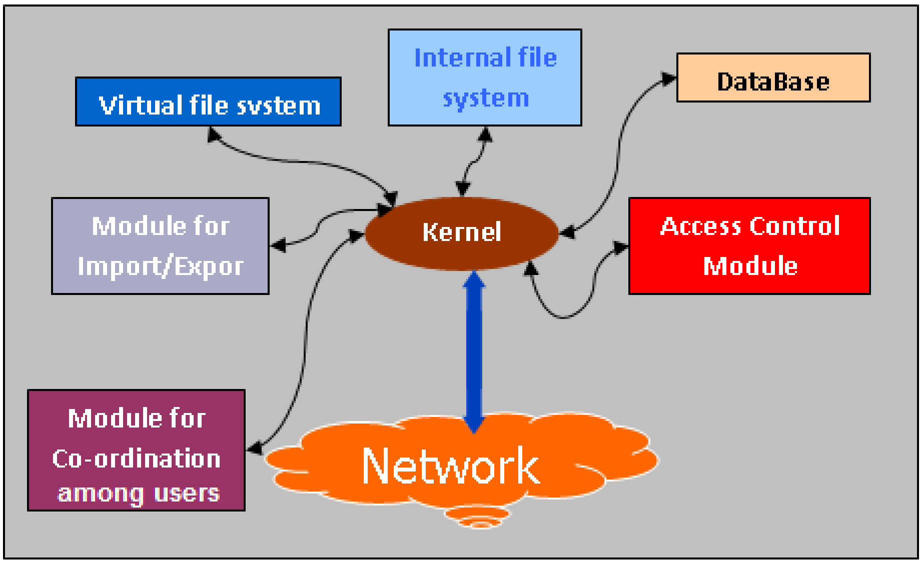

Fig. 1. General structure of the E-master Server functionality. Different modules are linked together to make E-master work as the server.

THE INTELLIGENT TEXT CLASSIFICATORY SYSTEM

The Intelligent Text Classificatory System (as referred as TC system in the following text), is an independent module which can be added to the E-master's architecture. The task for TC system begins as soon as it receives a bunch of documents for training purpose. The documents can be in different text formats. Hence the first task for the TC system is to read text from these files in different formats. After decoding text from the files, the second stage is to "Read" these texts. Here the TC system will prepare text in its internal format and convert all the documents in a uniform format. This uniform format will include meta-data also. A special process for "understanding" the text will prepare meta-data. This process will understand text in Russian and English. Better algorithms for effective text processing are designed by applying some concepts of "Natural Language Processing". Generating meta-data from these two languages, automatically, is one of the more complex tasks in the whole system. Meta-data generation will also depend upon the given base of predefined text symbols. Once the meta-data is generated the text is ready to be processed by Agents. These Agents work on the principles of cognitive computer science. Within the framework of this science the approach to building intelligent systems with automatic acquisition of logical knowledge was generated by learning and self-learning. Development of a learned system, EURISCO [13], on meta-knowledge has put beginning to development of cognitive logical systems. The Agent based systems with such concepts, are called Cognitive Agent [14] based systems. These systems can be implemented using different architectures according the requirements. In our system, these Cognitive Agents read the text and meta-data and decide which node in the taxonomy is the best fitting for the given text and meta-data. The purpose for using such Agents is that they are autonomous and provide soft rules [15]. The system architecture, from the agents' point of functionality, is shown in fig. 2.

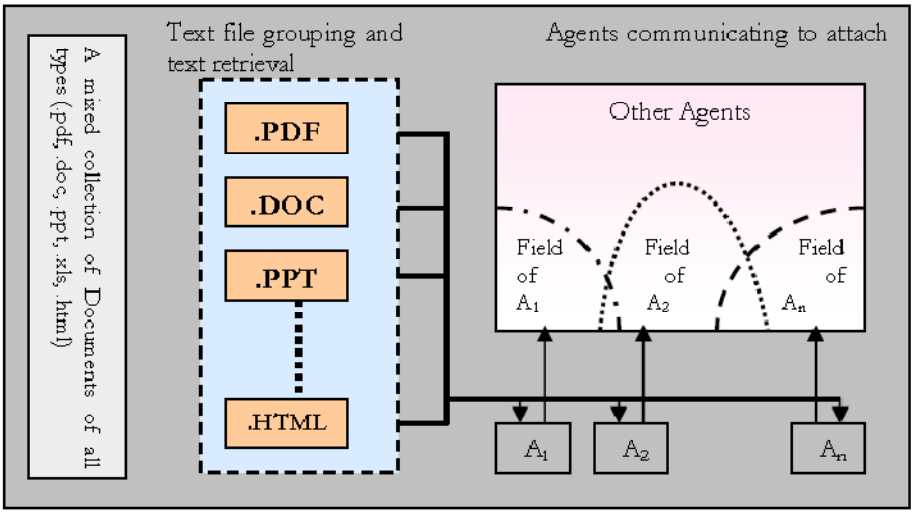

Fig. 2. A diagram showcasing agents' behaviour in general.

The figure 2 showcases general diagram indicating behaviour of agents. Here when input documents are passed to the agents A1, A2…An for categorisation, at first, these agents communicate with each other declaring the probability of the document to be in their respective fields. In other words, these agents together try to fit the input pattern with their own pattern in the best possible way.

The complete set of text prepared in the internal format with meta-data, is then attached to the taxonomy by two phase operation.

Feature Selection

During the first phase, a specialised feature selection technique is applied. There are many feature selection methods discussed in other literatures, for e.g. [16]. Feature selection for the system is not in the scope of this paper, but the basic idea is to extract features which are special to the Russian language grammar. The features are the word counts and the weight coefficient which is decided by the complexity of the terms (involving one or more simple words).

Training

After the features are extracted from the "training set" of documents, Agents are trained to recognize and attach correct documents using the fuzzy rules and fuzzy set of terms. For the training purpose, a small amount of documents is collected as an input into the system. The categories are assigned the documents to create the fuzzy rules. And the system is "trained".

Once the Agents are trained, the whole set of documents in large sets can be applied to the system. The TC system Agents then work competitively to claim the document's category and classify them and finally, automatically populate the taxonomy structure with these documents in the E-master's document archival system.

CONCLUSION & FUTURE WORK

As discussed above, the quality of such an intelligent system mainly depends upon the way the Cognitive Agents are trained to "read" and analyse the text. The concept of automatic processing of documents by competitive agents, is in the core of this system. Processing literature of more than one language is a challenge which shall be addressed in the future.

ACKNOWLEDGEMENTS

The presented work was developed at the St. Petersburg State Polytechnic University. The author of this paper is thankful to the advisor Prof. Lev Stankevich (St. Petersburg State Polytechnic University) for their help in developing the system; and Dr. Prof. Tatiana Gavrilova (St. Petersburg State Polytechnic University) for their help in learning Knowledge Engineering and Knowledge Management. The whole project is being realized with Business Engineering Group, St. Petersburg, Russia.

References

[1] Carl Frappaolo: "Ushering in the Knowledge-Based Economy"; Forbes Magazine, April 20, 1998, also appeared as electronic version, http://www.delphigroup.com/, in research/whitepaper_request_download.htm.
[2] A Delphi Group Survey: "Information Intelligence: Content Classification and the Enterprise Taxonomy Practice"; June 2004, appeared as electronic version, http://www.delphigroup.com/, in research/whitepaper_request_download.htm.
[3] Clack, C., Farringdon, J., Lidwell, P., And Yu, T. 1997. "Autonomous document classification for business". In Proceedings of the 1st International Conference on Autonomous Agents (Marina del Rey, CA, 1997), 201–208.
[4] Charu C. Aggarwal and Stephen C. Gates and Philip S. Yu. "On the merits of building categorization systems by supervised clustering", Proceedings of EDBT-00, 7th International Conference on Extending Database Technology, pp. 352-356, ACM Press, New York, US, 1999.
[5] Soumen Chakrabarti and Byron E. Dom and Rakesh Agrawal and Prabhakar Raghavan, "Using taxonomy, discriminants, and signatures for navigating in text databases", Proceedings of VLDB-97, 23rd International Conference on Very Large Data Bases, pp. 446-455, Morgan Kaufmann Publishers, San Francisco, US, 1997.
[6] Fabrizio Sebastiani, "Machine Learning in Automated Text Categorization", ACM Computing Surveys, Vol. 34, No. 1, March 2002, pp. 1–47.
[7] Ke Wang and Senquiang Zhou and Shiang Chen Liew, "Building hierarchical classifiers using class proximity", Proceedings of VLDB-99, 25th International Conference on Very Large Data Bases, pp. 363-374, Morgan Kaufmann Publishers, San Francisco, US, 1999.
[8] Nicolo Cesa-Bianchi and Claudio Gentile and Luca Zaniboni, "Incremental Algorithms for Hierarchical Classification", Journal of Machine Learning Research, Vol. 7, pp. 31-54, 2006.
[9] D. Lewis and M. Ringuette. A comparison of two learning algorithms for text categorization. In Symposium on Document Analysis and Information Retrieval, Las Vegas, NV, April 1994. ISRI; Univ. of Nevada, Las Vegas. To appear.
[10] Gerard de Melo and Stefan Siersdorfer, "Multilingual Text Classification using Ontologies", Proceedings of the 29th European Conference on Information Retrieval, April 2007.
[11] C. Apte, F. Damerau, and S.M. Weiss, "Towards Language Independent Automated Learning of Text Categorization Models," ACM SIGIR'94, July 1994.
[12] Business Engineering Group, St. Petersburg, Russia. The Company's website: http://www.big.spb.ru/
[13] Stankevich, L.: "A Cognitive Agent for Soccer Game"; Proc. CEEMAS'99, the First Workshop of Central and Eastern Europe on Multi-Agent Systems, St. Petersburg, Russia (1999).
[14] Huhns, M.N.; Singh, M.P. "Cognitive agents", Internet Computing, IEEE Volume 2, Issue 6, Nov.-Dec. 1998 Page(s):87 - 89.
[15] Chun-Che Huang, "Using intelligent agents to manage fuzzy business processes", Systems, Man and Cybernetics, Part A, IEEE Transactions on Volume 31, Issue 6, Nov. 2001 Page(s):508 – 523.
[16] D. Lewis. Feature Selection and Feature Extraction for Text Categorization. In Procceedings of the Speech and Natural language Workshop, pages 212{217, February 1992. Sponsored by the Defense Advanced Research Projects Agency.

EXPLICATIVE MODEL OF INTELLECTUAL CAPITAL

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Abstract: It is important to question, in the current context of globalization, if the notions of knowledge economics and intellectual capital are an indication of a short lived fad or of a long term fad that will leave an indelible print in management sciences, placing Man in the centre of the productive process, from where he'd been torn out of in the context of the developing industrial revolution.

The results obtained suggest that the theorists and specialists in management, namely where knowledge management is concerned, share different conceptual settings about this thematic set on two vectors, subjacent to the degree of appropriation and sharing and the individual/structural level of knowledge. This is not linear, but rather a complex vision of intellectual capital.

Keywords: Intellectual Capital, Knowledge Management, Knowledge economics

1. INTRODUCTION

Fads constitute an inherent phenomenon to the very evolution of management sciences (Lopes and Reto, 1990), noting that it's usual a simple change in rhetoric. In a time where neo-liberalism takes up a great deal of the visible space of corporate and even social activity, the same formula came to be: "the human factor constitutes the difference".

To designate the key concept in this new economic age of "intellectual capital" implies a long classification and measurement effort so that, in a sustained way, we can proceed to its generalization.

Indeed, the global economy is presenting important changes and transformations, caused by diverse factors, namely the significant technological advances, such as the appearance and diffusion of personal computers, high-speed telecommunications and the Internet. In fact, Drucker (1970) anticipated the three great orientations of change that the economy experiences:

- New Technologies will appear that will change the profile of the industry;

- Changes will take place in the global economy that will turn the world into one sole market;

- Knowledge will become capital, as an economic resource.

In this way, men of knowledge will be the men of power.

These changes in technology influenced and changed the corporate environment, the period in the past three decades having been denominated in several ways – information technology, digital economy, knowledge economy, risk society, and above all, age of quality and innovation.

2. CONTEXTUALIZATION OF THE PROBLEM

In a general way, we can refer to this epoch as the age of Knowledge Economics, where there are underlying qualitative and quantitative changes that transformed the structure, the operations and the rules of the economy such as we know them. In this new economy, like some insist in designating it, the keys to job creation, improved standards and pattern of life, are the innovative ideas and technology incorporate in services and products. It's an economy where risk, uncertainty and change are the rule, more than the exception.

In effect, knowledge has become one of the most important factors for the economic life. It is the main ingredient in what we buy and sell, the primal matter with which we work. In the growing new economic order, Intellectual Capital, much more than natural resources, machinery, or even financial capital, seems to assume in a growing way the role of key active element of a company, for it is it that allows the transformation of information into knowledge.

The investigation about strategic planning falls upon the importance of intangible resources, acknowledged as one of the main differentiating factors (Hoskinsson, Hitt, Wan and Yiu, 1999) and even competitive (Porter, 1986).

But these vital actives are still not, in these days, identified in the accountable peaces, and as such, are deficiently managed.

Knowledge is effectively much more than information. Information is constituted from organized data in logical archives. Information is transformed into knowledge when a person reads, understands, interprets and applies the information to a specific task. Without the intervention of intellectual capital there is no production of knowledge (Martins, 2000).

Indeed, the information of one person may constitute the knowledge of another. If a person can't understand and apply the information in any situation, it remains only as such – information. However, another individual, obtaining the same information, can understand it and interpret it in the context of its previous experiences and, through unique life experience and learned lessons, apply knowledge in a way that the second person might not even have considered. Each slice of knowledge gained in each of these situations will be as important as any other. The long road that Corporate Management has developed will be surely rewarding to understand, with better detail, the emergence of Intellectual Capital, in the Age of Knowledge.

The residual role to which intangible actives were usually relegated to is definitely and radically changing, possibly even assuming a central role, for example, in accounting.

The interest for Knowledge Management resides in the creation of a network constituted by rules that are used to transmit the power to the people, power that is substantiated in the intellectual factor, cultural and social aspect, and physical memory of the organization. Knowledge management is becoming the nerve centre of the organization because it gives primacy to the intangible over the tangible, this aspect being what clearly distinguishes this new form of management.

In this way, there are two important types of knowledge organizations to be considered:

A) The organizations in which their main product or service in knowledge itself. In this situation are those who manage it and those who act in the transfer of information. It is here that are included software organizations, biotechnology, hardware, information technology, whose professionals are mainly engineers, scientist, technological programmers and designers, their principal result being the transformation of their investigations into new products or services. The use of the great industrial complex, characteristic of the industrial age is practically nonexistent, the capital is reduced, if compared with the other types of companies and their stock capitalization far outweighs the nominal value per share. In fact, for being the engines of growth in the knowledge economy, these organizations are assuming a crucial importance in the economic system.

B) There are, on the other hand, organizations involved in the manipulation, processing and distribution of information. In this group are telecommunication companies, banks, stock exchange, insurance companies, publicity agencies and professions such as lawyers, salesmen, accountants and teachers. In these organizations, the manipulation and management of information are vital for success, with even greater importance than the creation of knowledge.

3. METHOD

In this way, it's important to present the data from the research undertook by Martins (2000), the study in question bearing two great parts, an initial exploratory study with recourse to three panels and the posterior study, resorting to two panels.

Firstly, it was sought through the revision of literature to obtain a comprehensive compilation of the studies produced in the area.

Thus, to the members of the three panels, the investigator asked them to participate in the first phase of the investigation, according to criteria elaborated, for methodological reasons, and similar to those used by Quinn and Rohrbaugh (1983), in elaborate research according to identical methodology.

Indeed, in the exploratory analysis of an explicative model of the new emerging paradigm, and faced with the panoply of theoretical production on the matter, it was imposed the construction of a perceptual map.

The necessity to produce and integrating element of the perceptual diversity present in the investigations, previously conducted, led away the possibility of using traditional methodologies of multivariate analysis, for they don't bear into account the specificities demonstrated by theorists and researchers.

4. RESULTS

The identification of a model with two axels, **x** (type of knowledge, from tacit to explicit) and **y** (capital of knowledge, from individual to organizational) represents a conceptual diversity mirrored in four quadrants.

The classification of the four quadrants clearly results from their positioning, having assumed the designations:

- Tacit knowledge/human capital = knowledge of the individual;

- Tacit knowledge/structural capital = knowledge of the clients;

- Explicit knowledge/structural capital = applied experience;

- Explicit knowledge/human capital = team reflexion.

In this way, we present the only global explicative model, identified in our analysis.

Human Capital

Explicit Knowledge

Team	**Knowledge of the individual**
Applied experience	**Knowledge of the clients**

Structural Capital

Fig.1 - Explicative model of intellectual capital

Model for Intellectual Capital adapted from A. Eduardo Martins (2000)

In the presented model, it is designated as knowledge of the individual the quadrant tacit knowledge/individual capital, for in reality it's knowledge that's inscribed into the individual himself, non formalized and constituting a veritable source of value. Here, we include the individual's theoretical and practical knowledge and their aptitudes of different types, such as artistic, sports or technical.

In contexts where it's important to obtain elevated levels of individual performance from the employees, it's fundamental the existence of knowledge of the individual and technical knowledge from the team.

On the other hand, if we are faced with the same individual capital, but the knowledge is of the explicit form, we are in the level of the team or group, in that this shares the explicit knowledge in its bosom and recreates it. In this field knowledge presents itself to the individual in the form of facts, concepts or tools.

But if instead of individual capital, explicit knowledge gets associated with structural capital we are in the presence of applied experience, for all the organization holds knowledge that is formalized and likely to be operated and transmitted. This quadrant represents the set of shared knowledge, summed up by specialists, being acknowledged as the most advanced form of knowledge (Boisot, 1995).

Lastly, Martins (2000) identifies the knowledge of clients that results in from the junction of structural capital with tacit knowledge, this is, that which is tacitly at the disposition of the organization and which results from the interaction with the means and the clients. This typology represents organizational knowledge in its practical form and which resides in the tacit experiences formalized in the collective (Brown and Duguid, 1991). Despite being hidden, this knowledge becomes accessible through interaction, being a distinctive factor of the performance of highly specialized teams (Spender, 1994) that follow the necessities of the clients.

Since there is no concept of intellectual capital that is met with widely generalized acceptance (Bontis, 1998; Ghoshal and Nahapiet, 1998), capable of producing universal models of practical use, the previously delineated investigation was held, so as to establish an explicative model that presents pertinent and revealing results that the model of intellectual capital must privilege the concepts of tacit knowledge, explicit knowledge, individual capital and structural capital.

Thus, we see that the explicative model of constructed intellectual capital sets in four distinct patterns, for the different existent theories reflect the intensity and focus on its various quadrants, constituting themselves as aggregator of the conceptual diversity existing in this domain.

If on the one hand the more structural visions prevail, giving privilege to the quantitative aspects, supported by indicators, to the vision present in the methodology proposed by Skandia (Swedish insurance company pioneer in the divulgence of Intellectual Capital); on the other hand, the markedly individual side assumes a dominant position in diverse observed models.

Indeed, this theme has entranced theorists and practitioners in five continents, who base their theories in its very existence and training assuming a truly contingent setting.

In this fashion, we encounter a stunning diversity of concepts regarding this thematic, to which we have previously alluded. However, if on the one hand we have watched the emergence of more particulars derived from the outbreak of interest on the matter of knowledge management, time, as recognized by Charles Darwin for the natural selection of species, refined and brought out some of the currents, for managing to bring to the ranks if their own defence, and increasingly large number of adepts, both on a theoretical and on a more practical level. The proposed explanatory model joins in its bosom the diversified organizational complexity, the levels of knowledge appropriation and the diverse studied concepts on knowledge management.

As previously mentioned, intellectual capital is more encompassing than the traditional vision of intangible actives. It's about the capacity of the company's members to understand, analyse and react to the dynamic of changing opportunities and threats from their environment. It encompasses still aspects such as the capacity for collective reorganization of resources to face new challenges (in constant change), formulating and conceiving new modus operandi (rather than applying old forms of management) that allow the company to remain competitive.

The vision of the company's knowledge suggests a role for managers in the application of their capacities, so as to allow the creation and integration of knowledge in their organizations, to direct and control the processes of the transformation of knowledge and then evaluate report and audit the results of those processes in a continuous basis.

These functions will depend critically from the capacity to classify advantages originated by the application of knowledge management, to identify how they increase the intellectual capital and following that how they interconnect with the strategic global goals of the organization, and lastly to evaluate how they contribute to the intellectual capital of the company compared with that existing in other companies.

5. CONCLUSIONS

It is in this context and regarding, namely, the diverse studies that relate intellectual capital with the strategic goals of the organization (Brooking, 1996; Stewart, 1997a; Edvinsson and Malone, 1998) that particular importance falls upon the construction of an explicative model of intellectual capital, presented by Martins (2000).

Results indicate that the approaches to the theory of intellectual capital are clearly insufficient. Thus, as results from the model, there exists a clear separation between tacit knowledge and explicit knowledge, which has been previously explored by some authors (Bontis, Nonaka, Polanyi and Sveiby).

However, the model distances itself from traditional approaches when evidencing that the other dimension is situated in a plane of organizational capital/individual capital.

Indeed, the theories that base their existence in human capital (Edvinsson, Saint-Onge, Stewart), seem to the maladjusted to the observed reality, for human capital, despite assuming different definitions, according to theory, doesn't place the basis of the question in the flow of knowledge.

So, when Saint-Onge claims that human capital are the accumulated capacities of the individuals responsible for supplying solutions to the client, or when Bontis (1998) considers human capital to be synonymous for intellectual worker they are reducing the true dimension of the question. Schultz (1998) wrote that the decisive factors of production are the increments in the improved quality of life of the population and of their knowledge and that these advances can be reached through appropriate investment in human capital. Human capital requires investment in both physical resources and economic capital.

The evidences show that the recourse to the terminology that specifies individual capital and team capital is best adequate to the conceptualizations of theorists and researchers than the terminology of human capital in general.

It should be pointed out that large investments to the development of applied experience have been verified, for companies intend to increase and share their knowledge (Quinn, Anderson and Finkelstein, 1996).

Organizations reach their objectives and maintain their reasons for being by what they know and how they use their knowledge. Without it, natural resources could not be developed, just like a great portion of manufactured products possesses great dependence in the degree of knowledge integration.

In fact, Stewart (1997s) defines intellectual capital as the intellectual material – knowledge, information, intellectual property and experience – that can be used to generate value.

The importance of managing the flow of knowledge, to which we previously alluded, reveals itself to be fundamental so that an organization can reach its objectives. In fact, like Ghosha and Nahapiet (1998) remind us, there is no methodology that can aggregate the diversity of theories present in literature.

However, in the theoretical conceptualization prevails the previously pointed flaw and like it was demonstrated, is present in some of the theories about this thematic, to which it will surely be no stranger the fact that they developed quite closely, whether geographically (Sveiby and Edvinsson) or conceptually (Edvinsson, Saint-Onge, Sulivan and Petrash) and even by scientific affinity (organizational branch, corporate branch, accounting branch).

Thus, the theory has evolved exponentially without bearing into account an integrating concern (Bontis, 1998; Ghoshal and Nahapiet, 1998), given the rapidity with which new approaches spring up. Indeed the thematic of management of intellectual capital is permanently present in corporate objectives, since the intellectual actives of a company are on average three or four times their accounting value (Handy, 1989).

And we couldn't help refer that the different subdivisions, constituting the intellectual capital mutually interact, independently of the designation they assume or the model in which they are inserted (Bontis, 1998; Nonaka and Takeuchi, 1997).

In equal fashion, we'd like to point out the delicate nature of the thematic, which justifies its little openness to the realization of empirical research, for the intellectual capital is directly related to with the future of the organization, in both the strategic, and the operational branch.

Several authors have focused on this matter, having Nonaka and Takeuchi (1997) claimed that the vision of knowledge in the science of strategy is similar to that of Taylorism, emphasising logical and analytical thought and the recourse to explicit knowledge existent in the top of the organization.

The transversal character of this new paradigm – in a new age – has the particular aspect of gathering within its ranks characters from all quadrants of society.

Indeed, as said the Pope John Paul II (1991), previously the primordial productive factor was land, then capital assumed that role, and today the decisive factor is increasingly man himself, that is, his knowledge.

The importance of the research in intellectual capital consists in the discovery of this bold new frontier, the discovery of an inexhaustible resource that opens the doorway to the world of knowledge.

References

Barney, J. B. (1991). Firm resources and sustained competitive advantage. Journal of Management, 17, p. 99-120.

Barro, R. J. e Sala I Martin, X.. (1995). Economic Growth, McGraw Hill.

Bassi, Laurie J. (1997). Harnessing the power of intellectual capital. Trainning e Development, 51/12, p. 25-30.

Becker, G.S. (1975). Human Capital. Second Edition. National Bureau of Economic Research and Columbia University Press, New York.

Belasco, James A. (1990). Teaching the Elephant to Dance: Empowering Change in Your Organization. Crown. New York.

Boisot, Max H. (1995). Information Space - A framework for learning in organisations, institutions and culture, Routledge, London, New York.

Bontis, Nick (1998). Intellectual Capital: An Exploratory Study That Develops Measures And Models. Management Decision, 36/2, p. 63-76.

Brooking, Annie (1996). Intellectual Capital, Core Assets for the Third Millenium Enterprise, International Thomson Business Press, London.

Brooking, Annie (1997). The Management of Intellectual Capital. Long Range Planning, 30/3, p. 364-365.

Brown, J., Duguid, P. (1991). Organizational learning and comunities-of-practice: Toward a unified view of working, learning, and innovation , Organization Science, 2, p. 40-57.

Carter, A. P. (1996). Measuring the performance of a knowledge-based economy. OECD. Employment and Growth in the Knowledge-based Economy. Paris.

David, P.A. e Foray., D. (1995). "Accessing and Expanding the Science and Technology Knowledge Base," STI Review: OECD-Science, Technology, Industry, 16, Fall: p. 13-68.

Drucker, P. F. (1970). Uma era de descontinuidade. Zahor, Rio de Janeiro.

Ducharme, Louis-Marc (1998). Measuring Intangible Investment. OECD - Organisation for Economic Co-Operation and Development, 1ª edição.

Edvinsson, Leif e Malone, Michael S. (1998) . Capital intelectual. Makron Books do Brasil editora, 1ª edição. (Tradução do original em Inglês Intellectual Capital, Harper Collins Publishers Inc., 1997).

Farrell D. (1983). Exit, voice, loyalty, neglect as response to job dissatisfaction : a multidimensional scaling study. Academy of Management Journal, 26/4, p. 596-607.

Flamholtz, E. G. (1985). Human Resource Accounting. San Francisco: Jossey-Bass.

Foray, D. e Lundvall, B-A. (1996). The knowledge-based economy: from the economics of knowledge to the learning economy. OECD. Employment and Growth in the Knowledge-based Economy. Paris.

Freeman, C. (1982). "The economics of industrial inovation", Capítulo 8, France Pinter, London.

Ghoshal, S., & Nahapiet, J. (1998). Social capital, intellectual capital and the organizational advantage. Academy of Management. The Academy of Management Review, 23/2, p. 242-266.

Godfrey, P. C. & Hill, C. W. L. (1995). The problem of unobservables in strategic management research. Strategic Management Journal, 16/7, p. 519- 33.

Grantton, Lynda e Ghoshal, Sumatra (2003). Managing Personal Human Capital: New Ethos for the ´Volunteer´ Employee. European Management Journal 21/1, p. 1-10.

Greenhaus, J. H., Bedeian, A. G., e Mossholder, K. W. (1987). Work experiences, job performance, and feelings of personal and family well-being. Journal of Vocational Behavior, 31, p. 200-215.
Handy, Charles (1989). The age of unreason. Business Books Ltd, 1ª edição.
Hoskisson, R. E., Hitt, M. A., Wan, W. P., Yiu, D. (1999). Theory and research in strategic management: Swings of a pendulum. Strategic Management Journal, 25/3, 417-456.
Lopes, A. e Reto L. (1990). Identidade da empresa e gestão pela cultura, Sílabo, Lisboa.
Lucas, R.E. (1988). On the mechanics of economic development. Journal of Monetary Economics, 21, p. 32.
Malone, T. W., K.Crowston, J. Lee, B. Pentland, et al. (1999). "Tools for inventing organizations: Toward a handbook of organizational processes" Management Science 45/3, p. 425-443.
Martins, António Eduardo (2000). Capital Intelectual – Ensaio Exploratório de Modelo Explicativo. Dissertação de Mestrado em Ciências Empresariais, ISCTE, Lisboa.
Martins, António Eduardo (2006). Determinantes do Investimento Directo Estrangeiro – O caso da Polónia. Dissertação de Mestrado em Economia e Estudos Europeus, ISEG, Lisboa.
Morin, Estelle M. (1994). L' efficacité de l'organisation: Théories, représentations et mesures, Canadá - Québec, 1ª edição.
Nahapiet, Janine (1998). Social Capital, Intellectual Capital, and the Organizational Advantage. Academy of Management Review, 23/2, p. 242-266.
Nelson, R.R., Winter, S.G., (1982). An Evolutionary Theory of Economic Change, The Belknap Press of Harvard University Press, Cambridge MA.
Nohria, N. e Gulati, R. (1997). What is the optimum amount of organisational slack? European Management Journal, 15/6, December, p. 603-611.
Nonaka, Ikujiro e Takeuchi, Hirotaka (1997). Criação de conhecimento na empresa: Como as empresas japonesas geram a dinâmica da inovação. Editora Campus, 3ª edição. (Tradução do original em Inglês The Knowledge – Creating Company, Oxford University Press, 1995).
Pavitt, K. (1997). Technologies, Products e Organisation in the Innovating Firm. Science Policy Research Unit. University of Sussex.
Penrose, E. (1959). The Theory of the Growth of the Firm. John Wiley & Sons. New York.
Petrash, Gordon (1996). Dow's Journey to a Knowledge Value Management Culture. European Management Journal, 14/4, p. 365-373.
Polanyi, M. (1966). The tacit dimension . Routledge and Kegan Paul. London.
Porter, Michael E. (1986). Estratégia Competitiva. Editora Campus, 8ª edição. (Tradução do original em Inglês Competitive Strategy, 1980).
Quinn, James Brian; Anderson, Phillip; and Finkelstein, Sydney, (1996). Managing Professional Intellect: Making the Most of the Best, Harvard Business Review,74/2, March-April, p. 71-80
Quinn, Robert E.; Rohrbaugh, Jhon (1983). A spatial model of effectiveness criteria: Towards a competing values approach to organizational analysis. Management Science, 29/3, p. 363-377.
Reis, Elizabeth e Moreira, Raúl (1993). Pesquisa de mercados. Edições Sílabo, Lda, 1ª edição.
Rogers, Debra M. Amidon (1996). Knowledge Management Gains Momemtum in Industry. Research - Technology Management, 39/3, p. 5-7.
Romer, P. M. (1986). Increasing returns and long-run growth. Journal of Political Economy, 94, p. 1037.
Romme, G. e Dillen, R. (1997). Mapping the Landscape of Organisational Learning. European Management Journal, 15/1, February, p. 68-78.
Rusbult, C. E., e Farrell, D. (1983). A longitudinal test of the investment model: The impact on job satisfaction, job commitment, and turnover of variations in rewards, costs, alternatives, and investments. Journal of Applied Psychology, 68, p. 429-438.
Rusbult, C. E., Farrell, D., Rogers, G., e Mainous, A. G., III (1988). Impact of exchange variables on exit, voice, loyalty, and neglect: An integrative model of responses to declining job satisfaction. Academy of Management Journal, 31, p. 599-627.
Saint-Onge, Hubert (1996). Tacit Knowledge: The Key to the Strategic Alignment of Intellectual Capital. Strategy e Leadership, 24/2, p. 10-14.
Schopler, J., Rusbult, C. E., & McCallum, R. (1979). Conceptual dimensions of crowding: A multidimensional scaling analysis. - M. R. Gurkaynak & W. A. LeCompte (Eds.), Human consequences of crowding (pp. 205-217).. Plenum. New York.
Schultz, T. W. (1971). Investment in Human Capital. The Role of Education and of Research. The Free Press, New York.
Schultz, Theodore W. (1981). "Investing in people: The economics of population quality". Berkeley and Los Angeles, CA: University of California. (citado em Bontis, 1998).
Senge, Peter M. (1990). The fifth discipline, the art and practice of the learning organisation. Doubleday Currency, London.
Simon, Herbert Alexander (1997). Administrative behavior: a study of decision – making process in administrative organizations. Free Press, 4ª edição.
Sonnenberg, F. K. (1994). The age of intangibles. Management Review, 83/1, p. 48-53.
Spender, J. (1994). Organizational knowledge, collective practice and penrose rents , International Business Review, 3, p. 353-367.
Spender, J. (1996): Organizational knowledge, learning and memory: three concepts in search of a theory. Journal of Organizational Change, 9/1, 63-78..
Stewart, Thomas A. (1997a). Intellectual Capital: The new wealth of organizations. Nicholas Brealey Publishing, 1ª edição.
Stewart, Thomas A. (1997b). Brain Power: who owns it ... how they profit from it. Fortune, 135/5, p. 104-110.
Stewart, Thomas A. (1997c). Grab a pencil—it's a knowledge quis. Fortune, 136/11, P. 241-242.
Stiroh, K. J. (1999). Computers and Productivity. Federal Reserve Bank of New York.
Stuart, T. E. e Podolny, J. M. (1996) "Local search and the evolution of technological capabilities." Strategic Management Journal, 17, p. 21-38.
Sveiby, Karl Erik (1998a). A nova riqueza das organizações. Editora Campus, 1ª edição.

(Tradução do original em Inglês The new organizational wealth, Berrett-Koehler Publishers, Inc., 1997).

Sveiby, Karl-Erik (1998b). Intellectual Capital: Thinking Ahead. Australian CPA, 68/5, p. 18-22.

Sveiby, Karl-Erik (1998c). What is Knowlegde Management?, http://www.sveiby.com/articles/KnowledgeManagement.html.

Thornburg, Linda (1994). Accounting For Knowledge. HRMagazine, 39/10, p. 54-56.

Ulrich, Dave (1997). Human Resource Champions: The next agenda for adding value and delivering results. Harvard Business School Press.

Wernerfelt, B. (1984). A resource-based view of the firm. Strategic Management Journal, 5, p. 171-180.

A METHOD TO IDENTIFY CRITICAL RESOURCES: ILLUSTRATION BY AN INDUSTRIAL CASE

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Keywords: multi-criteria approaches, critical failure factors, manufacturing systems, production management

I. INTRODUCTION

Nowadays, one of the essential concerns for a company is the improvement of its economic performance and one of the pillars of this performance is the resources of the company's manufacturing system. The ability to control these resources constitutes a success key for the company's competitiveness. Therefore, to ensure the required availability for production and to meet the customer's requirements, identifying the critical resources appears to be a crucial task. For example, the first aim of an airline is to make its planes fly. In this case, it seems easy to identify the critical resource. However, in the case of a small business with several means of production and many different products and customers, the prioritization of the resources is less obvious. The major interest in identifying the critical resources lies in helping managers to focus on the efficient actions and on the problems that penalize the global performances of the company. Significantly, the company has to constantly review its production system, to be flexible and able to apply quick and right decisions. Giving the lack of time and the more and more competitive market, it becomes necessary to know the resources that cause the greatest loss of profit faced to disruptions.

Different studies have shown a particular interest in the prioritization of the physical resources of companies [1], [2], [3], [4]. One of them suggests prioritizing the physical resources of an agribusiness company's according to the PIEU method, developed by Lavina [4], [3]. This method enables the classification of a set of equipments by attributing to them the following four criticality indexes: the failure index (P), the importance of the equipment (I), the condition of the equipment (E) and the using rate (U). On the other hand, Chelbi and Ait-Kadi's [1] suggest identifying the criteria to prioritize the resources by the means of an organization method developed by Roy [5]. This method is organised in 4 stages: (1) identifying the set of equipments to be classified, (2) establishing a coherent list of priority criteria, (3) evaluating the performance for each part of equipment according to their global performance, and (4) applying an aggregation procedure to class the equipment according to their global performance. On the basis of this step, 9 prioritization criteria have been identified, such as the contribution of the resource to the flow process, the average of the resource's repair time and the importance of the line, in which the equipment is part [2]. A more recent study, carried out at a production unit of plastic products classifies the equipment according to a multi-criteria matrix weighted coefficients for each part of equipment [1]. The retained criteria are importance of the machine, security and consumption. These studies lead to different ways of prioritization of the resources in the context of the maintenance. Nevertheless, the resources of the company can not be perceived as being only physical, but more accurately as a combination of physical and human ones. Yet, it is the control of the company's human resources, which is at the heart of the competitive advantage [6], [7], [8]. The originality of our method consists to consider directly both human resources and the economical aspect. Indeed, in order to maximise its performance, the company should identify the resources that most influence its economic performance.

Based on a multi-criteria approach, this article suggests a new method of resources prioritization more adapted to economic demands and strategic needs of a company. In order to achieve this objective, the principal criteria of the resources' prioritization will be identified, as linked directly to their impact on the profit loss, taking into account the human resources. The aim of this method is to help the planning of preventive and improvement actions. This method was applied to actual data gathered at a screw cutting company.

II. PROPOSED METHOD

A. Resources' prioritization method based on a criticality matrix

On the basis of a multi-criteria approach founded on a criticality matrix, a new resources' prioritization method is developed. This method uses a desirability function which makes it easy and quick. This is very important since the company undergoes constant changes and then requires a perpetual knowledge of resources which impact the economical performance. Moreover, the using of a criticality matrix is perfectly adapted to a multi-criteria approach.

To build the criticality matrix, we explored the principal criteria which are necessary for the application of the method. At first, we propose to identify the criteria directly impacting the company's profit margin. Then, we define additional qualitative criteria necessary to improve this matrix.

The proposed method allows to quantify the loss of profit margin caused by the different types of stop for each one of the company's resources. As the loss of the company's profit margin depends on a complex mix between the production loss and the combination of multiple factors, the set of the criteria directly influencing the margin will have to be looked for.

Hence, the profit margin (PM) can be calculated in the following way:

$$PM=\sum_{i=1}^{n} Pqi.RPi.pPMi$$

Where,

n: number of products types produced by the company

Pqi: estimated produced quantity of the product i ($Pqi=TPqi-LPi$)

TPqi: theoretical production of the product i

LPi: estimated loss of production of the product i, linked to the physical and human failures

SPi: Selling price of product i

pPMi: percentage of the profit margin for product i

Therefore, in order to identify the critical resources of a company, the following five criteria are to be taken into consideration: the selling price, the percentage of profit margin, the reliability rate, the proportion of the quantity of products manufactured by machine and the unavailability. However, these five criteria are not the only ones which can used to measure the risk of a financial loss for a company. Indeed, the failures of some resources can generate a risk in customer's satisfaction and then a loss of market. Some resources present a risk to the safety of the employees of company. Therefore, the following four other important criteria are added to the first five already cited: the customer's risk, the safety of employees, the uniqueness of production means and the costs of maintenance.

Thus, the detailed presentation of the nine identified criteria is as follows:

1) The selling price (SP),

In order to build the criticality matrix the company has to identify the selling price of each product type.

2) The percentage of profit margin (pPM),

This criterion corresponds to the estimated percentage of the profit margin for each product type. It is evaluated by the company according to the estimated cost systems.

3) The estimated reliability rate (Err):

The estimated reliability rate is calculated in the following way:

$$\mathrm{Err}=\frac{TPqi\ .Ct}{Ot}$$

Where: *TPqi: theoretical production of product i*

Ct: cycle time (the processing time for product i)

Ot: opening time

4) The proportion of the quantity of products that can be manufactured (pM)

This criterion is calculated in the following way: $pMj = \frac{TPqj}{\sum_{i=1}^{n} TPqi}$

Where- n: number of machine

pMj: proportion of parts for machine j.

TPqi: theoretical production of machine i

5) Unavailability (material and human failures)

The loss of production linked to the failures depends on the machine reliability rate. Indeed, it is possible that the failures do not have any influence on the produced quantity when the reliability rate of the resource is low.

The availability criterion, which is being referred to in this study, takes into account the risk linked to the absence of human competences. A new idea suggested in this study is to calculate the human-machine Mean Time Between Failures (MTBF).

In order to consider the risk of the production loss linked to both physical and human resources, the theory of reliability science is applied here.

The human resource is considered in the MTBF calculation only if it demonstrates that it is the unique competence for a given machine. Indeed, in this case if the human resource having the specific skills for a physical resource is absent, the resource to which it is habitually assigned is then stopped. On the other hand, where several human resources have the necessary skills for a given machine, the risk linked to the absence of a competent human resource is then without consequence. The main two parameters needed to evaluate the reliability function are: the repair rate (μ) and the failure rate (λ).

If we consider an exponential distribution, the mathematical expectation E(t) between failures, which represents the MTBF, is: $MTBF = E(t) = \frac{1}{\lambda}$

And the mathematical expectation for downtimes E(tar), representing the Mean Time To Repair (MTTR) is:

$$MTTR = E(tar) = \frac{1}{\mu}$$

The risk of downtimes for the machines having a unique human competence is represented by the human-machine MTBF and MTTR ($MTBF_{HM}$, $MTTR_{HM}$).

Both of the elements – Machine and Human M_{HM} – are represented by a serial system from the viewpoint of reliability, consequently:

$$\lambda_{HM} = \lambda_H + \lambda_M$$

$$\lambda = \frac{\text{Numbers of downtimes}}{\text{Observed time}}$$

With:

Number of human downtimes = number of absences

Number of machine downtimes = number of failures

Then,

$$MTBF\ HM = \frac{1}{\lambda M + \lambda H}$$

For the evaluation of the $MTTR_{HM}$ the average of the weighted downtime is given by:

$$MTTR_{HM} = \frac{\lambda_H \times MTTR_H}{\lambda_H + \lambda_M} + \frac{\lambda_M \times MTTR_M}{\lambda_H + \lambda_M}$$

For the evaluation of the unavailability, the calculation is given by:

$$I = 1 - \frac{MTBF}{MTBF + MTTR}$$

In some conditions, breakdowns do not have any effect on the produced quantity. Consequently, the related criteria influencing the profit margin are only considered when the availability ratio of the resource is lower than the estimated reliability rate.

6) Customer’s risk

This criterion can be related to the strategy adopted to satisfy a specific customer or the customers representing a majority of the company’s market. The aim of this criterion is to identify the resources which harm to the satisfaction of most essential customers.

7) Safety of employees

It is necessary to follow resources which could put in jeopardy the employees of a company. In the extreme case, if not considered, the employee’s safety could generate a financial loss and harm the survival of the company. Failures of some resources are more dangerous than others.

8) Uniqueness of production means

Several resources could have a specific and single manufacturing process. If this kind of resource is stopped some products cannot be produced, which could harm the satisfaction of customers involving in some cases a loss of market.

9) Costs of maintenance

The costs assigned to the maintenance are different according to the technology or the age of a machine; some resources can generate a higher financial loss. This criterion is necessary to build a hierarchical organisation of the different machines of a company.

This method of resources' prioritization – elaborated with the help of a criticality matrix – is based on the attribution of criticality indexes to these nine criteria. These criticality indexes are attributed thanks to a desirability function (d). For the evaluation of the desirability d_i the calculation is given by:

$$di = \frac{vi}{\max(vj)}$$

Where,

j: number of criterion

v_i: the value of criterion i. The overall desirability D, another value between 0 and 1, is defined by combining the individual desirability values. The overall desirability is defined by the geometric mean:

$$DG = (d_1.d_2.d_3....d_k)^{1/k} = \left(\prod_{i=1}^{k} d_i\right)^{1/k}$$

This overall desirability corresponds to the criticality of the studied resources.

It is possible to introduce a weight in this calculation then we have:

$$DG = \left(\prod_{i=1}^{k} d_i^{w_i}\right)^{1/\sum_{i=1}^{k} w_i}$$

The desirability transforms a characteristic in an undimension scale between 0 and 1.Three cases are generally considerate: the higher is the best, The lower is the best, the target is the best. Figure 1 illustrate the case higher is the best.

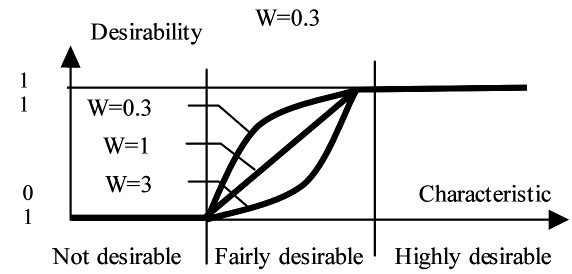

Fig. 1. Illustration of the approach of the desirability

III. APPLICATION AND RESULTS

A. Application of the proposed criticality method to the data of a screw cutting company:

The example of a screw cutting company has been chosen. This company is located at the heart of the Arve valley (Haute-Savoie region, France) and then constitutes a particularly interesting application field. The Arve valley is considered to be one of the principal local French productive systems. The companies of the valley generate more than 60% of the French turnover of the screw cutting activity, i.e. fabrication of machine parts out of essentially metal materials. In the case of most of the parts manufactured in a screw cutting company, the product generally undergoes the following two successive transformation operations: screw cutting and washing. One of the particularities of the screw cutting company resides in the configuration of its production system (cf. Figure 2).

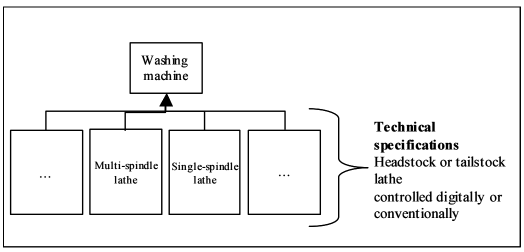

Fig. 2. Configuration of the producing department of the examined screw cutting company.

Resource/ Machine(M)	Product(P)	Selling price(in euros)	Cycle time(in minutes)	Average percentage of the margin by product	MTBF Human-Machine (in minutes)	Estimated Reliability rate	Production carried out (in number of parts)	Proportion/ contribution to the total production
M1	P1	0.07	0.06	10%	4500	0.84	2784	41%
M2	P2	0.9	0.75	15%	4500	0.93	249	4%
M3	P3	0.23	0.07	2%	4160	0.73	2112	31%
M4	P4	0.5	0.11	5.50%	4500	0.95	1728	25%
M5	All	0.425	0.017	8%	4500	0.58	6873	100%

Table 1. Data gathered in the studied company

Machine (M)/ Resource	Opening time in minutes per year	Average number of failures per year	Average down time in minutes	MTBF Machine in minutes	MTBF Human-Machine in minutes	Availability
M1		45		4500	NA	0.65
M2		45		4500	NA	0.65
M3	202500	NA	2400	NA	4160	0.63
M4		45		4500	NA	0.65
M5		45		4500	NA	0.65

Table 2. Failure parameters

Machine (M)/ resource	Profit margin					Customers		Employees	Maintenance	Criticality Overall desirability (OD)
	(If availability< relability rate) Unavailability	Flow-process grid contribution	Estimated reliability rate	Selling price	Previsional percentage of the profit margin	Uniqueness of production's mean	Consequence customer	safety	Costs of maintenance	
M5	NA	NA	NA	NA	NA	1	1	NA	1	1.00
M4	0.97	0.25	1	0.56	0.37	NA	NA	NA	NA	0.55
M2	0.97	0.04	0.98	1	1	NA	NA	NA	NA	0.52
M1	0.97	0.5	0.88	0.08	0.67	NA	NA	NA	NA	0.47
M3	1	0.3	0.77	0.26	0.13	NA	NA	1	NA	0.45

NA: No Applicable

Table 3. Classification of the resources according to the proposed method

In this company, three types of resources are studied: two multi-spindle lathes, two single-spindle lathes and a washing machine. As it is depicted by the diagram 1, the lathes are independent from each other. Another particularity of this system is the importance of the only resource contributing to the flow-process of the company, i.e. the washing machine.

B. The company's data:

The data presented below are those gathered during the observations carried out in this company and the interviews with employees (table 1). The data used to calculate the unavailability of machines are summarized in table 2. The examined company processes its production during a period of 45 weeks per year. The average maximal number of failures occurring per month is 4, i.e. 45 per year. The opening time during the period of 45 weeks comprises 202500 minutes. The maximal downtime of a machine is estimated to be 40 hours (2400 minutes).

The failure rate of each machine has been calculated on the basis of the maximal number of stops – rather than the average number – in order to ensure the examination of the maximal impact of a failure on the production. Likewise, the repair rate has been calculated on the basis of the maximal time of the repair.

Except for machine M3, the machine MTBF is equal to 4500 minutes. For the machine M3 a human-machine MTBF has been calculated.

More, this new approach is carried out according to the other following data:

- Average number of absences per person and per year: 1.97

- Average duration of an absence per year: 5 days

- Time worked by a person per year: 108 000 minutes (8h x 5days x 45weeks x 60)

- Human failure rate: $\lambda H = \frac{1.96}{108000} = 1.83x10-5$

- Machine failure rate: $\lambda H = \frac{45}{202500} = 2.22x10-4$

- Human-machine MTBF:

$$MTBF\ HM = \frac{1}{\lambda M + \lambda H} = \frac{1}{2{,}40x10-5} = 4160\ mn$$

- Human-machine MTTR: 2400 minutes

C. Criticality matrix: obtained results

A weighted scale is used; the highest value is rated as 1. To evaluate the risk linked to the loss of profit margin, the resource M5 which has an estimated rate lower than the availability is not considered. The risk of the production loss of this machine linked to the risk of failures calculated by the MTBF and the MTTR is null. For the other resources the desirability is calculated (cf. Table 3). For example, for the criterion related to the selling price, the calculation of the scale is as follows:

The highest selling price is that of the product produced by the machine M2 (0.9 €), and consequently, its rating value is the highest (1).

In the case of the machine M4, whose product selling price is 0.5 €, the rating is carried out through desirability (d): $dM4=\frac{0.5}{0.9}=0.56$

The final index of the criticality is calculated for each machine according to the overall desirability for nine prioritization criteria that have been retained. It enables the prioritization of the resources in relation to their impact on the company's profit margin and on the financial loss.

The identified resource as critical is the machine M5. This is a uniqueness of production means and it contributes to the satisfaction of all customers of the company since it is essential to the production of all products.

IV. DISCUSSION

A. Criticality matrix: nine criteria

Our new prioritization method is based on the attribution of the criticality index for the 5 quantitative criteria directly influencing the company's profit margin and 4 qualitative criteria. We tested a part of our method based on the quantitative criteria influencing the profit margin by simulation. Prioritization results obtained by simulation are the same of those obtained with our prioritization method. In the present case, the resources generating the biggest financial loss are resources M4 and M5. In order to combine quantitative and qualitative criteria we used the desirability approach by the calculation of an overall desirability. The overall desirability allows combining different kinds of data. This approach transforms estimated data in the same scale between 0 and 1. Comparing overall desirability of each resource is then easier.

B. Qualitative criteria

The qualitative criteria used in our method are targeted on the risk of unsatisfied customers, uniqueness of production means, costs of maintenance and the risk linked to employees' safety. Considering these criteria seems essential since it generates a risk of financial loss for the company. Indeed, in some cases, the no satisfaction of a customer can lead to generate a financial loss linked to the break of a contract. The criterion linked to the uniqueness of production means is necessary in the methods of resources' prioritization [1]. In the present case the resource failures which have a uniqueness of production means generates a no satisfaction of all customers; it is necessary to ensure the availability of this resource. The third criterion such as the risk linked to the employees' safety is essential in the methods of resource's follow-up. This criterion can, in the extreme case, generate a financial loss. Moreover the taking into consideration of the employees' safety contributes directly to the improvement of work conditions that constitutes a competitive advantage.

C. Consideration of the risks linked to the human resources:

One of the criteria used in our method of the resources' prioritisation is the unavailability linked to the failures. It seems advantageous to consider the company's human resources by calculating the human-machine MTBF on the basis of the number of absences of the company's employees. Therefore, our model is believed to be more representative of the company and of all of the resources influencing its profit margin. The human-machine MTBF, calculated for the machine M3 (the only machine presenting a unique human resource) is lower than the machine MTBF of all the other machines. In fact, as it was expected, the consideration of the human "failure" risk increases the number of possible stops. Until now, this notion of human "failure" has not been considered in any classification study, thus neglecting a risk for the company. Obviously, this risk is linked to the issue of absenteeism, so common in every company.

D. Criticality matrix: improvement actions

Several preventive actions can be identified in order to improve the performance due to the risks linked to financial loss. In order to improve the availability of its resources, the company would implement preventive actions of maintenance, Maintenance Based on Reliability (MBF) or (RCM) Reliability Centred Maintenance [9], and also with a long-term orientation, Total Productive Maintenance (TPM) [10].

The failure rate of a machine is variable and depends on dysfunctions of production and organisation. This variation depends on different stops of resources as breakdowns, stops for quality control, and machine starvation. The decrease and the disappearance of risks are thus based on the control of maintenance (RCM and TPM), the quality control (SPC) [11] and supply management. The right application of these methods is based on a good knowledge of the level of quality required by the customer.

Indeed, the customer could appraise defective products considered being acceptable by the supplier [12]. On the other hand, sometimes it is useless to reduce defects which will not be perceived like such by the customer. According to [13], the companies have difficulties to define the desired value by the customer. Indeed the value is variously defined according to speakers, each one defines the value in its way, according to its needs. It is necessary, to define with customers, criteria which will define the defects and thus the desired value [13]. These actions will allow decreasing the risk linked to customer's loss. The risk linked to the safety of employees could be decreased by the implementation of preventive actions, such as the fast supply of spare parts, a plan of safety for resources identified as critical [14], [15].

V. CONCLUSION

This study has enabled the introduction of a new method for the prioritization of the companies' critical resources according to their profit margin, their customer satisfaction, the costs of maintenance and the employee's safety. This method rests upon a multi-criteria approach based on the use of a criticality matrix, composed of 9 criteria directly linked to the financial loss. This step is advantageous in its referring to the profit margin itself, an essential parameter of the economical performance. More importantly, it takes into account – by calculating the human-machine MTBF – the impact of the absence of human skills on the material resources.

The desirability function approach is advantageous to combine qualitative and quantitative data. This prioritization method is simple and fast in use, and addresses to the companies wishing to know at any moment which resource generates the biggest loss of the profit margin, as much for the sake of their everyday management, as for the development of a new strategy. Having quickly prioritized its resources, a company can introduce the actions aiming at improving the situation, more centred around the resource itself, in order to increase the economical performance. Our method is adapted to screw-cutting companies. These companies produce in mass and have specific manufacturing systems. To validate this method in company of different types and environment we will apply it in other companies. On the basis of this prioritization of the resources, a company can ensure the required availability for production in order to increase the economical performance, the customer satisfaction and the safety's employee.

References

[1] Herrou B & Elghorba M, Démarche d'Optimisation du plan d'action maintenance, étude de cas d'une PME marocaine, Congrès Conception et Production Intégrée, 2005
[2] Chelbi A. & Ait-Kadi D., Classifying equipment with respect to their importance for maintenance: a multicriteria approach, Journal of decision systems, Volume 11-No.1/2002
[3] Jamali M. A., Ait-Kadi D., & Artiba A., Aid tools in implementation of maintenance management system, Conception et Production Intégrée, 1999
[4] Lavina Y., Audit Maintenance, Editions d'organisations, Paris, 1992
[5] Bouyssou D. & al., Aiding Decisions with Multiple Criteria Essays in Honor of Bernard Roy, Kluwer Academic Publishers, 2001
[6] Nanda A., Resources, capabilities and competencies, Working Paper 94-035, Harvard Business School, November 1993.
[7] Dosi G., Teece D.J. & Winter S.G., Toward a theory of corporate coherence, in Dosi G, Giametti R. et Tonelli P.A. (ed), Technology and the enterprise in a historical perspective, Oxford University Press, 1991.
[8] Hofer C. & Schendel D., Strategy formulation: analytical concepts, West Publishing, 1978.
[9] D. Richet, N. Cotaina, M. Gabriel & K. O'Reilly., Application of reliability centred maintenance in the foundry sector, Control Engineering Practice, 1995
[10] Nakajima S., Introduction to TPM: Total Productive Maintenance, Cambridge, MA, Productivity Press, 1988
[11] Pillet M., Appliquer la maîtrise statistique des procédés, Edition d'organisation, 1994.
[12] Shingo S, Study of the Toyota Production System from industrial engineering viewpoint, Association, 1981
[13] Womack J & Jones D, from lean production to the lean enterprise, Harvard Business Review 72, 1994
[14] Hessa S M., Albano A. M., & Gaertner J. P., Analysis and insights from a dynamical model of nuclear plant safety risk, reliability engineering and system safety, 2007
[15] Kai-Yuan Cai, System failure engineering and fuzzy methodology, an introductory overview, Fuzzy Sets and Systems, 1996

AN ANALYSIS ABOUT THE RESOURCES SELECTION PROCESS IN AGILE/VIRTUAL ENTERPRISES

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Abstract: We intend in the context of this work, to do an analysis on studies, literary revisions and mainly on existent models, in the universe of virtual enterprises resources selection, in order to allow us to put on perspective, in a sustainable way, new slopes to be incorporated that contributes to an improvement of the whole global process. This analysis for the A/VE was focused in several areas and basic slopes for the whole global process of the problem in question, namely in terms of the pre-selection phases and requisites; selection phases, requisites and methods; mathematical models, used tools and other important areas.

There were incorporated the decision process of create an A/VE project and the requisites of the process principal phases. We approach the essential aspects for the work that is intended to develop, such as the integration of the existent models with the tasks plan (PT) of the product, namely if there are contemplated the reformulation and evaluation of the PT, and other important characteristics such as the weighting of resources and the incorporation of the value concept in the existent models, being that in our opinion an integration of a methodology of the type of Value Analysis will be able to incorporate surplus values in all this process. Conclusions were withdrawn on the whole global process, pointing to gaps and limitations and trying to do an approach which allows to sinthetize and put in perspective an efficient analysis of the whole extent of the problem in question.

Keywords: Agile/Virtual Enterprises, Resources Selection, Value Chain, Integration

1. INTRODUCTION

Since thousands of years ago, namely in military campaigns, the supply chain and the resources selection always has assumed basic importance. For example, Sun Tzu [1] in its classic "The Art of War" has already emphasized the relevance of this question. It can also be understood as a form of contribution between suppliers, customers and consumers for the value creation. It is then, all the global process of the customer satisfaction through the creation of a value chain that integrates, in an optimizing form, all the intervening ones that are in the origin of a product or family of products execution. It is necessary to implement a global management based in the added value creation of a product, since the raw materials production phase until the distribution of the final product, in order to improve the quality of the global product performance that is proposal to the final consumer.

The technological development and the information technologies (IT) have evolved extremely fast, which originated a bigger attention to the area of the selection of resources. These more and more dynamic and complex chains provoked a strong increment of the investigation in these thematic of the resources selection. In this work the resources selection process is considered in the form of A/VE projects to frame all this thematic in a global perspective of all problematic inherent to the resources selection.

2. SELECTION OF RESOURCES IN AGILE/VIRTUAL ENTERPRISES

In the context of the intense bibliographical review and in the revision of the literature found on this theme, which sometimes is not linear and comprises other vectors and different extents, there were considered for analysis the models to be next referred, being that they all treat the problem of resources selection in organizations designated by virtual enterprises, or according to our model, agile/virtual enterprises.

The models analyzed are presented in the following table:

MODEL	Year
Sluga et al [2]	2001
Ko et al [3]	2001
Chu et al [4]	2002
Ávila [5]	2004

Fischer et al [6]	2004
Huang et al [7]	2004
Wu et al [8]	2005
Sha et al [9]	2005
Zeng et al [10]	2006
Jarimo et al [11]	2007
Chen et al [12]	2007

Table 1 Resources / Partners Selection Models in Agile/Virtual Enterprises

In this listing we tried to have an approach that was as exhaustive as possible on this theme, which has been a target of intense investigation, not intending to effectuate a "complete" literary revision, but a exhaustive and careful analysis in order to match the main objectives of the present work being of giving particular emphasis to Ávila model [5], which is interconnected in the context of the BM_VEARM agile/virtual enterprise model [13], in which the present work is inserted.

2.1. Pre-Selection Phase in the Resources Selection Models in Agile/Virtual Enterprises

2.1.1. Requisites of Pre-Selection Resources

The pre-selection requisites, that were considered in the analysis of the existent models are those identified in previous underlying works to our A/VE model [13], and they are: **Product/Task, Product/Task Project, Production Process, Production Planning and Others** (it includes quality management systems, geographical location, financial situation, cultural aspects, organizational factors, history of collaborations and others).

2.1.2. Phases of Pre-Selection Resources

The resources pre-selection process, in our A/VE model, has two principal phases [5]: the **Resources Search** and the identification of the pre-selected resources (**Automatic Identification**, **Indirect Negotiation** and **Direct Negotiation**).

In the next table (table 2) it is presented the main conclusions of the pre-selection requisites and phases.

Models	Resources Pre-Selection Phases				Consider Pre-Selection	Pre-Selection Requisites				
	Resources Search	Automatic Identification	Indirect Negotiation	Direct Negotiation		Product / Task	Product / Task Project	Production Process	Production Planning	Others
Sluga	Net Diffusion	N	Y	N	Y / NE	Y	N	N	Y	N
Ko	Net Diffusion	N	N	N	Y	Y	Y	Y	N	Y
Chu	Data Bases, Group Tecn.	Y	N	Y	Y	Y	Y	Y	ND	Y
Ávila	Y / NE	Y / NE	Y / NE	Y / NE	Y	Y	Y	Y	Y	Y
Fischer	Data Bases	N	N	N	Y / NE	Y	Y	Y	Y	N
Huang	Data Bases	N	Y	Y	ND	N	N	N	N	N
Wu	Net Diffusion	N	Y	Y	Y	Y	Y	Y	Y	Y
Sha	ND	N	Y	Y	Y	N	N	N	Y	N
Zeng	ND	Y / NE	ND	ND	N	N	N	N	N	N
Jarimo	ND	N	Y	ND	ND	Y	Y	ND	ND	N
Chen	Data Bases	Y/ NE	N	N	ND	Y	Y	N	N	N

Legend: Y – Yes ND – No Determined N – No NE – No Explicit

Table 2 Analysis of the Resources Pre-Selection Phase

Of the analysis of the previous table it emphasizes the fact that most of the models do not contemplate this phase of pre-selection formally and even those who consider this phase, they just attend to some of the requisites associated to this phase. We consider that this is an important limitation because this is a fundamental phase to the success of an A/VE project, and which we intend to develop in our future work. Of this table we can also withdrawn conclusions that in what respects to the considered phases of pre-selection, the resources search is the one where the existent models that consider this phase intervene. This phase is approached in different forms, since the models in which this phase are characterized by not defined, they effectuate obviously this resource search, not with the intention of pre-selection, but already incorporated in the phase of final selection. In what it concerns to the identification of the resources (phases of automatic identification, indirect negotiation and straight negotiation) only some of the models that consider the resource pre-selection attend these phases, a great deal of the times in a not formal or not explicit way. This is a subject that is more deepened [14] in investigation connected with the technologies of information (IT) for A/VE and is less referred in the relative literature to the models of selection that we are analyzing, nevertheless its incorporation seemed to us relevant in this analysis.

2.2. Selection Phase in the Resources Selection Models in Agile/Virtual Enterprises

2.2.1 – Requisites of Selection Resources

The selection requisites, that were considered in the analysis of the existent models are those identified in previous underlying works to our model of A/VE, and they are: **Number of Enterprises, Production Time, Transport Time, Production Cost, Transport Cost, Resources Quality, Earliest Date and Others.**

2.2.2. Phases and Methods of Selection

The resource selection process, in our A/VE model, has three principal phases (**Space Solutions Evaluation**, **Selection and Integration of the Selection Algorithms** and **System Final Selection** and we also distinguish two methods of selection of the resources (**Independent Selection Method** and **Dependent Selection Method**) [5]. These phases and methods of selection are next described, in a succinct form.

Space Solutions Evaluation: This phase has two principal objectives: the limits of selection parameters, in other words, the quantification of the limits of the resource systems performance which these systems can tend and the determination of the space of solutions dimension, in order to analyze how complex and / or feasible the project can be.

Selection and Integration of the Selection Algorithms: In this phase there is planned the model of selection that is going to be applied in the selection of the resource system. Besides the selection of the algorithms is necessary his integration, in other words, to adapt them to the problem in question and to integrate them.

System Final Selection: This phase consists in executing the algorithms of selection in the search of the best system of resources.

Independent Selection Method: Method of selection that defines the resource system in order that integrates the A/VE project in function of his performance in the total execution of all the tasks of the task plan of the product cycle of production. It means that each resource is selected for each task without considering its affection for the rest of the resources system, e.g., in time and transportation cost.

Dependent Selection Method: Method of selection that defines the resource system in order that integrates the A/VE project in function of his performance in the execution of the task plan considering parameters that reflect the distributiveness of the resources (e.g., transport time and cost) of the product cycle of production.

In the next table (table 3) it is presented the main conclusions of the selection requisites phases and methods.

Models	Phases			Selection Method	Requisites								Model Type	Mathematic Model	Final Selection Tools
	Space Solutions Evaluation	Selection and Integration of Selection Algorithms	System Final Selection		N° Ent.	Prod. Time	Transp Time	Prod. Cost	Transp Cost	Res. Quality	Earliest date	Others			
Sluga	Y	N	Y	Dependent / Independent	N	Y	N	Y	N	N	Y		Quantitative	Constraint Logic Programming	B&B
Ko	ND	N	Y	Dependent / Independent	N	N	N	Y	Y	N	N	Service, Finantial Stability	Quantitative	Integer programming	Tabu Search
Chu	ND	N	Y	Independent	ND	Y	ND	Y	Y	Y	ND		Qualitative / Quantitative	Goal Programming / ND	AHP, MADM
Ávila	Y	Y	Y	Dependent / Independent	ND	Y	Y	Y	Y	ND	ND		Quantitative / Qualitative	Goal Programming / ND	
Fischer	Y	N	Y	Independent	ND	Y	ND	Y	Y	ND	Y	Similarity	Qualitative	Goal Programming / ND	AHP, ACO
Huang	ND	N	Y	Independent	ND	Y	ND	Y	ND	Y	Y	Technology Type	Qualitative / Quantitative	Goal Programming / ND	Taguchi Functions
Wu	Y	N	Y	Dependent / Independent	ND	Y	Y	Y	Y	ND	Y		Quantitative	Integer programming	ECT
Sha	Y	N	Y	Independent	ND	ND	ND	Y	ND	Y	ND		Qualitative / Quantitative	Integer programming	AHP, MAUT
Zeng	Y	N	Y	Independent	ND	Y	ND	Y	ND	ND	Y		Quantitative	Integer programming, NP complete	B&B
Jarimo	Y	N	Y	Dependent / Independent	ND	Y	Y	Y	Y	ND	Y	Capacity Risk, Org. Depend	Qualitative / Quantitative	Mixed integer programming	EDR
Chen	Y	N	Y	Dependent / Independent	Y	ND	ND	ND	ND	ND	ND	Capability Basic Unt.	Qualitative / Quantitative	Polynomial	AHP, MADM, MAUT, EDA, Fuzzy

Y – Yes ND – No Determined N – No NE – No Explicit

Table 3 Analysis of the Resources Selection Phase

Of the previous table analysis we can note that the models treat the requisites of this phase in different forms. For example one of the vectors crucial to the resource selection process for an A/VE project is related with the questions inherent of the product transport from a task to the next task, in other words must attend not only to the costs but also to the transport times. The models that consider in some form, these requisites and that treat them in accordance to it particular importance, are focused more in the question of the costs and less in the times. Obviously these factors affect, in different ways, the complexity and resolution time of the selection algorithms inherent to the models as well as its performance. The analysis of these transport requisites stipulates also the type of mathematical formulation presented by the models reviewed. The requisite earliest date is also not attended in all the models, when actually this is a more and more essential requisite where factors as delivery time and flexibility assume primordial relevance. Also the remaining requisites of this phase are treated in a different form by the considered models, being that none considers all the considered requisites. We can note also that only one of the models [12] attends in the formal way to the aspect of the number of potential resources / partners of the project, being that in this model the objective is minimize the number of enterprises participants. Some of the models incorporate in this phase other requisites besides the defined ones and these can be visualized in the final column of the table (column “others“).

In our opinion one of the gaps of some of these models is that they do not contemplate the requisite resource quality. This requisite assumes nowadays particular relevance since the quality factor is more and more crucial for any project success.

It is also relevant, the fact that in the space solutions evaluation phase of the models that contemplate it, they do not quantify the performance limits of the resource systems for which these systems can tend towards but only the determination of the space of solutions dimension, in order to analyze if the project can be feasible, in other words they attend only to the second factor of what it was defined previously as the objectives of this phase. The only model that contemplates a selection and integration of the selection algorithms is the Ávila model, because it is the only that comprise the whole type of problems, it leaves opened which algorithm is selected to treat a determined problem. The remainder models specifies the respective problems and proposes a decision model/algorithm(s), in other words, they boards what we define for the resource system final selection. The tools/methods used for the resource system selection attending to the respective requisites, are of several types (AHP, Fuzzy, EDR, BB, MAUT, MADM, etc.) and they can be characterized as support techniques to the decision process and jointly with the mathematical models of the selection models, already analyzed previously, allow, according to the respective authors, the resolution of the selection process of the inherent resources systems.

Models	Task Plan (TP) Integration		Decision Taking A/VE	Other Characteristics	
	TP Ref.	TP Eval.		Resources Weighting	Value Concept
Sluga	Y	N	ND	N	N
Ko	N	N	ND	N	N
Chu	Y	Y	ND	Y	N
Ávila	Y	N	ND	N	N
Fischer	Y	Y	ND	Y / ND	N
Huang	N	N	ND	Y	N
Wu	Y	Y	Y	N	N
Sha	Y	ND	ND	Y	N
Zeng	Y	ND	Y	N	N
Jarimo	Y	Y	ND	Y	Y
Chen	N	ND	N	N	N

Legend: Y–Yes ND–No Determined N–No

Table 4 Global Table of Resources Selection Models in A/VE

In the previous table, there were represented slopes that we intend to deepen in the course of this work: the integration of the existent models with the product tasks plan (TP), namely if they contemplate the reformulation and evaluation of the TP, and other important characteristics such as if the models incorporate the weighting of the resources candidates and if they do any type of reference to the value concept.

Of these slopes analysis we can conclude that in what it concerns to the models integration with the TP, this is not contemplated by all the models. As a matter of fact there is a myriad of approaches, so it is possible to state that each model treats this question in a more or less different way from the remainder. As for the decision process of create an A/VE, the models do not contemplate the phase of decision taking of A/VE through a comparative analysis with a conventional process, the references to this decision [8, 10] have to see with the determination of the project exequibility face to the selected resources and eventual constraints of the model. In what it respects to the resources weighting there are several models that incorporate this weighting what goes towards the approach that we intend to use in our work.

3. ANALYSIS OF THE GLOBAL PROCESS OF RESOURCES/PARTNERS SELECTION

There was presented a revision of the existent literature and state of the art in this selection of resources process comprising to the A/VE universe. In what it respects to the selection models for A/VE, the majority is not associated in explicit form to A/VE reference models, in other words, there has not been defined the type of A/VE which the model is associated.

Most of the models do not contemplate the pre-selection phase in a formal way, they just attend to some of the requisites associated to this phase. In what it concerns to the considered phases of pre-selection, the resource search is the one where the existent models more intervene. This phase is approached in different forms, sometimes, not with the intention of resources pre-selection, but already incorporated in the final selection phase. In what it concerns to the identification of the pre-selected resources only some of the models attend to these phases.

The resources system selection is the principal motivation of the presented models. The models treat the requisites of this selection phase in different forms. For example one of the crucial vectors to the resource selection process for an A/VE project is connected with the issues inherent to the product transport from a task to the next task, e.g. we must attend not only to the costs but also to the transport times. These requisites not always are considered explicitly what constitutes an important gap since they affect the complexity and time of resolution of the selection algorithms inherent to the models as well as its performance. Also the remaining requisites of this phase are treated in different forms by the considered models. The models do not attend in a formal way to the number of resources/partners of the project, being that, this requisite is basic for the creation of synergies, relations of partnership/confidence and inter-organizations relations. The requisite earliest date is not always attended, when this is actually a more and more essential requisite when factors as delivery time and flexibility assume primordial relevance. Another limitation of some of these models is that they do not contemplate the resources quality requisite. This assumes, at present, particular relevance since the factor quality is fundamental for the success of any project.

The models specify the respective problems and propose a decision model/algorithm(s) which approach mainly the final selection of the resource system. The space of solutions evaluation phase is not attended by the presented models. They do not quantify the limits of the resources system performance for which these systems can tend towards. Only some models determine the space of solutions dimension, in order to analyze if the project can be feasible. The methods of selection that have to see with the problem specification are varied and the tools/methods used for the final selection of the resources system are of several types, namely support tools of the decision process and together with the mathematical models allow the resolution of the selection process of the inherent systems of resources. These are methods, per excellence, for use in multi-criteria type of problems and they contain aspects that go towards the methodology that contemplate the value concept. Almost all the mathematical models, propose the problem resolution of the resources selection with support of complete enumeration algorithms, or define goal functions for the considered variables.

4. CONCLUSIONS

An important aspect for our future work and which regards of the considered models analysis for A/VE has to see with the reference and incorporation of the value concept in the existing models. None of the models found and analyzed in the existent literature incorporates formally the value concept, which indicates that there is a whole basic slope, that is a paradigm actually, the value creation, which is not treated, not even analyzed, and not integrated in the aspects inherent to the resource selection process. It is our objective the integration of this concept through the application of the Value Analysis, where we expect that this application provides an important surplus value for an A/VE project [15, 16]. In what it respects to the resources/requisites weighting this is an area that has been developed and which several of the models consider. This consideration goes towards the methodology used in the Value Analysis and we intend to incorporate these weighting in the model to develop.

The existent models do not contemplate the decision process of creating an A/VE, through a comparative analysis with a conventional process. When the selection process is finished and even perhaps in intermediate phases, there must be done an evaluation of the same process. This evaluation will have to attend, as it is obvious, to the costs but also to other factors such as the project quality, the synergies and partnerships advantages that will develop with the A/VE project and others. This comparison decision is considered very important in our work, attending to all the previous and different considerations, the creation of an A/VE or the possibility to develop the project through a conventional process, eventually resorting to an outsourcing. It is based in this comparison decision that will take into account criteria of several types, quantitative and qualitative, that an effective decision of creating an A/VE must be taken.

Another slope of interest, in the context of the work, is related with the existent interconnection between the resources selection process and the tasks plan (TP) defined for a determined product. This is an issue that, in spite of joining some consensus of its importance, is not contemplated by all the models. There are models that contemplate the reformulation and evaluation of the TP while others do not attend to this situation. Also this aspect of the evaluation does not appear generally with a final evaluation, of the TP performance itself, but as a sequential and iterative evaluation task by task. As a matter of fact there is a myriad of approaches, so it is possible to state that each model treats this question of a more or less different way from the remainder. We think that in this area there will be space and relevance for a more deep and efficient investigation that leads to a better integration of the TP in the whole process of the resource selection of an A/VE project.

References

[1] Sun Tzu, (2000), A Arte da Guerra, L&PM Editores
[2] Sluga, A., Butala, P. (2001), Self-organization in Distributed Manufacturing System based on Constraint Logic Programming, Annals of CIRP, vol.50, nº1.
[3] Ko, C.S., Kim, T., Hwang H. (2001), External Partner Selection using Tabu Search Heuristics in Distributed Manufacturing, International Journal of Production Research, vol.39, nº17, pag. 3959-3974.
[4] Chu, X.N., Tso, S.K., Zhang, W.J., Li, Q. (2002), Partnership Synthesis for Virtual Enterprises, International Journal of Advanced Manufacturing Technology, 19 (2002), pag. 384-391.
[5] Ávila, P. (2004), Modelo Rigoroso de Selecção de Sistemas de Recursos para o Projecto de Empresas Ágeis / Virtuais para Produtos Complexos, Tese de Doutoramento, Universidade do Minho.
[6] Fischer, M., Jahn, H., Teich, T. (2004), Optimizing the Selection of Partners in Production Networks, Robotics and Computer-Integrated Manufacturing, 20 (2004), pag. 593-601.
[7] Huang, X.G., Wong, Y.S., Wang, J.G. (2004), A Two-Stage Manufacturing Partner Selection Framework for Virtual Enterprises, International Journal of Computer Integrated Manufacturing, June 2004, vol.17, nº4, pag. 294-304.
[8] Wu, N., Su, P. (2005), Selection of Partners in Virtual Enterprise Paradigm, Robotics and Computer-Integrated Manufacturing, nº21 (2005), pag. 119-131.
[9] Sha, D.Y., Che, Z.H. (2005), Virtual Integration with a Multi-Criteria Partner Selection Model for the Multi-echelon Manufacturing System, International Journal of Advanced Manufacturing Technology, 25 (2005), pag. 793-802.
[10] Zeng, Z., Li, Y., Zhu, W. (2006), Partner Selection with a Due Date Constraint in Virtual Enterprises, Applied Mathematics and Computation, nº175 (2006), pag. 1353-1365.
[11] Jarimo, T., Salo, A. (2007), Optimal Partner Selection in Virtual Organisations with Capacity Risk and Network Interdependencies, in URL: www.sal.hut.fi/publications - manuscript submitted for publication in Systems, Man and Cybernetics.
[12] Chen, Q.X., Chen, X., Lee, W.B. (2007), Qualitative Search Algorithms for Partner Selection and Task Allocation in the Formulation of Virtual Enterprise, International Journal of Computer Integrated Manufacturing, vol.20, nº 2-3, March-May 2007, pag. 115-126.
[13] Putnik, G., Cunha, M.M., Sousa, R., Ávila, P. (2005), BM_Virtual Enterprise: A Model for Dynamics and Virtuality, in Putnik, G., Cunha, M.M. (Eds.) Virtual Enterprise Integration: Technological and Organizational Perspectives, IDEA Group Publishing, Hershey, PA, USA, Chapter VI, págs. 124-143.
[14] Kumar, K., (2001), Technology for Supporting Supply, Communications of the ACM, June 2001/Vol.44, nº6, pag. 58-61.
[15] Ávila P., Putnik G., Cunha M.M., Pires A. (2006), Broker and Market of Resources as Organizational Mechanisms for Sustainability of Resources Selection Processes in Agile/Virtual Enterprises, Proceedings of SymOrg 2006 - X International Symposium, Belgrade / Zlatibor, Servia, June 2006.
[16] Pires, A., Putnik G., Ávila, P. (2007), The Potentialities of the Application of Value Analysis, Proceedings of the 24th International Manufacturing Conference , pag. 745-751,Waterford, Ireland.

BUSINESS FRAMEWORKS FOR VIRTUAL ENTERPRISES IN COLLABORATIVE PRODUCT DESIGN

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Keywords: Virtual enterprise; brokering; teleservices; web-based integration and management; business architecture; business framework; product design and development.

INTRODUCTION

Product design and development is a highly iterative and interactive activity that requires a wide range of competences. Traditionally, this activity has mostly been performed by relatively small teams, either composed of designers (with a stronger focus on product design) or of engineers (with a stronger focus on product engineering). Often, these teams were comprised of a single individual. However, it is clear that the development of advanced products, with a high degree of innovation and added value, should involve a multidisciplinary team that may include designers, engineers, scientists, market experts, and process managers. The specific team depends on the characteristics of the product to be developed. Collaborative product design is an approach for supporting networked designers who participate in a distributed and dynamic product development environment [1]. There are currently several examples of products developed under such a team framework which have had an excellent market acceptance and are cited as paradigms of how new products should be developed. The same could be said about the redesign of existing products.

One of the major issues of setting up such multidisciplinary teams is how to bring the different professionals together and how to have them work collaboratively. In most cases the team is endemic to the company and works in a common space. However, ideally, the development team should not be constrained to a single geographical place, but comprised of experts in each of the main areas of competences required for the specific project, wherever those professionals may be located. This model considers a team of designers and other geographically dispersed professionals who collaborate by using platforms (supported by software tools) and are integrated under a management and organizational strategy.

Another important barrier to collaborative product design is related to safety, trust, and confidentiality. In order to achieve adequate synergies between team members, it is necessary that they share as much information as possible between them. However, controlling information access is vital to ensure customer confidence. Not only is it necessary to have well established roles and access levels for each of the team members, but the information must also be stored and exchanged through secure means. The team should resort to the most robust and reliable data security systems available. Aside from the legal and confidentiality issues, a certain level of trust is required among team members that work cooperatively, and this becomes even more important when they work remotely. Since full task decomposition is not possible (or even desirable) for most projects, team members must trust that their contributions will be recognized and rewarded. In many cases, it is difficult to establish this quantitatively; therefore, project managers should pay special attention to this issue.

In this paper we introduce the elements that are present in Virtual Enterprises (VE) for collaborative product design, namely the resources providers and brokers. We then present the brokerage function and its relation with VE formation and operation and discuss three business frameworks of collaborative product design in virtual enterprises. Finally, we highlight the potentials and the limitations of each framework.

FUNDAMENTALS

There is a growing body of literature on this topic of Virtual Enterprises (VE) [2]. A VE is characterized by Cunha & Putnik [3, p. 1896] as "a dynamically reconfigurable global networked organization, networked enterprise, or network of enterprises, sharing information, knowledge, skills, core competencies, market and other resources and processes, configured as a temporary alliance (or network) to meet a (fast-changing) market window of opportunity, presenting as main characteristics agility, virtuality, distributivity, and integrability".

A VE is a temporary and dynamic association of independent resources providers, designers and other professionals, which bring to the VE its best practices and core competencies in order to achieve the highest competitiveness. On the other side, in order to obtain the best experiences and competencies, it is desirable that as many resources providers as possible concur to the integration in the VE. Essentially, the VE will require a number of strategic relationships, however not necessarily long-term. When business alignment is a main requirement for competitiveness [4, 5] this network of distributed designers is no longer a static network. Its configuration evolves along time as a succession of instances, in order to include the best or the most adequate participants/nodes.

In [1], an Internet-based environment able to manage communication, negotiation, coordination and cooperation among participants, as well as to manage preparation and to follow-up design changes and conflicts is proposed. Chen et al [6] introduce an adaptable collaborative module for Internet-enabled Distributed Computer-Aided Design, based on a platform-independent model that enables designers to communicate and collaborate. In [7] the authors present some approaches of web-based project management that can be used in various forms of collaborative activities over the Internet and may be applied to virtual enterprises

VE FOR COLLABORATIVE PRODUCT DESIGN

We focus on two major dimensions that will influence the models or frameworks: the first is the type of organizational structure and relationships of the participating VE members that are in place; the second is the distribution of responsibilities and roles of the members, managerial aspects and decision-making.

Note that there is (at least) one fundamental difference between a collaborative team assigned with designing a new product (or re-designing an existing one), and typical VEs that offer services or perform a set of well established tasks: the role of creativity and subjectivity that is inherently involved in the product design process. This seemingly minor detail is in fact the core issue, and the major obstacle, of any attempt to reach a successful product design VE. In order to conciliate the input from several designers into a cohesive and coherent result an experienced and versatile broker is required. This paper will not discuss the methodologies that may enable this.

Specifications

The specific requirements of a VE framework that enables collaborative product design include: (1) access to the most efficient computational tools and (2) the most robust project methodologies [8].

Thus, the VE framework should consider the following specifications:

- high speed voice and data communication mechanisms between VE members;
- secure repository to share and transfer very large files, including a version manager;
- common platform and software directives, set at the administration level, to ensure inter-operability and seamless exchange of data between VE members;
- individual data access profiles and automatic access control;
- project management software for all VE members with the capability to assign penalties for task delay or task failure.

Aside from these technical specifications, there are other social and perceptual requirements, namely, a certain level of trust and confidence is required at two levels. The first, is between the VE and the clients, and can be supported by previously completed projects, by the status of the broker in that area, and by the quality of the project workplan proposed by the VE. The second, is between the VE administration and the broker (the service providers both correspond to management), and the pool of service providers. The service providers must have full confidence that their work is adequately recognized and rewarded, and that the broker is responsible for maintaining the team spirit during the execution of the project.

The entities

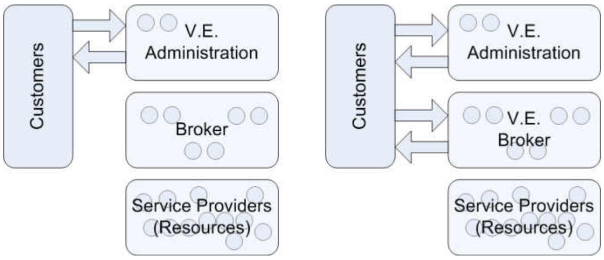
The proposed frameworks consider three entities: (1) the VE owner or administration, (2) the broker or VE configurations manager and (3) pools of resources providers (designers and engineers).

The broker mediates or facilitates the matching between (1) a VE owner – who captured and translated a market opportunity into product requirements and is looking for potential designers for integration in a VE team – and (2) eligible designers.

The brokerage function

The brokerage function can be _external_ to the firm, as represented in Figure 1-a). For each project (i.e. for each product design project), a new VE is created, starting with seizing (by the administration or VE owner) a market opportunity and its translation into product specifications and requirements for a new project that will drive the VE design and the creation of a project. This procedure is followed by the contractualization with a broker (a service provider or expert freelancer).

Alternatively, the brokerage function can be *internalized* to the firm as represented in Figure 1-b), meaning that the broker or brokers work exclusively on behalf of that firm, belong to its staff, and participate in the process of translating a market opportunity into product specifications and requirements for VE design, i.e., the search and selection of designers and their integration in the VE.



(a) internalised *(b) externalised*

Fig. 1. Brokerage function within the organization

In both cases, the set of activities performed by the broker consist of: (1) search for resources providers, (2) identification of the eligibility of a given product, (3) the negotiation among them, (4) the selection and integration in the VE, (5) the monitoring of the resources performance and (6) the operation management, identification of reconfiguration opportunities and reconfiguration management. The search and selection of resources providers takes place within a pool of resources providers.

FRAMEWORKS FOR VE COLLABORATIVE PRODUCT DESIGN

We propose three frameworks or models, all of them integrating the three mentioned entities: the administration or VE owner, the brokers, and the pools of resources providers. The three introduced models are distinguished mainly by (1) the position/role of the broker within the organization (administration), which determines its degree of dependence/independence in the activities of resource search and selection, negotiation and VE management, and consequently its responsibilities and functions in the organization and (2) the "ownership" of the pool of designers.

In the first two frameworks/models the brokerage function is external to the firm.

Model 1

In the first model, schematized in Figure 2, the VE owner or administration selects and contractualizes with a broker the process of creating a VE able to answer to a business opportunity. The contact between the VE and the customer is assured exclusively by the administration and the broker has no interference in it.

The administration controls the broker performance and the VE results, but does not directly contact the VE members, who belong to the brokers' pool, and who contractualize with the broker for a given project. VE creation, reconfiguration, performance monitoring, enforcement etc. are the main responsibilities of the broker.

The dimension and adequacy of its pool of resources is one of its main critical success factors, for each broker creates and maintains its own pool. Each broker will naturally want to recruit the best possible professionals for his/her pool, offer them attractive work conditions, and find motivating projects for them to work on. However, the exclusiveness of each resource provider is not mandatory to the broker. In fact, some resources may be part of more than one broker's pool without the brokers realizing this.

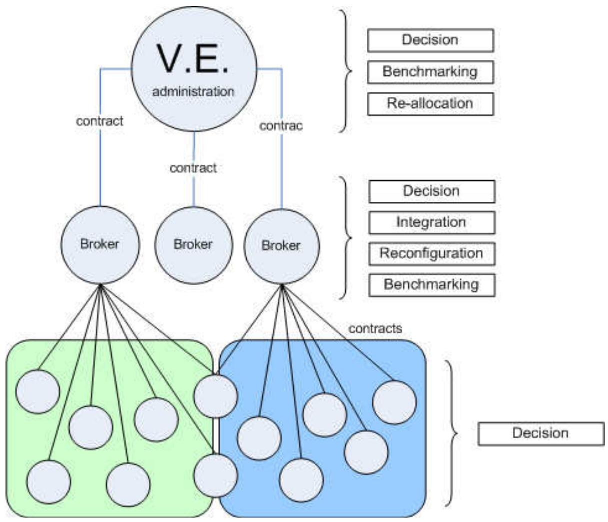


Fig. 2. Model 1 – independent brokers are sub-contracted for a project, and select their team among their own pool of resources

The administration assumes a contract with the broker but if this one fails to accomplish the project conditions, he/she can be substituted, with the inherent consequences of the VE project. Each broker has full disclosure to replace a member of his/her team during the execution of a project, without having to even inform the administration of this.

Model 2

The second model, schematized in Figure 3, differs from the previous one since after contractualization with the broker, he/she configures a VE whose members/participants contractualize with the VE owner. A broker can be disentailed, if he/she fails to accomplish the contractualized responsibilities, but the VE can remain with the same configuration as the brokers are subcontracted by the VE owner. In this model, the pool still belongs to the broker. VE management, monitoring and reconfiguration, are still the broker's functions.

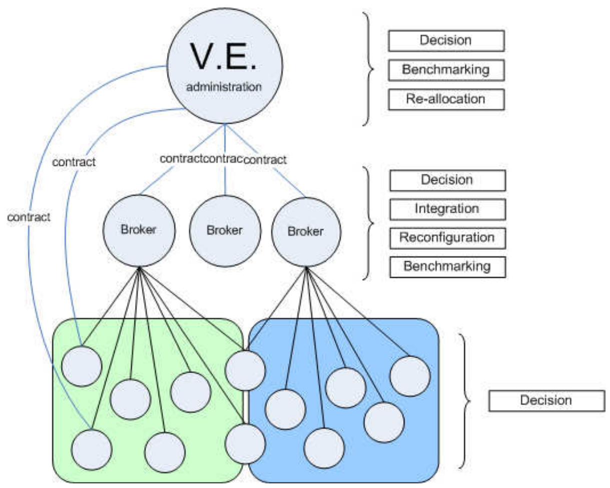


Fig. 3. Model 2 – independent brokers are sub-contracted for a project, and indicate their team, which is sub-contracted by the VE (teams are not disclosed to other brokers)

This model implies an agreement between the Brokers and the VE administration as long as the administration does not disclose a broker's team to other brokers. However, if the broker fails and is replaced, the "new" broker will necessarily be provided that information. The risk of project failure for the VE administration is smaller, but this scenario is less attractive for the brokers. As for the pool of resources, the model is quite interesting, since their work can be valued even in cases where the broker has been dismissed and replaced.

In model 2, there is an additional advantage for the administration in terms of more control over costs, since they know the cost of each resource and not only a global value managed by the broker. For the brokers, this is obviously a disadvantage, but it does offer two positive aspects: the broker has less financial management responsibilities and has to deal with less accounting bureaucracy.

Model 3

In this model, as represented in Figure 4, the brokerage function is performed by the VE owner and the brokers are staff of the VE. Knowledge about the pool of resources providers and its management is a common task to all the firm's brokers; in other words, the pool belongs to the organization. The contact between the VE and the customer can either be done by the administration or by experienced brokers.

This model is entirely different from the previously described ones. There is no confidentiality in the VE regarding which professionals are available, and there are no cost conflicts between the VE and the broker. However, the pool of resources providers will typically be more limited than in the case of independent brokers, since these have their own (and very particular) contact networks worldwide.

The brokers have all the interest in optimizing the pool of resources along time and in having successful projects, since this provides sustainability to the VE they belong to. In fact, the VE can assign multiple brokers to share the management of several complex projects, and can easily switch brokers from project to project (although obviously with several implications which we will not discuss here).

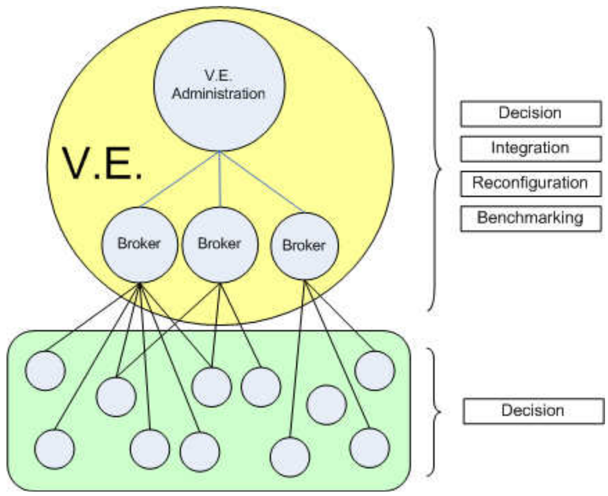


Fig. 4. Model 3 – brokers are staff of the VE which are responsible for managing the VE's projects, each selecting a team for each project from the VE's pool of resources providers (common to all brokers)

DISCUSSION

We can say that Model 1 is not a VE model according to the 'common' definition, since the collaborative network does not include the administration or owner. The collaborative network reports to the broker who is contracted by the owner. The broker is the one setting up and managing a collaborative network whose configuration is hidden from the administration. This model is suitable for small projects, with reduced complexity and limited responsibility, as all the responsibility for the development of the product is committed to the broker. Model 2 can be seen as an improvement of Model 1, allowing the broker and the VE owner to share responsibility, given the direct contractualization between the resources providers integrated in the VE and the administration.

One of the most relevant requirements of the VE organizational model is to allow a high reconfigurability dynamics of the collaborative network, which must be permanently aligned with the customer requirements, and assure maximum performance (cost and time). Thus, for each VE configuration or instantiation must apply the “best” resources providers, so that the combination of VE members at a given time is the ideal one. The competition between brokers contributes for this, since they must endeavor to have a competitive pool of resources providers, such that it offers the largest possible probability to achieve an almost ideal combination of resources providers for a given project. That is to say, to the satisfaction of the VE owner. This is a major advantage of Models 1 and 2.

Model 3 represents a more formal and long-term structure, less flexible, corresponding to more stable partnerships. In this model there is no competition between brokers, but there is the risk of a broker deciding to use the firm’s contacts to create its pool of resources providers.

We now present a more detailed specification of the overall process of creating of a VE for collaborative product design according to Model 2, as it is the most flexible and dynamic of the three introduced models. The overall process is represented in Figure 5 using the IDEF0 methodology[i]. The process consists of designing a VE project able to undertake the collaborative product development challenge (process 1), the creation and integration of the projected VE (process 2), where reconfiguration is seen as a special case of creation and integration, and the operation of the VE, i.e. the collaborative design of the product opportunity captured by the VE owner that meets customer requirements (process 3). The global process is bounded by a *VE Collaborative Design Reference Model*, which is adjusted by the broker and the VE owner for each VE.

CONCLUDING REMARKS

In this paper we presented different possible models for the organization of virtual enterprises for collaborative product design and development. The major specifications for such enterprises were defined and described in the context of the supporting business models.

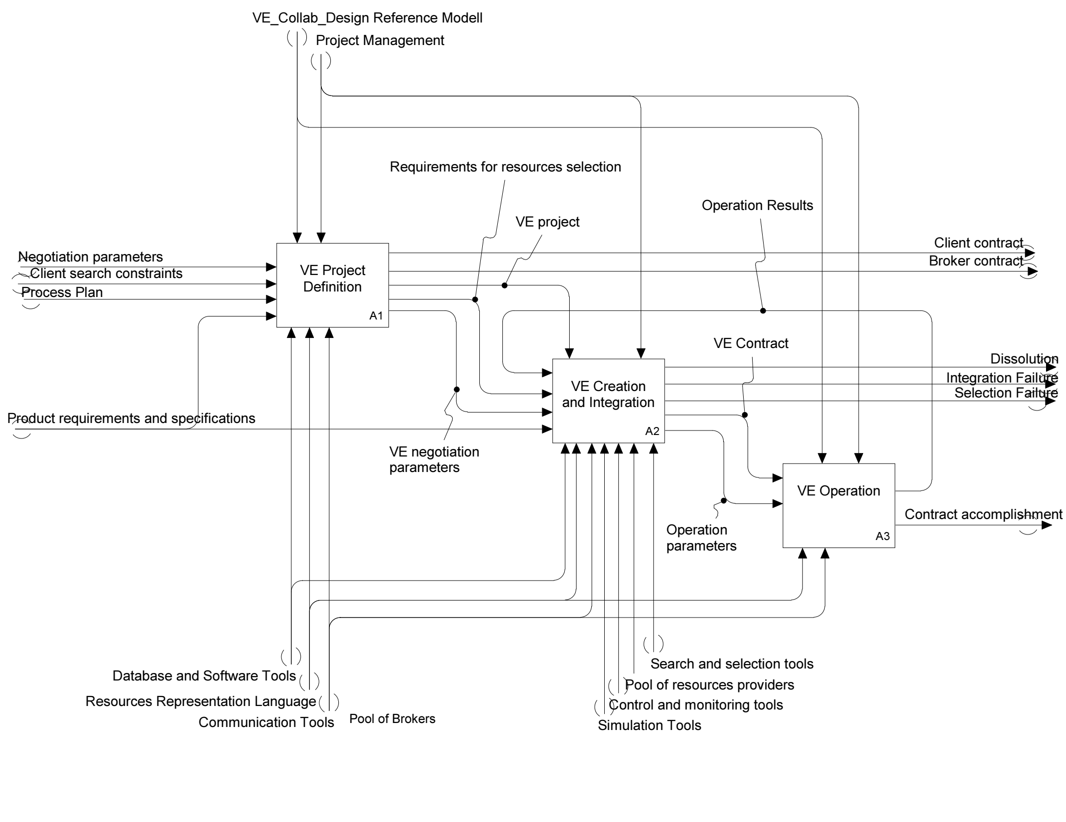


Fig. 5. IDEF0 representation of the global process for the creation of a VE for collaborative product design

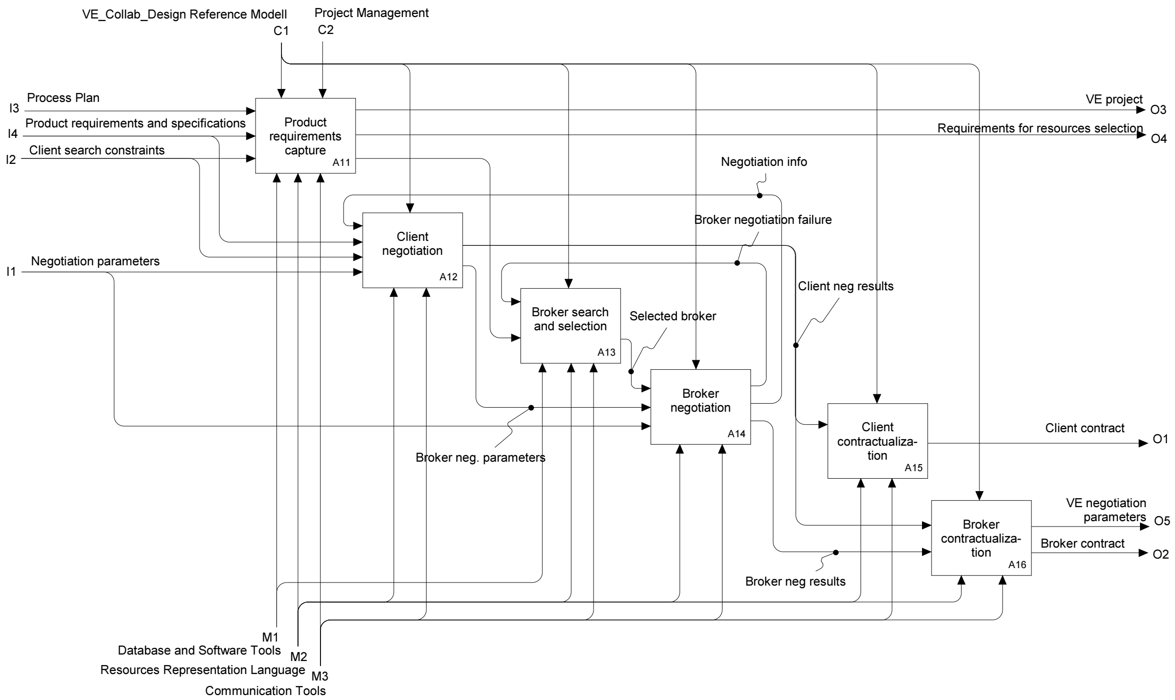


Fig. 6. IDEF0 representation of Process 1 – VE Project Definition

The most robust of the proposed models was analyzed and described using an IDEF0 specification methodology. This model meets most requirements for an agile VE focused on collaborative product design, including high reconfigurability dynamics and access to an optimal resource configuration in useful time.

The next steps of this work will include benchmarking the proposed VE frameworks through simulation tools and analytical models, developing a project management model, and comparing one of these models with a traditional approach (such as searching online for project partners). Aside from these, we will identity a VE collaborative design reference model that can be used as a standard.

References

[1] M. Sadeghi, F. Noel, and k. Hadj-Hamou, "Toward a Framework for Effective Collaborative Product Development," in *The Future of Product Development, Proceedings of the 17th CIRP Design Conference* Berlin: Springer, 2007.

[2] G. D. Putnik and M. M. Cunha, "Encyclopedia of Networked and Virtual Organizations," Hershey, PA: IGI Reference, 2008.

[3] M. M. Cunha and G. D. Putnik, "Market of Resources for Agile/Virtual Enterprise Integration," in *Encyclopedia of Information Science and Technology*, M. Khosrow-Pour, Ed. Hershey, PA: Idea-Group Publishing, 2005, pp. 1891-1898.

[4] M. M. Cunha and G. D. Putnik, "Business Alignment Requirements and Dynamic Organizations," in *Virtual Enterprise Integration: Technological and Organizational Perspectives*, G. D. Putnik and M. M. Cunha, Eds. London: Idea Group Publishing, 2005, pp. 78-101.

[5] M. M. Cunha and G. D. Putnik, “On the Dynamics of Agile/Virtual Enterprise Reconfiguration”, *International Journal of Networking and Virtual Organizations*, vol. 3, pp. 102-123, 2006.

[6] X. L. Chen, J. Y. H. Fuh, Y. S. Wong, Y. Q. Lu, W. D. Li, and Z. M.-. Qiu, "An Adaptable Model for Distributed Collaborative Design," *Computer-Aided Design & Applications,* vol. 2, pp. 47-55, 2005.

[7] C. Breu, N. Meckl, and J. Sametinger, "Project-Based Customer Relationship Management in Virtual Enterprises," *VISION: The Journal of Business Perspective,* vol. 5, pp. 38-45, 2001.

[8] R. Simoes, “Virtual Modeling and Prototyping in Collaborative Product Design”, in *Encyclopedia of Networked and Virtual Organizations*, G. D. Putnik and M. M. Cunha, Eds. Hershey, PA: IGI Reference, 2008, pp. 1812-1818, 2008.

[9] D. T. Ross, “Applications and Extensions of SADT” *Computer*, vol. 18, pp. 25-34, 1985.

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[i] IDEF stands for ICAM DEFinition methodology (ICAM – Integrated Computer-Aided Manufacturing). IDEF0 diagrams illustrate the structural relations between two processes and the entities present in the system. It is composed of a hierarchical series of diagrams that gradually display increasing levels of detail (tree) describing functions and their interfaces within the context of a system The processes (represented as boxes) transform the *inputs* into *outputs* (respectively the left and the right arrows of a process), using the *mechanisms* for the transformation (the bottom arrows) and constrained by *control_information or*

conditions under which the transformation occurs (the top arrows) [9].

FROM 'TRADITIONAL' ENTERPRISES TO VIRTUAL ENTERPRISE: A CONTRIBUTION TO THE TRANSFORMATION PROCESSES

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Abstract: Enterprises that stays in the market for long periods, decades even centuries, always had the ability to manage new market demands and to transform themselves according to the environment. Some authors affirm that nowadays business environment is turbulent. Our proposal for enterprise in turbulent environment is the Virtual Enterprises approach. In the first part of this paper, we present the differences between the 'Traditional' Enterprise and the Virtual Enterprise approach. Then, in the second part, is presented a contribution to Transformation Processes. In the third part, are presented paper conclusion and future work.

Keywords: Virtual Enterprises, Transformation Strategy, Processes.

INTRODUCTION

The main objective of this paper is to contribute to the transformation processes to aid 'Traditional' Enterprise (TE) transform in a proposed organisational concept: Virtual Enterprise (VE), aligning with the evolution of the business environment.

This business environment is being one of the key areas for worldwide organisations for research in manufacturing. For example, Intelligent Manufacturing System (IMS) considers that one of five technical Areas (Total Product Life Cycle Issues, Process Issues Strategy/Planning/Design Tools, Human/Organisational/Social Issues and Virtual/Extended Issues [1]) is related with Virtual Enterprise. In the description of this area, IMS refers a crucial aspect of nowadays Virtual Enterprise paradigm and the central point of the contribution of this paper for the transformation processes in enterprises, "However, the main challenge (of Virtual Enterprise) is organisational rather than technological" [1]. Also in the Manufacturing European Technology Platform Manufuture, refers that one of the enabling technologies for competitiveness and sustainability is "new business models" [2].

So if all the stakeholders recognize the advantages of VE, why Enterprises don´t use them? Is there any missing links? There are some disables like trust, transaction costs and intellectual property rights that constrain the development of the VE paradigm. But some literature already refers to mechanisms and specific organisational structure, to minimize these disablers.

In this paper, Enterprises, "an organization created for business ventures"[3], are divided into two approaches: 'Traditional' and Virtual. We consider the 'Traditional' Enterprise (TE) as a 'stable' structure that develops low level of partnerships (only with few customers and suppliers), do not produce high level of dynamic and with a long "life", if they are capable of. In opposition, some authors mentioned that Virtual Enterprise (VE) is characterised for short "life" and presents a high level of dynamism.

In the first part of this paper, we present the differences between the 'Traditional' Enterprise and the Virtual Enterprise approach. Then, in the second part, is presented a contribution to Transformation Processes. In the third part, are presented paper conclusion and future work.

'TRADITIONAL' ENTERPRISE VS. VIRTUAL ENTERPRISE

The organisational paradigm proposed is the VE concept. This concept has been developed in the past decades to respond to the needs that companies and markets are now requiring, agility, market alignment, competitiveness, innovativeness and sustainability.

In 1984 the authors Miles and Snow [4] referred what is characterized as VE "…companies must be able to form network of reliable subcontractors … held in temporary alignment by a variety of market mechanisms". Then labels have born: network organisation [5], value-adding partnership [6], organic network [7], intelligent enterprise [8], and virtual enterprise models, such as virtual value chains [9], virtual enterprise [10], virtual corporation [11], extended enterprise [12], electronic markets and electronic hierarchies [13], Electronic commerce or Electronic markets [14]. There is a broadened terminology to range VE concept, some sharing similarities and sometimes exclusive.

However, unfortunately or not, until today, there is not a universally accepted definition, or model, of the VE. But Putnik et al.[15] refers that there are three fundamental features of the VE concept that make the fundamental difference between the VE and the TE, and that generate a number of consequences, making that paradigm "shift". These are:

1. Dynamics of network reconfiguration,
2. Virtuality, and
3. External entities (meta- (virtual) enterprise structures) as environment for enabling, or supporting, the VE integration itself as well as a reconfiguration dynamics

In the following table (Fig. 1), a comparison between 'Traditional' Enterprises and Virtual Enterprises potentials, concerning the three above-mentioned features, and a number of their consequences, are presented.

Nº	Criteria	'Traditional' Enterprise	Virtual Enterprise
1	**Number of products by enterprise**	**Multi**	**One**
1.1	"Flow" of products through the enterprise	Yes	No
2	**Organisational reconfiguration dynamics**	**None**	**Yes**
2.1	Enterprise "life" time	Long	Short
2.2	Inter-enterprise networking	Low	High
2.3	Organization's reconfiguration "transaction" cost (networking and dynamics disabler)	High	Low
2.4	Trust assurance and management (networking and dynamics disabler)	Low	High
2.5	Organisation reconfiguration time (networking and dynamics disabler)	High	Low
2.6	"Flow" of enterprises through the product	No	Yes
2.7	Number of organizational structure instances	One/Low	Very high
2.8	Leanness	Medium	Maximum
2.9	Agility	Medium	Maximum
2.10	Operations management importance	High	Low
2.11	Organisation design / integration complexity	Low	High
2.12	**Virtuality** (dynamics enabler)	No	Yes
2.13	Creativity	Medium	Medium
3	**External entities as organisational dynamics enablers**	**No**	**Yes**
3.1	"Meta-enterprise" as enterprise environment	No	Yes

Fig. 1. "Traditional" Enterprise (TE) vs. Virtual Enterprise (VE) potentials [13]

After analysing this table, we could affirm that TE and VE are almost antagonist approaches. Due to the characteristics of these two approaches (TE and VE), the transformation term is almost reaching the revolution term.

Transformation Strategies

This type of transformation requires a shift in the enterprises. In literature there are some transformation strategies like Total Quality Management (TQM), Business Process Reengineering (BPR) and more recently Chaordic System Thinking (CST) that impulses enterprises to change.

According to the American Society for Quality, "...Total Quality Management (TQM) is a management approach to long-term success through customer satisfaction."[16] and further "... all members of an organization participate in improving processes, products, services and the culture in which they work." [16]. This strategy begins in the Japanese manufacturing industry and focuses essentially in the incremental improvements of the enterprise members pointing to customer satisfaction. Some authors consider that TQM involves all organisation and aiming quality as a strategic objective.

The Business Process Reengineering was introduced in 1990 when Michael Hammer introduced the term 'reengineering' in an Harvard Business Review article: Reengineering *Work: Don't Automate Obliterate* [17] and then in his book, co-author with James Champy, Reengineering the Corporation [18], they expressed the need for transformation. The definition the authors set for reengineering as: *"the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance..."* These authors refer that this definition contains four keywords, but we emphasise three explicit keywords and one implicit in this definition: <u>fundamental</u>, <u>radical</u>, <u>processes</u> and, the implicit, <u>people</u>.

BPR stays up-to-date because environment is still unstable and highly dynamic. This non-deterministic dynamism is called, by some authors, as turbulence. For these reasons it is **fundamental** to generate mechanisms to support business sustainability. As showed in the previous table, TE does not have intrinsic characteristics to be competitive and sustainable in turbulent markets, as examples, the organisation reconfiguration time and the agility. The shift is essential and requires a **radical** change in 'traditional' organisations. These changes will affect how enterprises develop their business model and **processes** will be different. And for the involvement and commitment of these challenges is necessary that **people** participate actively.

Most recently, Eijnatten presented Chaordic System Thinking (CST) "...a recent, qualitative framework in the domain of Complexity that both combines and generalizes exiting ideas from various disciplines, rather than inventing new concepts." [19]. CST is based in the Chaos and complexity theory and provides a new strategy for "...uncontrollability, uncertainty and complexity..." [20] in enterprises.

Eijnatten refers to five core properties of Chaordic System: "Consciousness", "connectivity", "indeterminacy", "dissipation" and "emergence", and puts human in the central of CST strategy.

CONTRIBUTION TO THE TRANSFORMATION PROCESSES

In the strategies we mentioned before about the clear intention of these strategies to transform enterprises, in some cases in a conservative way (TQM) and in other cases in an almost revolutionary way (BPR and CST).

In this paper, we will contribute to the transformation from TE to VE focusing in the following points:

- Preparedness of all Enterprise staff, from blue-shirt to white-collar, to the VE approach.
- To transform 'Traditional' Enterprises (and not to manage enterprise changes);

Some other processes should be included but in this paper we contribute with 3 (three) transformation processes:

- Development of supporting tools;
- Raise awareness;
- Provide in-house consultancy in 'Traditional' Enterprise.

Process	Activities
Development of supporting tools (A-1)	• Produce demonstrators to simulate the advantages of the VE concept (A-11) • Produce a handbook on VE (A-12) • Develop of the Meta-enterprise (A-13) • Develop of a webpage and videos for broadcasting on Internet (A-14)
Raise awareness (A-2)	• Encourage awareness of entrepreneurs and SME and Large companies managers (A-21) • Promote of VE concept and Meta-enterprise (A-22)
Provide consultancy in "Traditional" Enterprise (A-3)	• Prepare for the transformations, manage the transaction phase until the desired end state (A-31) • Create fundamental shift in the way of thinking, activities and business model (A-32)

Fig. 2. Activities and Transformation Processes

Transformation Processes

For the specification of the transformation processes, we chose a modelling methodology, composed by a modelling language called ICAM Definition Method (IDEF). And the modelling language technique is the IDEF0. The IDEF methodology was selected due to the representation of the transformation activities of the system and because it is accessible to any reader.

The following IDEF0 diagram (Fig. 3) represents the overall operation of the Transformation Strategy that consists on the Development of supporting tools (Process A-1), then Raise of awareness (Process A-2) of enterprise owners, managers and others high-level employees (stakeholders) for the VE approach, and Provide consultancy in 'Traditional' Enterprise (Process A-3) of interested stakeholders to prepare enterprises for VE. The preparation and implementation of this Transformation will involve a group of researchers.

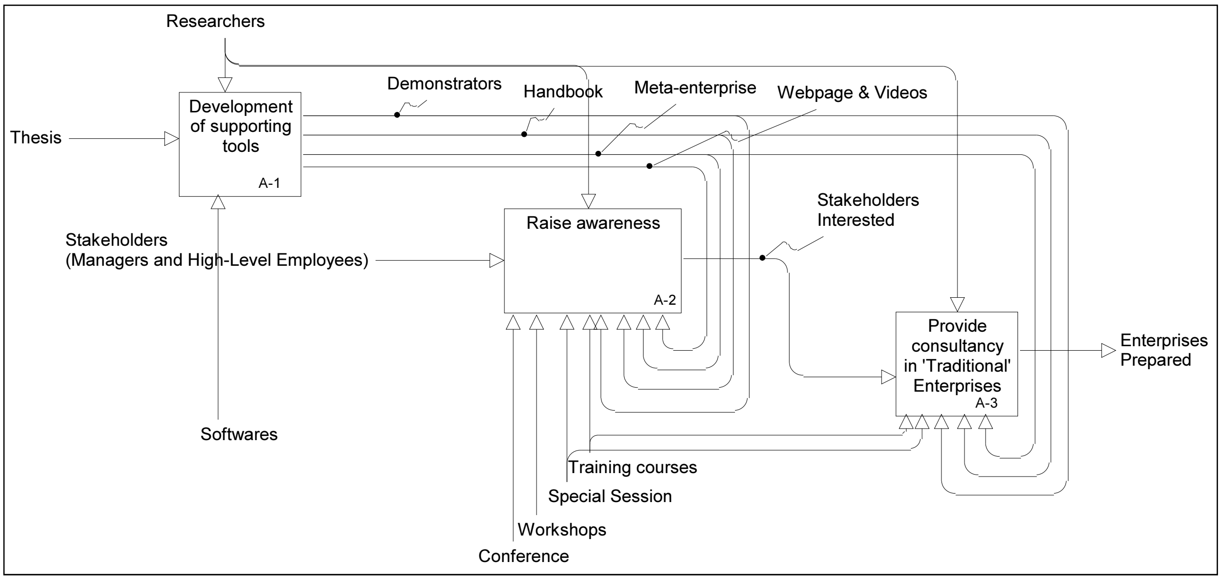

Fig. 3. IDEF0 representation of Process A-0 – Transformation Processes

Process A-1: Development of supporting tools

This process corresponds to the development of supporting tools to disseminate and corroborate the validity of the concept. Tools are critical to affirm and support the new paradigms.

So, it will be important to: 1) produce simulators to demonstrate the advantage of VE; 2) produce a handbook on VE; 3) support the development of a Meta-enterprise; and 4) develop of a webpage and videos for broadcasting in Internet.

Indeed, this process consists on the creating and spreading of instruments to create general consciousness for VE paradigm.

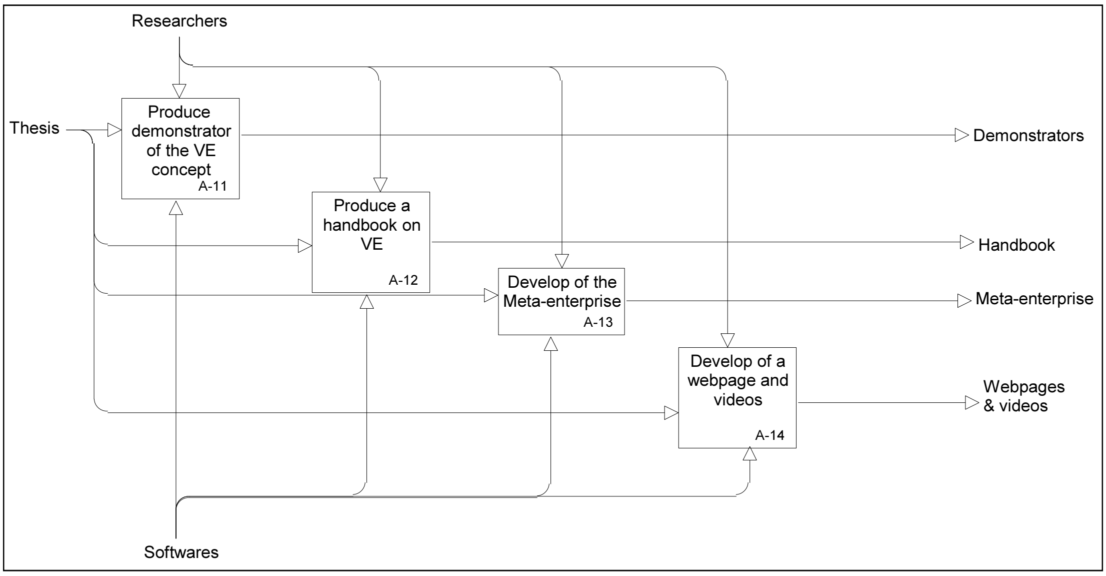

Fig. 4. IDEF0 representation of Process A-1 – Development of supporting tools

Process A-2: Raise awareness

This process consists on Encourage awareness of entrepreneurs, Small and Medium Enterprises, and large enterprises; and to Promote the Virtual Enterprise concept and Meta-enterprise. The encouragement of the awareness of entrepreneurs and all type of enterprises will require organisation and development of conferences and workshops. To achieve to a higher level of understanding of the VE concept and mechanisms, as Meta-enterprises, it will prepared Training courses, Special Session and use of tools to Promote VE concept and Meta-enterprise.

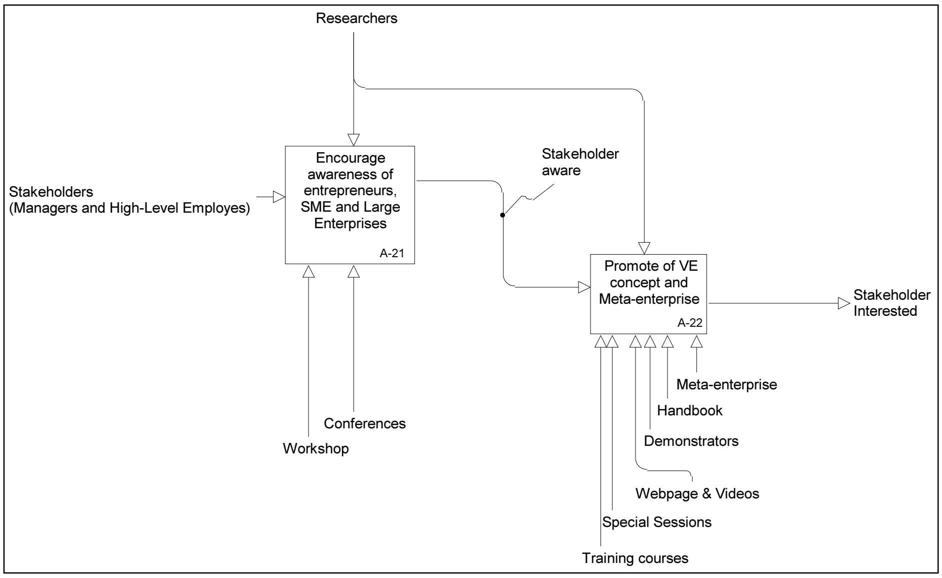

Fig. 5. IDEF0 representation of Process A-2 – Raise Awareness

Process A-3: Providing consultancy in 'Traditional' Enterprise

This process represents detailed tailored made work in each TE interested in transform towards a VE. First of all, is necessary to support/help enterprises to prepare the transformations, manage the transaction phase until being prepared to develop VE, the desired end state. Then, create a fundamental mind-set of all staff, a shift in the way of thinking, activities and business model.

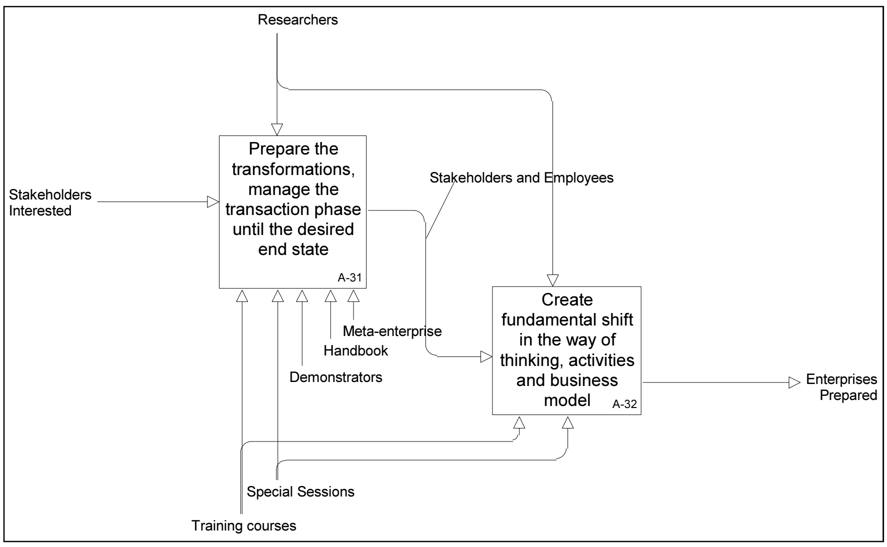

Fig. 6. IDEF0 representation of Process A-3 – consultancy in 'Traditional' Enterprises

CONCLUSION

This paper contributes to an approach for Transformation Processes to develop in 'Traditional' Enterprises for new business challenges. The 'Traditional' Enterprise especially Entrepreneurs, Micro, Small and Medium Enterprises are facing the need to swift to a global business dynamics and must be prepared to grab this opportunity applying Virtual Enterprise paradigm. They must be trained to adapt their business models and switch to the proposed organisational model, Virtual Enterprise.

FUTURE WORK

The Future work will be on creating supporting tools to explain and demonstrate the VE paradigm, and presentations to, for example, training courses and special sessions.

References

[1] http://www.ims.org/menu2/menu2_1.html
[2] Manufuture – Strategic Research Agenda, Executive Summary, Assuring the Future of Manufacturing in Europe, September 2006
[3] WordWeb 5.2. Princeton University. 2006
[4] Miles, R. E., & Snow, C. C. Fit, Failure and the Hall of Fame. 1984. California Management Review, 26, 10-28.
[5] Miles, R. E., & Snow, C. C. Organizations: New concepts for new forms. 1986. California Management Review, 27, 62-73.
[6] Johnson, R. R. And Lawrence, P., Beyond Vertical Integration – The Rise of the Value Adding Partnership. Harvard Business Review, July-August, 1988, p. 94-101.
[7] Morgan, G. (1989) Creative Organization Theory: A Resource Book. Newbury Park Ca: Sage
[8] Quinn, J. B. The Intelligent Enterprise, 1990, New York, The Free Press.
[9] Benjamin, R. and Wigand R., Electronic Markets and Virtual Value Chain on the Information Super Management Review, vol. 36, p. 62-73,1995.
[10] Drucker, P.F., The Emerging Theory of Manufacturing. Harvard Business Review. May/Jun. 1990
[11] Davidow, W. H. and Malone, M. S. The Virtual Corporation - structuring and revitalising the corporation for the 21st century. New York HarperCollins Publishers, 1992
[12] Browne, Jim, Sacket, P.J. and Wortmann, J.C. Future Manufacturing Systems - Towards the Extended Enterprise, 1995, Computers in Industry. Volume 25, p. 235-254
[13] Malone, T.W. Yates, J. Benjamin, R. Electronic Markets and Electronic Hierarchies. 1987. Communications ACM. Volume 30, Number 6, p. 484-497
[14] Bakos, Y. Information Links and Electronic Marketplaces: The Role of Interorganizational Information Systems in Vertical Markets. Journal of Management Information Systems. 1991. Volume 8 Number 2 p. 31-52
[15] Putnik, G. P., Cunha, M. M., Sousa, R. and Ávila, P. Virtual Enterprise Integration: Challenges of a New Paradigm. 2005. Idea Group, Inc. p. 3-9
[16] http://www.asq.org/learn-about-quality/total-quality-management/overview/overview.html
[17] Hammer, M. Reengineering work: Don't automate, obliterate. 1990. Harvard Business Review. July/August. Vol. 68 Issue 4, p. 104-112.
[18] Hammer, M. and Champy J.A.. Reengineering the Corporation: Manifesto for Business Revolution. 1993. Harper Business Books, New York.
[19] Eijnatten, F. M. van. Chaos and Complexity: An Overview of the 'New Science' in Organizations and Management, Revue de Gestion. Volume 40. Pag. 123-165. Seen in Eijnatten, F. M. van, Putnik, G. D., Sluga, A,. Chaordic Systems Thinking for Novelty in Contemporary Manufacturing, 2007. Annals of the CIRP. Volume 56/1/2007. Pag. 447-450.
[20] Eijnatten, F. M. van. Chaos Systems thinking – Some suggestions for a complexity framework to inform a learning organization. The Learning Organizations. Volume 11. No. 6. 2004. Emerald Group Publishing Lilited. Pag. 430-449.

CONTRIBUTION TO ALIGN THE SMALL/INDIVIDUAL COMPANIES TO THE GLOBAL PLAYERS

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Abstract: Nowadays the quality of the products, customer satisfaction and customer's fidelity are of most importance. However to **commercialise** a product it's critical the "time to market", so how can the small companies compete in the global market? And how can they work with the global **players**?

We may think that to implement an organization into a Supply Chain Management (SCM) the companies must already be a global player (strong economic groups) and have a high developed dimension. Yet, smaller enterprises may still have many opportunities if they give significant importance to the "aptitude" to cooperate. Besides that, they must not only **cooperate** in **business information**, but also **in technologies, capacities**, and to **take advantage** of small gains to **increase** more and more **business efficiency**.

The question that we will try to help the answer is: Is it possible to be a small company and participate in one or many global supply chains? We will see in this work that is possible but some procedures have to be implemented.

Firstly this work intends to characterize the problem and then gives some orientations to prepare small /individual companies to work with the global "players". It defines a process of change of the traditional logistics management for the supply chain management, and above all alert to the need to **collaborate** in **information**, **technology and process management.**

Keywords: logistics align; Supply chain management; Steps of change.

1. INTRODUCTION

Enterprises usually consist of a great percentage of small or individual (isolated enterprises-unique production system), whose processes have no dimension and are not even adapted to create its logistic chain themselves so it is necessary to find a solution for the following:

How do these enterprises, align their activity with the logistic chains of the clients? Or more complicated, How to align to a set of supply chains (several clients, and different logistic chains)? Is it possible for a small dimension enterprise to be visible by these economic groups?

The first aspect that catches the attention of the buyers is the price, although, it is not a sufficient condition itself. In fact it is required a high quality standard as to have some capacity of development and be able to demonstrate financial stability.

When these "first" difficulties are overcome, "operational issues" appear**. How can they communicate with these players.** Will our informatics System (SI) be compatible with SI of the Clients? What volume(s) can be agreed? Which level of promise do Clients assume? Must we invest in capacity? Or, on the other hand, do the installed resources respond to the contracts?

The global Players tend to make a deal of volumes of production without any obligation of consuming (it is possible they have an agreement concerning the asserted correction of price having in mind the volume of sales). Small companies tend to accept the deals. However when the problem is extended to several clients the restrictions of capacity emerge rapidly. What happens if all the Clients ask at the same time for the maximum of the volumes agreed, retrieving marge to the adequate management of the resources capacity.

2. CHARACTERIZATION OF THE PROBLEM

2.1 The Changing World

Globalization of business and the changing consumer behavior, creates a new demand of total differentiation of products, with short life cycle and therefore, the demand for a lean supply chain, increases the frequency of delivery, increasing the demand added value in service delivery.

On the other hand there are the producers working in order to maximize production volumes, minimizing the diversity and looking for obtaining scale economies. Their Model type of management is highly centered in "Know how technology", and not focused on the design of the business.

It is important to establish a trade-off to make a bridge between both sides (consumer and producer) to solve the paradigm exposed above. It is therefore important that companies have a different way of looking abroad of the enterprises to understand what goes on in the business from the in-bound → companies → to the out-bond, making it possible to obtain a design of the business in order to integrate all the evolutions and tendencies of the Market, and making possible the creation of value in a competitive rhythm.

So, the management of the supply chain is one of the steps that allows the enterprises to do transaction for a more efficient management business and consequently more competitive.

2.2 Management of the Supply-Chain

The supply chain is a set of systems which inter-links the amount of different processes and activities that produce value in the form of products and services, for the final client.

Management of the chain logistics is not the same as a vertical integration. The vertical integration normally implicates the property (of suppliers, producers, distributors, etc.) for a part of an alone entity. This one was had like the desirable solution, but more and more organizations are be focusing in his "core business", everything of it more is looked abroad of the enterprise.

In the past, the relations between suppliers and clients were those of adversaries, instead of being of frank cooperation. It is still the case, today, of enterprises that try to reduce costs or to increase profits to the cost of his matching (assumptions) of the chain of supply. These companies do not see that with this attitude they do not become more competitive, since all the costs will be going to fall back on the price to pay for the final client. *The enterprises real leaders already saw that the real **competition** is not an enterprise against enterprise, **but supply chain against supply chain [1]***

For that, the management of the supply chain is determinant in the success of the companies. However, it means solving some pre-conditions (which we will analyze) and eliminating some restrictions.

Pre-conditions:

Have a good organization logistics and some maturity in the process management; and to be able to implement techniques to "make agile" the production processes.

Restriction analysis:

Financial capacity; compatibility of information system; capacity to get information; standardization level in each supply chain; level of adaptability of the industrial process; and the level of the lean manufacturing stage.

3. HOW TO ORGANIZE THE COMPANIES TO OVERCOME THESE DIFFICULTIES?

We have already mentioned the pre-conditions and restrictions. Nevertheless, to implement the strategy it is not necessary to resolve all the requirements and restrictions. Its resolution must be included in the master plan of short and medium term.

The industrial process will be able to be (more or less) copied by all the enterprises; the differentiation is obtained through the creative capacity (to develop products well adjusted for the necessity of the clients) and through the global implemented organization. **An organization by processes centered in the necessity of the key clients, in which the logistic/supply chain works as the focal point of the whole activity and decisions, will make the differentiation easily.**

In order to implement the suggested organization for the small/individual companies, a model of change is proposes below, developed in three steps:

- *Guarantee the internal integration of the logistic function – organize the logistic process at the centre of the operations;*
- *Progress from the integrated logistic to supply chain management;*
- *Get profits from the global chain.*

3.1 First step - Guarantee the Internal Integration of the Logistic Function – Organize the Logistic Process at the Centre of the Operations

The Logistic Function Changes

The Logistic function must depend on the administration in a hierarchy way. It has to be a horizontal department without external influences, with great autonomy and professionalism. The aim of any organization should be to ensure that production satisfies only what the market needs, purchasing supplies production with what it needs to meet its immediate requirements. The “service to clients” function is vital in the logistic department and inside the enterprise. T**he key lies in the recognition that the client order and the associated information flows should be at the heart of the business** [2]. These orders should dominate completely the global logistic flow. In other words, to effectuate the planning of the orders, since the suppliers until the clients.

Everything that the company does should be directly linked to facilitating this process, and the process must be itself reflected in the organizational design and in its planning and control systems.

The control of logistics operations, production, supply and expedition, have to be synchronized with client requirements. The enterprise resources planning (ERP) acquires the orders sent by EDI and it then effectuates the proposals of production orders (beginning of the flow).

Logistics Coordination with the most Important Departments to the Business (picture 1)

Information System (SI) Department implements the necessary tools to a good reception and expedition of information (EDI or web-EDI) in a way to make possible the connection (communication computer) with all the clients and all the suppliers (e.g., order, invoice).

The Development Department works in a close relation with the Logistics and Direction of Operations in the development of new products and in the efficient management of the capacities. The level of the capacity of production is vital in this model. The maximum of capacity production must be announced to be able to maximize the level of industrial activity of the Enterprise. We have to be careful if several clients are going to have different behaviors concerning the volumes of the contract. The sum of the total volumes of the contract must not exceed the equivalent of the capacity of the production of 20 teams (8 hours per team) weekly, remaining 8 hours for preventive maintenance.

The Operations Direction together with the Logistics, receives every day the customers orders planning and ensures its manufacturing. To be able to guarantee the customers planning orders, the activities of production and maintenance has its priority basis of management in ”lean manufacturing and total productive maintenance”. The processes must be designed with the goal to minimize the size of the “set up” and to make possible the techniques of "postponement" in other words "customizing" the products to the clients as near as possible of the expedition operation.

Also, the search for “Zero” defects is a daily concern of the operations. They develop plans to guarantee the quality of the product and the final solutions to solve the quality problems are incorporated in the new projects.

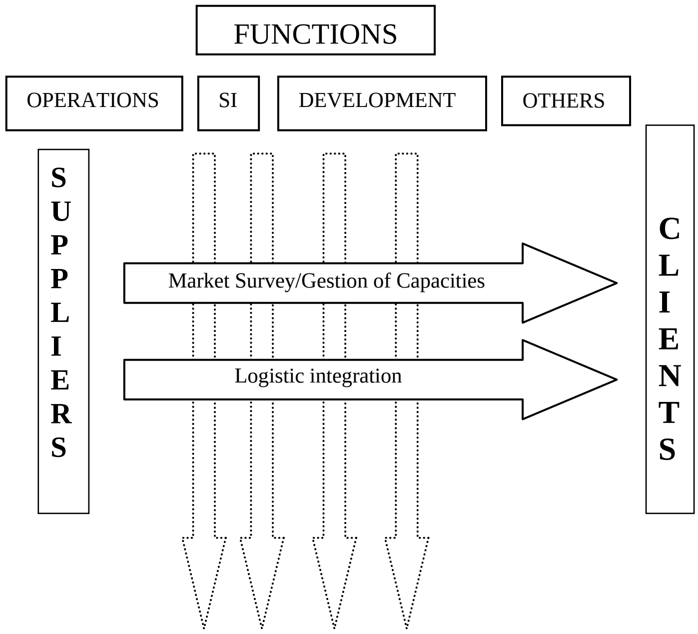

Fig. 1. logistics in the center operations of the enterprise

Problems to Implement the First Step Strategy

The major barrier to the implementation of the logistics concept is organizational. The danger is on the fact that companies do not recognize the need for organizational change because the conventional organization is based on a functional basis.

Each of the vertical functions is normally headed up by senior managers. In many companies these functional heads have considerable power and guard their territories from unwarranted incursions from others functional departments. Such organizations leave the clients needs apart**.**

3.2 Second step – Progress from the Integrated Logistic to Supply Chain Management

When we want to work ultimately in the global logistics (multi - client, multi-supply chain) the unique way of being able to continue to increase the levels of efficiency (cost / service), to reduce the time of cycle of the global chain logistics is to change its DIMENSION. **It means, the management of the supply chain extends itself to all the external operations (see picture 2): clients /partners/ suppliers,** managing the supply chain as a whole system (Supply Chain management**)** looking for profits in the external integration.

How to / which ways?

With the increasing of visibility on the "real" search along the supply chain logistics (removing the effect **bullwhip** of the variation of the search), using **collaborative processes for getting the good information,** allowing to synchronize the supply chain, adapting the questions of capacity and production to the real demand (customers) of the products.

The goal is to get as soon as possible the best information from all parts of the chain, integrating it in the form of global supply chain planning and sharing it with all the players in the chain.

Most of the times, we can think it isn't possible to change into a SCM organization with a few resources. Actually, "starting" the re-organization between integrated logistic and SCM means the changing the position of the logistics management. So, is to say, **the logistics** management **leaves the inside of the companies and look to the global flow between customers and suppliers.** The most **important issue is the changing of management attitude.** The company is willing to work with the global chain, and later be able to learn the process collaboration step by step.

Before any investment by the management of the supply chain (SCM) we must be sure that the company has already evolved culturally to the collaborative process.

The level of sophistication in the changing process can be high or low, as the same with the technology associated, but *we can increase the efficiency of orders fulfilment with a simple excel file shared by the customers and suppliers. The difficulty is to obtain their collaborations.*

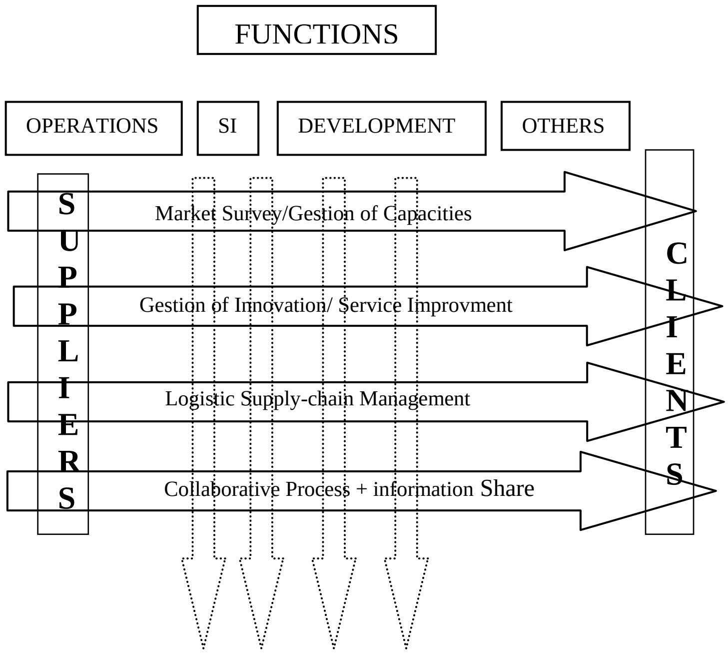

Fig. 2. Supply chain management.

Problems to implement the second step strategy

To participate in a supply chain or a combination of supply chains is necessary to be **prepared to collaborate.** To manage supply chains is largely trying to relate all the needs and realities of those involved in the chain. It is a collaborative plan of operations and business. That is, a plan shared and validated by the majority of participants in the chain.

Since the beginning of the process of collaboration companies have many problems in sharing information, motivated by cultural resistance, business or system (technical) problem. At this stage it is very important to invest in the relationship, transparency and the tools to share information as quickly as possible throughout the chain.

The attitude of collaboration and sharing in the supply chain will be rewarded by an increase in confidence and efficiency of the company, both through the business results and customers service. Basically it confirms the statement already used above:

*"The enterprises really leaders already saw that the real **competition** is not an enterprise against enterprise, **but supply chain against supply chain"**. **[1]***

3.3 Third step – Get profits from the Global Chain

As it is already stated, companies can get competitive advantages to seize the opportunities gained from the collaboration process. Here we will show, trough some possible examples, how we can obtain the profits:

In Distribution Process – Choose an **ex-works** condition in the **contracts of distribution** conditions **"Incoterms".** The distribution condition of the product is purchased at the door of the company (seller) and the distribution is the responsibility of the customer, which is a great advantage. In fact it is not necessary managing the distribution and the levels of service client (distribution) only depends on the industrial efficiency of the company.

In Supply – Either use the outsourcing of global transport (global player) in the supply flow or use the nets of supply of the partners in order to take advantage of its volume to be able to increase the number of deliveries with competitive cost.

In Information System – It's possible to make a deal with one SI supplier with the payment indexed to sales (variable costs). However, it is also possible to use the SI network for sharing information as to lower costs of integration, or use open source systems.

In Production System – Do partnerships with partners with common interests, as for example, the share of capacities of production, decrease de developer time **(**picture 3), outsourcing of commodity of production (chassis, structures, etc.). This strategy enables economical **important profits** and **reduces the risk of investment** and speeds the process of production up.

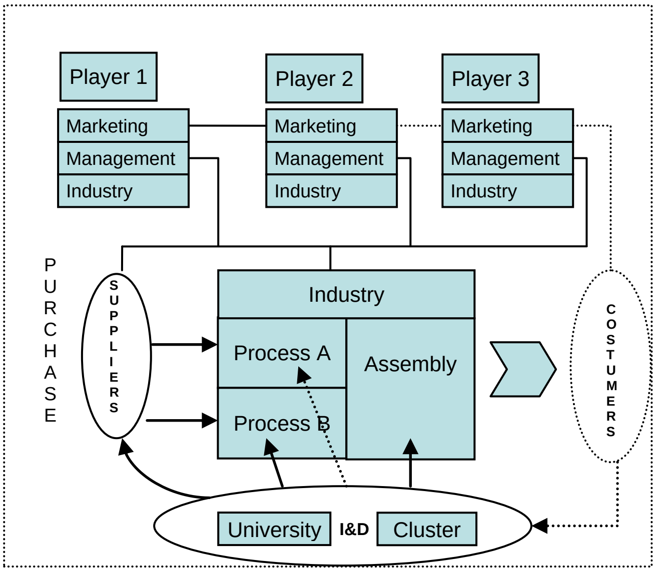

Fig. 3. collaborative capacity model

4. CONCLUSION

We saw that the "isolated" enterprise will not survive much time in the current context. The key to overtake the difficulty it is at the "**maturity**" of the enterprise to organize its processes as to become a **link of n-chains of supply**.

It is also required that the company endows the organization to **listen** the Client, to **share** information and resources, to **rationalize** resources of the Supply chain, and to speed up processes and to **synchronize** into the supply chain.

The implementation of the organization should direct the Company for the **excellence level.** We may have business opportunity when it is based on the low cost of the labor or other factors but **only the excellence in the global process can give the necessary advantages to have a "sustainability" position in the market: competitive price, guaranteed quality and excellent quality service.**

References

[1] Crespo de Carvalho, J. (2004) Lógica da Logística, Edições sílabo, 1ªEdição.

[2] Christopher, M. (1998) Logistics and Supply Chain Management, Pitman Publishing,Uk.

[3] Guedes, A. (2004) Logística 2010 que Desafios, COTEC Portugal. retrieved from internet: www.cotecportugal.pt.

IMPLEMENTATION OF VIRTUAL ENTERPRISE ASPECTS: AN ANALYSIS OF OUTSOURCING INDUSTRY

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Abstract: This paper talks about realisation of a new type of organisational structure – Virtual Enterprises (VE) – which has emerged as a tool for companies to stay sustainable, competitive and provide cutting edge services even with changing market environments. Substantial research work has been going on about the effectiveness and implementation of a VE, from many different perspectives, often with conflicting ideas and meanings. In order to identify what is more appealing, it is necessary to look at the different aspects of Virtual Enterprise implementation as implemented by some major market paradigms of today's world. Looking at the current industry and market scenario, we consider "Outsourcing" as an example of VE implementation analysis. Since there has been no universally accepted definition of a Virtual Enterprise, we take a reference model, namely BM_VEARM, as this model considers the four largely accepted characteristics of Virtual Enterprises – Integrability, Distribuitivity, Agility and Virtuality. We discuss these properties and analyse how the outsourcing industry has implemented these aspects, in varying degrees.

Keywords: Virtual_Enterprises, Integration, Integrability, Distributed_Agent_System(s), Distributivity, Agility, Virtuality, Market_Analysis, Outsourcing, Virtual_Enterprise_Implementation

INTRODUCTION

In the changing market environments, completely different strategies are needed to stay competitive. Sometimes, the whole existence of a particular enterprise comes under question, if no measures are taken to cope up with the new market scenario. In the past few decades we have seen a very firm industrial growth with the supply chain model, however formally the term "Supply Chain Management" was coined in 1982 by Keith Oliver [1], [2] (as cited by [3]), with goals of providing better services to the customer. The business model has always, essentially been a supply chain model. Then, in the year 1985, Porter established the concept of Value Chain [4]. With Value Chain, the emphasis came to the (production) activities and more research work [5] with new models shifted their focus from the customer oriented activities to the overall product development processes, i.e. different participants and activities in product development life cycle.

But today, in the globally dynamic market environments, even the process enhancement is not enough to stay competitive. As the competition grows in all aspects of businesses, and new technologies emerge, the complete shift is needed in organisational architectures and not just in processes and sub-processes. In the recent years, one such emerging strategy is Virtual Enterprises (VE), which is a new kind of organisational form – a temporary and objective alliance of individual enterprises.

Due to its characteristics, the concept of Virtual Enterprises seems to be promising in the new information age, as it brings significant changes to the entity relationships and to the activities, i.e. to both Supply Chain and to the Value Chain. In many cases, it has completely changed the organisation work flows and in some cases, created a new type of industry. We consider one such new type of industry as Outsourcing industry.

In this paper, first we will briefly discuss about defining a Virtual Enterprise by considering some major characteristics and then will see how Outsourcing implies these characteristics towards becoming a Virtual Enterprise implementation.

Defining Virtual Enterprise(s)

In the past few years, many researchers have defined Virtual Enterprises. For e.g.:

- "A Virtual Enterprise is a temporary partnership of independent companies and/or individuals - suppliers of specific goods and services, customers - who are linked through modern telecommunications to exploit and profit from rapidly changing business opportunities" [6]:
- "A Virtual Enterprise is a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose cooperation is supported by computer networks…" [7];

- “A Virtual Enterprise (VE) is an optimised enterprise synthesised over universal set of resources with the real-time substitutable physical structure. The design (synthesis) and control of the system is performed in an abstract or virtual environment.” [8].

Although, there have been many different interpretations of the term “Virtual Enterprise”, a common idea about the term, from the hierarchical business model point of view, is to combine four major aspects, namely – Integrability, Distribuitivity, Agility and Virtuality in an organisation [8]. We consider BM_VEARM as the reference model to quote these four aspects of Virtual Enterprises.

Outsourcing as a Virtual Enterprise

Outsourcing can also be as part of changing business strategies [9] (as cited by [10]). According to [11] “a Virtual Enterprise (VE) is formed when a business decides to commit to a new workflow, while outsourcing some of the work involved in that workflow.” From the above definitions, it is evident that a virtual enterprise is an enterprise which outsources majority of its processes and functions, or distributes a task in the network of organisations. In the following section we will see how Outsourcing industry applies the Virtual Enterprise properties.

Virtual Enterprise Properties

Integrability: In a network of enterprises, each individual enterprise is a partner or an associate partner in the network. These partners can be homogeneous or heterogeneous, i.e. they may either provide same kind of services, or they may have their own specific expertise and roles different from others in the network. Also, for any given task, some of the partners play role of resources while others become receivers of the resources. In [8], the partner enterprises are called as “heterogeneous” resources by considering the fact that internally, each of these partner enterprises work on their own protocols or specifications. But, all these heterogeneous partners must be compatible to each other, in order to interact with each other. In other words, they must be able to exchange information and provide services to each other in a way that the supplied information or services are recognised and acceptable by the receiving partner, which means there must be a protocol which ensures this Integrability.

Outsourcing companies must agree upon a standardised protocol to exchange information like product specification, result data, analysis and even to receive the product itself. In case of Software development outsourcing, for e.g. the outsourcing companies giving contracts to more than one development company (resource/service provider) overseas must provide specifications in an industry standard format that is understandable by every service provider, else it may result into misunderstandings, unnecessary delays and even wrong product development.

However, in [12], they consider Outsourcing as an opposing strategy to Integration, and address a simple model to obtain equilibrium by combining both, integration and outsourcing. This also shows how Integration and Outsourcing are necessary to be combined to achieve the goal of staying competitive.

A lot of integration depends upon the information systems used in the network. As quoted by [13] “Information systems are the central element of how the modern enterprise governs itself, how it responds to external opportunities, and how it manages its resources.” And in the same paper he mentions “the operative term for information systems is not optimization but balanced integration. What matters is not so much what each element does technically but how it fits with everything else.”

With this we can say that, **“Integrability and Integrity are the underlying necessary condition for Outsourcing. Without established integrity, there is no reliable networking.”**

Distributivity: According to the BM_VEARM model “Distributivity, especially for the manufacturing system or enterprise are related to the distributed control of the (manufacturing) enterprise, based on multi-agent system model, and to the spatial (or geographical) distribution of the (manufacturing) enterprise functions and physical components.”

Outsourcing, by its foundation, is all about distribution of work and enterprises working distributed. Outsourcing is a solution to the problem that a product/service is very expensive to manufacture in-house, and is more affordable and sometimes more efficient to sub-contract some other resource provider, physically located at some other place.

A lot of work has been done about building multi-agent system based Virtual Enterprise architecture, for e.g. [14], [15], [16], [17]. These agents, conceptually, are the building blocks of Distributed systems. In case of the Outsourcing, each partner enterprise, either a client or a resource, is essentially an “agent”.

During the establishment of a VE, a distributed, multi-organizational workflow emerges from the dynamic merging and re-configuration of workflows representing E-Services in the participating enterprises [9].

In case of Software development Outsourcing, different phases of project management are executed at different geographic location, efficiently. The chief systems designer may be situated in one country and the software programmer can be in another country, both understanding each other by proper integrating and communicating mechanisms.

The Outsourcing industry takes its biggest advantage from the property of Distributivity. Due to this nature, the **"Outsourcing enterprises take an immediate advantage of different economical, geographical and even political conditions in their resource provider enterprises, at the time of sub-contracting, thus taking a bigger profit from Distributivity."**

Agility: Outsourcing is essentially a Business to Business channel, and an important aspect of Business to Business E-Commerce is the agile Virtual Enterprise (VE) [9]. Agility means rapidness or nimbleness. In the context of Virtual Enterprises, the agility refers to the characteristic of forming rapid new partnerships when a requirement changes or new requirements appear.

Goran Putnik and several others in their pioneering works [18], [8], [19] gave the concept of agility for Virtual Enterprises and called "Agile/Virtual Enterprises (A/VE), and during the same period Goranson [20], also, called them as Agile Virtual Enterprises (AVE), but with making a distinction between Virtual Enterprises and Agile Virtual Enterprises. According to Goranson, "a VE is agile only if it is formed with the intent of dissolving, or reconfiguring, so it is possible to have a VE without having an AVE".

In the model BM_VEARM, the agility is "a capability for fast adaptability or fast re-configurability in order to respond rapidly to the market (or customer demand)" [8]. Also the raising importance of reconfigurability was recognised by [18], [21].

Now, let's take a look at the current scenario in the Outsourcing industry.

A 2007 research study by BBC's Globalisation reporter Steven [22], says that the export advantages no longer lie in low labour costs only. The service providers have started to hire high skilled personals and more sophisticated equipments and have focused on specialized products, which mean that the Outsourcing firms have to move to different suppliers for different products. This means, reconfigurability in the contract networks.

As quoted by [23], "Outsourcing agreements created ten, five, even three years ago are now being renegotiated because they were essentially conceived in another era. According to market research analysts, approximately 50 percent of outsourcing transactions have either reached a maturity date or have been in existence for more than three years." And further, as they say "the increasing level of sophistication in modern IT and business process outsourcing best practice produces agreements that are far more flexible and, to a greater extent, 'futureproofed.' Such agreements contain important change management tools that allow flexibility to adjust to changing circumstances of both the client and the service provider."

Outsourcing is now well equipped with information and communication technologies which make the rapid establishment of communication and commerce channels easily available.

We can say that **"Outsourcing businesses have started to adapt to Agility and will continue in future with more dynamic partnership making mechanisms, made feasible legally and technologically."**

Virtuality: According to the definition in BM_VEARM, Virtuality means, "no physical existence but made by software to appear to be so." In the model BM_VEARM, the authors strongly argue about the elimination of the direct personnel contacts among partners, or individuals from the partnering enterprises, in order to establish complete Virtuality in Virtual Enterprises. They continue with the argument that to bring the Virtuality in VE, the VE must not be reduced to a simulation program.

The authors then continue to explain a hierarchical model with 3 levels, bringing in another level of "sub-contracting agents" or "brokers" between the two partners - clients and resources. And this brings many different aspects to the Virtual Enterprises, i.e. no direct approach yet complete direct negotiation, reconfigurability and physical execution of orders (and not just "virtual reality" simulation).

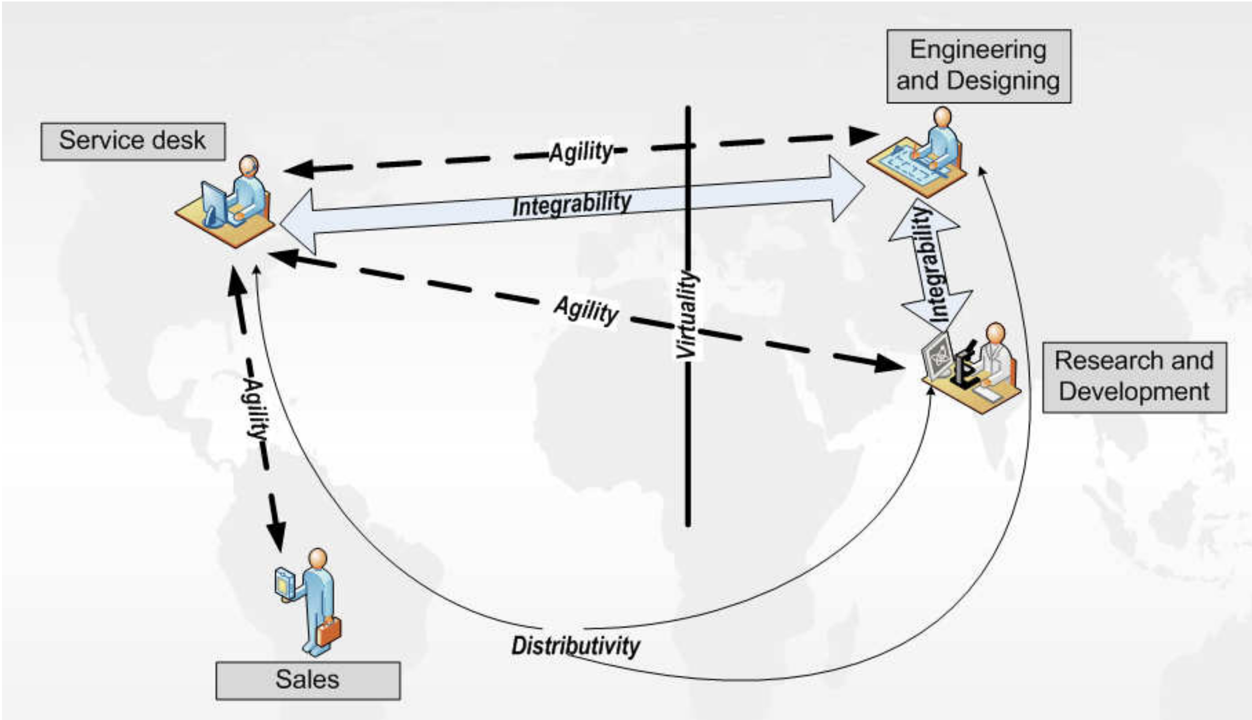

Fig. 1. Virtual Enterprise networking aspects illustrated for a model VE physically spread across the different continents

And, Outsourcing industry has many very good examples of Virtuality – Software Development Outsourcing, Business Process Outsourcing, Clinical Outsourcing, Call-centres etc. In each of these businesses, the Outsourcing firms (clients) located, for e.g. in the United States, do not approach directly to the service providers in India or China. They take services of other types of firms, known as Outsourcing Agents or Contractors, who give complete legal and technical guidance to their clients about many different service providers in the region of the clients' desired services market.

In case of the Call-centre service providers, we can see Virtuality at a different level. A call-centre company provides customer care via telephone lines, to the entire or a part of the customer base of their client (the outsourcing firm) and the end users of such services, the customer of the original Outsourcing firm doesn't know if the person assisting from the other end of the telephone line is speaking from where. Thus, Call-centres implement Virtuality, by eliminating the social and geographical barriers, to provide unbiased customer care to their clients' customers without any time-zone conflicts.

CONCLUSION

From the above analysis of the implementation of VE characteristics we can say that the Outsourcing industry implies different aspects of Virtual Enterprises in a very idealistic manner.

References

[1] Bacheldor, Beth, (2003), "Supply chain management still a work in progress", InformationWeek, May 23.

[2] Laseter, T., Oliver, K. (2003), "When will supply chain management grow up?", Strategy + Business, No. 32, pp. 20-5.

[3] Feller, A., Dr. Shunk, D., Dr. Callarman, T., "Value Chains Versus Supply Chains", BPTrends, March 2006.

[4] Porter, M. E. (1985). Competitive Advantage: Creating and Sustaining Superior Performance. New York, NY: The Free Press.

[5] Ranganathan K., Aryasri, A.R., Darshan, S., "Supply Chain as Value Chain", The ICFAI Journal of Supply Chain Management, Vol. 3, No. 3, pp. 7-11, September 2006.

[6] VEA (1998), "The Virtual Enterprise Concept", The Virtual Enterprises Association, http://www.vea.org.

[7] Camarinha-Matos, L. M., Afsarmanesh, H., Garita, C., & Lima, C. (1997). Towards an Architecture for Virtual Enterprises. Journal of Intelligent Manufacturing, 9(2), 189-199.

[8] Putnik, G. D. (2001) BM_Virtual Enterprise Architecture Reference Model, in A. Gunasekaran (Ed.), Agile Manufacturing: 21st Century Manufacturing Strategy (pp. 73-93), Elsevier Science Publ., UK.

[9] Michael E. McGrath, Product Strategy for High-Technology Companies, McCraw Hill, 1995.

[10] Raglan Tribe, David Allen, "Implementing Business Strategy with Virtual R&D Teams", IEEE, 2003.

[11] Alan Berfield, Panos K. Chrysanthis, Ioannis Tsamardinos, Martha E. Pollack, Sujata Banerjee, "A Scheme for Integrating E-Services in Establishing Virtual Enterprises", Proceedings of

the 12th Int.l Wrkshp on Research Issues in Data Engineering: Engineering e-Commerce/ e-Business Systems (RIDE.02), IEEE, 2002.
[12] Gene M. Grossman, Elhanan Helpman, "Integration Vs. Outsourcing In Industry Equilibrium", CESifo Working Paper No. 460, April 2001.
[13] Paul A. Strassmann, "The Internet: A Way Of Outsourcing Infomercenaries?", American Programmer, August 1995.
[14] Weiming Shen, Hamada Ghenniwa, Yinsheng Li, "Agent-Based Service-Oriented Computing and Applications", 1st International Symposium on Pervasive Computing and Applications, 2006.
[15] Chrysanthis P., T. Znati, S. Banerjee, S. Chang., "Establishing Virtual Enterprises by means of Mobile Agents", Research Issues in Data Engineering, 1999.
[16] Charles Petrie, Christoph Bussler, "Service Agents and Virtual Enterprises: A Survey", IEEE Internet Computing, IEEE Computer Society, July-August 2003.
[17] Sobah Abbas Petersen, Jinghai Rao, Mihhail Matskin, "Virtual Enterprise Formation with Agents – an Approach to Implementation", Proceedings of the IEEE/WIC International Conference on Intelligent Agent Technology (IAT'03), 2003.
[18] Cunha, M. M., Putnik, G. D., & Ávila, P. (2000). Towards Focused Markets of Resources for Agile / Virtual Enterprise Integration. In L. M. Camarinha-Matos & H. Afsarmanesh & H. Erbe (Eds.), Advances in Networked Enterprises: Virtual Organisations, Balanced Automation, and Systems Integration (pp. 15-24). Berlin: Kluwer Academic Publishers.
[19] Cunha, M. M., Putnik, G. D., & Gunasekaran, A. (2002). Market of Resources as an Environment for Agile / Virtual Enterprise Dynamic Integration and for Business Alignment. In O. Khalil & A. Gunasekaran (Eds.), Knowledge and Information Technology Management in the 21st Century Organisations: Human and Social Perspectives (pp. 169-190). London: Idea Group Publishing.
[20] Goranson T. (1999) The Agile Virtual Enterprises – Cases, Metrics, Tools, Quorum Books; Westport.
[21] Cunha, M. M., & Putnik, G. D. (2002). Discussion on Requirements for Agile/Virtual Enterprises Reconfigurability Dynamics: The Example of the Automotive Industry. In L. M. Camarinha-Matos (Ed.), Collaborative Business Ecosystems and Virtual Enterprises (pp. 527-534). Boston: Kluwer Academic Publishers.
[22] Steve Schifferes, "The changing face of outsourcing", BBC News, May 2007.
[23] Mark H. Robinson and Stan Lepeak, EquaTerra, "Renegotiating Your Outsourcing Contract", BPOIndia.org

DATA ANALYSIS APPLIED TO THE EVALUATION OF A TECHNOLOGICAL NATURE TEACHING MODEL AS A REGIONAL DEVELOPMENT TOOL

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Abstract: This paper presents the creation and development of technological schools directly linked to the business community and to higher public education. Establishing themselves as a key interface between the two sectors they make a significant contribution by having a greater competitive edge when faced with increasing competition in the traditional markets.

The development of new business strategies supported by references of excellence, quality and competitiveness also provides a good link between the establishment of partnerships aiming at the qualification of education boards at a medium level between the technological school and higher education with a technological foundation.

We present a case study as an example depicting the success of *Escola Tecnológica de Vale de Cambra*.

Keywords: Business, competitive responses, data-analysis, development, education, learning, technology

CASE STUDY

Ten years have now passed since the Technological School of Vale de Cambra (ETVC) opened its doors and it is time to make a balance assessment and look to the future regarding the influence on the business community of the deployment of this type of education in a geographical area of heavy industry.

Founded in January 1995, FORESP - Association for Training and technological expertise, was the result of joint efforts of ACIC - Commercial and Industrial Association of Vale de Cambra, the Town Hall of Vale de Cambra, INETI - National Institute of Engineering and Industrial Technology ,IAPMEI - Institute of Support to Small and Medium Business and Investment and also the Polytechnic Institute of Porto, gave substance to the Technological school of Vale de Cambra. Later, 6 of the most important companies of the region joined thus totaling 11 entities as founding members. [1]

Taking one of the main criticisms directed at the school – that being its inability to supply necessary skills for the work force, the creation of FORESP / ETVC took on the primary objective of resolving the deficiencies identified at the level of middle management of skilled personnel to meet the clear needs of the metal and metal mechanic industries, by far the sector with the greatest weighting in the economic structure of the region concerned.

As well as the first objective mentioned above, a second proposal and one of no less importance saw the establishment of protocols between ETVC and the Polytechnic Institute of Porto (IPP) with the view of possible further integration of the students in the Institute of Engineering of Porto (ISEP), So that they, the students, may continue their studies while working. In this respect, it is the responsibility of IPP to provide scientific and educational supervision as well as to supply the majority of teachers from ISEP to teach the courses, with the remaining educators being locally recruited from among senior management of companies in the region.

Overview of the Regional Framework

Though originally located in Vale de Cambra, where professional activity began in April 1998, ETVC later started a process of geographical diversification, and now has a satellite school in Arouca. Its influence is making itself known throughout the sub-region of Entre-Douro-and-Vouga, (EDV) (an area with approximately 860m2 and around 300 thousand inhabitants, but which covers other neighbouring areas such as Sao João da Madeira, Santa Maria da Feira, Oliveira de Azeméis, Sever do Vouga, Oliveira de Frades, Ovar, Castelo de Paiva, Estarreja and Albergaria) due to that fact that ETVC has received students that have residence and / or a professional address in these regions.

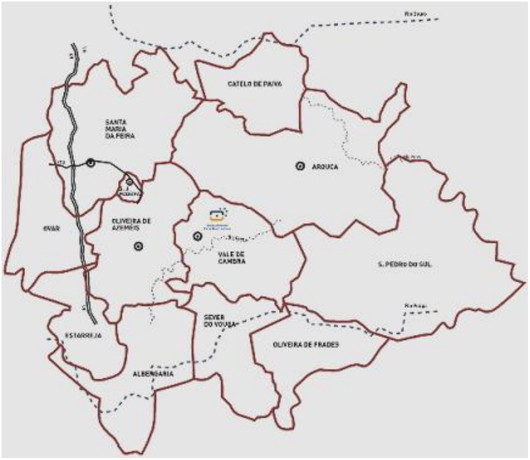

Fig. 1. Localization of ETVC

It is important to indicate that there are students from other areas, but in a more residual way, and that 5 areas from those mentioned above are the most represented, these being; Arouca, Oliveira de Azeméis, S. João da Madeira, Sta. Maria da Feira and Vale de Cambra.

This representation refers to either the origin of students or to the official address of the companies that welcome the students.

Suitability of education provision

The provision of training in ETVC has essentially covered the courses of technological specialization, in which we have seen approximately 1000 registered enrollments so far,around a total of 850 students. The current education provision concerning the courses of technological specialization (CET) at level IV contains the following areas:

- Applications of information technology management;
- Industrial Organization and Management;
- Management of Mechanical Production;
- Automation, Robotics and Industrial control;
- Industrial Maintenance.

In relation to courses for professional improvement of the worker, many courses of short duration have been held in various areas such as Information technology, Maintenance, Automation and many others.

In addition to these learning activities some initiatives were implemented to allow greater development between partners of the School, namely the students and companies, and of which the project HPCN (in partnership with ADRIMAG), the Program for Coordination and Business Participation (PAPE) and the implementation of an evaluation System of the School (SAFE) stand out.

Business community

To assess the adequacy of education provision of ETVC and the needs of businesses from surrounding municipalities, a study was conducted [1] which revealed the existence of a community of 9280 companies registered in the 11 areas above. This high initial number was reduced, in two phases, so that in the first phase only those that pertained to the 5 most represented areas where stratified. The table of fig.2 corresponds to their geographical distribution.

council	companies
Arouca	345
Oliveira de Azeméis	1609
S. João da Madeira	1162
Stª Mª da Feira	2880
Vale de Cambra	580
total	6576

Fig. 2. Number of companies per area.

However, the predominance of micro enterprises, most of which have a labour force at or below 5, and not all of which interact with ETVC, led us to work only with companies which have 50 or more employees, stratified in 3 categories. Even like this, the study still focused on a total of 308 companies. The graph of fig.3 is representative of the distribution of classes (between 50 and 100 employees, between 100 and 250 employees and over 250 employees) per company and per area.

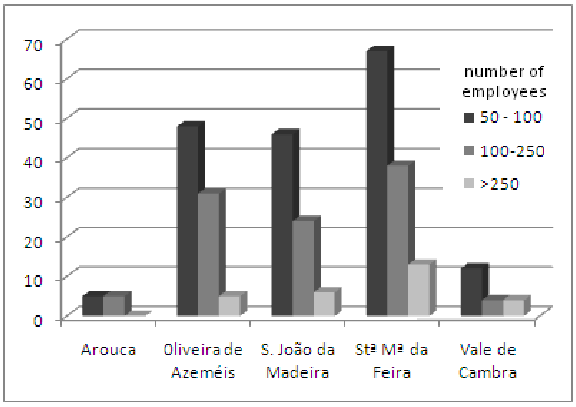

Fig. 3. The number of employees per company, per area.

The analysis of data collected concluded that the comparative percentage of companies per area with average schooling of employees that allowed them to enroll in courses of technological specialization was similar in 3 of the areas, highlighting S. J. Madeira positively and Arouca negatively as can be corroborated by reading figure 4.

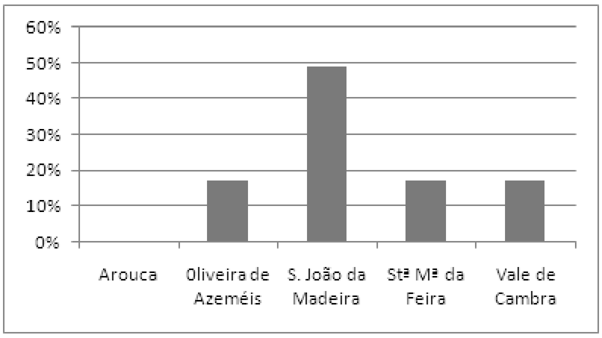

Fig. 4. Comparative average education of workers, per area, with average schooling that allows them to enroll in CETs.

SUCESS EVALUATION

The evaluation of educational quality of a technological nature has been a constant concern in ETVC since its formation. As such, it presents some main data and findings from a study that was carried out in order to deepen the knowledge of the student population, considering factors, as seemingly disparate, but at the same time so significant, such as the entry classifications or geographical origin.

One objective was the development of a measuring methodology that would define a conceptual framework where basic concepts were discussed, together with methods of analysis, in order to carry out a structured assessment with clearly defined objectives.

Characterization of the population

The statistical data to consider in this type of study from a management perspective should initially be those that allow the classification of students as a whole. However, from the point of view of society in general and of the individual student we may jump to the conclusions about the image of the institution that may not be favourable and there will be disparity either amongst the students (working students or not) or in the levels of the current courses.

Thus, at the early stage we initially look at the population as a whole in order and then we establish populations with individualistic features, and study them separately.

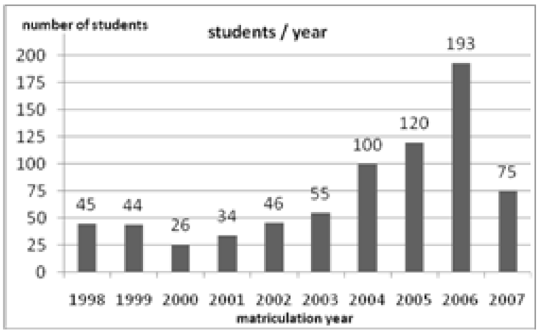

Fig. 5. Changes in the number of students throughout the first 10 years of ETVC.

With the graph of fig.5 we intend to show the evolution of the number of enrollments over the ten years of existence of ETVC.

The criteria for classification that allowed us to differentiate populations on the whole were the *age*, the distinction between *student worker* and *ordinary student* and *geographical origin*.

In this way, and in accordance with the input variables mentioned, the 738 students who have attended the technological courses so far at ETVC, are distributed according to what is shown in the graphs of fig.6 and in subsequent ones.

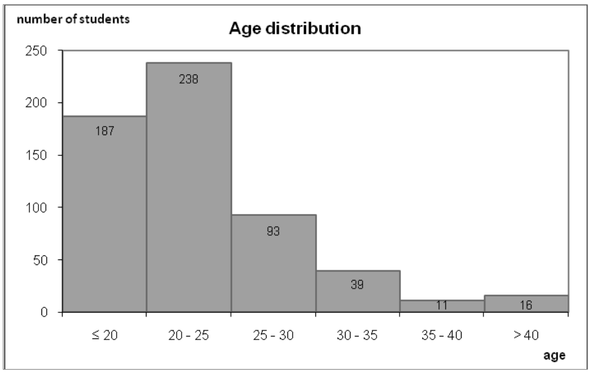

Fig. 6. A chart representing the distribution of student ages.

The analysis of the chart in fig.6 shows that though the number of students below the age of 20 is significant, the class that is the most representative is the [20.25[, and that 75% of students are, upon enrollment, aged over 20. This fact is highly significant and, combined with the reading of the chart in fig.7, speaks volumes of this type of education that aims to attract most students from industry. These people were early school leavers who, according to the student themselves, had thought that their study days were behind them.

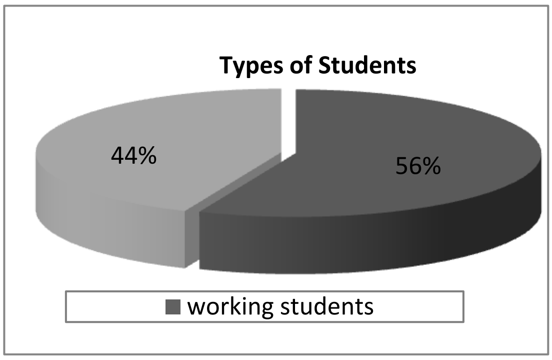

Fig. 7. Distinction between working students and regular students.

Characterizing the geographical origin of students, as shown in the pie chart below, illustrates that 6 groups were considered, five of which were the most significant areas. The sixth group represents those students who originated from an area not belonging to one of the five previously mentioned.

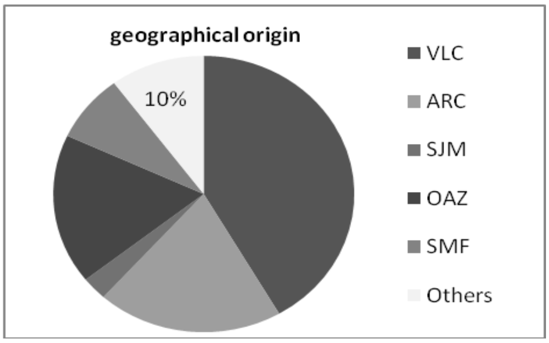

Fig. 8. Distribution of students according to their geographical origin.

It is clear to see that the area which provides more students is Vale de Cambra, where the main school ETVC is located. Unsurprisingly there is also a significant influx of students from Arouca (20%). What is significant is the percentage of students from Oliveira de Azeméis (18%), which speaks well of the amount of influence that ETVC exerts. To support this fact, the 10% of students from other origins are spread over 8 different areas.

Failure analysis

The analysis of data collected shows that there is a significant number of dropouts (table in fig.8) and that an analysis of these drops outs- the students that give up, those that annul enrollment, those that transfer to another course and those that transfer to higher education needed to be carried out.

Abandonments			
reasons		number of students	percentage of students
defined	transference to university	10	3%
	course change	53	14%
indefinite		306	83%

Fig. 9. Distribution of student drop-out motives.

For the collection of such data a sample of 585 students was considered, of whom 226 were already qualified.

From the analysis of fig.9 we can conclude that only 17% of students dropped out for a good reason. What is important is the analysis of the 83% who gave up or simply cancelled their registration. There is a number of reasons in explanation of this including personal, professional, illness and non specified motives. In an attempt to find other motives for justifying the dropout rates we analyze (in fig 10) the frequency of student type drop-out.

Characteristics		
student type	number of students	percentage of students
working students	225	61%
regular students	144	39%

Fig. 10. Distribution of student type dropout rates.

The highest percentages of students leaving school are the workers, which comes nothing as a surprise. However the high withdrawal among regular students represents an unexpected result, which should merit the attention of the school in respect to the selection process of candidates.

It should be noted that despite there being a slightly higher rate of worker student drop out, there is also a higher number of worker-students that complete the course or are in the final stages of completion.

This drop out study is complemented with the phase analysis where the same withdrawal is given. (table of fig.11).

Abandonment phase		
phase of the course	number of students	percentage of students
< 5%	35	24%
5% - 50%	92	64%
> 50%	18	12%

Fig. 11. Dropout rates during course phases.

A higher percentage of students withdrawals are to be expected at the early stage of the course. However this has not happened, so it is necessary for the school to focus on the high percentage of dropouts among those who were integrated into the normal functioning of the course. The low percentage of dropouts from among students who completed at least half of the course says a lot for its success. This analysis of phase withdrawals must, however, be carried out in more detail so that it encompasses in the same group students who withdrew after 5% of course completion and students who left after completing half the course. The third group should consider students who withdrew shortly after the completion of half of the courses along with students who left in a final phase of the course.

Sucess Analisys

The analysis of success involves the determination of the rate of success, which is the ratio between the number of graduates and the total number of students.

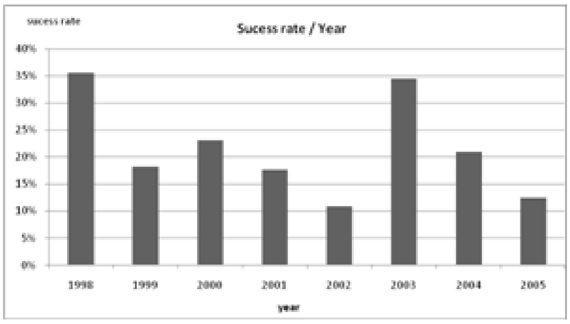

Fig. 12. The yearly success rate.

It is necessary to point out that although this study relates to all the courses within the ETVC, it is important to distinguish between the courses of Level III and Level IV in that the first tend to disappear while the latter are the current main bet of ETVC. In fact, among the courses in Level IV, the course designers chose to distinguish the courses that have a greater number component of curriculum units in the area of mathematics, from those that do not have this component. This option is due to the fact that mathematics is, in Portugal, a reason for failure at school, and there are those who even cite it as a reason for leaving school. However, as we shall have occasion to appreciate, this theory will be completely denounced by the truth of the facts, at least in what concerns this case.

In the graph of fig.13 we can verify that the current option to invest efforts in the development of courses at Level IV is a sure bet as achieve higher rates of success are achieved.

When it comes to math, much of the propaganda has been demystified and therefore concentrating on a solid education of basic mathematics is absolutely essential to the education of a technological nature.

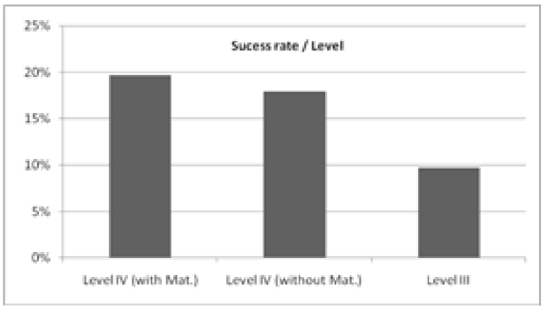

Fig. 13. Success rate for each course type.

An evaluation of success over time implies a comparative analysis of development of the final average grades of the students. This analysis is plotted in fig.14, where the average of the marks is presented over 9 years and as can be seen there is a trend around the 14 to 15 mark which leads to a classification of Good according to the standards of education in Portugal.

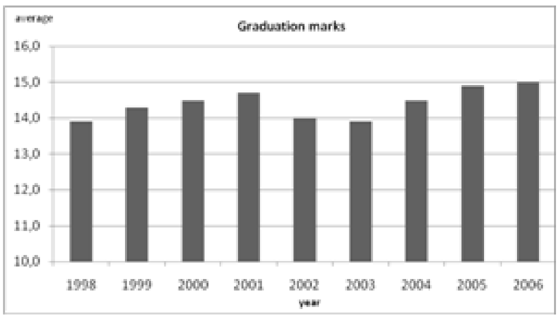

Fig. 14. Marks over a nine year period.

Once again we make the separation between the courses of Level III and Level IV, and in the latter we distinguish between those which have a strong mathematical component and the ones that do not. By examining the graph of fig.15, we can conclude in a similar way as previously done in examining the graph of fig.13, particularly where the mathematics component is concerned.

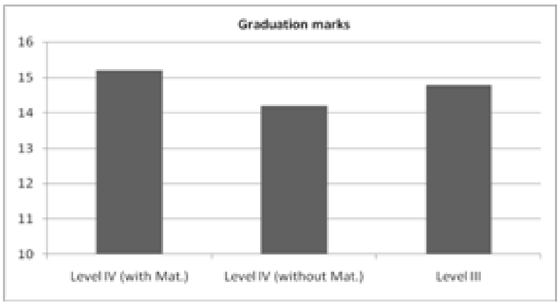

Fig. 15. Marks for each type of course.

CONCLUSION

The evaluation of various parameters of success points to highly satisfactory conclusions. We see that the number of students has grown over the last 10 years (fig.5).The most representative class (75%) are students between 20 and 25 years which speaks well of the aim of this type of education of attracting those people from the work force who had interrupted their studies (fig.6) According to a survey of graduate students, 65% claim to have enhanced their professional conditions in some way as a result of the completion of the course (fig.16)and 46% of student graduates continued onto higher education, all of them gaining places at the Institute of Engineering of Porto (fig.17).

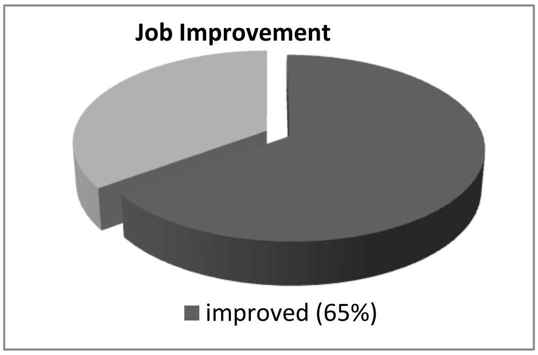

Fig. 16. Chart of Job improvement.

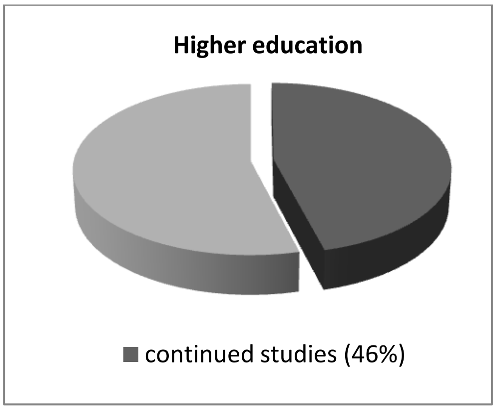

Fig. 17. students who continued their studies.

References

[1] *Escola Tecnológica de Vale de Cambra, Relatório de Auditoria*, 2007.
[2] http://foresp.pt
[3] *Relatório de Apreciação dos Inquéritos às Empresas*, Meixedo, J.P., Teixeira, A., 1999.
[4] *Dec-Lei n.º88/2006 de 23 de Maio, DR – I Série-A*.
[5] *Escola Tecnológica de Vale de Cambra, Regulamento Interno – Orientações e Procedimentos*.
[6] *Probabilidades e Estatística*, Vol. 1 e 2, J. Tiago Oliveira, McGraw-Hill
[7] Probabilidades e Estatística, Vol. 1 e 2 , Bento Murteira, McGraw-Hill.

E-LEARNING AT UNIVERSIDADE ABERTA: AN EMPIRICAL STUDY APPLIED TO MANAGEMENT COURSES

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Keywords: E-learning, learning technologies in university, on-line services, ICT, IT, Performance measurements.

INTRODUCTION

Over the last decades, we assisted to unprecedented changes in economic and social environment. People and organizations needed to learn in order to deal with changes, innovations and uncertainty, and almost of all them needed to adopt new ways to cope with unknown situations. Therefore, organizations need people with strong and up-to-date knowledge in strategic areas. This led to changes in the demand for higher education courses, in students' characteristics and needs and in the nature of instruction provided to them.

Traditionally, distance education in higher education offered solutions to students who could not be in a traditional classroom. However, the growing need for continuous learning and the unprecedented technological innovation in communications led to methodological changes in the traditional distance education. The change is deep. With the exception of a few studies [1], most of what have been written about distance education in the middle of the 1990s is out of date.

The objective of this paper is to define and share the conception of a research about the population of Portuguese Open University students enrolled in curricular units of the Bachelor in Management. We focus on the transformation process centred on the students environment and their study behaviour and highlight the basic methodological issues with the coming new waves of students that will interact on a much more different context compared with that of the 1990s.

Our intent is therefore to get a better understanding of the transformations of the online higher education in management studies and make progressive contribution to the comprehension of how learning and teaching have changed. There is already a vast literature on online management teaching experience [2, 3] but there is a need for empirical studies. Consequently, we are trying to see how theories and principles are describing correctly the practices of the teachers and students and how expectations and other variables can contribute to that better understanding of management studies as they were and as they are practiced.

We are still far from a large-scale computer-mediated training for management teachers [4], but our teaching staff is undergoing a process of change and upgrading its online teaching skills [5].

UNIVERSIDADE ABERTA AND E-LEARNING

Universidade Aberta was, until 2006, a traditional Open University with still similar learning methodologies that emerged decades ago. The student, alone with the materials proposed by the teacher, should read the books or didactic texts, interpret them and try to understand the contents. In other words, it was a learner-content interaction [6]. The student could interact with the teacher to get some study orientation or some answers to specific questions. This learner-instructor interaction [6] was possible through correspondence or telephone calls. More recently, e-mail communication has begun to be used. But only a small group of students was receptive to this new way of communication and still most of the students preferred to speak with the teacher, because they did not have access to Internet or they did not feel comfortable to use a computer. The learner-learner interaction didn't exist.

Within the last decade, traditional distance education has turned obsolete. Technological advances and development of new tools to communicate and interact in environments like internet, changed the reality of distance education. The student population has become more knowledgeable with using computers and internet. Students feel the need to interact with peers. And Universidade Aberta needed to adapt its landmarks. A new Pedagogical Model was developed, based on didactic and pedagogical frameworks and models.

Holmberg [7] proposed didactic elements –like reflection questions, self-evaluation activities– in order to promote dialog between teacher and students. Moore [8, 9] developed the transactional distance theory so that the real «distance» between teacher and student is essentially «pedagogic» and not time-space based.

Garrison, Anderson and Archer build up a theoretical model whish constitutes a hallmark in distance learning development [10]. These authors stated three critical components of an on-line educational community: cognitive presence, social presence and teaching presence.

Cognitive presence means that development and growth of critical thinking skills are supported by 'serious' learning environment [11]. Social presence states that the expression of ideas in a collaborative context should imply students' feeling of comfort and safety. Teaching presence has three critical roles:

- first, the learning experience design and organization;
- second, the encouragement of discourse between and among students through devising and implementing activities;
- and third, the role that "…goes beyond that of moderating the learning experiences when the teacher adds subject matter expertise through a variety of forms of direct instructions. […] In many contexts […] teaching presence is delegated to or assumed by students as they contribute their own skills and knowledge to the developing learning community" [11].

Garrison, Anderson and Archer's approach is mirrored in the four major building blocks of the Portuguese Open University Pedagogic Model:

1. Learning focused on student;
2. Flexibility principle;
3. Interaction principle;
4. Digital inclusion principle.

This Pedagogic Model focus on student as a learning community member. The student, an active individual, builds his own knowledge and learning process based upon rigorous planning provided by the teacher. Student's active role implies sharing and exchange information, goals definition, and learning self-monitoring [12]. Teaching presence is essential to develop cognitive and social presence.

Flexibility places Discussion Forums has a crucial pedagogic element. Asynchronous communication allows time-space flexibility for students to read, process information, reflect and interact. Asynchronous instruments provide a more democratic access to knowledge and learning, and increases student's participation in the education community. Consequently, the interaction principle implies the development of student-student collaboration and the growth of teacher's visibility in terms of curricular unit plan, messages and moments of previously planned contacts.

The digital inclusion principle implies educational promotion strategies towards acquisition and development of digital literacy.

CONCEPTUAL AND EMPIRICAL FRAMEWORK

We intend to define and share the conception of a research about the population of Portuguese Open University students who are enrolled in curricular units of the Bachelor in Management. The study will be based upon five dimensions:

- Dimension 1 – Study and work practices of students in current traditional distance learning;
- Dimension 2 – Student interactions with administrative services;
- Dimension 3 – Student interactions with new technologies;
- Dimension 4 – Student electronic interactions with Portuguese Open University;
- Dimension 5 – Student's expectations towards on-line learning.

These five dimensions focus on essential elements constituting two of the building blocks of Portuguese Open University actual transition:

- The transition from traditional distance learning to on-line learning;
- The adoption and acceptance of ICT.

Dimension 1 – Study and work practices of students in current traditional distance learning

Dimension 1 allows us to characterize traditional distance learning. Respective didactic-pedagogical frameworks and models were proposed by Wedmeyer [13] and Peters [14, 15].

Wedmeyer – who was fundamental in Open University creation - argued that education should promote autonomous and independent individuals who are free to make their choices. However, this author also sustained that teachers have to support and guide student. This model implies the separation between the teaching process and the learning process.

Peters' model allowed growth and dissemination of distance learning. This organisational model sustained that «package-learning» should be efficiently distributed to motivate students interactions with programs and content. Accordingly, industrial production systems were applied to distance learning and this point could be developed in further study.

Dimension 2 – Student interactions with administrative services

The second dimension deals with the characteristics of the interaction of the students with the administrative staff and services of the university. The objective here is to define the types of interactions, whether on campus, by fax, email, web agents and software, by post or by phone and to find out about the motives or reasons of the communication between students and administrative staff. In other words, this dimension is trying to get information on how and why students communicate with the administrative services of the University. This is a very important issue to deal with in the transition from traditional distance education to online education and e-learning methodologies [16].

This aspect of the communication of the students with the administrative staff has been neglected in the literature but some of the information that we can get here can help interpret better the data of the other dimensions. Moreover, these services to the student incur costs both to the university and the student and it is important to know if those services correspond to the expectations students have. This point could be extended in further studies but now we will limit to the how and why questions of the interaction.

Dimension 3 – Student interaction with new technologies

The new Pedagogic Model implemented in Portuguese Open University is based in an online learning context within which students work with software applications and internet tools [12, 17]. Some examples are: word processor, e-mail, information research in Internet, Internet forums and chats.

We want to evaluate students' degree of interaction with technology to conclude about their technical ability to be engaged in on-line courses. Interaction with technology is defined as the students' experience and skills in working with tools and applications that are needed in an on-line course [17, 18]. We identified the variables listed in Table 1.

Variable	Examples of subscales
Knowledge about basic software applications [19-21]	experience in using basic software applications like word processor and spreadsheets
Frequency of basic software applications use [21]	time spent in using basic software applications
Knowledge about Internet and Internet tools [19, 21, 22]	years of Internet experience; experience in using e-mail, forums and chats
Frequency of Internet use [19, 21, 22]	time spent on Internet
Motive to use Internet [19]	e-mail; shopping; information search

Table 1. Variables to "student interaction with new technologies"

Dimension 4 - Student electronic interaction with Portuguese Open University

Portuguese Open University has two systems of electronic communication: a web site, with a wide set of information in subjects like: university's history; list and characterization of courses offered in university; exam's dates; professors' contacts; list of publications and links to courses web pages, for example; and a portal, where students could communicate with administrative services of the university, to have information about their classifications and to make matriculation in courses and exams.

We pretended to evaluate the degree of actual interaction of students with these two systems and their experience of operating with them. Students' perceptions about these systems could explain their expectations, and future success of e-learning in Portuguese Open University. We will adopt a model widely used in information systems field named Technology Acceptance Model [23, 24] recently extended to e-learning field [21, 25].

Technology Acceptance Model (TAM) posits that an individual's beliefs and perceptions of information technology have significant influence on its usage [23, 24]. This model posits that perceived usefulness and perceived ease of use, determine an individual's intention to use a system with intention to use serving as a mediator of actual system use [23, 24]. These are important concepts to our study because digital inclusion is one of the principles of the Pedagogical Model implemented in Portuguese Open University [12].

In our study, we will apply TAM to Portuguese Open University web site and to the portal. We identified the variables listed in Table 2.

Variable	Examples of subscales
Web site (or portal) use [12]	experience in use the system; frequency of use
Perceived usefulness [14, 15, 21, 23-25]	time reduction; information usefulness; impact in individual performance
Perceived ease of use [21, 23-25]	easy to understand; easy to navigate
Intention to use the web site (or portal) [21, 23-25]	future use; divulgation to other students

Table 2. Variables to "student electronic interaction with Portuguese Open University"

The model conceived by Davis [23] is frequently used in studies of Communication and Information Systems and their respective efficacy. 'Perceived usefulness' and 'perceived ease of use' have been developed and validated as specific variables and hypothesized as essential determinants of user acceptance (idem: 319). Perceived usefulness relates to situations when "… people tend to use or not use an application to the extent they believe it will help them perform their job better" (idem: 320). Perceived ease of use states that "…if potential users believe that a given application is useful, they may, at the same time, believe that the system is too hard to use and that the performance benefits of usage are outweighed by the effort of using the application." (ibidem). The set of related theoretical frameworks (like self-efficacy or adoption of innovations) supports the assumption that these two variables have a central role in determining computer and new technology use.

Dimension 5 – Student's expectations towards on-line learning

Recently, other models based on Davis (1989) seminal paper have been applied on on-line learning situations [21]. These authors consider that internet technology favours opportunities for learners in disadvantage and remote locations, and promote exchange of expertise and information [21]. The internet learning environment is enriched because teachers can provide tools to encourage initiative, creativity and learning development whish favours the strength of an educational community. For Saadé and Bahli, the student perspective is essential for this kind of analysis: "the introduction of internet-based learning environments may hinder the learning process if the technology is perceived as being complex and not useful to enhanced performance, and thus a distraction to learning." [21] We pretend to identify students' expectations related with on-line learning in Portuguese Open University. On-line learning is already a reality to some courses in Portuguese Open University, but not to Bachelor in Management. However, next year this course will be teach on-line, so students already read and eared about the new Pedagogic Model and have some expectations related with aspects like: assessment, methods of study, interaction with instructors and interaction with other students [8, 9, 12, 13, 17]. Student is assumed to be an active individual who builds his own knowledge and learning process [12]. Learning environment is ready to drastically change in aspects such: types of interaction; professor/instructor roles; students' involvement in knowledge construction; and types of assessment [11, 18]. Consequently, it is important to evaluate what students really know about these issues and what are their expectations. The variables are listed in Table 3.

Variable	Examples of subscales
Knowledge of Pedagogic Model [12]	existence; assessment; possible interactions; type of tasks; student's role; professor's role
Moodle's experience [10, 11, 14, 15]	experience in use; frequency of use; easy to understand; easy to use
Expectation about study process [6, 11]	comparison with traditional distance learning; type of learning materials; regularity of study; expected number of hours dedicate to study in a week
Expectation about interaction with instructs [6, 10, 11]	comparison with traditional distance learning; type of contacts; regularity in the contacts; motives to contact
Expectation about interaction with other students [6, 10, 11]	comparison with traditional distance learning; type of contacts; regularity in the contacts; motives to contact
Expectation about effort [11]	comparison with traditional distance learning
Expectation about success [11]	comparison with traditional distance learning

Table 3. Variables to "student's expectations towards on-line learning"

CONCLUDING REMARKS AND FUTURE WORK

Traditional distance education changed and Universidade Aberta needed to implement a new Pedagogical Model. These transformation were motivated by the growing need for continuous learning and the unprecedented technological innovation in communications with still further economic and social consequences.

With our study we want to understand the changes in management education and their consequences on students' actions, perceptions and expectations.

The next step is to develop a questionnaire based in the conceptual and empirical framework presented paper. The questionnaire, after validation, will be responded by the population of Portuguese Open University students who are enrolled in curricular units of the Bachelor in Management.

This study could lead to a better strategy in the online education of management studies to make easier the planning of teaching and learning activities in this new configuration of teaching and learning.

References

1. Harasim, L.M. and L. Teles, *Learning Networks: A Field Guide to Teaching and Learning Online*. 1995, Cambridge MA: MIT Press.
2. Arbaugh, J., *How Classroom Environment and Student Engagement Affect Learning in Internet-based MBA Courses.* Business Communication Quarterly, 2000. **63**(4): p. 9.
3. Arbaugh, J., *Learning to learn online: A study of perceptual changes between multiple online course experiences.* Internet and Higher Education, 2004. **7**(3): p. 169–182.
4. Salmon, G., K. Giles, and J. Allan, *Large-scale computer-mediated training for management teachers.* Information Research, 1997. **3**(1).
5. Keaster, R., *Distance Education and the Academic Department: The Change Process.* Educause Quarterly, 2005. **2005**(3): p. 48-55.
6. Moore, M., *Three Types of Interaction.* American Journal of Distance Education, 1989. **3**(2).
7. Holmberg, B., *Theory and Practise of Distance Education.* 1992, London: Routledge.
8. Moore, M., *Editorial: distance education theory.* The American Journal of Distance Education, 1990. **5**(3): p. 1-6.
9. Moore, M., *Theory of transactional distance*, in *Theoretical Principles of Distance Education*, D. Keegan, Editor. 1993, Routledge: London. p. 22-38.
10. Garrison, D., T. Anderson, and W. Archer, *Critical inquiry in a text-based environment: Computer conferencing in higher education.* The Internet and Higher Education, 2000. **2**(2-3): p. 87-105.
11. Anderson, T.L., *Teaching in an online learning context*, in *Theory and Practice of Online Learning*, T.L. Anderson and F. Elloumi, Editors. 2004, Athabasca University: Athabasca. p. 273-294.
12. Pereira, A., et al., *Modelo Pedagógico da Universidade Aberta*. 2007, Lisboa: Universidade Aberta.
13. Wedemeyer, C.A., *Independent study*, in *Encyclopedia of Education IV*, R. Deighton, Editor. 1971, McMillan: New York. p. 548-557.
14. Peters, O., *Introduction*, in *Otto Peters on Distance Education: the Industrialization of Teaching and Learning*, D. Keegan, Editor. 1994, Routledge: London. p. 10-23.
15. Peters, O., *The transformation of the university into an institution of independent learning*, in *Changing University Teaching: Reflections on Creating Educational Technologies*, T. Evans and D. Nation, Editors. 2000, Routledge: London. p. 10-23.
16. Bates, T., *Managing Technological Change: Strategies for College and University Leaders*. 2000: Jossey-Bass.
17. Pereira, A., et al., *Instrumentos de Apoio ao Ensino Online: Guia do Professor/Tutor e Guia do Estudante Online.* Revista Discursos - Série Perspectivas em Educação, 2004. **n.º 2**: p. 195-221.
18. Pereira, A., et al., *A Universidade Aberta em qualquer lugar do mundo: Um modelo pedagógico para a educação a distância*, in *Unpublished working paper*. 2007, Universidade Aberta: Lisboa.
19. Bernardo, M.d.R., *Os Agentes de Software e o Processo de Tomada de Decisão - Estudo Empírico do Impacto de um Shopbot*, in *Instituto Superior de Economia e Gestão*. 2006, Universidade Técnica de Lisboa: Lisbon.
20. Hostler, R., V. Yoon, and T. Guimaraes, *Assessing the Impact of Internet Agent on End Users' Performance.* Decision Support Systems, 2005. **41**(1): p. 313-323.
21. Saadé, R. and B. Bahli, *The impact of cognitive absorption on perceived usefulness and perceived ease of use in on-line learning: an extension of the technology acceptance model.* Information & Management, 2005. **42**(2): p. 317-327.
22. Holster, R., V. Yoon, and T. Guimaraes, *Assessing the Impact of Internet Agent on End Users' Performance.* Decision Support Systems, 2005. **41**(1): p. 313-23.
23. Davis, F.D., *Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology.* MIS Quarterly, 1989. **13**(3): p. 319-340.
24. Davis, F.D., R.P. Bagozzi, and P.R. Warshaw, *User Acceptance of Computer Technology: A Comparison of Two Theoretical Models.* Management Science, 1989. **35**(8): p. 982-1003.
25. Gong, M., Y. Xu, and Y. Yu, *An enhanced Technology Acceptance Model for Web-Based Learning.* Journal of Information Systems Education, 2004. **15**(4): p. 365-374.

NEW APPROACH TO RISK ANALYSIS IN MARKETING COMMUNICATIONS USING FAULT TREE ANALYSIS

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Abstract: The application of certain methods of assessment of success or failure of the concrete mix of markteting communications has been proven as necessary in order to plan instruments of marketing communicationss. This paper presents an original approach to risk analysis in marketing communications (MC). It is shown on example that the risk can be analyzed qualitatively using the fault tree analysis. Failure of MC is observed as a top event of a coherent fault tree which basic events model failure of MC instruments and their elements.

Keywords: marketing communications, fault tree analysis, risk

1. INTRODUCTION

Marketing communications represents a cluster of all communication aspects of marketing mix instruments intended to influence consciousness and behavior of existing and prospective shoppers, consumers and/or users, so as to motivate them to shop and to establish long term relationships with a specific organization based on mutual trust and loyalty. The purpose of this work is to analyze risks involved in marketing communications using the fault tree analysis method. The fault tree analysis constitutes one of the basic methods of system security analysis. One of the results of this analysis is the combination of environment factors, human errors and element failures which can cause an undesirable event in the system.

This paper consists of three main sections. The following section shall present a description of instruments of marketing communications: advertising, public relations, self-selling, sale promotion, economic publicity, communication aspect of direct marketing, communication aspect of the product (package), communication aspect of distribution and sale (marketing environment) and communication aspect of the price. This section shall also present the events which lead to failure of each of the stated instruments, and subsequently create the risk of failure in marketing communications.

The last section of this paper shall attempt to present the previous analysis using the fault tree method, which represents one of the basic methods of system security analysis and which indicates, within the quality analysis, consequences of a certain event (failure) and points out to the events which have the greatest impact on the failure of the whole system.

2. MARKETING COMMUNICATIONS RISK ANALYSIS

Relative to the concept of promotion (advertising, sale promotion, self-selling, public relations, economic publicity and communication activities of direct marketing), marketing communications include communication aspects of other instruments of marketing mix (in this case, particularly: product image and packaging, communication aspect of the price and marketing environment). The risk analysis was applied to each of these instruments as well as for selected activities.

2.1. Economic propaganda risk analysis

2.1.1. Press advertising risk

- Advertising in press not read by a target group
- Advertisement is placed in a less visible place
- Poor creative solution of the message

2.1.2. Risks of outdoor advertising means

- Placing the message on a less visible spot
- Saturation of a certain location
- Wrong location relative to a target group
- Damaged outdoor advertising or changed outlook of the message
- Poor creative solution of the message

2.1.3. Risks of audio and audio-video means of entertainment

- TV advertising risks
    - Choice of TV station not watched by a target group

- Message not conceptualized in a manner to call attention
- Unsuitable run times
- Message does not contain the right kind of information
- Poor creative solution of the message

- Radio advertising risks
  - Choice of radio station not listened to by a target group
  - Unsuitable run times
  - Message is too long and does not hold the attention
  - Poor creative solution of the message

2.2. Public relations risks
- Date base does not contain information possibly required by a consumer
- Insufficient communication with consumers
- Sponsored events are not closely related to a target group
- Late response to crises

2.3. Self-selling risk analysis
- Agent does not possess communication skills
- Agent is not familiar with the nature of a consumer
- Agent is not using selling techniques
- Consumer is not interested in that form of shopping

2.4. Sale promotion risk analysis

2.4.1. Risks of distributor and retail oriented sale promotion

2.4.1.1.Risks of presenting advertising materials
- Presenting clients with gifts which they can't adequately expose
- Gift materials are not attractive enough to be exposed

2.4.1.2.Risks of organizing competitions among distributors
- Awards are not attractive enough

2.4.1.3. Risks of show casing of products in retail
- Show case assistants do not possess sufficient skills

2.4.1.4.Risks of offering discounts and bonuses
- Discount is not attractive enough
- Large order is needed in order to get a discount

2.4.1.5. Risks of special presentations of the product
- Products are presented on locations not frequented by a target group

2.4.2. Risks of consumer oriented sale promotion

2.4.2.1.Risks of voucher offers
- Unsuitable voucher distribution canals (for example, voucher distribution through a newspaper not read by a target group)
- Discount or gift does not attract attention of consumers
- Discount or a gift are offered for an unsuitable quantity

2.4.2.2.Product price discount risk
- Discount is offered for an unsuitable quantity
- Competition is engaged in the same form of sale promotion

2.4.2.3. Risks of sample offering
- Samples are to small
- Samples are inconvenient for use
- Consumers are saturated with such a form of sale promotion

2.4.2.4.Risks of presenting voucher in/on the package
- Unsuitable quantity of the product to which the voucher is attached
- Awards are not practical

2.4.2.5. Risk of offering products with gifts
- Damage of the gift in transport
- Gift is not practical

2.5. Risk analysis of the communication aspect of direct marketing

2.5.1. Telemarketing risks
- Telemarketing agents are not sufficiently trained
- Telephone call is not place at the right time
- Lack of ability to engage a prospective consumer
- Potential consumer is not interested in that form of shopping

2.5.2. Risks of offers and orders via the Internet
- Target group is not an Internet user
- Lack of interest for that form of shopping
- Impossibility of electronic payment
- Lack of trust with this form of shopping (Will the product really be delivered?)

2.5.3. Risks of computerized automatic sales
- Placing a computerized automatic sale facility in a less busy spot
- Lack of interest for that form of shopping
- Consumers are having trouble with using the facility

2.5.4. Risks of direct marketing via television, radio and magazines

- Target group does not use the given means of information
- Lack of interest for that form of shopping
- Long delivery times
- Impossibility of direct contact with the product

2.5.5. Risks of catalogue sales

- Catalogues are offered to consumers who are not interested
- Catalogues do not contain tall free telephone number for ordering
- Consumer's lack of trust in that form of shopping

2.5.6. Risks of direct mail

- Consumer saturation
- Lack of interest for that form of shopping
- Mail design is such that it does not attract attention

2.6. Risk analysis of economic publicity

- Media are not interested in information to be placed by a company
- Message does not reach consumers due to wrong run times
- Message is reaching a consumer to early or to late
- Media has delivered the message to the public in an altered form or with wrong contents
- Negative publicity

2.7. Risk analysis of the communication aspect of product packaging

- Packaging is not user friendly
- Competition has better packaging solutions for their products
- Size of the package does not satisfy needs of a consumer
- Design is inadequate and not sufficiently attractive

2.8. Risk analysis of the communication aspect of distribution and sale – marketing environment

- Exterior and interior appearance does not attract a consumer
- Interior arrangements are inconvenient
- Insufficient circulation within the marketing environment

2.9. Risk analysis of the communication aspect of price

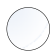
- Price discount is potentially perceived by the public as an indicator of the diminished quality of the product

3. RISK ANALYSIS OF THE MARKETING COMMUNICATIONS BY APPLYING THE FAULT TREE METHOD

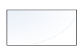
The fault tree analysis represents one of the basic methods in the system security analysis. It was develped in the 60's by Boeing laboratories for application in the armament system, and it has been widely used for various purposes such as, for example, nuclear powerhouses, chemical processes, weaponry systems to verify reliability of complex systems, product quality, etc.This work shows how this method can be used in the field of business or, more accurately, marketing communications.

The qualitative fault tree analysis provides an asnwer as to the consequences of a certain event and it reveils combinations of events which have the greatest impact to failure of the whole system (minimum cut sets). The fault tree analysis relies on a diagram, the fault tree. The purpose of forming the fault tree is to symbolically represent the sequence of occurance of conditions causing a type of failure or an undesired event affecting the system on the whole. The fault tree scheme consists of two basic kinds of symbols: events and logical circles or gates. The term „event" signifies a dynamic change of the condition existing within the system element.Gates indicate the connection between concrete events necessary for the occurance of the greatest event – the total system failure.

Basic symbols and logical circles in the fault tree analysis are [7]:



Basic event– source failure not further developed. This type of event is independant from the others.



Intermediate event – represent the fault event occuring because one or more previous events had activated the logical circle. This event can be further developed.

Logical circle AND– ouput failure shall occur if all input failures occur

Logical circle OR– output failure shall occur if at least one input failure occurs

This work shall discuss only coherent fault trees containing only AND or OR cicles and primary event without their negations. Apart from this, the following three types of events shall be considered:

T – top event – in this case it is: failure of marketing communications

G_i , i=1,2.... – Intermediate events (*gates*) – events such as: failure of press advertising, failure of audio and audio- visual means of entertainment, risk of TV advertising or, in other words, failures of marketing communications instruments or failure of their elements which can be further broken down to activities.

P_n. – primary events – all activities which can't be broken down further, such as: Message placed in the less visible spot, Poor creative solution of the message, Choice of TV station not watched by a target group etc.

After defining events, we determine the logical connection among them. For each intermediate as well as top event, it is necessary to establish whether it occurs when occurs one of the primary events of which it consists (the logical circle OR) or when all of primary events occur (the logical circle AND). After this it is possible to form a fault tree.

Due to space limitations, the approach here shall be illustrated only on one of the instruments of marketing communications: advertising. Activities of this instrument, from the aspect of fault or failure can now be expressed in the following way:

1. Failure of advertising (G1) (occurs if occurs each of the failures: G11,G12,G13, or AND *gate)*
   1.1. Failure of press advertising (G11) (if occures at least one of the failures: P1,P2,P3, or. OR *gate)*
   - Press advertising not read by a target group (P1)
   - Message is placed in the less visible spot (P2)
   - Poor creative solution of the message (P3)

   1.2. Failure of means of outdoor advertising (G12) (P4,P5,P6,P7,P8, OR gate)
   - Placing the message on a less visible spot (P4)
   - Saturation of a certain location (P5)
   - Wrong location relative to a target group (P6)
   - Damaged outdoor advertising or changed outlook of the message (P7)
   - Poor creative solution of the message (P8)

   1.3 Failure of audio and audio-visual means of entertainment (G13) (G131, G132, AND gate)
   - Failure of TV advertising (G131) (P9,P10,P11,P12,P13, OR gate)
     - Choice of TV station not watched by a target group (P9)
     - Message not conceptualized in a manner to call attention (P10)
     - Unsuitable run times (P11)
     - Message does not contain the right kind of information (P12)
     - Poor creative solution of the message (P13)
   - Failure of radio advertising (G132) (P14,P15,P16,P17, OR gate)
     - Choice of radio station not listened to by a target group (P14)
     - Unsuitable run times (P15)
     - Message is too long and does not hold the attention (P16)
     - Poor creative solution of the message (P17)

The fault tree modeling defined activities and connections is shown in graph 1.

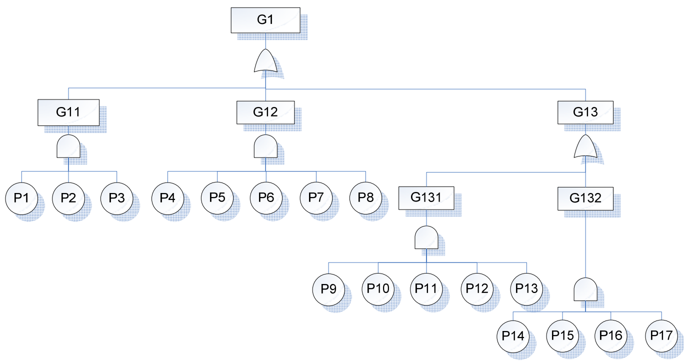


Figure 1 Advertising fault tree

Using Bull's equations for each logical circle we obtain:

G1=G11*G12*G13

G11=P1+P2+P3

G12=P4+P5+P6+P7+P8

G13=(P9+P10+P11+P12+P13)*
(P14+P15+P16+P17)

or:

G1=(P1+P2+P3)*(P4+P5+P6+P7+P8)*
(P9+P10+P11+P12+P13)*
(P14+P15+P16+P17)

We than apply commutative, associative and distributive law of the Bull's algebra in order to obtain a normal form of which each member represents a single minimum cut set or the combination of primary events leading to the failure of the whole system. Since this example invlolves 300 minimum clusters of averages each with four primary events, we shall present here only some of them.

P2*P6*P9*P15

P2*P6*P10*P15

P2*P6*P10*P16

P2*P6*P10*P17

P2*P6*P10*P14

P2*P5*P13*P17

P2*P5*P13*P16

P2*P5*P13*P15

P2*P5*P13*P14

If we singled out as minimal the cut P2*P6*P9*P15, and provided that events P2 (when a message is placed in the less visible spot), P6 (when a message, as the means of outdoor advertising, has poor creative solution), P9 (when a message is broadcasted on a TV station not watched by a traget group) and P15 (when a radio message is broadcasted at unsuitable times) occur at the same time, it would mean that this would lead to the top event failure or failure of marketing communications. This means that in the course of planning marketing communications activities to be implemented, it is necessary to pay attention to these activities. Minimum cut sets can indicate failures that have irrevocably occured and those that still can be influenced and prevented in order to avoid, in this case, the failure of advertising.

4. GENERATING MINIMUM CUT SETS

The first task of quantitative analysis, as mentioned in the previous section, is to obtain minimum cut sets. Using the following algorithm, we obtain minimum cut sets. We use Bull's equations for each logical circle.

T=G1*G2*G3*G4*G5*G6*G7*G8*G9

G1=G11*G12*G13

G11=P1+P2+P3

G12=P4+P5+P6+P7+P8

G13=G131*G132

G13= (P9+P10+P11+P12+P13)*
(P14+P15+P16+P17)

G1= (P1+P2+P3)*(P4+P5+P6+P7+P8)*
(P9+P10+P11+P12+P13)*
(P14+P15+P16+P17)

G2=P18+P19+P20+P21

G3=P22+P23+P24+P25
G4=G41*G42
G41=G411*G412*G413*G414*G415
G41=(P26+ P27)* P28 *P29 *(P30+P31)*P32
G42=G421*G422*G423*G424*G425
G42=(P33+P34+P35)*(P36+P37)*(P38*P39+P40)(P41+P42)*(
P43+P44)
G4=(P26+ P27)* P28 *P29
*(P30+P31)*P32*(P33+P34+P35)*(P36+P37)*
(P38+P39+P40)*(P41+P42)*(P43+P44)
G5=G51*G52*G53*G54*G55*G56
G5=(P45+P46+P47+P48)*(P49+P50+P51+P52)*(P53+P54+P5
5)*(P56+P57+P58+P59)*(P60+P61+P62)*(P63+P64+P65)
G6=P66+P67+P68+P69+P70
G7=P71+P72+P73+P74
G8=P75+P76+P77
G9=P78

T= (P1+P2+P3)* (P4+P5+P6+P7+P8)*
(P9+P10+P11+P12+P13)*(P14+P15+P16+P17)*
(P18+P19+P20+P21)*(P22+P23+P24+P25)*(P29+P30)*P26*P
27*(P31+P32)*P28*
(P33+P34+P35)*(P36+P37)*(P38+P39+P40)*(P41+P42)*(P43
+P44)*
(P45+P46+P47+P48+P49)*(P50+P51+P52+P53)*(P54+P55+P
56+P57)*
(P58+P59+P60)*(P61+P62+P63+P64)*(P65+P66+P67)*(P68+
P69+P70)* (P71+P72+P73+P74)*
(P75+P76+P77)*P78

It has been determined that this expression can not be calculated without the suitable software, in order to obtain adequate minimum cut sets. The software *Relax*, downloaded from *www.relex.com* was used in an attempt to simplify this expression. The available software version could not accept dimensions of this tree. A similar attempt was made with the software package *Math lab*, downloaded from the Internet site www.mathlab.com. However, just like with the previous software, this software also couldn't accept dimensions of this expression. The only solution was to divide the tree into parts and to calculate minimum cut sets for each separate part or instrument of marketing communications.

Upon calculating minimum cut set for each instrument separately, we obtained cuts with the same number of elements. This means that it is not possible to single out a cut whose occurrence would have the greatest probability of contributing to the failure of the whole system or, in our case, marketing communications on the whole.

Considering dimensions of the cut obtained, we shall present only the part related to the advertising risk (G1):

G1

p2*p6*p9*p15

p2*p6*p10*p15

p2*p6*p10*p16

p2*p6*p10*p17

p2*p6*p10*p14

p2*p5*p13*p17

p2*p5*p13*p16

p2*p5*p13*p15

p2*p5*p13*p14

If we singed out as minimal the cut p2*p6*p9*p15, (which, in this case, is not possible, since they are all of the same length) and provided that events p2 (when a message is placed in the less visible spot), p6 (when a message, as the means of outdoor advertising, has poor creative solution), p9 (when a message is broadcasted on a TV station not watched by a traget group) and p15 when a radio message is broadcasted at unsuitable times), occur at the same time, it would mean that this would lead to the top event failure of the failure of marketing communications. This means that in the course of planning marketing communications activities to be implemented, it is necessary to pay attention to these activities.

Considering that it is not possible to attain the final objective, which is determining the key activities leading to occurrence of the top event, the fault tree method is not suitable for application in planning of marketing communications instruments as separate and independent entities. Considering that this method has proven to be very successful in representation of various processes, the basis has been established for further analysis of conditions for precise determination of conditions for success or failure of marketing communications.

5. CONCLUSION

This work has described all instruments of marketing communications as well as related risks. It has been shown that the risk of success of marketing communications depends on the risk of its instruments and their individual activities. Further, it has been described how these risks can be analyzed by use of the fault tree method. In the course of analysis, we encountered the well known problem of combinatorial explosion in fault tree analysis. The reason for this, in this case, was the premises that marketing communications shall succeed if succeeds at least one of its instruments, or shall fail only if all of its instruments prove to be unsuccessful. However, in developed countries, there has been a clear tendency lately directed towards innovations in all business fields, named the integrated marketing communications. In the early stage of development of marketing concepts, elements of communication were treated as different and separate activities, while the contemporary marketing philosophy has been introducing the integration of elements as something of absolute, and sometimes crucial, importance for the success on the market. We feel that such connection among elements of marketing communications indicates the need for achieving their mutual synergy, which would also allow for the complete qualitative fault tree analysis. The entire approach could be broadened by introducing failure probabilities for individual activities of instruments of marketing communications.

References

Belch E.G., Belch A. M., „Advertising And Promotion – An Integrated Marketing Communications Perspective“, 6th edition, McGraw-Hill, New York, 2004.

Fidler R., “Mediamorphosis – razumevanje novih medija“, CLIO, Belgrade, 2004.

Fill C., „Marketing Communications – engagements, strategies and practise“, 4th edition, Prentice Hall, Harlow, 2005.

Katz H., „The media Handbook“, NTC Business Books, Illinois, USA, 1995.

Pickton D., Broderick A., „Integrated Marketing Communications“, Prentice Hall, Harlow, 2001.

Surmanek J., „Media Planning – A Practical Guide“, NTC Business Books, 1996

IMPROVING MEDIA PLANNING BY MODELING COMMERCIALS SCHEDULING IN SERBIA

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Abstract: This paper presents one flexible mathematical model for determining optimal scheduling of advertising messages (commercials) that are broadcasted on television. Nonlinear mathematical model maximizes target rating points (TRP), while keeping constraints on daily TRP, CPP, number of commercials and desired reach. This model encompasses specific characteristics of media and media buying process in transition countries.

Keywords: Advertising, Media, Scheduling, Mathematical model

1. INTRODUCTION

At the very beginning of the planned and organized marketing communication, planning and buying of media space and time was basic and often the only task of the marketing agencies. Not until recently was in the marketing practice in Serbia special significance and deserved attention given to this part of realization of the process of the marketing communication. Namely, advertisers were often wrong and they simplified the process - media planning was for them just an activity of the technical character, while special accent was put on the creative solution of the promotional message. The fact that in our country there are no specialized studies for the job title of the 'media planner', as well as the fact that in the domestic literature about marketing communication and advertising insignificant attention has been dedicated to it, contributes to this attitude.

In the contemporary conditions of business and development of media market, planning and buying of media space becomes incredibly complex activity. Among numerous factors that have influenced the change of media planning and the change of perception of its significance at the global level, the following can be singled out:

- Appearance and development of new types of media
- Fragmentation of media
- Advertising cost increase
- Saturation of the market by promotional messages
- Improvement of the existing and appearance of new media research methodologies
- Changes in the buyer's behavior – evolution of needs and the way of media consumption.

Global transition from centrally planned to market economy that started at the end of the past century in Serbia, had an influence on the media market also, that is on the business of media houses and marketing agencies, that are responsible for buying media space and time. Concerning the above mentioned, the model for media planning, suggested by the authors in this study, took into consideration every specific aspect of media planning characteristic for a business environment in a country in transition:

- Media environment of Serbia – number, type and characteristics of available media;
- Characteristics of the process of media planning – from the client's request, the way the negotiations with media house are realized and media plan making, to its implementation and evaluation;
- Available strategies for media planning concerning time schedule, characteristics of the target group and competition activity.

Taking into consideration real needs and problems that the media planners face in practice, this model refers to media planning process for national and local television in Serbia. In the following part of the study, basic variables and constraints that are part of the model are described.

2. PROBLEM DESCRIPTION AND MATHEMATICAL MODEL OF MEDIA PLAN OPTIMIZATION

Model is used to optimize schedule of broadcasted commercials (TV ads) made for a known buyer – advertiser for different terms of TV stations. The criterion of optimization is evaluation of the achieved TRP based on the previous periods. Entry data can be obtained from the data base of the agencies specialized in media monitoring. Optimization is done for every TV station individually, while total budget is defined in advance.

Since the programme plans are defined weekly, optimization is done for the given number of weeks.

s – number of weeks for which media plan is made, t=1,...,s,
J_t – number of days in a week,
$J_t = J_1 \cup J_2$, J_1=(1,2,3,4,5) – work days, J_2=(6,7) – Saturday and Sunday, $j \in J$

Programs (TV programs, news, series, movies ecc.) represent terms for broadcasting a commercial. An assumption is made that the programme plan is relatively constant and that the number of terms for commercial broadcasting is the same every working day and every Saturday and Sunday. For that reason, it is allowed for different programs that are broadcasted in two different days but at the same time, to have the same index.

N – set of all programs broadcasted in the planned period,
N_j – set of programs broadcasted on every day j,

$$i \in N_j, \ \underset{\substack{t=1 \\ j \in J_t}}{\overset{s}{\cup}} N_j = N .$$

Television stations in Serbia introduced different coefficients for price correction of a broadcasted commercial, depending on the position in the advertising block. Practice has shown that the greatest rating of the advertising block is at the very beginning, because the viewers still do not change the channel and do not go away from TV sets, as well as at the end of the advertising block, when the viewers 'go back' to the channel that broadcasts the show they have been watching and wait for it to continue. In that sense, the price of broadcasting is the highest in case of buying first or the last position, followed by the second or penultimate, etc.

L – set of positions of commercials in a block, $l \in L, L = \{1,2,3...\}$, where 1 marks first or ultimate positin, 2 – second or penultimate, etc.

2.1. Variables

In the suggested model, the problem is narrowed down to the two most frequent cases:

- Term and frequency planning of broadcasting of commercial in duration of 30 sec.
- Term and frequency planning of broadcasting of commercial shorter than 30 sec.

Even though the price lists of the domestic TV stations show different coefficients for more than one option of shorter commercial (for example, 10, 15, 20 and 25 sec.), in practice there is usually only one shorter version of the same commercial. This is the reason why the commercial is divided into two variables in the model:

$$x_{tjil} = \begin{cases} 1 & \text{if 30 sec long commercial is broadcasted on the j-day of the k- week in the i-show on the l-position in the block} \\ 0 & \text{otherwise} \end{cases}$$

$$y_{tjil} = \begin{cases} 1 & \text{if a commercial shorter than 30 sec is broadcasted on the j-day of the k- week in the i-show on the l-position in the block} \\ 0 & \text{otherwise} \end{cases}$$

2.2. Objective function

Since the data on the target group rating of some programs and commercial breaks (TRP) are available to the media planners in Serbia, that TRP is used as parameter in the model, i.e. the percentage of the target audience that watch TV show at the moment of observation.

trp_{tji} - TRP of the show i on the day j of the week t,

$$\max f(x,y) = \sum_{t=1}^{s} \sum_{j \in J_t} \sum_{i \in N_j} trp_{tji} \sum_{l \in L} (x_{tjil} + y_{tjil}) \quad (1)$$

Objective function is total achieved TRP which we want to maximize.

2.3. Constraint for planned budget of advertising

In order to do a precise evaluation of an alternative, it is necessary to compare relative and absolute costs of advertising on certain type of media. Absolute costs represent concrete amount of money needed for buying certain media space or time for announcing an advertisement. Relative costs, on the other hand, show ratio between money invested into buying media and volume of the audience that will be exposed to the advertising message thanks to that broadcasting. It is obvious that intermedia and intramedia cost analysis can be done based only on the relitive costs, while absolute costs have an influence on the final decision about the way and amount of buying media space and time (Katz, 1995).

That is the reason why NET is observed as an absolute cost of advertising.

NET – total cost of media buying upon which an agency and a client have agreed

cpp - one rating point price.

Rating price in practice of the Serbian TV stations is adjusted by the coefficients whose value depends on the period of the day, position of the commercial in the block and the duration of commercial.

D – set of time periods during the day, $d \in D, D = \{1,2,3...\}$. *It is now possible to group the programs that are broadcasted during one day as follows:*

N_{jd} *– set of programs broadcasted on the j day in the period d,.*

k_d *- Coefficient for the time of the day,* $d \in D$.

k_l *- Coefficient for the position of the commercial in the block,* $l \in L$.

k_k *- Coefficient for the shorter duration of time of the commercial.*

Budget constraint is presented with the formula (2).

$$\sum_{t=1}^{s}\sum_{j\in J_t}\sum_{d\in D}\sum_{i\in N_{jd}} trp_{tji} cpp k_d \sum_{l\in L} k_l x_{tjil} +$$

$$\cdot k_k \sum_{t=1}^{s}\sum_{j\in J_t}\sum_{d\in D}\sum_{i\in N_{jd}} trp_{tji} cpp k_d \sum_{l\in L} k_l y_{tjil} \le NET \quad (2)$$

2.4. Constraint for prime time and non-prime time

Media planner also has to make a decision on the number of commercials that will be broadcasted during one day on a certain TV station, also. On that occasion an agreement is made with the TV station about the wanted ratio of the commercials that will be broadcasted in *prime time* and the commercials that will be broadcasted in *non-prime time*.

It has already been mentioned that *D* is a set of time periods during the day. These time periods are part of the greater time ensemble during the day: *prime time* and *non-prime time*, where follows that $D = D_p \cup D_{np}$ at the same time, where D_p is *prime time* and D_{np} is *non-prime time*. Division of time periods into these two ensembles is different for every TV station.

Programs can now be divided to:

N_{jD_p} - set of programs that on the day *j* are broadcasted in *prime time* and

$N_{jD_{np}}$ - set of programs that on the day *j* are broadcasted in *non-prime time*.

$N_{jD_p} \cup N_{jD_{np}} = N_j$

p - number of commercials in *prime time*

np – number of commercials in *non-prime time*.

Parameters *p and np* are defined as wanted percentage divided by one hundred, therefore *p*+*np*=1.

Constraint for the number of commercials in *prime time* on the day *j*:

$$\sum_{i\in N_{jD_p}}\sum_{l\in L}(x_{tjil}+y_{tjil}) - p\cdot\sum_{i\in N_j}\sum_{l\in L}(x_{tjil}+y_{tjil}) \ge 0,$$

$$j \in J_t,\ t = 1,\dots,s \qquad (3)$$

This constraint is formed as follows:

$\sum_{i\in N_{jD_p}}\sum_{l\in L}(x_{tjil}+y_{tjil})$ total number of commercials broadcasted in *prime time* on the day *j*

$\sum_{i\in N_j}\sum_{l\in L}(x_{tjil}+y_{tjil})$ total number of commercials broadcasted on the day *j*

Ratio of these two numbers should be *p*, that is:

$$\frac{\sum_{i\in N_{jD_p}}\sum_{l\in L}(x_{tjil}+y_{tjil})}{\sum_{i\in N_j}\sum_{l\in L}(x_{tjil}+y_{tjil})} \ge p \Rightarrow$$

$$\sum_{i\in N_{jD_p}}\sum_{l\in L}(x_{tjil}+y_{tjil}) \ge p\cdot\sum_{i\in N_j}\sum_{l\in L}(x_{tjil}+y_{tjil}) \Rightarrow (3)$$

Constraint for the number of commercials in *non-prime* time on the day *j*:

$$\sum_{i \in N_{jD_{np}}} \sum_{l \in L} (x_{tjil} + y_{tjil}) - np \cdot \sum_{i \in N_j} \sum_{l \in L} (x_{tjil} + y_{tjil}) \le 0,$$

$$j \in J_t,\ t = 1,\ldots,s \quad (3')$$

This constraint is formed in analogy to the prevous case.

Since: $N_{jD_p} \cup N_{jD_{np}} = N_j$ and *p+np=1,* constraint (3') is automatically met with meeting of the constraint (3). Because of that, this constraint can be excluded from the model.

2.5. Constraint for the daily TRP

Balance of the TRP per day is met by the following constraint:

$$ddr_j \le \sum_{i \in N_j} trp_{tji} \sum_{l \in L} (x_{tjil} + y_{tjil}) \le gdr_j,$$

$$j \in J_t,\ t = 1,\ldots,s \quad (4)$$

Where: ddr_j, gdr_j - are bottom and upper bound of the TRP on the day *j*, $j \in J_t, t = 1,\ldots s$.

2.6. Constraint for the daily number of commercials

Balance of the number of commercials per days is met by the following constraint:

$$dbs_j \le \sum_{i \in N_j} \sum_{l \in L} (x_{tjil} + y_{tjil}) \le gbs_j,\ j \in J_t,\ t = 1,\ldots,s \quad (5)$$

Where: dbs_j, gbs_j - are bottom and upper limit of the total number of commercials on the day *j*.

2.7. Constraints for the reach

Reach is expressed as a percentage of population which is at least once exposed to a certain programme during the observed time. So, as a measure of accumulation of auditorium, reach is the number of different individuals (or households) that are exposed to the given media (Surmanek, 1996). In Europe reach is also called 'opportunity to see' (OTS). In the electronic media reach is most often calculated for the period of four weeks.

Precise data on the accomplished reach can be gathered only after the broadcast of commercials. However, experienced media planners achieve higher reach by limitating the number of broadcasts of commercials in the same types of programs (episodes of the same serie, daily news in the same term).

In the set of all programs broadcasted in the planned period *N*, programs that are broadcasted every day, every work day and every Saturday or every Sunday are distinguished. That means that in the set *N* four disjunktive subsets can be distinguished:

N_{J_1} - set of programs broadcasted every day in the same term, $i \in N_{J_1}$

N_{J_2} - set of programs broadcasted every work day in the same term, $i \in N_{J_2}$

N_{J_3} - set of programs broadcasted every Saturday in the same term, $i \in N_{J_3}$

N_{J_4} - set of programs broadcasted every Sunday in the same term, $i \in N_{J_4}$

Where is: $N_{J_1} \cup N_{J2} \cup N_{J_3} \cup N_{J_4} \subset N$

a_1, a_2, a_3, a_4 – parameters which represent total number of broadcasting of commercials in the planned period in the programs (terms) from the sets: N_{J_1}, N_{J_2}, N_{J_3} and N_{J_4}.

There are two possible variants of constraints that depende on whether the 30sec long and shorter commercial can or can not be broadcasted in the same term.

If the same commercials of the different length can not be broadcasted in the same period, constraints are:

$$\begin{aligned}
&\sum_{t=1}^{s} \sum_{j \in J_t} \sum_{l \in L} (x_{tjil} + y_{tjil}) \le a_1,\ i \in N_{J_1} \\
&\sum_{t=1}^{s} \sum_{j \in J_t} \sum_{l \in L} (x_{tjil} + y_{tjil}) \le a_2,\ i \in N_{J_2} \\
&\sum_{t=1}^{s} \sum_{j \in J_t} \sum_{l \in L} (x_{tjil} + y_{tjil}) \le a_3,\ i \in N_{J_3} \\
&\sum_{t=1}^{s} \sum_{j \in J_t} \sum_{l \in L} (x_{tjil} + y_{tjil}) \le a_4,\ i \in N_{J_4}
\end{aligned} \quad (6)$$

If the same commercials of the different length can be broadcasted in the same term, constraints are:

$$\begin{aligned}
&\sum_{t=1}^{s}\sum_{j\in J_t}\sum_{l\in L}x_{tjil}\le a_1,\ \sum_{t=1}^{s}\sum_{j\in J_t}\sum_{l\in L}y_{tjil}\le a_1,\ i\in N_{J_1}\\
&\sum_{t=1}^{s}\sum_{j\in J_t}\sum_{l\in L}x_{tjil}\le a_2,\ \sum_{t=1}^{s}\sum_{j\in J_t}\sum_{l\in L}y_{tjil}\le a_2,\ i\in N_{J_2}\\
&\sum_{t=1}^{s}\sum_{j\in J_t}\sum_{l\in L}x_{tjil}\le a_3,\ \sum_{t=1}^{s}\sum_{j\in J_t}\sum_{l\in L}y_{tjil}\le a_3,\ i\in N_{J_3}\\
&\sum_{t=1}^{s}\sum_{j\in J_t}\sum_{l\in L}x_{tjil}\le a_4,\ \sum_{t=1}^{s}\sum_{j\in J_t}\sum_{l\in L}y_{tjil}\le a_4,\ i\in N_{J_4}
\end{aligned}\qquad (6')$$

When alocating commercials on different programs and weeks, media planner himself defines:

- how many 30 sec long commercials and how many shorter versions of the same commercial will be broadcasted in the observed period;
- in what week the broadcasting of the shorter version will start;
- whether both versions can be broadcasted in the same advertising block.

In practice, at the beginning of the campaign the whole version of 30 sec is usually broadcasted, and after one or two weeks, when it is evaluated that the great part of auditorium has seen the whole commercial, broadcasting of the shorter version starts. If planner has higher budget on the disposal and if the strategy of the so called 'concentrated advertising' concerning the time period is carried, it is possible to decide that both versions, shorter and longer, should be broadcasted.

2.8. Additional constraints

Constraint for ratio of longer and shorter commercials is:

b – minimal requested participation of 30sec long commercials in the total number of commercials

$$(1-b)\sum_{t=1}^{s}\sum_{j\in J_t}\sum_{i\in N_j}\sum_{l\in L}x_{tjil}-b\sum_{t=1}^{s}\sum_{j\in J_t}\sum_{i\in N_j}\sum_{l\in L}y_{tjil}\ge 0 \quad (7)$$

Constraint for non-broadcasting of shorter commercials during certain number of weeks is:

$$\sum_{j\in J_t}\sum_{i\in N_j}\sum_{l\in L}y_{tjil}=0,\ t=1$$

Constraint for broadcasting 30 sec long and shorter commercial in the same program is:

If media planner decides to broadcast longer and shorter version of the commercial in the same advertizing block, following constraints are introduced:

$$\sum_{l\in L}(x_{tjil}+y_{tjil})\le 1,\ i\in N_j,\ j\in J_t,\ t=1,\dots,s$$

3. CONCLUSION

In this paper the authors presented one flexible mathematical model for optimal scheduling of commercials on TV stations, considering the specific characteristics of media environment in a transition country. Since the process of media planning and buying has become one of the key factors of advertising campaign efficiency, scheduling of commercials cannot be left to the intuitive and subjective estimation of media planners. The model suggested in this paper has taken into consideration all the constraints such as prime time and non-prime time ads ratio, balance of the daily TRP, daily number of broadcasted commercials, reach and other, in order to maximize total TRP achived during one advertising campaign.

References

Belch E.G., Belch A. M., „Advertising And Promotion – An Integrated Marketing Communications Perspective“, 6th edition, McGraw-Hill, New York, 2004.

Fidler R., “Mediamorphosis – razumevanje novih medija“, CLIO, Belgrade, 2004.

Fill C., „Marketing Communications – engagements, strategies and practise“, 4th edition, Prentice Hall, Harlow, 2005.

Katz H., „The media Handbook“, NTC Business Books, Illinois, USA, 1995.

Pickton D., Broderick A., „Integrated Marketing Communications“, Prentice Hall, Harlow, 2001.

Surmanek J., „Media Planning – A Practical Guide“, NTC Business Books, 1996.

PRODUCTION SYSTEMS DESIGN – A PRODUCT ORIENTED APPROACH AND METHODOLOGY

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Abstract: Production systems design is critical to achieving manufacturing performance and objectives. Although generic approaches to this design are available they may not be able to objectively address specific manufacturing configurations. Here it is argued that product oriented manufacturing (POM) organization offers advantages in relation to the function oriented one. Based on this, a methodology specially addressing POM systems design, and prototype of a Computer Aided Design System based on the methodology were develop. A brief description of both is presented.

Keywords: manufacturing_systems, design, methodology, reconfiguration

INTRODUCTION

In the present global economy, due to competition, companies are compelled to deal with an ever increasing product demand variety.

Function Oriented Manufacturing (FOM) Systems – FOMS - have been adopted in industry for many years due to their apparent ability and flexibility for dealing with large variety of products in small quantities. However, FOMS do not perform well. They are unable to achieve good use of resources and quickly respond to customer demands, two requirements for companies' sustainability and competition ability in the global market of today. There are two important reasons for this. The first is the lack of manufacturing focus on the products. The other is the highly intermittent nature of the flow of materials during manufacturing cycle. The first reason has a severe impact on utilization of manufacturing means and facilities and the second highly hinders the manufacturing systems ability for quickly responding to changes in demand.

Due to these reasons, manufacturing systems organization focused on manufacturing requirements of products, not on manufacturing functions, is a good concept to explore as a means for overcoming the problems associated with FOMS. Here, such a concept is referred as Product Oriented Manufacturing - POM. Under POM systems a close relationship between manufacturing requirements of products and manufacturing system organization is established.

Well known advantages of product focused manufacturing systems are their better and more efficient use of manufacturing resources, speed of production and ability to deliver products faster and of comparatively higher quality than FOMS. This is mainly due to their configuration for dealing with specific manufacturing requirements of each product or family of similar products. Moreover, POM organization provides a much better environment to respond to demand changes. This is because, a clearer view of each product and related manufacturing process is offered with this organization. Due to this, when demand changes the system provides a much better understanding of what accordingly has to be changed in manufacturing. Therefore POM constitutes a better environment for quickly respond to product demand changes.

The suitability of manufacturing systems for high product variety environments is linked to the quickness how they can be adapted to manufacture different products. This, essentially means, quick system reset-up or reconfiguration.

This paper is focused on manufacturing system reconfiguration, presenting in section 2 the POM system – POMS concept. Section 3 presents a summarized view of the Generic-Conceptual-Detailed (GCD) methodology for POMS design or reconfiguration, developed by the author, and in section 4, a Computer Aided Design System for POMS design - CADS_POMS - is briefly described. The final section presents some concluding remarks.

PRODUCT ORIENTED MANUFACTURING SYSTEMS - POMS

POMS Concept

A Product Oriented Manufacturing System – POMS, is defined as a set of interconnected manufacturing resources and/or cells that in a coordinated and synchronized manner address the manufacture of a particular product or a range of similar products, including the necessary assembly work. Fig. 1 schematically illustrates the concept.

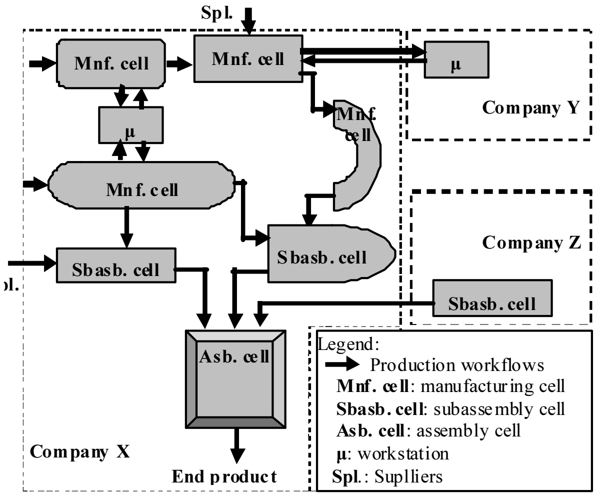

Fig. 1. A schematic representation of a POM System

In POMS a product may be simple, like a part, or complex, having a product structure with several levels. When the product is simple, POMS may simply take a form of a cell. For complex products several cells and or resources may be required. The coordination of work between manufacturing resources or cells is an essential requirement of POMS.

Requirements of POMS and design strategies

The resources available for POMS may exist distributed in space and may be either put together in a localized site or, alternatively, organized into virtual POMS. To be successful, production under this concept must be able to fully and dynamically consider and involve resources that are locally or globally available to a company, over a time period, either belonging to its own or to manufacturing service providers. Therefore, not only internal resources to a company, but also, external ones should be considered in the POMS reconfiguration process. The approach to virtual configuration of manufacturing systems was initially introduced by McLean, Bloom and Hopp [1], and studied by several authors afterwards such as McLean and Brown [2], Drolet et al. [3], Ratchev [4], Ko and Egbelu [5] and Slomp et al. [6] Today, POMS can benefit from intranet and internet based technologies, a prerequisite for the widely discussed Virtual Enterprise concept [7][8].

At local scale, a POMS can be seen as a network of balanced manufacturing resources and cells. This balancing must explores alternatives of manufacturing associated with process plans of products [9], manufacturing flexibility of machines and enlarged skills of operators, which are also requirements of POMS.

One underlying requirement in today's market is the need for frequent adaptation of manufacturing systems to changing manufacturing requirements due to product demand changes. This, together with the dedicated nature of POMS to specific products, means that, for ensuring high levels of system operational performance, POMS need frequent reconfiguration. To achieve this it is important to draw upon design strategies such as modular production system design [10][11][12][13], modular production [14] and standardization of equipment and operating procedures.

The POM concept lends itself to large quantities and small variety product environments, as well as to repetitive production [15]. Nevertheless it can also be seen as a viable concept to the "Make to Order" (MTO) and even "Engineering to Order" (ETO) environments. This viability can be ensured by exploring strategies, techniques and tools associated with Lean Manufacturing (LM) [16], Agile Manufacturing (AM) [17] and Quick Response Manufacturing (QRM) [18]. Both LM and QRM favour production systems organization in multifunction autonomous units or cells working under integrated coordination for achieving production objectives. AM emphasizes the importance of rapidly changing system configuration to matching processing requirements from product demand changes. AM is also highly dependent on modular production [14], which has been considered essential to product customization [19]. Product Oriented Manufacturing - POM can also be associated with concepts such as focused factory, advanced by Skinner [20], and systems OPIM (One-Product-Integrated-Manufacturing) put forward by Putnik and Silva [21].

Reasons for adopting POMS

Traditionally a Cellular Manufacturing System (CMS) has been identified as a system dedicated to the manufacture of a family of identical parts. A more comprehensive definition of a manufacturing cell refers to a manufacturing system that groups and organizes the manufacturing resources, such as people, machines, tools, buffers, and handling devices, for the manufacture of a part family or the assembly of a family of products with identical or similar manufacturing requirements. This has its origins in the Group Technology concept [22][23].

CMS rarely have been designed having into consideration the need for coordinating and synchronizing production, from raw materials to complete assembly of specific customer orders. The strategy has been to decouple production and relying on inventories at different production stages, from parts manufacturing to full assembly, based either on a MRP aggregation of part needs or on some repetitive schemes of part replenishment inventories.

Thus, the need for quick response to customer orders, which has been recognized as an important strategic objective under the present market competition paradigm, is not frequently taken explicitly and appropriately into full account when designing manufacturing and production control systems. However, there have been movements towards POM direction with proposals of systems design and management approaches focussing on coordinated manufacturing of parts and assemblies towards efficient production and delivery of customer orders. Examples are what Black [24] refers as Linked-Cell Manufacturing System and also the Quick Response Manufacturing concept referred by Suri [18].

Thus, to effectively respond to the market demand challenges of today, CMS must evolve to Product Oriented Manufacturing System - POMS, frequently reconfigured for fitting and efficiently respond to product demand changes.

This approach is radically different from Function Oriented Manufacturing System – FOMS - organization, supposedly adequate for dealing with demand changes and large product variety without needing reconfiguration. However, as it was already argued in section 1, this is not the case.

DESIGN METHODOLOGY FOR POMS

In general, designing systems is a complex task that involves much data and information and requires a variety of methods and tools. Therefore, it is advantageous to have a methodology that guides the designer through design steps showing the required data and methods to use in order to reach design solutions.

This design approach was tried in an industrial case of apparent simplicity in the apparel industry [25]. Difficulties encountered clearly showed the need for a laborious and iterative process of analysis and synthesis to reach an acceptable POMS configuration. This experience was important for developing the GCD methodology [26][27].

Generic-Conceptual-Detailed (GCD) Design Methodology

The GCD methodology addresses the POMS design in three dimensions, namely, the Generic (G), the Conceptual (C) and the Detailed (D) one, corresponding to the three sequential and iterative phases of the methodology.

At the G Design one generic manufacturing system configuration is chosen. A decision has to be made for a FOMS, a POMS or a hybrid POMS. The hybrid POMS usually considers FOM of parts and POM of assemblies and, possibly, of parts as well. The Generic Design is carried out through three interrelated design activities, namely Strategic Production Planning (A11), Analysis of Company and Market Manufacturing Situation (A12) and Generic Manufacturing System Selection (A13). The choices are determined by several factors relevant to the company manufacturing strategy. Particularly relevant are production requirements derived from forecasted demand, available resources and services, and company present manufacturing position and situation. Product variety and volumes of production are also important in the G design phase.

The main and fundamental purpose of Conceptual design is selecting conceptual cell configurations. Conceptual cells are classes of cells, based on the complexity of materials flow, which need to be instantiated with basis on product and process specific information. Additionally, a first approximation to product and part families based on both forecasted and settled customer orders and process plans must be made. Also important at this phase is to specify the nature of workstations and operators. Based on such purposes two main activities must be carried out, namely, Conceptual Cell Configurations Selection (A21) and Workstation Selection (A22). The conceptual cells that can be chosen are the basic ones, i.e. autonomous and independent cells configuring lines, job-shops and single workstations, and their shared cell counterparts, called non-basic [28].

At the Detailed design, instantiation of conceptual cells is done having in consideration customer orders for products. The results are cells which are the building blocks of the POMS to establish. Additionally coordinated control of work among cells for POM is devised. The D design activities have been described in Carmo-Silva and Alves [29] and are: Formation of Families of Products (A31), Instantiation of the Conceptual Cells (A32), Instantiation of Workstations (A33), Intracellular Organization and Control (A34) and POM System Organization and Intercellular workflow Coordination and Control (A35). For carrying these out, a range of methods and tools needs to be used. Important ones deal with the technical and economical evaluation of alternative solutions.

Design frequency and design agents

Design of POM systems is a dynamic activity at all levels. The frequency of design depends on system and resources state and, naturally on product demand and mix changes.

Generic design is clearly carried out infrequently and only when major changes on technology and processes of manufacture and, also, on demand, take place.

Detailed Design is an on going design activity necessary for fitting the system to short term variations of demand or capacity. System reconfiguration, at detailed design level, may have to be carried out every time production requirements changes due to change in product mix to be released. Some D design tasks may have an impact only on operation and production control others may show the need for manufacturing system changes.

Conceptual design needs to be done before detailed design can go ahead. It takes place when substantial changes in product demand and mix occurs, or changes in production process or capacity take place. This is likely to call for a re-evaluation of the conceptual cells to use. This can have an impact on the configuration cells to build.

In the design process several decisions at strategic, tactical and operational levels, are made and used successively and iteratively at each design phase. This design process involves different design agents. In particular, three classes of design agents are identified, namely consulting team, company design team and production control teams. Fig. 2 presents an overview of the design methodology showing design activities and relating them with design frequency, time horizon, flows of information and decisions and design agents involved in the design process.

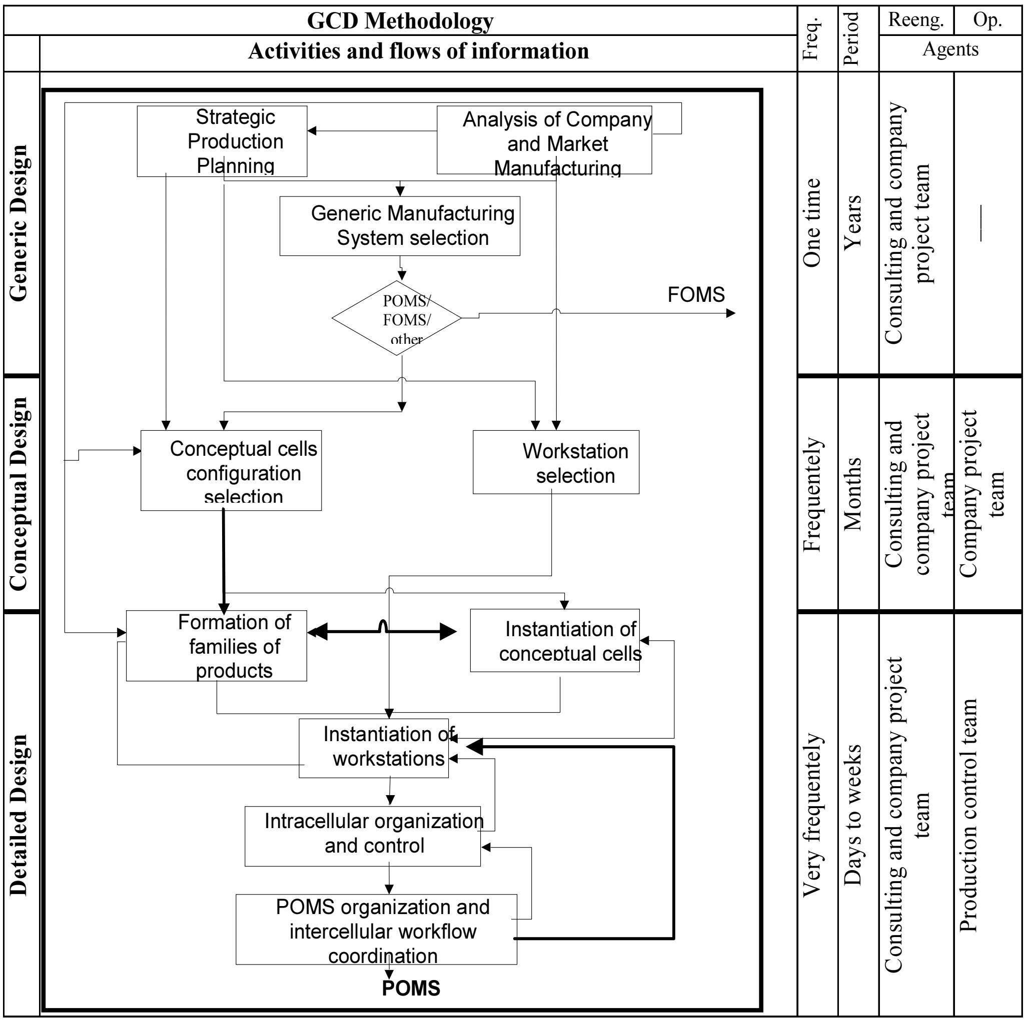

Fig. 2. Overview of the GCD design methodology for POMS and implications

COMPUTER AIDED DESIGN SYSTEM FOR POMS (CADS_POMS)

To be able to quickly attain good POMS designs and fast reconfiguration, computer aided design systems directly addressing POMS design should be used. Reported computer aided design systems – CADS - for manufacturing systems design tend to be restrictive, and not focussed on a particular manufacturing concept. They implement general approaches or methodologies addressing manufacturing systems design in general [30][31] without any focus on a particular concept such as POMS. Another approach addresses particular design aspects of manufacturing system, like the works reported by Luong et al. [32] and Manzini et al. [33] or using libraries of available methods [34][35].

Here a Computer Aided Design System for Product Oriented Manufacturing System - CADS_POMS - developed around the GCD methodology, presented in Carmo-Silva et al. [9][36], is shortly described.

The Microsoft SQL relational database was used. The main fundamental elements of the CADS_POMS system is a database, a user interface and knowledge base that holds design methods for system design and for evaluation at several design stages. The system design capability is both highly dependent on user interaction and on the availability of design methods.

The critical set of data used by CADS_POMS is shown in fig. 3.

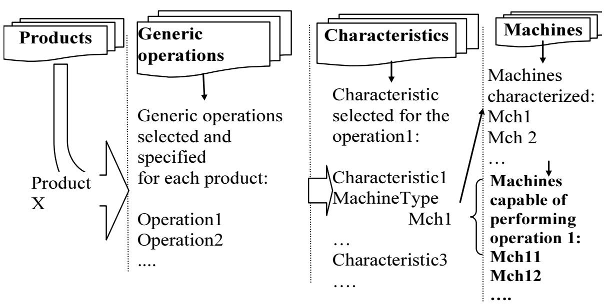

Fig. 3. Fundamental data sets for POMS design

For each product a process needs to be specified based on generic manufacturing operations. Each operation has a number of characteristics or attributes whose values are different according product manufacturing requirements. The attribute values are important for selecting manufacturing resources, namely workstation or machines. For this selection a matching procedure between machine and operation characteristics is implemented. This is an essential step for machine selection and ultimately to build the POMS to manufacture a given product or a family of products.

CONCLUDING REMARKS

Designing POM systems is a complex task requiring a methodology for framing the steps that should be followed in the design process and, at the same time, showing constraints, data, tools and methods that should be considered or used at each step. The GCD methodology, summarily described in this paper, addressing the POMS design interrelated functions, is a contribution to this.

The complexity and iterative nature of the design process points to the need for a computer aided tool to carry it out. This led the authors to specify and develop a prototype of such a computer aided system for POMS design, called CADS_POMS, briefly described in this paper and based on the reported GCD methodology.

References

[1] McLean CR, Bloom HM, Hopp TH. The Virtual Manufacturing Cell. Proceedings of the 4th IFAC/IFIP Conference on Information Control Problems in Manufacturing Technology, USA. 1982:105-111.

[2] McLean CR, Brown PF. The Automated Manufacturing Research Facility at the National Bureau of Standards. H. Yoshikawa & J. L. Burbidge, New Technologies for Production Management systems, North – Holland: Elsevier Science Publishers B. V., 1987.

[3] Drolet JR, Montreuil B, Moodie CL. Empirical Investigation of Virtual Cellular Manufacturing System. Symposium of Industrial Engineering - SIE'96, 1996.

[4] Ratchev SM. *Concurrent process and facility prototyping for formation of virtual manufacturing cells*. Integrated Manufacturing Systems, 2001; 12: 4, 306-315.

[5] Ko K-C, Egbelu PJ. *Virtual cell formation*. International Journal of Production Research, 2003: 41:11:2365–2389.

[6] Slomp J, Chowdary BV, Suresh NC. *Design of virtual manufacturing cells: a mathematical programming approach,* Robotics and Computer-Integrated Manufacturing, 2005:21:273–288.

[7] Camarinha-Matos LM, Afsarmanesh H. The Virtual Enterprise Concept. In Working Conference on Infraestructures for Virtual Enterprises (PRO-VE'99), L. M. Camarinha-Matos and H. Afsarmanesh, ed., Kluwer Academic Publishers, 1999.

[8] Putnik G., Cunha MM. (2005) "Virtual Enterprise Integration: Technological and Organizational Perspectives", Eds., Idea Group Publishing

[9] Carmo-Silva S, Alves AC, Costa M. A Computer Aided Design System for Product Oriented Manufacturing Systems Reconfiguration. Intelligent

Production Machines and Systems (Proceedings of the 1st I*PROMS Virtual International Conference), D. T. Pham, E. E. Eldukhri, A. J. Soroka Eds., Amsterdam, Elsevier, 2005: 417-422.
[10] Kleiner M. *Modular system permits optimal turning machines*. European Production Engineering, 1993:17:3.
[11] Rogers GG, Botacci L. *Modular production systems: a new manufacturing paradigm*. Journal of Intelligent Manufacturing, 1997:8:147-156.
[12] Koren Y, Heisel U, Jovane F, Moriwaki T, Pritschow G, Ulsoy G., Van Brussel H. Reconfigurable Manufacturing Systems. Annals of the CIRP, 1999:48:2:527-540.
[13] Mehrabi MG, Ulsoy AG, Koren Y. *Reconfigurable Manufacturing Systems: key to future manufacturing*. Journal of Intelligent Manufacturing, 2000:11:403-419.
[14] Starr, MK. *Modular production – a new concept*. Harvard Business Review, 1965: 43:6, p. 131-142.
[15] Carmo-Silva S, Alves AC, Moreira F. Linking production paradigms and organizational approaches to production systems. In Intelligent Production Machines and Systems (Proceedings of the 2st I*PROMS Virtual International Conference), Eds. D. T. Pham, E. E. Eldukhri e A. J. Soroka, Amsterdam, Elsevier, 2006.
[16] Womack J, Jones DT, Roos D. The machine that changes the world. Rawson Associates, 1990.
[17] Kidd PT. Agile Manufacturing forging new frontier. 1994.
[18] Suri R. Quick Response Manufacturing – A Companywide Approach to Reducing Lead Times. Oregon: Productivity Press, 1998.
[19] Duray R, Ward PT, Milligan GW, Berry WL. *Approaches to Mass Customization: Configurations and empirical validations*. Journal of Operations Management, 2000:18:6: p. 605-625.
[20] Skinner, W. *The focused factory*. Harvard Business Review, 1974.
[21] Putnik GD, Silva SC. One Product Integrated Manufacturing. In: Balanced Automation Systems, L. M. Camarinha-Matos, H. Afsarmanesh, eds. Chapman & Hall, 1995.
[22] Gallagher CC, Knight WA. Group Technology. Butterworths, 1973.
[23] Burbidge JL. Production Flow Analysis for planning Group Technology. Clarendon Press, 1989.
[24] Black JT. The Design of the Factory with a Future. McGraw-Hill, 1991.
[25] Silva SC, Alves AC. An Industrial application study of the GCD design methodology for Product Oriented Manufacturing. Proceedings of the Group Technology/Cellular Manufacturing, Eds. D. Sormaz and G. A. Suer, World Symposium 2003, Columbus, Ohio, USA, 2003:65-70.
[26] Silva, S, Alves AC. Design of Product Oriented Manufacturing Systems. In Knowledge and Technology Integration in Production and Services, V. Marik, L Camarinha-Matos and H Afsarmanesh, Eds. Kluwer Academic Publishers, 2002: 359-366.
[27] Alves AC. Projecto Dinâmico de Sistemas de Produção Orientados ao Produto. PhD Thesis. Departamento de Produção e Sistemas, Escola de Engenharia, Universidade do Minho, 2007. *(in portuguese)*
[28] Silva SC, Alves AC. A framework for understanding Cellular Manufacturing Systems. In e-Manufacturing: Business Paradigms and Supporting Technologies, Ed. J. J. Pinto Ferreira, Springer, 2004:163-172.
[29] Carmo-Silva S, Alves AC. Detailed design of product oriented manufacturing systems. Proceedings of Group Technology / Cellular Manufacturing 3rd International conference – 2006, J. Riezebos and Ir. J. Slomp Eds., University of Groningem, Holland. 2006: 44, 260-269.
[30] Cochran DS, Arinez JF, Duda JW, Linck J. *A decomposition approach for manufacturing system design*. Journal of Manufacturing Systems, 2001:20:371-389.
[31] Suh NP, Cochran DS and Lima PC. Manufacturing Systems Design. Annals of the CIRP 47 (1998).
[32] Luong L, He J, Abhary K, Qiu L. *A decision support system for cellular manufacturing system design*. Computers and Industrial Engineering, 2002.
[33] Manzini R., Gamberi M., Regattieri A., Persona A. *Framework for designing a flexible cellular manufacturing system*. International Journal of Production Research, 2004, 42:17, p. 3505-3528
[34] Mahadevan B, Srinivasan G. Software for manufacturing cell formation: issues and experiences. In: Proceedings of the Group Technology/Cellular Manufacturing Columbus, Ohio, 2003, p. 49-54.
[35] Irani SA, Zhang H, Zhou J, Huang H, Udai TK and Subramanian S. *Production Flow Analysis and Simplification Toolkit (PFAST).* International Journal of Production Research, 2000:38:8:1855-1874.
[36] Carmo-Silva S, Alves AC, Novais P, Costa M, Carvalho C, Costa J. e Marques, M. Distributed Design of Product Oriented Manufacturing Systems. In: Establishing The Foundation Of Collaborative Networks, Springer Boston, 2007, p. 596-600.

A DECENTRALIZED PREDICTIVE MAINTENANCE SYSTEM BASED ON DATA MINING CONCEPTS

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Keywords: Management, maintenance, data_mining, e-collaboration_protocols, reference_architectures

INTRODUCTION

In the last years we have assisted to several and deep changes in industrial manufacturing. Induced by the need of increasing efficiency, bigger flexibility, better quality and lower costs, it became more complex [1]. Enterprises had had the need to cope with market expectations, incorporating in their production philosophies new paradigms such as JIT- Just in time, MTO- Make to order, Mass Customization, agile manufacturing or Lean Manufacturing, that allow them to satisfy markets with a big diversity of products and also big quantities, becoming therefore more competitive. All this complexity has caused big pressure under enterprises maintenance systems. Maintenance mission is to make equipment and facilities available when requested. Maintenance function, seen as a non value aggregator one, became more and more requested to contribute to cost reduction, based on bigger and consistent equipment reliability. This perspective is stressed when enterprises existing equipment has an advanced service life. It is expected a profusion of breakdowns at those scenarios and consequently a smaller usability of equipment driving to less productivity.

From an economic perspective, maintenance function is seen to the enterprise as a cost [2]. In fact, experience shows that a major percentage of the overall costs of the business concerns with maintenance [3]. Considering this perspective, decreasing costs with equipment operationalization will increase maintenance productivity and consequently overall productivity [4].

BACKGROUND

Maintenance

Usually, manufacturing systems recognize high level costs due equipment breakdown. This type of events is directly connected with inspection costs, repair costs as well as costs associated with non production time or equipment non utilization. Thus, the quality of the maintenance that is performed affects directly the performance level of a specific business or activity. This global world where we live it is fertile in the existence of high expectations. The appearance of expensive normative constrains, dynamic changes in technological paradigms and, apparently, in strategic or functional reorganizations, will have deeply impact in maintenance teams and their activities.

Technologies used by maintenance function are in an open path of discovery of applications that will stop performance deterioration. Maintenance teams must decide which techniques are more suitable to each situation having in mind that a wise choice must increase the system efficiency as well as reducing global costs. An erroneous choice could be the source of new problems while the existent ones could became worse than they were before.

Breakdowns, usually, have more impact or visibility, because they may affect negatively the outputs of the system, security, environmental health, quality, client service, competiveness or unit costs. The severity or frequency that a breakdown deals with described consequences will dictate which breakdown management technique should be used. Maintenance policy must be effective in the utilization of resources (people, materials, reposition parts, tools, etc.). Maintenance costs are dependent not only of the maintenance team but also of equipment operators and/or designer.

An effective maintenance passes through i) integration of maintenance and process engineering functions at the phase of selection and application of machines and equipment; which must be extended to ii) pro-active actions on those machines and equipments that will necessarily passes by preventive and predictive maintenance and also by changes at the project [4]. Literature points out three generic types of maintenance [5]; [6]

1. Corrective maintenance, which consists in repair actions when some equipment or machine is broken-down. The equipment is in action until the moment that it fails. At that moment it will be repaired or changed. The main disadvantages of this approach included fluctuant and unpredictable production, high levels of non-conform products and scrap yard as well as high levels of maintenance due interventions motivated by catastrophic fails [7]

2. Preventive maintenance, characterized for periodic maintenance operations in order to avoid equipment fails or machinery breakdowns, bases its functionality in manufactures manuals and some heuristics [8].

3. Predictive maintenance uses some indicator values to "feel" when some breakdown is eminent. This type of maintenance intends to make interventions on machinery before malicious events may occur [9].

Data Mining

Nowadays the databases are associated with all the activity areas, resulting in an accumulation of large amounts of data. However, the existence of large quantities of data by itself does not imply the possession of knowledge; this existence is just the first step in obtaining information and knowledge. After data processing the results lead to knowledge that can be used in monitoring, analysis and process prediction [10]. The path which starts with the existence of data to obtain knowledge passes through intermediate steps such as obtaining information or facts, or by the establishment of rules or values.

Data mining is defined to be the exploration and analysis, by automatic or semiautomatic means, of large quantities of data stored either in databases, data warehouses, or other information repositories to discover interesting knowledge including meaningful patterns and rules [11]. In general, the Data Mining term is the process of analyzing data from different perspectives, categorizing them and summarizing identified relations in order to return useful and usable information. Technically it can be seen as the process to find or identify correlations or patterns among dozens of camps in large relational databases [12], which can also be data warehouses or other information repositories [13].The most used techniques in Data Mining are:

1. Artificial Neural Networks: Consisting in a non linear predictive model that learns through training; their structure is similar to a biological neural network;

2. Decision trees: Structures in the shape of a tree representing sets of decisions. These decisions create rules for classification of data sets. The specific methods of the decision trees include Classification Trees and Regression (CART Classification and Regression Trees) and Chi Square Interactive and Automatic Detection (CHAID Automatic Interaction Detection Chi Square);

3. Genetic algorithms: Optimization technique that uses processes such as genetic combination, mutation and natural selection, based on the evolution concept;

4. Neighbourhood closer Method: Technique based on the classification of each record of all data on a class combination of k records that resembles more a history of a data deposit. It is sometimes called technique of k closest neighbours;

5. Induction Rule: extracts if-then rules from data based on statistical significance.

SYSTEM FUNCTIONALITY

In literature there are some approaches that use data mining concepts to improve manufacturing activities (14). It isn't so common to find approaches that use it to improve the capacity of predicting behaviours based on historical data. In fact, if the case is the possibility of a distributed collaboration of independent enterprises sharing data between them, even if they are competitors, the examples are even reduced.

We have found some examples which work on historical failure data and provide suggestions for an appropriate preventive maintenance schedule [14]. At the same work exist other references to the utilization of data mining techniques, including decision trees, rough sets, regression, and neural networks to predict component failure based on the data collected from the sensors of an aircraft. Other references to neural networks utilization for prediction effects in maintenance scope are present at [15], or references of equipment maintenance using optimized support vector machine existent at [16]

Data bases utilization with statistics is a tool well established in engineering scope. Maintenance activity, as well as other issues, have been influenced and evolved based on information and communication (ICT) developments. Technology evolution has lead to an increasing number of data flowing from all the processes of the organization such as product and process design, material planning and control, assembly, scheduling, maintenance, recycling, etc [14]. On their activity of reactive, preventive and predictive maintenance enterprises produce huge amounts of information that are stored to build historic profiles that can be helpful in future interventions. Data storage is usually made in a local perspective either in electronic or paper support. Nevertheless, it is known that the integration of those tools not always is effectively achieved.

Usually, enterprises do not share data produced from their maintenance interventions. This investigation intends to create an organizational architecture that makes the integration of data produced in factories on their activities of reactive, predictive and preventive maintenance. The main idea is to develop a decentralized predictive maintenance system based on data mining concepts similar to those that support virtual enterprises functionality.

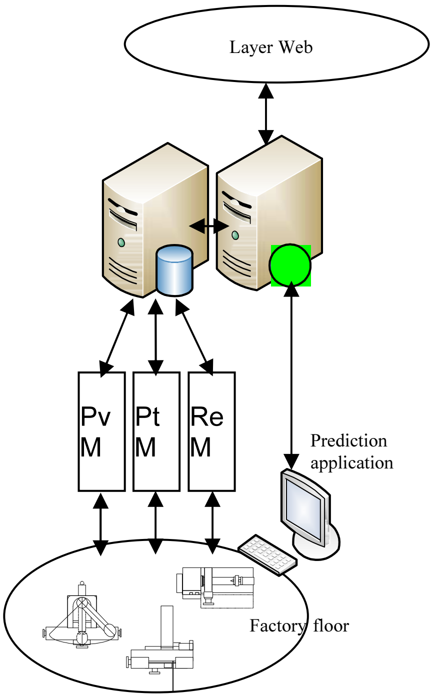

Fig. 1. al activity of maintenance

Data will flow from a local perspective to a higher layer that will integrate local data (see figure 1). Over that layer, data mining tools will operate to achieve and use implicit and hidden knowledge to generate predictive behaviour patterns. The possibility of an inevitable and eminent equipment failure will be reported to local layers through a prediction system unit existent in each node of the network. Data concerning the maintenance process used material, consequences of a non intervention and scenarios generation will be available in a decision support system base.

The main significant difference proposed by this system concerns to the possibility of using maintenance data originated from similar machines working in different factories dispersed through the globe. This particularity will allow the existence of higher amount of data and also data that reflects different natures and utilization of similar machines in different environments (see figure 2).

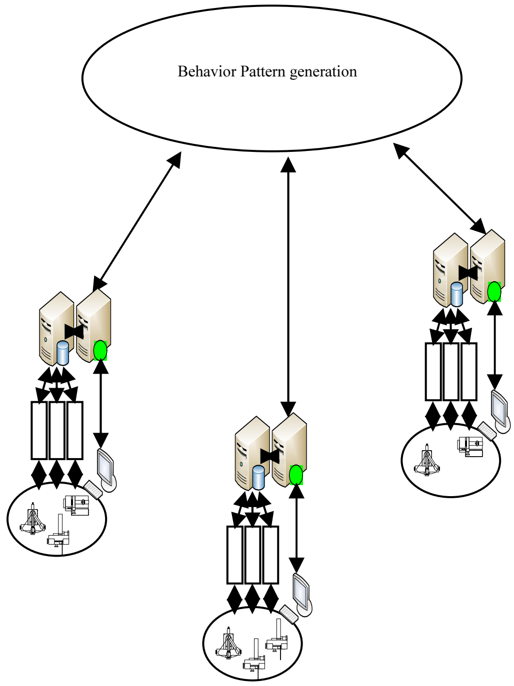

Fig. 2. Interaction of individual units

In a local perspective, data on the factory floor will be collected through maintenance operators using a formalized internal registry. Data will pass from a local layer to the prediction layer using a XML application. This application, designated by extractor, will be responsible for the integration in a common database (DB) data from external DB. The extractor will be a generic one, must be able of working with any DB schema or document type. Consequently, its development will force the existence of an appropriated specification language that allows describing the sources structure, the structure of the central DB and the transference schema.

Next the overall functionality will be explained deeply recurring to IDEF0 method. IDEF0 method is used to specify function models, representing high-level activities of a process and its decomposition in lower hierarchical sub activities or processes. IDEF0 models portrait a view of the process in terms of Inputs, Controls over the process, Outputs, and Mechanisms acting on the process, named ICOM's. IDEF0 Function Modeling is designed to model decisions, actions, and activities of an organization or system. IDEF0 model notation uses functions and activities abstracted from temporal sequence. The diagrams in this notation show activation (of functions, processes), not flow. More information may be found at [17].

activity will try to infer knowledge from formatted data. It is expected that data mining activity will perceive relations that allow a better understand of machinery behaviour and lead expert systems to predict events that may damage equipment or at least to perform a behaviour pattern to a better understand of equipment functionality.

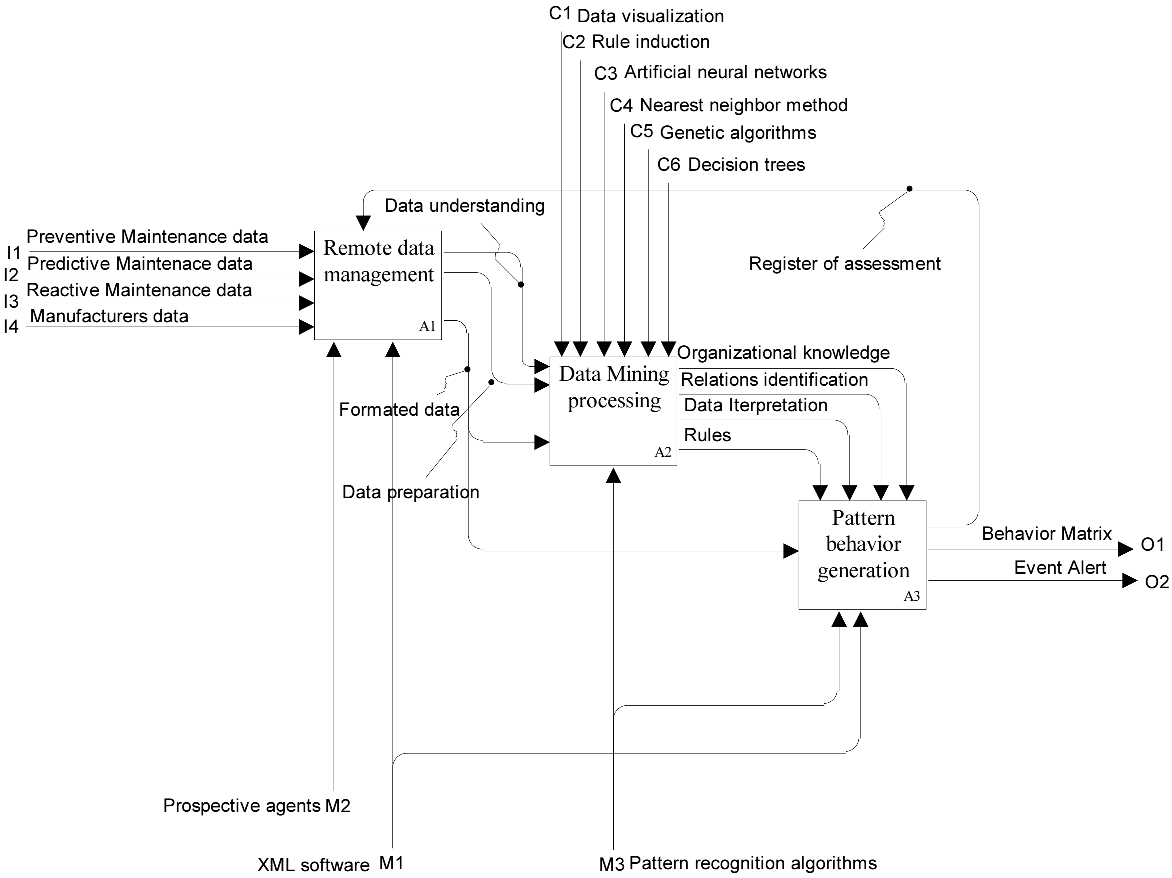

Fig. 3. Overall functionality using IDEF0 Format

When data concerning maintenance arrives from different sites will be treated at “Remote data management”, A1 activity. This activity uses as mechanism prospective agents that are responsible for gathering data from remote systems and XML applications to make transparent data collected in the private databases of each participant and usable by data mining algorithms. Remote data management will be responsible for producing data understanding, formatted data and data preparation. Those three types of data will be used by “Data Mining processing” activity as inputs. This A2 activity will be controlled by five control arrows: Data visualization, rule induction, artificial neural networks, nearest neighbor method, genetic algorithms and decision trees. Data mining activity will be responsible for producing organizational knowledge, relations identification, data interpretation and definition of rules. In fact those are some of the five steps of data mining knowledge discovery process. This

The referred outputs will be control inputs for pattern behaviour generation. This A3 activity will send to local partner’s information concerning the eminence of events that may damage machines and thus allowing maintenance teams to act before breakdowns happen. With this system it is expected a higher accuracy in predicting the occurrence of equipment breakdowns. We believe that more amounts of data produced on diverse environments, combined with machine manufactures information and also with registries of assessments will increase levels of reliability based on machinery maintenance activity.

CONCLUSIONS

Equipment maintenance prediction is an important and widely studied topic since it has a significant impact on equipment maintenance prediction and reliability. The existent huge amount of data from maintenance actions are not fully used for increase the efficiency of maintenance prediction. Data mining seems to be the step forward that will change the actual state.

The proposed system will help enterprises to collect, extract and create knowledge in a way that enterprises will predict with more accuracy the moment to realize maintenance actions and thus improve the productivity of manufacturing process. The innovative point of this system is the capability of collecting and treats data dispersed in different facilities that result from maintenance interventions in different environments. The contribution of machinery manufacturers it is also an important contribution.

References

[1] BJEST – A reverse algorithm for the real time predictive maintenance system. Bansal, D, Evans, D e Jones, B. 2005, International Journal of Machine tools and manufacture, pp. 1-11.
[2] The raison d'être of maintenance. Narayan, V. 1998, Journal of Quality in Maintenance Engineering, pp. 1355-2511.
[3] Learning curve analysis in total productive maintenance." 29: 491-499. Wang, F-K e Lee, W. 2001, Omega - The International Journal of Management Science, pp. 491-499.
[4] Palmer, R. Maintenance planning and scheduling handbook. New Jersey : McGraw Hill, 1999.
[5] Predictive maintenance:The one-unit replacement model. Chu, C, Proth, J-M e Wolff, P. 1998, Int. J. Production Economics, pp. 285-295.
[6] An empirical investigation on the relationship between business and maintenance strategies. Pinjala, S K, Pintelona, L e Vereecke, A. 2006, Int. J. Production Economics, pp. 214-229.
[7] Linking maintenance strategies to performance. Swanson, L. 2001, Int. J. Production Economics, pp. 237-244.
[8] Maintenance scheduling and production control of multi machine manufacturing systems. Gharbi, A e Kenné, J P. 2005, Computers and Industrial engineering, pp. 693-707.
[9] Application of a real time predictive maintenance system to a production machine system. Bansal, D, Evans, D e Jones, B. 2005, International Journal of Machine tools and manufacture, pp. 1210-1221.
[10] Efficient Genetic Algorithm Based Data Mining Using Feature Selection with Hausdorff Distance. Sikora, Riyaz e Piramuthu, Selwyn. 2005, Information Technology and Management, pp. 315-331.
[11] Data mining for yield enhancement in semiconductor. Chien, Chen-Fu, Wang, Wen-Chih e Cheng, Jen-Chieh. 2007, Expert Systems with Applications, pp. 192-198.
[12] Decision supporting functionality in a virtual enterprise network. Lau, HCW, et al. 2000, Expert Systems with Applications, pp. 261-270.
[13] Data mining for yield enhancement in semiconductor manufacturing and an empirical study. Chien, Chen-Fu, Wang, Wen-Chih e Cheng, Jen-Chieh. 2007, Expert Systems with Applications, pp. 192-198.
[14] Data Mining in manufacturing: A review. Harding, J, et al. 2006, Journal of Manufacturing Science and Engineering, pp. 969-976.
[15] Comparation of regression and neural network models for predictionof inspection profiles for aging aircraif. Luxhoj, James, Williams, Trefor e Shyur, Huan-Jyh. 1997, IIE Transactions, pp. 91-101.
[16] Prediction of equipment maintenance using optimized support vector machine. Zeng, Yi, et al. 2006, ICIC, pp. 570-579.
[17] Feldmann, C.G. e Tieso, J. V. The Practical Guide to Business Process Reengineering Using Idef0. New York : Dorset House, 1998.

HYBRID DYNAMIC SCHEDULING COORDINATION TROUGH MAS AND BIO-INSPIRED TECHNIQUES

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Keywords: Dynamic_scheduling; distributed_agent system; meta-heuristics; manufacturing_systems

INTRODUCTION

Scheduling Coordination can be seen as the intelligent allocation of resources among individuals and their goals in social society, which makes individuals using their resources more beneficially, so as to promote the achievement of individual and/or social goals. Usually, the requirement of coordination comes from the distribution and interdependencies of resources, entities and information. In scheduling coordination, considering the resource constraints, individual plans are to be evaluated and refined, and it may be needed to acquire available resources from external environment, including other individuals.

Agent-based computing is a promising approach for developing applications in complex domains. A number of challenges still need to be faced to turn agent-oriented software abstractions into practical tools for facing the complexity of a modern application like solving dynamic and distributed scheduling problems. Probably the most important challenge is to discover the best option to define the way like all the agents present in a system communicate and interact among them. Coordination of Multi-Agent Systems is an important clue when this approach is considered to solve distributed and complex problem like the one that is object of our work.

Bio-Inspired Techniques form a class of powerful and practical solution techniques for tackling complex, large-scale combinatorial problems producing efficiently high-quality solutions. From the literature we can conclude that they are adequate for static problems. However, real scheduling problems are quite dynamic, considering the arrival of new orders, orders being cancelled, machine delays or faults, etc. Scheduling problem in dynamic environments has been investigated by a number of authors [1][2].

This paper addresses dynamic scheduling resolution and suggests the interest and utility of hybrid multi-agent coordination. This work is included in project MASDScheGATS [1] that aim to continuously and efficiently adapts the current solution to a changing environment.

The remaining sections are organized as follows: initially section Multi Agent Systems and Scheduling Problems introduces MAS concepts that we consider fundamental to solve our problem. Section Coordination in Multi Agent makes an overview about related works concerned with this area of application. In section MASDScheGATS System, the developed system is described and a coordination algorithm is proposed in order to allow the improvements of systems' performance and reliability. Finally, the paper presents some conclusions and puts forward some ideas for future work.

MULTIAGENT SYSTEMS AND SCHEDULING PROBLEMS

Multi-Agent Systems (MAS) definition depends on the domain where agents are used and because of that MAS definitions abound. We believe that a solid and generic definition is presented by [2] that define MAS as a system capable to "*solve complex problems in a distributed fashion without the need for each agent to know about the whole problem being solved*". This definition and many others imply the existence of an organizational model, or management mechanism, that allows for interaction, communication and achievement of objectives within the group of agents, regardless whether the system is comprised of self-interested, group oriented or both types of agents. A proper definition for such mechanism is given by the definition of the word coordination, particularly if one considers coordination applied to MAS. Notice that in [3] we can find several reasons on why agents need to be coordinated:

- Chaos and anarchy prevention – coordination is desirable because in distributed system anarchy is easy to implement,
- Global restrictions – agents must obey to a set of restrictions in order to be well succeeded,
- Knowledge, resources and information is distributed – agents can have different capacities and specializations. Alternatively agents can have different information resources, responsibilities and limitations.
- Dependency between agents actions – agents' objectives are normally inter-dependent, a situation that requires coordination of actions.
- Efficiency – autonomous agents can work in an independent way, but at the same time they may have the necessity to coordinate their actions with other agents. The information of an agent can be sufficient for in group with another agent solve a problem quickly.

Scheduling problems arise in a diverse set of domains, ranging from manufacturing to hospitals settings, transports, computer and space environments, amongst others. Most of these domains are characterized by a great amount of uncertainty that leads to significant system dynamism. Such dynamic scheduling is receiving increasing attention amongst both researchers and practitioners.

In spite of all previous contributions, the scheduling problem is known to be NP-complete [4]. This fact incites researchers to explore new directions and Multi-Agent technology has been considered an important approach for developing industrial distributed systems [5-6].

COORDINATION IN MULTI-AGENT SYSTEMS

In a real manufacturing system a product is produced, step by step, passing on several machines. In each machine it will be performed at least one operation (job) of the process plan. However, if solutions obtained are joined by machine agents will be observed that in most of cases the founded solution is not feasible. In fact, if operation Op_1 (in machine m_1) precedes operation Op_2 (in machine m_2) and Op_2 precedes Op_3 (in machine m_3) in a manufacturing process, it is not guaranteed that the initial time for Op_2 in m_2 will be after the end of Op_1 in m_1 nor that the end of Op_2 in m_2 will be before the start of Op_3 in m_3.

Cooperation and negotiation are the two main types of coordination protocols developed in the literature and implemented in the existing systems. Therefore some of these protocols and mechanisms will be listed in the next paragraphs.

Cooperation is generally defined in the literature as the act of combining efforts, in order to accomplish a common objective that one autonomous agent alone cannot reach by itself. In other words, "*cooperation refers to a coordination protocol among nondisputant agents*" [7]. Such protocol is suited when agents need to share tasks or results as a way to reach the system's objective, so normally it is used in team like based architectures.

On the other hand, "*negotiation is the coordination among competitive or simply self-interested agents*"[7]. Negotiation can be described like the process in which at least two agents negotiate through a protocol in order to accomplish an agreement. This protocol is suitable for systems composed by a set of agents that pursuit their own individual goals but need interaction with other agents to achieve a satisfactory outcome. The buyer-seller situation is the best analogy to demonstrate this protocol. Negotiation is normally used in market like based approaches.

In [6] can be encountered a recent state of art related with the application of Multi-Agent Systems to solve production planning and scheduling problems.

There exist some important approaches on agent-based production scheduling and control [8] [9], therefore, here we concentrate on the most important aspects.

A Collaborative coordination control (CCC) mechanism is proposed in [5].

In [10] a hybrid, agent-based scheduling and control system architecture is presented in order to solve task allocation problems.

A multi-agent software system RIDER (Real-Time Decision Making in Manufacturing) has been developed for a cable producing company and for a carpet manufacturer [12]. Upon the occurrence of an event (machine breakdown, new orders, etc.), the agents use a mechanism for generating local alternatives and follow a message exchange procedure to build decision trees, which are evaluated by user defined cost-based objective functions.

A system that uses an agent-based collaborative production control framework capable of conducting scheduling and dispatching functions among production entities is reported in [13].

Cooperation and conflict resolution are the main concerns in agent-based scheduling systems. For solving this kind of problems, the idea of negotiated factory scheduling is normally considered.

A market-based negotiation mechanism, called precedence cost tâtonement (P-TÂTO), is described in [14]. The system is composed of a project manager agent, task agents, resource manager agents, resource agents, and coordinator agents.

In [15] and [16] a market based mechanism was proposed which made cooperation in the control of distributed manufacturing systems possible. The system included self-interested, autonomous agents that the main objective is to pursuit their goal. The planning problem is responsibility of a central agent, machine agents were responsible for generate and execute local generated schedules at machines. Non feasible schedules was the responsibility of the central agent, but scheduling decisions were reached using a system of bides between the central agent and the machine agents.

Considerably new is Stimergy that is a coordination mechanism for multi-agent systems based on animal interactions i.e. animal-animal interactions, evolved significantly and, presently, the analogy with the social insects confuses rather than helps the discussion [17]. This system is a coordination protocol applied to PROSA reference architecture [18]. It is inspired by natural systems i.e. food foraging behaviour in ant colonies. Stigmergy is an indirect coordination tool within an insect society where parts of global information are made available locally by pheromones informing other ants about remote facts.

In [19], the problem of distributed resource allocation in collaborative environment, such as distributed manufacturing environment or network of enterprise in supply chain, is a main focus especially in the environment where there is a high degree of autonomy among the independent entities, e.g. factories, companies, and enterprises. It is based in a centralized control, where the given tasks are assigned based on a specific resource allocation algorithm, the coordination protocol guides the interaction among the independent entities (task and resource owners) via communication channel.

Xue [20] introduces a system where two scheduling strategies are used to optimize the solution, the first earliest-delivery-time-based that allow to give the product the customer as soon as possible and the second due-time-based to start the product manufacturing as late as possible in order to reduce the time to store the finished product. Constraint based search and agent-based are used to identify the optimal schedule.

In [21] the allocation of resources to production jobs is carried out in a way similar to an open marketplace. Each part agent tries to full the processing requirements to achieve its own set of objectives (due date, quality, costs, etc.); for this purpose it is given a certain amount of currency, representing its own purchase capacity, in order to acquire the needed service from the single production resources.

Tseng *et al* [22] proposed a collaborative control structure for the mass customization manufacturing system. Each workstation is considered as an autonomous agent seeking the best return. The individual work order is considered as a job agent that vies for the lowest cost for resource consumption. The system schedule and control are integrated as an auction based bidding process with a price mechanism that rewards product similarity and response to customers' needs.

A MAS-based platform [23] to integrate manufacturing planning and control with systems reconfiguration and restructuring is proposed. This system has the capability to model complex heterogeneous systems, their structures and physical constraints, and also product orders. It allows the hierarchical structures of complex manufacturing systems to be modeled but avoids centralized control in classical hierarchical and hybrid control frameworks.

In [24] are developed some extension to the work represented in [20] in order to introduce a reactive mechanism for responding to changes of production orders and manufacturing resources.

Dumond *et al* [25] argues that algebra provides an appropriate context both for specifying the agents and their global coordination. They use the p- calculus for the description of the following entities, the internal behavior of the agents, i.e. the treatments to be achieved in response to external requirements, the agents' respective interfaces with the other agents, the coordination layer, i.e. the global outline of the agents' collaboration.

Shehory *et a*l [26] adopt methods used by physicists to study interactions among multiple particles. The physics-oriented methods are used to construct a coordinated task-allocation algorithm for cooperative goal-satisfaction.

In [27] there are enumerated very important approaches referents to agent coordination like mutual adjustment, direct supervision, coordination by standardization, mediated coordination, coordination by reactive behaviour.

MASDSCHEGATS SYSTEM

MASDScheGATS Architecture

Distributed environment approaches are important in order to improve scheduling systems flexibility and capacity to react to unpredictable events. It is accepted that new generations of manufacturing facilities, with increasing specialization and integration, add more problematic challenges to scheduling systems. For that reason, issues like robustness, regeneration capacities and efficiency are currently critical elements in the design of manufacturing scheduling system and encouraged the development of new architectures and solutions, leveraging the MAS research results.

The work described in this paper is a system where a community of distributed, autonomous, cooperating and asynchronously communicating machines tries to solve scheduling problems.

The main purpose of MASDScheGATS (Multi-Agent System for Distributed Manufacturing Scheduling with Genetic Algorithms and Tabu Search) is to decompose the scheduling problem into a series of Single Machine Scheduling Problems (SMSP) and create a Multi-Agent system where each agent represents a resource (Machine Agents) in a Manufacturing System [28]. Each Machine Agent must be able:

- to find an optimal or near optimal local solution through Genetic Algorithms or Tabu Search meta-heuristics.
- to deal with system dynamism (new jobs arriving, cancelled jobs, changing jobs attributes, etc).
- to change/adapt the parameters of the basic algorithm according to the current situation.
- to switch from one Meta-Heuristic algorithm to another.
- to cooperate with other agents.

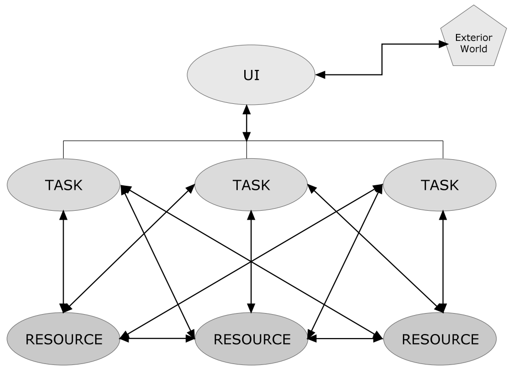

Fig. 1.MASDScheGATS System Architecture

The proposed architecture is based on three different types of agents. In order to allow a seamless communication with the user, a User Interface Agent is implemented. This agent, apart from being responsible for the user interface, will generate the necessary Task Agents dynamically according to the number of tasks that comprise the scheduling problem and assign each task to the respective Task Agent.

The Task Agent will process the necessary information regarding the task. That is to say that this agent will be responsible for the generation of the earliest and latest processing times, the verification of feasible schedules and identification of constraint conflicts on each task and the decision on which Machine Agent is responsible for solving a specific conflict. Finally, the Machine Agent is responsible for the scheduling of the operations that require processing in the machine supervised by the agent. This agent will implement meta-heuristic/local search procedures in order to find best possible operation schedules and will communicate those solutions to the Task Agent for later feasibility check (Fig. 1).

Coordination Mechanism

We propose an algorithm that in each time elects a machine to cooperate with another one. This process of election is based in the number of conflicts that each has in a determinate moment. The elect machine will be the one with the higher number of conflicts. After each negotiation round (we consider a round the act of a specific machine “negotiates” with another one) all conflicts are counted again and the machine with higher number of conflicts will be elected to cooperate. The elected machine will try to cooperate operations ordered by descending of processing time [28].

Job	Operation	Machine	p_{ijkl}	t_{ijkl}
j_1	o_{1111}	m_1	5	0
	o_{2121}	m_2	7	5
	o_{3131}	m_3	4	12
j_2	o_{1211}	m_1	2	0
	o_{2221}	m_2	9	2
	o_{3231}	m_3	4	11
j_3	o_{1311}	m_1	8	0
	o_{2321}	m_2	2	8
	o_{3331}	m_3	7	10

Table 1. Job Data for the Example

Initialization

Each machine is initialized with a flag (flagM1, flagM2, …, flagMn) that will be used to control which machine has been elected in the last coordination round. In the beginning the all the machine flags are equal to zero, and after each round the nominated machine flag will be -1. A machine cannot be elected in two contiguous rounds.

In the beginning a penalization for each task (job) is generated based on the it delivery date. For example if the delivery date of j1 is 30, j2 is 25 and j3 is 32, the penalization will be 2 for j1, 3 for j2 and 1 for j3 .

Each operation inherits the penalization from its job. With these values a penalization for each machine is calculated based in the penalizations sum of operations that are in conflict in each machine.

A variable count (countM1, countM2, ..., countMn) is created for each machine to save the number of time that a machine is elected to cooperate.

Algorithm

The machine with total higher number of conflicts will be elected to cooperate with the one with it has more conflicts. In a case in which more than one machine has the higher number of conflicts with the elected one, the penalization calculated for each machine will be used and the one with higher penalization will cooperate.

When the total number of conflicts of one machine reaches zero, the cooperation mechanism will not allow any change in the scheduling plan that can affect this.

1st Step

Generate locally in each machine a solution using MetaHeuristics.

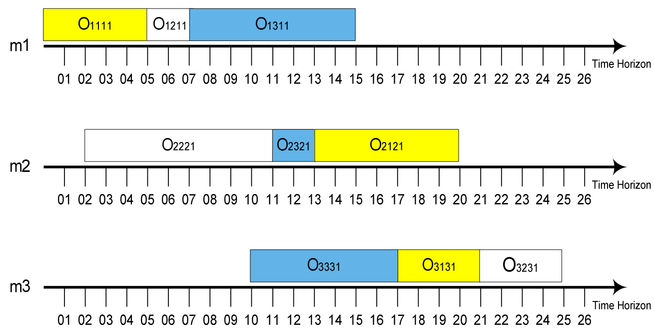

Fig. 2. Schedule generated by Meta heuristics

Machine agents will send local plans to Task agents that will recognize all conflicts. For example, we have the following conflicts:

- O1211 and O2221
- O2121 and O3131
- O1311,O2321,O3331

	M1	M2	M3
M1	0	2	1
M2	2	0	2
M3	1	2	0
Total	3	4	3

Table 2. Example of machine conflicts

Penalization

M1

- Conflicts O1211 and O1311

  PenM1 = 3 + 1 = 4

M3

- Conflicts O3331 and O3131

  PenM1 = 1 + 2 = 3

2nd Step

The M2 machine will cooperate with M1

Operation cooperation order O2221, O2121, O2321

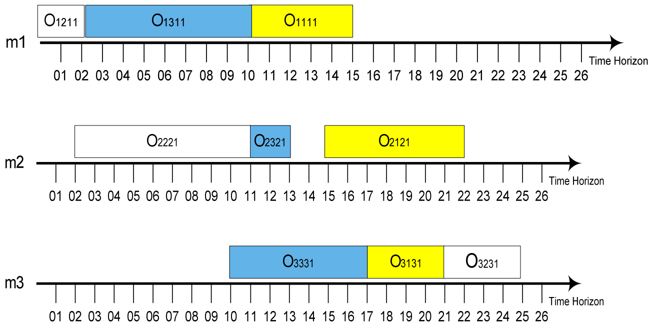

Fig. 3. Schedule plan after 1st round

	M1	M2	M3
M1	0	0	0
M2	0	0	2
M3	0	2	0
Total	0	2	2

Table 3. Example of machine conflicts

The flagM2 will be set to minus 1 and countM2 is increment by one.

3rd Step

The M3 machine will cooperate with M2.

The number of conflicts of M2 and M3 is the same, but flagM2 is set to minus 1 so M3 will be elected.

Operation cooperation order O3331, O3231, O3131.

In this case O3231, O3131 have the same processing time so the alphabetical order is considered to create operation.

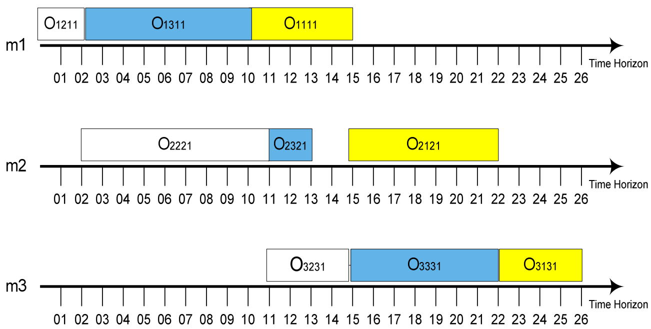

Fig. 4. Final Schedule Plan

	M1	M2	M3
M1	0	0	0
M2	0	0	0
M3	0	0	0
Total	0	0	0

Table 4. Example of machine conflicts

CONCLUSIONS AND FUTURE WORK

MAS coordination is for our work a very important clue, because our system will only produce good results if this all the agents communicate and cooperate among them. Many techniques can be applied to solve our kind of problem and the use the MAS will only be a good considerable one if its results demonstrate that its worth when compared with others already well known and tested.

Our future work is related with the implementation of the proposed algorithms and with the evaluation of their performance.

ACKNOWLEDGEMENTS

The authors would like to acknowledge FCT, FEDER, POCTI, POCI for their support to R&D Projects and GECAD - Knowledge Engineering and Decision Support Group Unit.

References

[1] Madureira, Ana, Santos, Joaquim, Developing a Multi-Agent System for Distributed Manufacturing, 2006, Knowledge and Decision Technologies, ISBN: 972-8688-39-3.

[2] Kim, B.I., Heragu, S.S., Graves, R.J., St Onge, A., , A Hybrid Scheduling and Control System Architecture for Warehouse Management, 2003, IEEE Trans. on Robotics and Autom., 19/6: 991-100

[3] Nwana, H., Lee, L. and Jennings, N. Coordination in software agent systems, 1996, BT Technol J Vol 14, No 4 October,.

[4] J. Blazewicz, K. H. Ecker, E. Pesch, G. Smith, J. Weglarz, Scheduling Computer and Manufacturing processes, 2001, Springer, 2nd edition, New York.

[5] W. Shen, and D. Norrie, Agent-based systems for intelligent manufacturing: a state of the art survey, 1999, Int. J. Knowl. Inform. Syst., vol. 1, no. 2, , pp. 129– 156.

[6] M. Yokoo and K.Hirayama, Algorithms for Distributed Constraint Satisfaction: A Review, 2000, Journal of Autonomous Agents and Multi-Agent Systems,.

[7] Weiss, G. MultiAgents Systems – A Modern Approach to Distributed Artificial Intelligence, 1999, The MIT Press.

[8] Caridi, M., Cavalieri, S., Multiagent Systems in Production Planning and Control: An Overview, Production Planning and Control, 2004, 15/2: 106-118.

[9] Babiceanu, R.F., Chen, F.F., Development and Applications of Holonic Manufacturing Systems: A Survey, 2006, Journal of Intelligent Manufacturing, 17: 111-131.

[10] Nof, S.Y., Weill, R., Collaborative Coordination Control (CCC) of Distributed Multimachine Manufacturing, 1992, Annals of the CIRP, 41/1: 441-444.

[11] Kim, B.I., Heragu, S.S., Graves, R.J., St Onge, A., A Hybrid Scheduling and Control System Architecture for Warehouse Management, 2003, IEEE Trans. on Robotics and Autom., 19/6: 991-100

[12] Papakostas, N., Mourtzis, D., Bechrakis, K., Chryssolouris, G., Doukas, D., Doyle, R., A Flexible Agent Based Framework for Manufacturing Decision-Making, 1999, Proc. of the 9th Flexible Autom. And Intell. Manufact. Conf.: 789-800.

[13] Lu, T., Yih, Y., An Agent-Based Production Control Framework for Multiple-Line Collaborative Manufacturing, 2001, International Journal of Production Research, 39/10: 2155-2176.

[14] Lee, Y., Kumara, S., Chatterjee, K., Multi agent based Dynamic Resource Scheduling for Distributed Multiple Projects Using a Market Mechanism, 2003, J. of Intell. Manufact., 14/5: 471-484.

[15] Márkus, A., Kis, T., Váncza, J., Monostori, L., A Market Approach to Holonic Manufacturing, 1996, Annals of the CIRP, 45/1: 433-436.

[16] Váncza, J., Márkus, A., An Agent Model forIncentive-based Production Scheduling, 2000, Computers in Industry, 43/2: 173–187.

[17] Valckenaers, P., Van Brussel, H., Holonic Manufacturing Execution Systems, 2005, Annals of the CIRP, 54/1: 427-432.

[18] Van Brussel, H., Wyns, J., Valckenaers, P., Bongaerts, L., Peeters, P., Reference architecture for holonic manufacturing systems: PROSA. 1998, Computers In Industry, 37:255-274.

[19] Anussornnitisarn, Pornthep , Nof, Shimon Y., Etzion, Opher , Decentralized control of cooperative and autonomous agents for solving the distributed resource allocation problem, 2005, Int. J. Production Economics 98, 114–128.

[20] Xue, D., Sun, J., Norrie, D- H., An Intelligent optimal production scheduling using constraint-based search and agent-based collaboration, 2001, Computers in Industry 46, 209-231.

[21] Cavalieri, Sergio, Garetti, Marco, Macchi, Marco, Taisch, Marco, An experimental benchmarking of two multi-agent architectures for production scheduling and control, 2000, Computers in Industry 43, 139-152.

[22] Tseng, Mitchell, M., Lei, Ming, Su, Chuanjun, A Collaborative Control System for Mass Customization Manufacturing, 1997.

[23] Anosike , A.I., Zhang , D.Z., An agent-based approach for integrating manufacturing operations, 2006, Int. J. Production Economics.

[24] Sun, J, Xue, D., Dynamic Reactive Scheduling for responding to changes of production orders and manufacturing resources, 2001, Computers in Industry 46 189-207.

[25] Dumond , Y., Roche, C., Formal specification of a multi-agent system architecture for manufacture: the contribution of the p-calculus, 2000,Journal of Materials Processing Technology 107,209-215

[26] Shehory, Onn , Kraus, Sarit, Yadgar, Osher, Emergent cooperative goal-satisfaction in large-scale automated-agent systems, 1999, Artificial Intelligence, 110, 1–55.

[27] Shen, Weiming , Hao. Qi, Hyun Yoon, Joong, Norrie, Douglas H., Applications of agent-based systems in intelligent manufacturing: An updated review, 2006, Advanced Engineering Informatics 20 415–431

[28] Madureira, Ana, Santos, Joaquim, Fernandes, Nuno Gomes and Ramos, Carlos, 2007, Proposal of a Cooperation Mechanism for Team-Work Based Multi-Agent System in Dynamic Scheduling through Meta-Heuristics, 2007IEEE International Symposium on Assembly and Manufacturing (ISAM07), Ann Arbor (USA), pp. 233-238, ISBN: 1-4244-0563

META-HEURISTICS SELF-CONFIGURATION FOR SCHEDULING

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Keywords: Intelligent_decision_support_system; distributed_agent system; meta-heuristics; computational_intelligence; dynamic_scheduling;

INTRODUCTION

Scheduling resolution requires the intervention of highly skilled human problem-solvers. This is a very hard and challenging domain because current systems are becoming more and more complex, distributed, interconnected and subject to rapidly changing. A natural Autonomic Computing evolution in relation to Current Computing is to provide systems with Self-Managing ability with a minimum human interference. This paper addresses the resolution of complex scheduling problems using cooperative negotiation. A Multi-Agent Autonomic and Meta-heuristics based framework with self-configuring capabilities is proposed.

Considering that Autonomic Computing is a grand-challenge vision of the future in which computing systems will manage themselves in accordance with high-level objectives specified by humans[1], we pretend with the proposed system to give a meaningful contribution in the field of Autonomic Computing application for dynamic scheduling in Manufacturing Systems.

Multi-agent paradigm is emerging for the development of solutions to very hard distributed computational problems. This paradigm is based either on the activity of "intelligent" agents which perform complex functionalities or on the exploitation of a large number of simple agents that can produce an overall intelligent behavior leading to the solution of alleged almost intractable problems.

Meta-heuristics (MH) form a class of powerful and practical solution techniques for tackling complex, large-scale combinatorial problems producing efficiently high-quality solutions. From the literature we can conclude that they are adequate for static problems. However, real scheduling problems are quite dynamic, considering the arrival of new orders, orders being cancelled, machine delays or faults, etc.

Hybridization and combination of different approaches seems to be a promising research field of computational intelligence focusing on the development of the next generation of intelligent systems.

The remaining sections are organized as follows: initially issues and links for Autonomic Computing are presented. Then some related work on dynamic scheduling and Meta-heuristics applications for scheduling are summarized. After that the proposed AutoDynAgents System and implemented mechanisms are described. Finally, the paper presents some conclusions and puts forward some ideas for future work.

AUTONOMIC COMPUTING

Autonomic computing was first introduced by IBM in 2001, the purpose of autonomic computing is reducing human intervention in configuration tasks, due to complexity and size of computers systems the time spent in configuration is bigger, occupying human resources in tasks not profiting to enterprises and organizations, with autonomic computing human resources have more time to focus in tasks more suitable to the organization goals. Some benefits of autonomic computing could be [1], [2]:

- The ability to release resources to more important tasks than maintenance of computer systems.
- Guarantee of managing ability through all process of business.
- Collaboration of different information sources to solve problems, information is always available.
- Mass simulation, calculations made 24 hours a day seven days a week.

Self-CHOP

CHOP stands for Configure, Healing, Optimizing and Protect. These characteristics are probably the most important for autonomic computing systems. These characteristics give the possibility of the autonomic computing system to adjust to the surrounding environment (Fig.1).

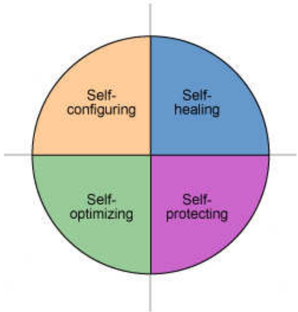

Fig. 1. Autonomic Computing attributes [2].

Self-configuration allows the system to adapt to the surrounding environment by adjusting components of the system. It may turn on components that were offline and vice-versa.

Self-optimization is concerned with tuning the several components in order to get the best performance of them. Or change priorities of tasks in scheduling.

Self-healing is responsible the resume the good functioning of the system after a crash, or part of it. It must be able to restore components in order to they resume their functioning.

Self-protect must be able to detect threats to the system, and take actions to prevent them, it must monitor the surrounding environment as well the system components searching for weaknesses in order prevent possible attacks or malfunctions [1], [2].

Autonomic computing elements

An autonomic computing system is composed by several elements. Each element in an autonomic computing architecture is responsible for certain tasks, the well functioning and synchronization of these elements are responsible for the success of the system [2]. It is possible to identify the following elements:

- Touch points are the components that allow the communication between the resources that are managed and the managers. The touch point is composed by sensors and actuators. The sensors allow receiving information from the managed resource, the actuators are responsible to send information to resource, by others words it controls the resource.
- Autonomic manager is the element responsible for the management for the resources. It must be able to gather information in an autonomic way and be able to analyze it in order to make any possible changes. The autonomic managers constantly perform a cycle usually called MAPE (Monitor, Analyze, Plan and Execute). This cycle is responsible for the constant monitoring and configurations of a resource.
- Knowledge sources are implementations of registers, data bases or other knowledge sources. In these knowledge sources exists information about the components of the autonomic system, policies to adopt, and even configurations that were made in order to look for similar solutions with similar symptoms.
- Manual manager is an implementation of an interface that allows human managing of the system. Usually is a console where user can make configurations and receive information from the autonomic managers.

All these components make the autonomic computing system. Autonomic managers can be managers of resources or orchestration managers, managers that manage others autonomic managers. All these components together form the autonomic computing architecture. IBM proposes an architecture that is only one possibility it is not a standard. There may be others architecture valid as this one.

DYNAMIC SCHEDULING

Dynamic scheduling can be defined as the constant maintenance of operations given to resources that are needed to maintain the scheduling up to date [3]. Problems with scheduling are clearly dynamic. There are too many variables to be able to elaborate an optimized plan, where we can predict all the possible failures. Some characteristics of dynamic scheduling are the ability to schedule in an environment where not all the information is available or it may change, be able to change plans already created according to information received in real time minimizing the disturbance of actual plans.

There are two types of events that are considered in dynamic scheduling. Events related with resources and events related with operations [4] [5]. Events related with resources can be considered machines breakdown, workers absenteeism, limit in production capacity and lack of correct tools to specific tasks. Events related with operations are operations that arrive to the system too late or too soon, new operations not initial predicted, delivery dates changed, priorities changed.

In order to react to these disturbances that totally or partial invalid production plans, dynamic scheduling permits to resume the plans by making changes to existing plans or making news ones. Rescheduling takes less evaluation effort than changing the actual scheduling. When rescheduling is made a new plan is created. These guarantees that the plan is up to date, generating requires time, if there are many disturbances it is generated news plans spending much time in this process, the implementation of a new plan has costs. Changing the existing plans takes more effort because it analyzes existing plans not creating new ones from beginning. The cost of implementation these plans are less than implement a totally new one. If changes are minimal is faster to incorporate them. By changing parts of the plan, others parts may not be up to date [5].

Changing parts of plans may prove to be good to minimal changes, having a reduced cost. However it takes more processing effort and may leave parts of the plan not updated. Creating a new plan guarantee that all parts of the plan are updated and are working, it takes less processing effort, but the cost and time to implement a new plan is usually bigger than implement part of it, if constants changes are made the production system may become instable [4][5].

META-HEURISTICS APPLICATIONS FOR SCHEDULING

Meta-heuristics are the set of computing techniques inspired by biologically systems that are derived from nature. The family of Meta-heuristics includes, but it is not limited, to Tabu Search, Simulated Annealing, Adaptive Memory procedures, Scatter Search, Soft Computing, Evolutionary Methods, Ant Systems, Particle Swarm Optimization and their hybrids. For literature on this subject, see for example [8].

The interest of this class of approaches is that they converge, in general, to satisfactory solutions in an effective and efficient way (computing time and implementation effort).

In last decades, there has been a significant level of research interest in Meta-heuristics approaches for solving large real world scheduling problems, which are often complex, constrained and dynamic. Scheduling algorithms that achieve good or near optimal solutions and can efficiently adapt them to perturbations are, in most cases, preferable to those that achieve optimal ones but that cannot implement such an adaptation. This is the case with most algorithms for solving the so-called static scheduling problem for different setting of both single and multi-machine systems arrangements. This reality, motivated us to concentrate on tools, which could deal with such dynamic, disturbed scheduling problems, even though, due to the complexity of these problems, optimal solutions may not be possible to find.

Hybridization of intelligent systems is a promising research field of computational intelligence focusing on combinations of multiple approaches to develop the next generation of intelligent systems. An important stimulus to the investigations on Hybrid Intelligent Systems area is the awareness that combined approaches will be necessary if the remaining tough problems in artificial intelligence are to be solved. Meta-Heuristics, Bio-Inspired Techniques, Neural computing, Machine Learning, Fuzzy Logic Systems, Evolutionary Algorithms, Agent-based Methods, among others, have been established and shown their strength and drawbacks. Recently, hybrid intelligent systems are getting popular due to their capabilities in handling several real world complexities involving imprecision, uncertainty and vagueness [2][7][8].

AUTODYNAGENTS SYSTEM

Distributed environment approaches are important in order to improve scheduling systems flexibility and capacity to react to unpredictable events. It is accepted that new generations of manufacturing facilities, with increasing specialization and integration, add more problematic challenges to scheduling systems. For that reason, issues like robustness, regeneration capacities and efficiency are currently critical elements in the design of manufacturing scheduling system and encouraged the development of new architectures and solutions, leveraging the MAS research results.

A natural Autonomic Computing evolution in relation to Current Computing is to provide systems with Self-Managing ability with a minimum human interference. Considering that AC is a grand-challenge vision of the future in which computing systems will manage themselves in accordance with high-level objectives specified by humans, we pretend with AUTODYNAGENTS (Autonomic Agents with Self-Managing Capabilities for Dynamic Scheduling Support in a Cooperative Manufacturing System) project to give a meaningful contribution in the field of Autonomic

Computing application for dynamic scheduling in Manufacturing Systems.

The concept of developing the next era of computing systems is driven by the convergence between Biological Systems and the Digital Computing Systems. AutoDynAgents is a project envisaging the use of Multi-Agent Systems paradigm for supporting dynamic and distributed scheduling in Manufacturing Systems with Autonomic properties, in order to reduce the complexity of managing systems and human interference.

As AutoDynAgents objectives we will try to make studies to prove the following assertions:

- Use Autonomic Computing to reproduce Life-like behavior in computation to explain, predict, reconstruct and deploy complex systems, with a minimum human interference.
- Multi-agent Systems are adequate to model and support dynamic and distributed scheduling with Cooperative Negotiation;
- Multi-agent paradigm is often inspired by biologically systems. Observing Manufacturing Systems like evolution-based social systems will be important in order to allow a better understanding and integration between the machinery and humans;
- Learning in Multi-agent Autonomic Systems is a challenging problem, so does Optimization. Optimization in such environments must deal with dynamism;
- Bio-Inspired Techniques can be adapted to deal with dynamic problems, reusing and changing solutions in accordance with system dynamism.

The final product of AutoDynAgents is an Autonomic Scheduling System in which communities of agents model a real manufacturing system subject to perturbations. Agents must be able to learn and manage their internal behaviour and their relationships with other autonomic agents, by cooperative negotiation in accordance with business policies defined by user manager. Cooperative Negotiation is quite important at this approach; we consider a Multi-dimensional Negotiation process depending upon the effort that the agents want to expend based on business.

AUTODYNAGENTS Architecture

The main purpose of AUTODYNAGENTS is to create a Multi-Agent system where each agent represents a resource (Machine Agents) in a Manufacturing System. Each Machine Agent must be able: to find an optimal or near optimal local solution trough an Meta-heuristics and to deal with system dynamism.

The Scheduling problem defined in [5], is decomposed into a series of Single Machine Scheduling Problems (SMSP). The Machine Agents (which has an Meta-heuristic associated) obtain local solutions and later cooperate in order to overcome inter-agent constraints and achieve a global plan solution.

The proposed Team-Work based approach is rather different from the ones found in the literature; as we try to implement a system where each agent (Machine Agent) is responsible for optimize the scheduling of operations for one machine through Tabu Search or Genetic Algorithms according to problem characteristics. It is based on three different types of agents. In order to allow a seamless communication with the user, a User Interface Agent is implemented. This agent, apart from being responsible for the user interface, will generate the necessary Task Agents dynamically according to the number of tasks that comprise the scheduling problem and assign each task to the respective Task Agent.

The Task Agent will process the necessary information about the job. That is to say that this agent will be responsible for the generation of the earliest and latest processing times, the verification of feasible schedules and identification of constraint conflicts on each job and the decision on which Machine Agent is responsible for solving a specific conflict.

Finally, Machine Agent is responsible for the scheduling of the operations that require processing in the machine supervised by the agent. This agent will implement meta-heuristic and local search procedures in order to find best possible operation schedules and will communicate those solutions to the Task Agent for later feasibility check.

The architecture was implemented using the Java Agent Development framework (JADE).

Coordination Considerations

In a real manufacturing system a product is produced, step by step, passing on several machines. In each machine it will be performed at least one operation (job) of the process plan. In our approach we have one agent for each machine. However, if we join solutions obtained by our machine agents we will observe that, some times, they will not be feasible. In fact, if operation Op_1 (in machine m_1) precedes operation Op_2 (in machine m_2) and Op_2 precedes Op_3 (in machine m_3) in a manufacturing process, it is not guaranteed that the initial time for Op_2 in m_2 will be after the end of Op_1 in m_1 nor that the end of Op_2 in m_2 will be before the start of Op_3 in m_3.

Two possible approaches, to deal with this problem, could be used. In the first, the AUTODYNAGENTS system waits for the solutions obtained by the machine agents and then apply a repair mechanism to shift some operations in the generated schedules till a feasible solution is obtained (Repair Approach) [5][9]. In the second, a coordination mechanism is established between related agents in the process, in order to interact with each other to pursuit common objective trough cooperation. These coordination mechanisms are prepared to accept agents subjected to dynamism (new jobs arriving, cancelled jobs, changing jobs attributes). The latter approach is the one implemented in the proposed system.

Self-Managing Mechanisms for Autonomic Agents

Generally, self-organization can be defined as the process by which systems tend to reach a particular objective with no external interference. All the mechanisms dictating its behaviour are internal to the system e.g. are autonomous. This field of research has received much attention trough Autonomic Computing paradigm [2] [10].

We envisage to define Self-Managing mechanisms for a Cooperative Scheduling System considering that AutoDynAgents must be able to perform scheduling in highly dynamic environments where there is incomplete information and changes often occur; modify previously formed schedules considering recent dynamic information, minimizing the disruption of earlier schedules and still aiming for the most effective possible use of resources and achievement of goals and provide flexibility to react robustly to any disruption in an efficient and timely manner. We intend to define the following Self-Managing mechanisms:

- **Self-Configuring** - enable agents to adapt to changing conditions by changing their own configurations, allowing the addition and removal of resources without service disruption. Machine Agents will be prepared to handle dynamism by adapting the solutions to external perturbations.
- **Self-Optimizing** - ability of the agent to monitor its state and performance and proactively tune itself to respond to environmental stimuli. Each machine agent adopt and provides self-parameterization of the solving method in accordance with the problem being solved (parameters can change in run-time).
- **Self-Healing** – giving agents the capacity to diagnose deviations from normal conditions and take proactively action to normalize them and avoid service disruptions.

Self-Configuring Mechanism

In this work each resource will have an autonomic manager. These autonomic managers will be responsible for monitoring, and send instructions to the resource, by doing this it can detect changes and disturbances to the original plan. By detecting the changes, the plan can be corrected. Information about the scheduling will be stores in a knowledge source, there will also exists information about older scheduling and changes effectuated in order to solve problems previously occurred. These older scheduling and special the changes previously made will be important in order to find a solution that incorporates the disturbances that happen. By searching in the knowledge source similar disturbances and their solutions, it can be adapted to current disturbance in order to adapt it and rearrange the plan.

Rescheduling is necessary due to two classes of events [5]: **Partial events** imply variability in jobs/operations attributes such as processing times, due dates or release times; and **Total events** imply variability in neighbourhood/population structure, resulting from new job arrivals, job cancellations, machines breakdown, etc.

While, on one hand, partial events only require redefining job attributes and re-evaluation of the objective function of solutions, total events, on the other hand, require a change on solution structure and size, carried out by inserting or deleting operations, and also re-evaluation of the objective function. Therefore, under a total event, the modification of the current solution is imperative.

Considering the processing times involved and the high frequency of perturbations, rescheduling all jobs from the beginning should be avoided. However, if work has not yet started and time is available, then an obvious and simple approach to rescheduling would be to restart the scheduling from scratch with a new modified solution on which takes into account the perturbation, for example a new job arrival. When there is not enough time to reschedule from scratch or job processing has already started, a strategy must be used which adapts the current schedule having in consideration the kind of perturbation occurred.

The occurrence of a partial event requires redefinition of job attributes and a re-evaluation of the schedule objective function. A change in job due date requires the re-calculation of the operation starting and completion due times of all respective operations.

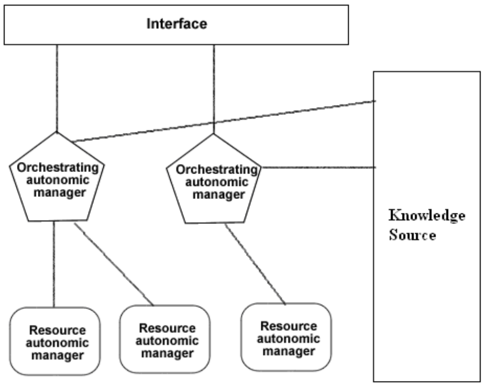

Fig. 2. Autodynagents project architecture.

However, changes in the operation processing times only requires re-calculation of the operation starting and completion due times of the succeeding operations. A new job arrival requires definition of the correspondent operation starting and completion times and a regenerating mechanism to integrate all operations on the respective single machine problems. In the presence of a job cancellation, the application of a regenerating mechanism eliminates the job operations from the SMSP where they appear. After the insertion or deletion of positions, neighbourhood regeneration is done by updating the size of the neighbourhood and ensuring a structure identical to the existing one.

There will also exist orchestrating autonomic managers. These autonomic managers are at a superior level, they permit to resources autonomic managers to communicate with each others. They serve as an intermediary. They also have the access to knowledge source, in this way there will be a more controlled access to information. Orchestrating managers will also provide information to users interfaces. The number of orchestrating managers may vary depending on the number of resource autonomic managers, if there are too many resource autonomic managers they should be divided to several orchestrating autonomic managers to have more efficient response times(Fig.2).

CONCLUSIONS AND FUTURE WORK

We believe that a new contribution for the resolution of more realistic scheduling problems was described in this paper. The particularity of our approach is the procedure to schedule operations, as each machine will first find local optimal or near optimal solutions, succeeded by the interaction with other machines through cooperation mechanism as a way to find an optimal or near-optimal global schedule.

As result of this project we expect to prove some ideas for which we are now claiming. From these we refer the use of Autonomic Computing to reproduce Life-like behaviour in computation to explain, predict, reconstruct and deploy complex systems, with a minimum human interference.

ACKNOWLEDGEMENTS

The authors would like to acknowledge FCT, FEDER, POCTI, POCI for their support to R&D Projects and GECAD - Knowledge Engineering and Decision Support Group Unit.

References

[1] IBM; Autonomic Computing White Paper- An architectural blueprint for autonomic computing; 2006.
[2] EMA. Practical Autonomic Computing: Roadmap to Self Managing Technology - A White Paper Prepared for IBM, Ent. Manag. Associates; 2006.
[3] M. Selim Akturk, Elif Gorgulu; Theory and Methodology Match-up Scheduling under a machine breakdown; European Journal of Operational Research 112, 81-97; 1999.
[4] Aytug, H., Lawley, M. A, McKay, K., Mohan, S.& Uzsoy, R., Executing production schedules in the face of uncertainties: A review and some future directions. European Journal of Operational Research, Volume 16 (1), 86-110, 2005.
[5] Madureira, A., Aplicação de Meta–Heurísticas ao Problema de Escalonamento em Ambiente Dinâmico de Produção Discreta. 2003 (in portuguese).
[6] Teofilo, F. Gonzalez, Handbook of Approximation Algorithms and Metaheuristics, Chapman&Hall/Crc Computer and Information Science Series, 2007.Parashar, Manish, Hriri, Salim; Autonomic Computing, Concepts, infrastructures and applications; CRC Press; 2006.
[7] Madureira, A., Santos, J., Gomes,N., Hybrid Multi-Agent System for Cooperative Dynamic Scheduling through Meta-Heuristics, 6th International Conference on Intelligent System Design and Applications, Rio de Janeiro (Brasil), 2007, pp.9-14, ISBN: 0-7695-2976-3.]
[8] Luck, M., McBurney, P., Shehory, O., Willmoth, S. , Agent Technology: Computing as Interaction. A Roadmap for Agent-Based Computing, AgentLink III, 2005.
[9] Madureira, A., Santos, J., Gomes, N., Ramos,C., Proposal of a Cooperation Mechanism for Team-Work Based Multi-Agent System in Dynamic Scheduling through Meta-Heuristics, 2007 IEEE Int. Symposium on Assembly and Manufacturing(ISAM07), Ann Arbor(USA), 2007, pp. 233-238, ISBN: 1-4244-0563-7.

[10] Monostoria L., Vánczaa, J., and S.R.T Kumara, Agent-Based Systems for Manufacturing , CIRP Annals - Manufacturing Technology, Volume 55, Issue 2, Pages 697-720, 2006.

SHORT-TERM WIND FORECAST USING ARTIFICIAL INTELLIGENCE TECHNICS

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Abstract: A decision making problem often becomes a problem of selection. In this kind of problems (decision making or forecasting problems) selection of effective input variables, which is usually a complex and sometimes an impossible process, becomes in almost real situations the main problem. The correct selection of the effective data in the assessment of a problem allows not only faster decision but the reduction of the prediction error. In this paper we use a hybrid model of a Genetic Algorithm (GA) as a heuristic tool, to select appropriate combinations of different variables that have more effect on forecasting decision making parameters, and Artificial Neural Network (ANN) as a fitness function of genetic algorithm. The model was then applied to predict the intensity of the wind in the short-term in the central-south region of Portugal. The results proved to be excellent regardless of the forecast horizon.

Keywords: Decision Making Parameters, Wind Speed Prediction, Genetic Algorithms, Artificial Neural Networks

1. INTRODUCTION

In practice, a forecasting system can be one basis for a better scheduling of conventional power plants leading to a lower spinning reserve and thereby to savings of fossil fuel and CO_2. Besides this, a better integration of wind energy in the existing electric energy supply systems leads to a better acceptance of this new technology.

In the near future, the trading with “green energy” will be an essential part of energy markets. The resulting price of green electric energy will depend on the day by day availability of this energy source. So not only “classic” energy suppliers but also “green traders” are becoming potential customers for wind power forecasts.

Portugal has no known resources of oil or natural gas and available resources of coal are practically extinct. In this situation Portugal needs to develop alternative forms of energy production, and in fact the level of wind energy, the situation today is free of dynamism. According [1] is expected in Portugal the installation of about 2500 to 3000 MW of wind converters by 2010. Despite the expected growth in the coming years for this sector, there are few tools for planning of infrastructure and systematic identification of areas presenting indicators of high wind energy potential. The production of a map of wind power for Portugal is a good starting point. It is very important, to have place a place, region to region a deep knowledge of the characteristics of the wind (particularly its intensity). This knowledge is vital, not only in the preliminary assessment of the potential of wind energy, but also as a tool to assist decision to invest in future trips to characterize the wind and planning of electricity grids and other infrastructure in a region [2].

The assessment of wind power is usually done using different methodologies. The European Wind Atlas/Wasp [3] uses, what is termed the classic methodology. In this methodology, the average wind speed, the wind rose, Weibull distribution, daily profile of the wind, flow of power and estimate the annual energy are the basic parameters. Other methods also used (for example the method spectral), also use the vast amount of information, essential to select and characterize the wind power and wind energy production.

The methodology that will be presented here, based on a hybrid model that uses a genetic GA as heuristic to select the most effective combination of variables to make short-term wind speed forecast in a particular place or region, and an ANN as a basis for evaluating the GA. As the Centro de Geofísica de Évora released a set of data relating to region of Évora (Mitra), the area under study is immediately set.

2. SELECTION OF VARIABLES

On issues where the aim is to forecast the wind speed (either the short, medium or long term), two situations are common: absence or virtual absence of weather information from place to study, or excess of information. If the first situation, the solution lies according Kalogirou [4] by using information from the local weather coming. In the second situation two questions might arise: Are all the information relevant to the solution of the problem? Is there an optimal mix of variables that translate efficiently the system?

In the case under study we have used data from Mitra (Évora). This station collects data (air temperature, relative humidity, intensity and direction of wind, precipitation and solar radiation) from 10 to 10 minutes, since 2002 up to today, which we consider important to add a number of other variables as the average hourly/daily and monthly speed, the maximum speed and minimum daily, variations hourly/daily and monthly speed and wind direction, daily minimum and maximum speeds, etc.

To address the problem that we propose to solve (the wind speed forecast for the next 24 hours), and given the large amount of information available, several methods could be followed. The older methods of forecasting are usually based on statistical models and historical data. More recently RNA's have been used with some success in problems of forecasting [5].

However, when we use a large number of data as ANN input variables:

- Training time increases significantly;
- Training error increases by using inappropriate variables;

We spend extra cost for gathering and processing non effective or inappropriate data.

More recently Makvandi [6] proposed that only the use of input data with actual impact in solving the problem should be considered at the stage of training the ANN.

The proposed model uses a GA to code the combination of effective variables and an ANN as a fitness function of the GA. The model is applied in a case study to determine effective variables on forecasting wind speed in the short-term. Reducing prediction error will be the main objective.

3. MODEL FRAMEWORK

The advantage of using GA for selecting the appropriate input variables, instead of using statistical methods, is that in the same time that the number of input variables is decreased the power of forecasting is maintained.

Figure 1 shows the structure of the model used, in the process of forecasting the wind speed.

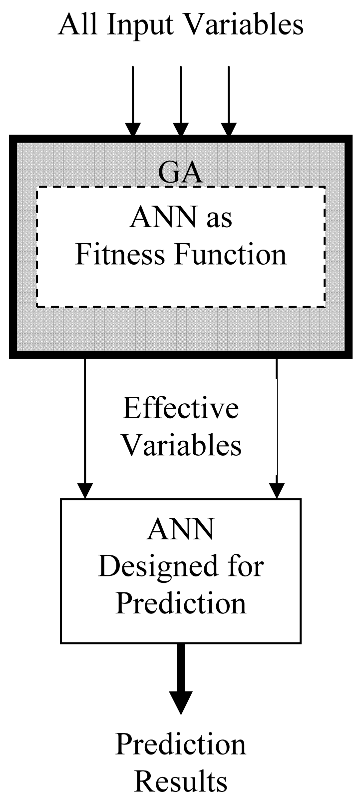

Fig. 1. Structure of the hybrid model

This is a hybrid model consisting of a GA and an ANN. Some authors [7] argue that the use of these hybrid models when used in forecasting problems allow the reduction of the prediction error.

All input variables are used in GA, which is used as a heuristic method to select the most appropriate combination of variables that would be the best outcome in terms of the ultimate goal, the minimization of error in forecasting. An ANN is used as a basis for evaluation for GA. Another ANN is then used to make a forecast of wind speed, using as input the variables that were previously selected by the GA.

3.1 Genetic Algorithm (GA)

This reduction in the number of variables at play helps accelerate the whole process of forecasting the level computing, will provide faster responses, which selects the variables in fact be the most effective in solving the problem, get a reduction of the error end of forecast, thus resulting in more accurate forecasts.

The GAs are models of machines that use of learning the metaphor of the evolution of species, in a simulation of these processes, with the ultimate goal of helping to solve problems, that is, aim to optimise a set of parameters that, instantiated, give us the solution of the problem.

As the GA work with a codification of parameters and not with their own parameters, we use a binary chromosome character to represent the variables of the problem. The number of genes of chromosome identifies the number of variables of the problem. In any chromosome, the 1 represent the presence of a variable and 0 their absence. Thus, for example, the chromosome [1 0 0 1 0 1] represent the choice of 1 st, 4 th and 6 th variables of the problem variables as effective.

The GA algorithm starts with a population of individuals (represented by a set of chromosomes) were each individual is a potential solution to the problem at hands. As in Nature each population may produce an off-spring by combination of genetic material of the individuals in the population. The Natural Selection law in GA is implemented by discarding the individuals less fit in the population and also by allowing only the most fit to participate in the next generation. In our implementation we have used the GA single-point crossover and the single-point mutation operations. In a GA the process of producing off-springs, selecting the most fit is an iterative process, maintaining the size of the population fixed and terminating only after a fixed set of cycles or when the fitness function reaches a desirable value. In our implementation the fitness function is an ANN trained with the input variables determined by the chromosome encoding.

While the successful application of a GA for the resolution of any problem is heavily dependent on the efficiency of the method of codification of the possible solutions of the problem in terms of chromosomes, a function of the use of appropriate assessment is important to make more efficient the process of training the ANN.

3.1 Artificial Neural Network (ANN)

According [8] connectionist models that are able to learn using historical data are adequate tools for predicting future situation where noise and incomplete information are present.

In the hybrid model that we present here, the Multilayer Perceptron (MLP) as well as GA fitness function is used for forecasting. The MLP consists of one hidden layer with Tan-Sigmoid activation functions of neurons.

Training of the network is carried out by using the algorithm of Levenberg-Marquard and is available in the ANN Toolbox of MATLAB [9].

Tests to determine the optimal size of the hidden layer of the network have come to conclusion that the best results were obtained with 6 neurons in that layer. This will be the size used for the hidden layer in all the predictions made. The size of the network layer varied in terms of input as to solve the problem but kept hidden 6 units and one output variable.

As [10] in this paper we will use, mean square error (MSE) as error function (equation 1).

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - \hat{y}_i \right)^2 \quad (1)$$

Where y_i is the actual value, $\hat{y}_i$ is the forecasted value and n is the number of validation data.

4. CASE STUDY – WIND FORECAST IN MITRA

The meteorological station of Mitra operates several years there, and it holds a considerable historical data. The station has recorded data at intervals of time of 10 minutes, wind (direction and speed) and humidity and air temperature, since 2002 until this year. We address the problem of forecasting the wind speed for the next day. Because April 2007 presents a considerably variation of hourly wind speed, one day of this month (1 April) was chosen.

For the purpose of forecasting were tested two models, one containing all the variables of the problem (not including the GA and allowing all variables enter the forecast for ANN) and the other including only the actual variables selected by the GA (the ANN is fed only with the variables selected). Thus it will be possible to make a comparative assessment of the merits of the proposed model.

3.2 Prediction of Wind Speed

For this short-term forecast (forecast the average wind speed at the hour for the next 24 hours), 10 variables were considered for entry (wind speed and direction, temperature and relative humidity of air, change of speed, change of direction wind, etc.). For this prediction was considered only the data from 24 hours prior to the forecast.

In the model that does not include the AG, which it uses to predict all 10 input variables. The results can be seen in Figure 2.

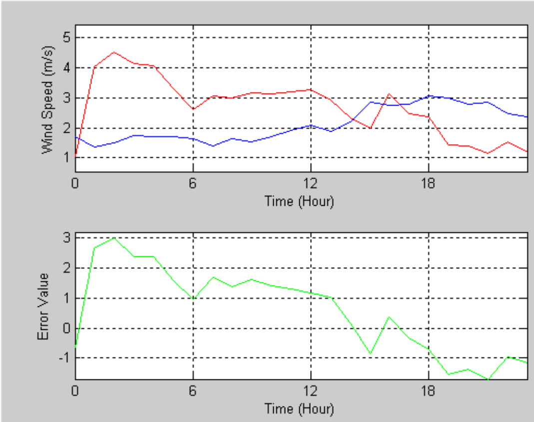

Fig. 2. One day ahead prediction of wind speed – without GA (1 April 2007)

Using now the hybrid model proposed by keeping the number of input variables constant, the optimal mix was produced following: [0 0 0 1 1 0 1 0 1 1] which means that the GA from 10 variables selected only 5 as possible variables effective to forecast.

Now using these 5 variables selected by the GA (intensity and direction of wind, relative humidity, direction change in the previous hour and difference between the wind intensity value and the day average), the results are seen in Figure 3.

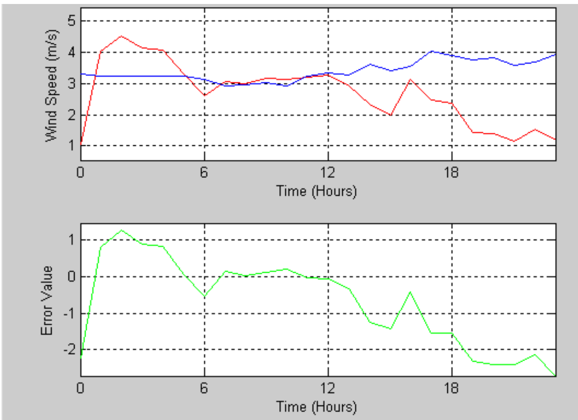

Fig. 3. One day ahead prediction of wind speed – with GA (1 April 2007)

As we can see there was a clear improvement in the results obtained, or in comparison with the previous model, both in absolute terms. Not only is gained in terms of speed of computing (less variables), and in terms of ultimate objective (effective use of variables). In fact, the hybrid model allows not only faster decision but the reduction of the prediction error.

5. CONCLUSIONS AND FUTURE WORK

The methodology that is presented here shows very promising results in terms of short-time wind forecast (24 hours). Indeed, the importance of such forecasting is very important when you want to do the assessment of wind energy potential of a place or a region. The hybrid model presented allows the one hand, increasing the speed with which the forecast is made, and secondly, reduce the number of variables involved, considering only the most relevant to the problem in question. The tests that were presented here show a region of weak winds and without major changes throughout the year. It will be so in the near future to test the model presented to a region of strong winds and variations with either daily or monthly bigger to take a test on the most effective mode it proposed.

6. References

[1] Castro R., "Energias Renováveis e Produção Descentralizada – Introdução â Energia Eólica", Universidade Técnica de Lisboa – Texto não publicado, Instituto Superior Técnico da Universidade Técnica de Lisboa, Lisboa, 2003.

[2] INETI, http://www.ineti.pt/projectos, 2008

[3] WASP, http://www.wasp.dk, 2008.

[4] Kalogirou S., Neocleous C., Pashiardis S. e Schizas C., "Wind Speed Prediction Using Artificial Neural Networks", Proceedings of the European Symposium on Intelligent Techniques. ESIT'99, Crete, Greece, 1999.

[5] Kariniotakis G., Pinson P., e Siebert N., "The State of the Art in Short-term Prediction of Wind Power – From an Offshore Perspective", Proceedings of 2004 SeaTechWeek. Brest, France, 2004.

[6] Makvandi P.,Jassbi J. e Khanmohammadi S., "Application of Genetic Algorithm and Neural Network in Forecasting with Good Data", Proceedings of the 6th WSEAS Int. Conf. on Neural Networks, Lisboa, Portugal, June 16-18, pp.56-61, 2005.

[7] Alvaro V., "A hybrid linear-neural model for time series forecasting", IEEE Transactions on Neural Network, V(11), pp.1402-1412, 2000.

[8] Preschelt L., "PROBEN1 A Set of Neural Network Benchmark Problems and Benchmarking Rules, Research Report", Research Report, Fakultt fr Informatik, Universitt Karlshuhe, 1994.

[9] Demuth H. e Beale M., "Neural Network Toolbox for Use with MATLAB User's Guide, Version 4", MathWoks, Inc, 2003.

[10] Makvandi P.,Jassbi J. e Khanmohammadi S., "Application of Genetic Algorithm and Neural Network in Forecasting with Good Data", Proceedings of the 6th WSEAS Int. Conf. on Neural Networks , Lisboa, Portugal, June 16-18, pp.56-61, 2005.

MEASURING MATERIAL FLOWS IN INDUSTRIAL PROCESSES
A KEY STEP TOWARDS SUSTAINABLE PRODUCTION

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Keywords: manufacturing; strategy; performance-measure(s); methodology; innovation

INTRODUCTION

Industrial wastes consist of unused resources in the production process, which create costs and no added value.

Measuring material flows at a company level is therefore crucial for waste prevention, which is a key path towards higher resources productivity. Waste prevention strategies focus in particular on reducing or eliminating undesired waste streams, and managing by-products within the production process, rather than treatment and disposal approaches. In the long run, prevention strategies are more cost-effective and environmentally sound than conventional pollution control approaches [1].

Waste prevention strategies apply to any manufacturing process and range from relatively easy operational changes and good housekeeping practices to more extensive changes such as replacing input materials, fine tuning or replacing equipment, or even making use of state-of-art technology [2].

This paper provides insights on the development and testing of a toolbox for the inventory and management of waste flows looking forward to implementing a ‘zero waste’ strategy in real industrial conditions.

MATERIALS & METHODS

Twelve case studies selected within seven Portuguese industrial branches were explored. The toolbox included an activity based costing methodology, as well as detailed process mapping and material balances used at company level to measure resource flows and undesired waste streams, and thus to fix optimisation targets by integrating waste prevention into business strategies.

Material Flows

Material flows were analysed at a process and operations level, and material balances performed and used to monitor resource productivity improvements and the environmental performance, at a company level.

Zero Waste Strategy

This strategy aims to avoid non-product outputs by integrating resource optimisation targets and waste prevention into business strategy.

Tool Box

Main complementary tools were used throughout a multistage process (fig. 1), which included process mapping and mass balances, activity based costing, Pareto analysis, cause-effect analysis, and cost-benefit analysis.

Fig. 1. The PreResi method

A Case Study Approach

Seven industrial branches were selected on the basis of their waste prevention potential, size (nr. companies) and waste volumes produced. In each of the 12 cases studied, after being previously involved in a cascade training process, actors from each company have been cooperating in practical work looking forward to using a activity based costing methodology to ‘zero-waste’ activities and to extending their gained experience to new initiatives with the support of a cooperative network.

Actors

INETI, INR-National Institute for Wastes, Branch Associations (8), Technologic Infrastructures (7), and the following Companies:

- Acatel, SA
- Erofio , SA
- Fitcom, Lda
- Hydro A. Portalex, SA
- Irmade, SA
- JSL, Lda
- Malhas Sonicarla, SA
- Olegário Fernandes, SA
- Offsetlis, Lda
- Peltéci, SA
- Tintas Dyrup, SA
- Toyota Caetano, SA

RESULTS & DISCUSSION

Cascade Training

The aim of performing a cascade training process was twofold: expert training on industrial waste prevention, eco-efficiency and on the zero waste strategy in particular, was provided to a wide group of actors (Industry, Branch associations, Government, University, Technological Centres, Consultants) considering their key role in value chains [3,4]; next, selected experts from the previous group, provided branch oriented training to companies on the pre-selected industrial branches enabling a previous contact both with the method and the toolbox, before getting involved in practical work in the companies.

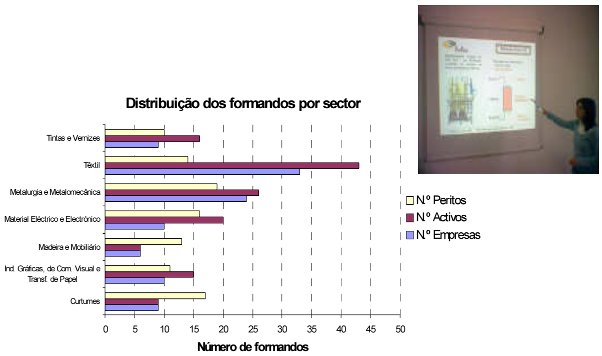

Fig. 2. Training provided to seven industrial branches

This step provided a 70 hours training program to 244 participants, 100 companies included.

Implementing the Method

In real industrial conditions, twelve case studies were performed from April '06 to April '07 following the different steps of the PreResi method, as represented in figure 1.

In each case studied, process analysis was performed on an activity basis, including auxiliary activities, with the identification and quantification of both the used resources (raw materials, auxiliary materials, water, energy and manpower), and the effluents & residues generated in each step.

Taking, for instance, the case of truck manufacturing [5] and a process step in particular, consisting of a primary and an enamel or metallic painting, as represented in figure 3.

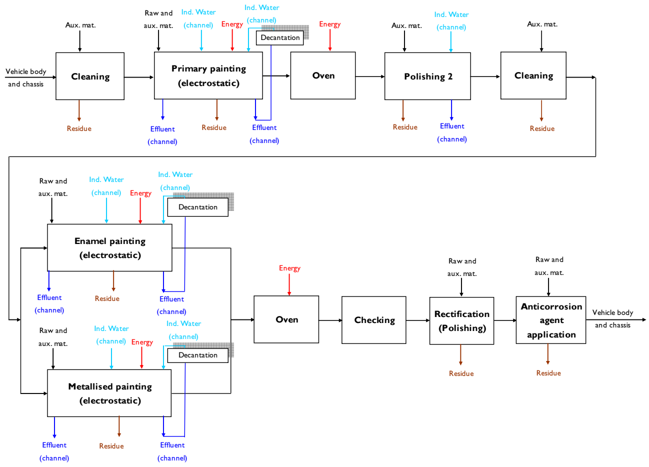

Fig. 3. Example of a painting process step within a case study approach

For a given process step, accountings of material flows and costs on a year basis regarding resources, effluents & wastes, such as the one represented in figure 4, enables to put in evidence the relative meaning of non-product outputs.

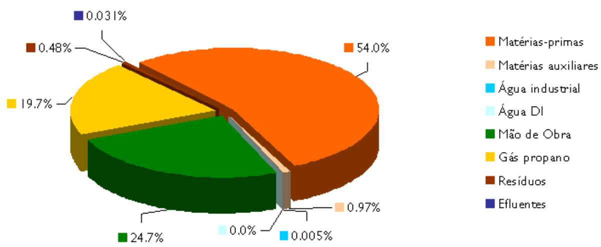

Fig. 4. Annual costs distribution in the painting process, focusing on a given booth

Activity after activity, having gathered detailed data throughout the whole process, in particular about the different non-product outputs occurring in each operation, it enabled to proceed with problem definition. In order to manage a wide variety of improvement opportunities, an effective approach consists in applying the Pareto principle and representing the hierarchy of waste costs quantified in those operations (fig. 5).

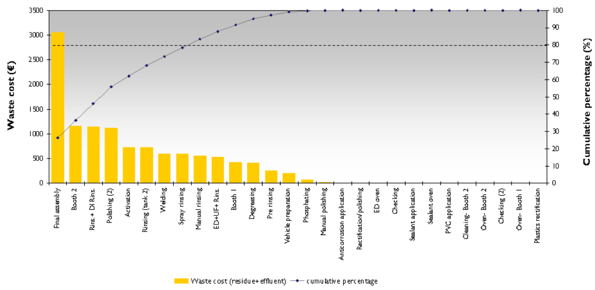

Fig. 5. Hierarchy of costs for waste prevention purposes

After using the Pareto's 80:20 rule it is time then to focus on the 20% of causes that are corresponding to the 80% of total costs. As a rule of thumb, each lost resource means an improvement opportunity to prevent such loss. This step enables therefore to define priority improvement opportunities on a costs basis. Other priorities and criteria may be considered (e.g. company's auditing issues) at this stage, before performing root-cause analysis focusing on each particular waste problem.

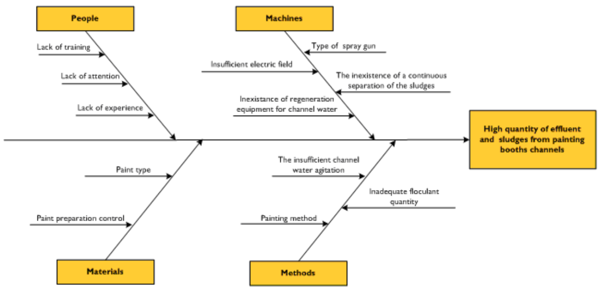

Fig. 6. Root-cause analysis: The case of painting wastes in booths channels

Taking for instance the painting booths and in particular the painting booth for the coating of metal parts. That particular booth includes a water channel for the collection of paint droplets that result from the overspray. In booth operations the main occurring wastes consist of sludge from booth channels cleaning and from the liquid effluent also generated in that operation (i.e. channel water). Taking four root-cause classes, the Ishikawa diagram in figure 6 represents the analysis performed focusing on the painting operation including the channel cleaning. The identification of root-causes in this particular case enabled to emphasize two main issues:

- The inexistence of a continuous sludge separation;
- Non sufficient water mixing in the channel, and inadequate amount of flocculating agent, which results in the existence of a solids layer (paint particles) on top of the water.

Having concluded this analysis, it was possible to explore improvement alternatives for each of the priority issues.

In the particular context of the painting process a deeper analysis was performed focusing on the amount of sludge and effluent that result from the channels in the painting booth.
Because of over-spraying effects occurring in that booth, the channel currently needs cleaning every 3 months. Such cleaning includes removing the sludge collected and sending the aqueous solution to the wastewater treatment plant (WWTP). The amount of sludge removed from the channels (about 5 ton/ y), and its management cost, justifies this analysis. In addition, even though the effluent volume (about 320 m^3/ y) sent to the WWTP and its costs are not a priority issue, it was considered an opportunity to be integrating such evaluation as potential was identified to reduce cleaning operations. Having decided that, the following issues were discussed:

a) Electrostatic painting - the existence of insufficient electric fields can originate higher paint dispersion. There is, consequently, a sludge amount increase that accumulates in the channel. It is thus convenient to periodically implement a check plan focusing on that equipment in use.

b) Flocculating/coagulant agent concentration - its optimization enhances paint particles precipitation. Therefore, the remaining water contains less paint in suspension, and consequently the cleaning cycles can be reduced.

c) Sludge and water consumption – Effective water/sludge separation is not a reality, thus resulting into a greater sludge quantity than technically feasible, as well as on greater transportation costs due to their higher water content. In addition, makeup water has to be introduced frequently. If an effective water mixing system could be installed, water would run in a closed loop circuit. It could thus move through a solid-liquid separation system (decanter; filter), enabling continuous particle removal. The effectiveness of sludge separation would consequently increase, and wastewater discharges would be less frequent. Adding to that, if water mixing could be installed, it would provide a sufficient air flow to prevent odour releases.

In brief, solutions identified and proposed after this stage, within the scope of the painting booth, were the following:

- Perform regular checking of electric fields in the electrostatic painting;
- Optimize the flocculating agent concentration;
- Set up an effective mixing system for the aqueous effluent;
- Implement water recycling in a closed loop circuit, running through a decanter/filter system, looking forward to solid particles removal and to the reduction of water consumption.

Finally, the solution evaluation stage provided an interesting discussion about competing technical alternatives, e.g. vacuum evaporation against flocculation and separation. After a first economic assessment, which lead to the conclusion that vacuum evaporation would require an 50 kEuros initial investment approximately, plus energy costs around 3.2 kEuros per year, then tests were performed focusing on a flocculation combined with a 200 μm filtration option. Main conclusion was that investments required would be about 20 kEuros, plus operating costs around 1.5 Euros per hour, which includes air injection in order to promote mixing effects. Within this option, equipment adjustments might be expected due to the variation of contaminants concentration along time. Following this path, the company may expect as well a longer effluent discharge period (1 year approx.) in the WWTP service, i.e. lower effluent volumes and treatment costs. This is a key input for the very final stage of the method: implementation and monitoring, which will have necessarily to match with company's own investment planning.

Extending this approach to the whole production process/ company, it enables the organisation to creatively enrol its staff within different departments, and to identify and evaluate improvement alternatives to solve the previously selected priority problems (fig. 7). In each one of the cases studied [6], empirical results showed:

a) The usefulness of the approach. Different statements from companies reflect that:

   1. "Value creation, by quantifying and analyzing graphically the resources involved, and thus preventing in the exact process stage that a given resource (e.g. raw-materials, energy, human power) might result into non-product outcomes and waste";
   2. "Immediate implementation of low cost solutions, and the definition of actions for continuous improvement" (resources; wastes);
   3. "Better insights on each process and operation in the production line"; "Measure to enable a better management"; "To focus and be very objective about existing problems, and have an hierarchy for action planning";
   4. "Integrate waste management into total quality management" (...trough continuous improvements, in practices, equipment and processes taking a zero-waste direction);
   5. "Using new tools" and "Doing better with less";
   6. "Involving workers in company's problems";
   7. "Creating (...or improving) Environmental Management Systems"; "Look at environmental management as an opportunity to stimulate productivity improvements, and other less succeeded issues".

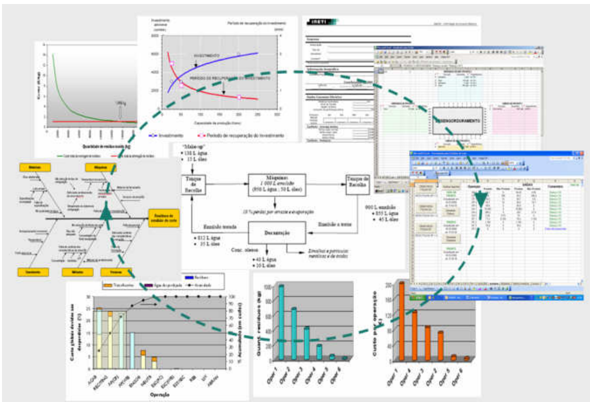

Fig. 7. The method after implementation

b) How powerful waste prevention is. It provides strategic inputs for decision making, and a hierarchy built on an economic and environmental basis. In whole, improvement solutions types as proposed to companies had in a aggregated form a distribution as represented in fig. 8. This shows in particular the key importance and the direct role workers have in waste prevention, together with the improvement opportunities regarding raw material selection and process changes as well.

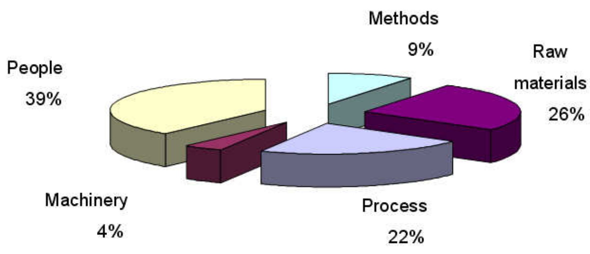

Fig. 8. Solutions aggregation by types to feed-in the improvement process

c) How critical operating conditions are, and therein both branch or company's culture, in order to influence the implementation of waste prevention initiatives.

CONCLUSIONS

Experimental data enables to have insights on:

- Companies' opportunities since they began involved in the program till their individual case study was over.
- The benefits of waste prevention approaches, as described in literature.
- The importance of operational conditions (company, sector), as well as of key actors enrolment inside each company, to make progresses in such kind of initiatives.
- The opportunity each industrial branch has to discuss conclusions achieved in each case study, and the potential they have, in particular when considering the EU Thematic Strategy on the Prevention and Recycling of Waste, the Portuguese National Plan on Prevention of Industrial Wastes (PNAPRI) [8], as well as the EU Strategy on Sustainable Use of Natural Resources.
- In case a particular waste type cannot be avoided, a key primary step consists on its reduction (quantity, danger) as far as it is technically possible, following the waste hierarchy [7] and a life cycle perspective.

Main conclusions drawn from those case studies enable to propose both at a:

- Micro level - new options for process and product improvement.
- Meso level - a chance to enroll companies within a given industrial branch and/ or a given region, to contribute for the mapping of wastes (quantity, quality). Those wastes might be addressed as resources eventually useful within other value chains beyond the boundaries of the original industrial branch.
- Macro level - hypotheses about how public policies may address waste prevention, and about the diffusion of eco-efficiency in those industrial branches, in order to pave the way towards sustainable production.

References

[1] Pearce, D.W. & Turner, R.K., The economic evaluation of low and non-waste technologies. Resources and Conservation, 1984 (11): p. 27-43.
[2] Dieleman, H. and De Hoo, S. Towards a Tailor-made Process of Pollution Prevention and Cleaner Production: Results and implications of the Prisma Project, in: Environmental Strategies for Industry – International perspectives on research needs and policy implications, K. Fisher and J. Schot Editors. 1993, Washington D.C.: Island Press, p. 245-275.
[3] Partidário, P.J. & Vergragt, Ph.J., Shaping Sustainable Technology Development in the Coatings Chain. Defining boundaries, environmental problems and main players. Journal of Cleaner Production, 2000 (8) 3: p. 201-214.
[4] Partidário, P.J., "What-If": From path dependency to path creation in a coatings chain; A methodology for strategies towards sustainable innovation, PhD Thesis, Delft University of Technology. 2002, Delft (NL): Druk Tan Heck.
[5] Ribeiro, C. et al, Manual para a Prevenção de Resíduos – Estudo de caso para o sector da metalurgia e metalomecânica: Toyota Caetano Portugal SA, J. Figueiredo e P. Partidário, Editores. 2007, Lisboa: INETI.
[6] http://preresi.ineti.pt
[7] Proposal for a EU Waste Directive, Working Document ref. 8696/07 ENV 204 CODEC 379, 2007: Brussels 25 April.
[8] Figueiredo et al, PNAPRI – Plano Nacional de Prevenção de Resíduos Industriais. 2001, Lisboa.

ANALYSIS OF THE SIMULATION METHODOLOGY OF PALLETS TRANSPORT PROJECTS BY AGVS

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Keywords: Technology, simulation, techniques and tools for industrial engineering, supply chain, return on investment, manufacturing systems.

INTRODUCTION

This paper analyzes the benefits of using the simulation tool in a pallets transport project by using automatically guided vehicles (AGVs). The simulation is currently recognized as a powerful and flexible tool which is becoming essential to the viability of a variety of existing systems/projects. In this paper we examine the specific models of the simulation created to analyze of AGV systems. To better understand the advantages inherent to the simulation and in order to understand what caused its development, this paper researches the analytical and simulation tools.

THE REAL PROBLEM

This project investigates the use of AGVs on the shop floor instead of transport using stackers, guaranteeing the continuous supply between the process supplier and customer. The problem is based on three machines that continuously produce 30 different kids of materials automatically put on pallets and that will be used by three distinct groups of final customers, all of them with different needs and consumption locations.

Currently, the transport is performed by two stackers and the management is done with a very high slack coefficient; in other words, for safety reasons, the amounts of pallets with rubber moved are superior to the demand. This way of functioning implies two extreme situations: large amounts of material for the final customers, or, in case of management failure, the customer makes an order for a determined article directly to the stacker collaborator. The simulation model should allow elaboration of the best solution to visit every customer fulfilling the requirements / needs / priorities of each one of them, appealing to the minimum number of AGVs in the solution.

The image presented at Figure 1 allows the identification of the complexity of the model, particularly the resources to model, and the needs and priorities to consider. It is necessary to determine the best route to define each AGV, considering the exceptions associated, such as the production failures of the internal suppliers or malfunctions of the automatic storage system. The obstacles (collaborators, AGVs, existing machines, etc.) are another important aspect in the route elaboration. The distances between suppliers to the warehouse to the customers vary between a minimum of 60 meters and a maximum of 450 meters.

The model developed will realise the transport of pallets with rubber at a FIFO methodology, and should readily obtain, among other factors, the optimum amount of pallets with rubber for each internal customer, guaranteeing the success of the production process, but also releasing the maximum space for each customer. This project presents advantages on the transport optimisation, the exploitation of resources, man power reduction and productive planning.

AGVS – AUTOMATED GUIDED VEHICLES

AGVs are modern equipment for handling/transporting materials [1]. At a technical level, they are characterized by autonomous movement with batteries that allow periods of functioning up to 24 hours, reducing the possible minimum times loading batteries.

The AGVs are controlled by a computer and follow established routes through physical lines marked on the pavement (conducting wire or colorful line) in regular intervals or virtually by radio or laser control.

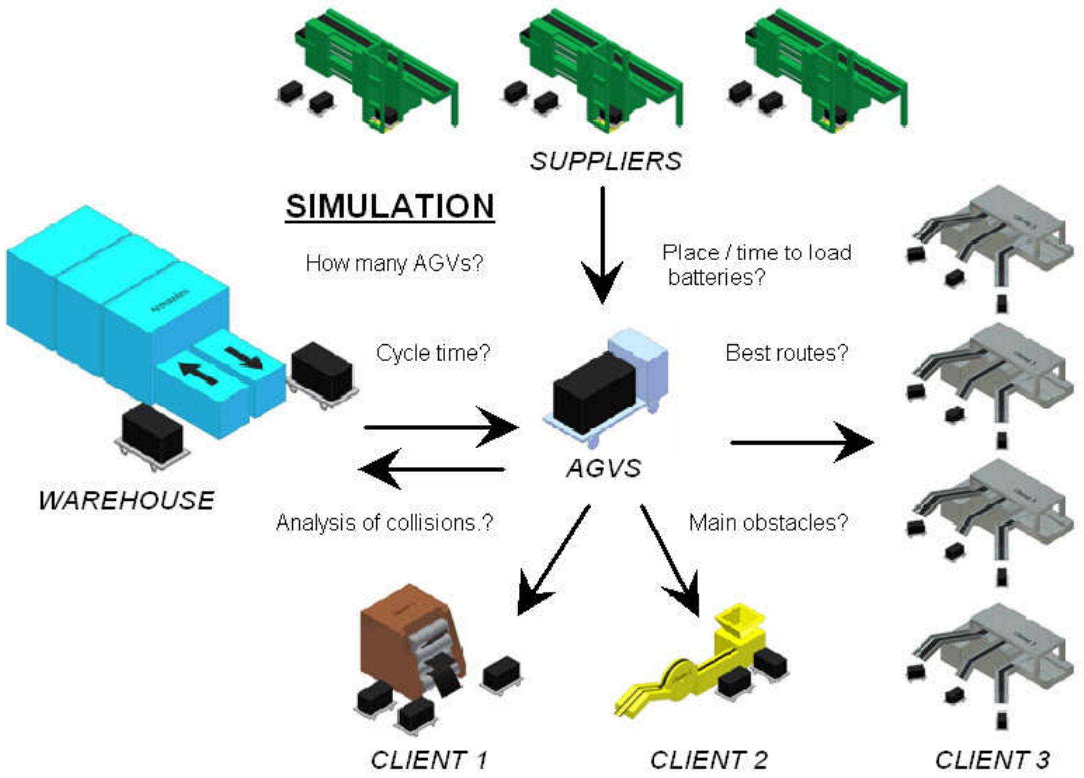

Fig. 1. Generic representation of the model to simulate

Regarding safety, the AGVs are equipped with ultrasound and optic sensors to prevent collisions with obstacles that can appear, such as collaborators or other AGVs. The navigation system follows the magnetic field generated by conductors implanted in the ground and covered by a sinusoidal electric chain. The magnetic field is detected by two antennas. This navigation system is technically known as wire-guided. The disadvantages of the wire-guided and optical guided systems are the difficulties of installation and movement limitations. These restrictions stimulated the development of techniques without wires (wireless solutions) such as the laser triangulation, matrix of references, or orientation by gyroscope. In this way, the available options to guide an AGV are the following: guiding systems by inertia, guiding systems by laser, wire-guided system, guiding systems by magnetic ribbon.

According to the Material Handling Institute of America (1993) the main benefits of the use of AGVs are the cost savings with man power, greater flexibility in the materials handling and transport, better organization of programming WIP (Work In Process), better use of the available space, bigger safety of the systems, increase of the production, and more efficient control of inventories.

Another important aspect to mention is the growth of the market in small systems, i.e., projects that do not have more than three to four AGVs, in comparison to the market of great and complex systems which use fifty or more AGVs. This situation is due to the maturity of the equipment and technological advances that allow successful solutions that are economically more flexible and attractive.

According to the Material Handling Industry of America, 1,144 AGV systems have been installed since 1990, resulting in a total of 6,127 vehicles; in 2005, there was an increase of 20 percent in the investment in AGVs in North America.

THE SIMULATION

With the development of computers and software, the simulation is seen today as one of the most powerful tools in the analysis of the viability of models that support real projects. Since the 1980s, simulation has occupied a prominence place among operational research tools.

From the analysis phase of the problem and definition of requirements until the conclusion of the project, the simulation can make the difference in the elaboration of a project into the most diverse areas of application, with prominence in production systems, including this research project. The growth in the use of simulation in the resolution of large-scale problems only became possible because of the great availability of the existing computational resources.

Pegden [2] defines simulation as the process to project a computational model of a real system capable of leading experiences with the intention of understanding its behaviour, allowing the evaluation of strategies for its operation.

It is important understand what systems and models are necessary to know the simulation's coverage. The first applications of simulation were developed in formal programming languages, as FORTAN [3]. These simulations demanded an enormous effort of modelling, which turned the use of simulation into an impractical use.

The first specific languages for simulation appeared around 1960. These languages supplied the user with a set of facilities to transform the formal model of the system into a computer program, and made available functions and routines destined to sampling, statistics analysis and control of the advance of the time in simulation. Although there is a simplification of the programming, the flexibility and the computation efficiency are partially sacrificed. Moreover, the maintenance cost tends to be higher, mainly because of the low availability of qualified staff, as a consequence of the reduced diffusion of these languages. Built into this scheme were languages such as GPSS (General Purpose Simulation System), GASP (Graph Algorithm and Package Software) and SIMULA.

Although these languages have been the solution to the problem for a long time, the bigger complexity of the systems allied to the requirement of showing the production people the real benefits of this tool compelled the evolution of the software to include animations, which are basically software that run simultaneously with the simulators and have the capacity to graphically reproduce the systems and the models. From these technological advances appeared software such as SIMAN / CINEMA and GPSS /H. At this point it becomes obvious that the users of the simulation models were the analysts themselves. This fact makes possible the development of the simulation application VIS (Visual Interactive Simulation). This technology is based on the modelling of icons that gather commands from the traditional languages of simulation and transform the development work into an easier task with an interface similar to Windows. In this kind of software, we have references such as ARENA, PROMODEL and AUTOMOD.

THE AUTOMATICALLY GUIDED VEHICLES SIMULATION

A system of AGVs is defined as an advanced material handling system through autonomous vehicles guided by a virtual path and controlled by a computer. In opposition to conventional materials handling systems, the AGV systems are capable of defining for themselves a better route or way to reach their destination. The forwarding commands, such as material to load, origin, and destination arrive at the AGV through a computer. These systems are known by their raised flexibility in material handling systems in the most diverse areas of application, particularly in Flexibility Management Systems (FMS) and Flexibility Assembly Systems (FAS).

The project to model the system and the correspondent control are two of the points of interest and development of the AGV systems. The first one is basically related to the disposal of the methods to follow and the amount of vehicles to use, whereas the control of the system is related to subjects connected to the decisions of the routes to take, forwarding orders and control. The success of an AGV system is strongly related and dependent of the quality of the projected system and of the type of control used. It is necessary to consider a great variety of factors when projecting an AGV system, such as the number of AGVs to use, net of paths to configure, type of control to use, rules of forwarding (types of load, load orders, destinations), definition of the routes between the origin and destination, and the interface with other material handling systems.

Partially due to the great complexity and dimension of the AGV systems, the traditional techniques of analysis such as analytical tools are not enough for the project, control, and system evaluation. These reasons stimulated the development of the tools associated to the simulation. The growth and popularity of the simulation is due to the development of dedicated tools such as ARENA, and to the competition between diverse software suppliers. One of the great intentions of the simulation tools, including ARENA, is to transform the model creation process into a simple and fast task.

CRITICAL ANALYSIS OF THE STATE OF THE ART

The research of the state of the art technology related to the use of the simulation methodology in the pallets transporting projects where the key solution is based on the use of AGVs has been the subject of study and scientific discussion since the mid-1950s.

This analysis has as its main goals the demonstration of the foundations of methodology, the evaluation of the strengths and weaknesses of the previous research, demonstrating that the level of knowledge in this area is up-to-date and include the most important research theories in the area.

On the basis of this critical analysis, we identify two tools used to model systems that appeal to the use of AGVs—the set of analytical tools and simulation tools. The first ones are mathematical techniques such as integer programming, heuristic algorithms or Markov chains. As for the simulation tools, it is an approach to the most popular systems on the market, through the presentation of case studies as references in the field of simulation of AGVs; in many cases they were the basis for the development of the currently available systems, such as ARENA, Promodel, and Automod.

Analytical Tools

Tanchoco et al. [4] compared the effectiveness of the analytical model based on the theory of queues for the analysis of work flow in a business/manufacturing system, called CAN-Q, with a simulation for the same situation using AGVSim software [5]. As a result, the analytical tool, CAN-Q, underestimated the number of vehicles driven automatically required for the solution. However, the results obtained through the CAN-Q are a basis for the construction of a simulation model.

Mahadevan and Narendran [6] developed an analytical model to estimate the number of AGVs to use in applications. The suggestion of these authors was to begin the processes with an analytical methods rough-cut, followed by the use of sophisticated mathematical models and only then use the simulation in case of high complexity of the AGV system. As the system parts were increasing, the problem became complicated in a way that the analysis by the simulation models became essential to achieve the solution for the problem.

In this way, the analytical techniques may have shortcomings when applied in actual cases in the industry and can give inaccurate estimates when used in random environments. In conclusion, the analytical techniques should be understood as a good way to a first approach for drawing a solution of AGVs systems and obtaining the initial estimates [7].

Recently, Koo and Jang [8] presented a stochastic model to determine the time of travel of the vehicle to solve the transport of materials in the manufacturing industry. This model shows the time of transport of empty loads. The model created was the basis for the creation of the model to simulate. The joint solution, an analytical tool/simulation, was formed by a simulation model with the capability to evaluate the performance of the AGV system and by an algorithm that minimizes the number of repetitions of the model in the search for an optimal solution.

The increased complexity of the problems modelling, as well as their physical dimension, when associated with the advances of computing power (processing and graphic animation times) led to the decrease of solutions based on analytical tools, through an initial phase in which integrated simulation models appeared, to a second phase used as the basis for specific studies of the model on which the simulation will not get very accurate results.

Tools and Simulation Methodologies

The software available for simulating AGV systems can be grouped into three groups [9]:

- Simulation languages of common use (e.g., SLAM II, SIMAN IV);
- Simulation packages specific to manufacturing systems (e.g., SIMPLE++, AutoMod II, ProModel, Arena);
- Simulation software created specifically for AGV systems analysis, based on the use of general programming languages such as the C programming language, FORTRAN, BASIC, among others, (e.g., AGVSim, SattControl or MATSIM).

NEXT STEPS OF THE RESEARCH

The new system should be able to ensure the supply of pallets with rubber to each internal customer without causing any stops in the production process. For the definition and study of the model it will be necessary to address the following aspects:

- Collect as much information as possible to characterize the problem;
- Set the inputs of the model;
- Identify the existing variables and understand the relation between them;
- Set priorities and exceptions;
- Structure the problem;
- Investigate equivalent practical cases developed to respond to problems with the same base, that allow discovery of options to be taken;

- Choose the software to use in the development of the model.

The choice of the software most appropriate to the reality of the project, by study and comparison to other "case studies" addressed in the critical analysis of the most advanced technology converges on ARENA software. The skills inherent in it, including the graphic and animation ability, ease of programming, verification and disposal / detection of errors tools (debugging tools) and the dedicated reports, respond well to the needs of the project.

CONCLUSIONS AND RECOMMENDATIONS

The AGV systems are particularly useful handling materials in manufacturing systems. The simulation is used frequently to assess the performance of existing systems or AGV projects in the initial phase of the feasibility study. Achieving a simulator flexible enough to model specific or general systems is, in our view, the development area to explore in the future of the simulation tools systems designed to AGVs systems.

Another area under development is related to the methods to guide and control AGVs, especially with the development of GPS applications dedicated to the control and placement of AGVs. The ease of implementing strategies, test layouts and control resources to raise the problems inherent to the control of the built model, based on assumptions of a full assessment of all the restrictions attached, shows the importance of simulation studies of specifications for AGV projects in the manufacturing industry.

References

[1] Hammond, L. (1986) AGVs at work, IFS Publications Ltd., UK.

[2] Pegden, C.D., Introduction to Simulation Using Siman. 1991, McGraw-Hill.

[3] Paiva, F., Geração Automática de Modelos de Simulação de uma Linha de Produção na Indústria Têxtil. 2005, MSc Thesis, Universidade do Minho.

[4] Tanchoco, J.M.A, Egbelu, P.J., and Taghaboni, F., *Determination of the total number of vehicles in an AGV-based material transport system*. Material Flow 1987. 4: p. 33-51.

[5] Egbelu, P.J. and Tanchoco, J.M.A, AGVSim User´s Manual. 1982, Technical Report Nº 8204. Department of Industrial Engineering and Operations Research. Virginia Polytechnic and State University, Blacksburg, VA.

[6] Mahadevan, B. and Narendran, T.T., *Estimation of number of AGVS for an FMS: an analytical model*. International Journal of Production Research, 1993. 31: p. 1655-1670.

[7] Egbelu, P.J., *The use of non-Simulation approaches in estimating vehicles requirement in an AGV based transport system.* Material Flow, 1987. 4: p. 17-32.

[8] Koo, P.H. and Jang, J., *Vehicle travel time models for AGVs systems under various dispatching rules*. International Journal of Flexible Manufacturing Systems, 2002. 14: p. 249-261.

[9] Tanchoco, J.M.A., Material Flow Systems in Manufacturing. 1994, Chapman & Hall.

EXPLORING THE USE OF NEURAL NETWORKS IN URBAN TRAFFIC MANAGEMENT

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Abstract: The work described was developed as part of our interest in testing and pursuing alternative solutions to the main problem of traffic management. We focused our attention in the control of the traffic lights used at crossroads in urban areas, and tested the ability of neural networks to predict traffic flows.

Using data from an existing urban traffic area we tested various solutions based on the *Backpropagation* type ANN and the *Levenberg-Marquardt* algorithm. The results obtained showed that it is possible to model the patterns associated with the traffic flows over large time periods. However it was difficult to model accurately, in short periods of time, the discrete behaviour of the traffic flows.

1. INTRODUCTION

Traffic management remains today as a major problem in big cities. Allocating limited resources, i.e. roads, to an increasing number of users with individual needs and objectives, turns out to be a highly complex problem in most cases.

Considering global objectives such as reducing pollution levels and provide for an efficient use of energy, together as the problems associated with the stress of drivers facing congestions and long queues, illustrates the importance of dealing successfully with traffic management. On the other side, the number of variables that can be associated with the problem, the specific characteristics of each traffic area involved, the implications of decisions made at local levels (i.e. specific traffic lights) to other parts of the system, contribute to the enormous complexity associated with traffic management.

Limiting the circulation and access to parts of the roads network or city areas, has been justifiably used to limit damages and keep the system manageable. However the continuous evolution of technology, at the sensors and communications levels for example, creates windows of opportunities to further enhance the techniques and methods used to support traffic management.

The use of traffic lights to coordinate and control the access to resources by users (cars, people), has been for long a solution which guarantees high levels of security, even if not always guaranteeing a good efficiency at all times. The technology evolution allows extending its basic use to a more evolved one, in which the fixed cycle times and sequences, can instead be defined or influenced directly by the localised traffic conditions, or as a consequence of traffic conditions and policies defined in a centralised traffic management and control system.

However, taking advantage of these new possibilities requires dealing with more complex decision problems, due to the increase on the number of variables involved and the ability to model adequately their interrelationships.

At a more general level it can be considered as involving optimisation and control type problems and as such it can benefit from the latest developments on these subjects and alternative approaches. Artificial Neural Networks (ANN) represent one of the alternatives which seem to fit well the characteristics of the traffic management and control problems: the capability to combine multiple types of information into one system; its inherent nonlinear and parallel processing; capability to model the problem through the use of existing data rather than an explicit definition of the variables and interrelations involved.

Although these characteristics of ANN qualify them as an alternative approach to certain types of problems, they entail at the same time the development of solutions that most often apply on specific or case based problems.

The approach we followed consists of testing the ability of an ANN to predict traffic flows through a crossroad, in a city centre from which data was available. The idea was to develop a method to predict traffic variables at a local crossroad in order to subsequently use that information to influence the control of the traffic lights. The approach would be at a later stage to model and detect traffic situations to be made available for global traffic management.

The results obtained with a one step ahead (5 min) prediction show that it was possible to follow the patterns of the traffic flows through the crossroad along each day. But it remains difficult to predict accurately the next value of the discrete behaviour of the traffic flow, on the time scale used. Using the *Levenberg-Marquardt* algorithm it was observed that most of the times the ANN converged for a minimum value in a few iterations (less than 10).

In the next section (2), we concentrate on describing the strategies for traffic management. In section 3, we introduce the basic principles of Artificial Neural Networks, and discuss the main differences between using standard *Backpropagation* and the *Levenberg-Marquardt* algorithm. In section 4 we describe the specific case and Neural Networks developed: characteristics of the crossroad, data available, input/output mappings and the results obtained. In section 5 we present our conclusions and plans for future work.

2. TRAFFIC MANAGEMENT

Considering traffic management at a global level is ever more justified by the rapid technology evolution which allows an efficient gathering and deploy of information on different places of the traffic system and its elements. Dealing effectively with these new conditions remains today a problem not yet completely solved [13, 14], and various approaches have been tried or are still under development to find appropriate solutions for the various problems involved. A considerable amount of efforts is devoted to the development of solutions based on various techniques which can be associated with Artificial Intelligence (AI) [4, 15, 16]. One main problem is the ability to characterize the dynamic behaviour of traffic and the ability to predict its evolution. It would obviously represent an advantage to implement a global traffic management system, but it would as well be of interest to deal with more localised, i.e. traffic lights control problem. The object of several research works has been therefore to follow a step by step approach, testing and developing solutions for isolated traffic lights control problems and later try to expand their approach to more global solutions.

M. Patel an N. Ranganathan [4, 9] proposed a method for making decisions on the control of traffic lights in real time, based on a hybrid solution where ANNs are combined with Fuzzy Logic. The ANNs are used to identify the dynamic evolution and status of the traffic based on various inputs, and its output will be cast into the rules or classes defined through Fuzzy Logic processing.

In November 2001, Wu Wei and Mingjun Wang [3] presented a method to adjust the cycle time or phases of a four approaches intersection based on an urgency degree obtained from and hybrid Neural-Fuzzy solution.

In September of 2002, L. Z. Gamarra et al, [2] propose a Neuro-Fuzzy control system for the traffic of vehicles in crossings, using reinforcement learning techniques. Based on the results obtained on a specific simulated intersection it is claimed a reduction on queue sizes.

Based on the cases reviewed we decided to test the use of artificial neural networks to predict traffic variables in intersections using real data. The ANN algorithms were based on the backpropagation and Levenberg-Marquardt algorithm.

3. ARTIFICIAL NEURAL NETWORKS (ANN)

Artificial Neural Networks have been object of great attention in the last decades as an alternative approach to a vast range of problems. Developments occurred at the algorithms and methods levels and on their application or mapping to different problems. In spite of the continuing research works and expected further developments, they can currently be considered as an established technique with recognised advantages and limitations.

The advantages result from the basic principles on which the various ANN types are based: multiple and possibly parallel processing elements, natural and easily inclusion of nonlinear functions, the use of multiple adjustment parameters distributed over a network. These characteristics are combined with a methodology for finding the values of the network parameters that can be based on existing data, examples or instances of the problem rather than on an explicit identification of the variables and interrelations of these variables, required in a mathematical formulation of the problem. These characteristics result in clear advantages when considering an approach to model a vast range of complex nonlinear problems in different areas.

A first indication of the limitations of using ANNs as a solution to a problem is illustrated by the common claim: they should be considered as a second alternative, when the conventional one does not give satisfactorily solutions to the problem considered. One of the reasons behind this claim is the high number of design variables involved in the process of modelling a problem using ANNs, and the lack of rules or guides to support the decisions to be made. This makes the solutions highly problem dependent and most often design dependent. Another aspect which can be of importance is the lack of explicit understanding or explanation that can be obtained about the problem through its modelling into an

ANN, even if it provides a good solution. In addition there is no a priori guarantee that an optimum solution will be obtained, and furthermore that it could be obtained in a priori known number of iterations, or time.

In spite of these limitations a vast number of successful applications have been reported over the last two decades, and ANNs have gained there place as an alternative approach deserving consideration. The problems involved in traffic management and control are still an open ground for alternatives providing better solutions, and that's why we decided to use ANNs in this work.

Among the various algorithms developed to implement ANNs we decided to concentrate on Backpropagation because it has been widely used and reported to be useful in addressing problems involving recognition of complex patterns and performing nontrivial mapping functions [17, 18]. The Levenberg-Marquardt algorithm can be considered as an extension of the Backpropagation ANN with potential for faster convergence i.e. reduced number of iterations required to reach a minimum value of the defined error function.

3.1 Backprogation type NNs

The main characteristics of Backpropagation type NNs are: a multilayer structure, feedforward operation, and a supervised learning mode. Each layer contains a number of processing units, or nodes, with each node processing its inputs to obtain an output normally through a non-linear function (Fig.1 and Eq.1). Three types of layers should be distinguished: the input layer, the output layer, and the hidden layers. The input and output layers are defined by the specific modelling or mapping of the problem into the NN structure, i.e. the number and representation of the input and output variables respectively. Each node in an hidden layers receive information from all the nodes in the layer below, and sends, through its output, information to the inputs of all the nodes in the layer above. The number of hidden layers is a design parameter and most often one or two hidden layers are used on this type of NN. Another design parameter of the NN is the weight (Eq.1) associated with each of the connections, or links, between the nodes.

The method used for adjusting the weights of the connections characterises the learning process. In backpropagation type NN a supervised learning mode is used, which basically consists of processing through the NN a given input pattern, and comparing the obtained NN output with a known, correct solution (Eq.2). In standard backpropagation a gradient descent algorithm is used to minimise the error function through the adjustment of the weight values of the connections liking the nodes. The learning rate, α (Eq.3), sets the step changes of the iterative search and a selection for its value has a significant effect on the network performance. In order to ensure the network will settle to a solution it should be a small number (i.e. 0.05-0.25) [17], but obviously this means a larger number of iterations and consequently greater computational cost.

$$net_j = \sum_i w_{ji} \times a_i + b_j \qquad (1)$$

a- input, b-bias, w- weights linking node i to j

$$SME = \frac{1}{2}\sum_j \left(t_j - Y_j\right)^2 \qquad (2)$$

t_j- target value, y_j- network output

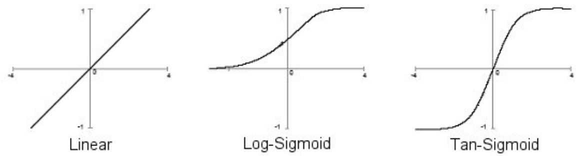

Fig. 1. Transfer functions

$$x_{k+1} = x_k - \alpha_k g_k \qquad (3)$$

x_k = weights and bias vector (current, updated value);

g_k = current gradient

α_k = learning rate

To improve the speed convergence of the algorithm several extensions to the original algorithm have being proposed. One of the possibilities that have been explored is to develop methods which make use of second order information [19, 20], i.e. second order derivatives, which allows for significant reductions in the number of iterations required to reach a stable minimum value of the error function. However, it is also involved calculating an inverse of the Hessian (second derivatives) matrix at each step, which can be very expensive computationally. The Levenberg-Marquardt algorithm is one of the methods developed which proposes to avoid this limitation by approximating the calculus of the Hessian matrix (Eq.4) [21].

$$x_{k+1} = x_k \left[J^T J + \mu I\right]^{-1} J^T \times e \qquad (4)$$

J – Jacobian matrix

I – Identity matrix

e – error vector of network

When the parameter μ approaches zero, the method approaches Gauss-Newton's method. When μ is high the method approaches gradient descending.

3.2 Training and Testing

Data represents a central issue in the process of designing a neural network based solution to a given problem. The learning phase is based on using examples, or instances of the problem, to provide an error function that can provide the basis for an adjustment of the network parameters (i.e. weights) throughout the learning algorithm. Backpropagation type algorithms generalise well but are not good at extrapolations [17]. Therefore attention should be paid to ensure the examples used are representative of the overall space of solutions for the given problem. The performance of the trained network will be tested on data not used during the learning phase. Allocating 15-20% of the available data for testing and the remaining for training is a common procedure.

Another aspect of the modelling phase is the codification of the input and output variables based on the objectives of the problem. This codification defines the number of elements and the values associated with each variable. One of the advantages of NNs is the possibility to include different types of variables. In order to equilibrate the influence of the different variables, it is common to use their values are normalised.

The number of hidden layers and elements are defined in a trial and test procedure. There are no universal guides on how to select the proper values for a given problem. We followed a basic assumption to enclose the values for the number of hidden nodes between a maximum and a minimum number. Increasing the number of nodes should guarantee better performance on the training set, but performance on the test set will be poorer, i.e. loose generalisation due to the higher number of parameters used in modelling the problem, which leads to “overfitting”. Conversely, reducing the number of hidden nodes will be less effective on the training set, but will comparatively increase generalisation over the test set.

Another issue is related with the criteria to stop the learning process. It can be set for example based on a fixed limit for the number of iterations, or a minimum error level to be reached. It has been used as well a simultaneously observation, i.e. at each iteration, of the results over the test set (Fig.2), rather than just after completing a training session. This allows an identification of the state at which the network starts to “overfitting” the training data.

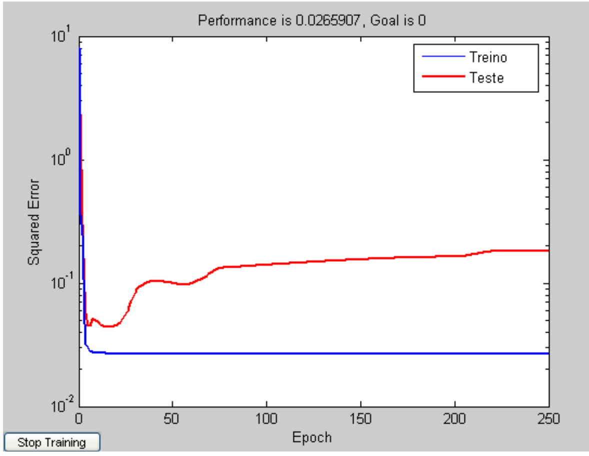

Fig. 2. NN learning phase: performance on training and testing data sets

4. CASE STUDY

The neural networks developed were based on data available for a crossing of four roads in an urban area (Fig.3). The data consisted of the number of vehicles counted in intervals of five minutes, collected over a month.

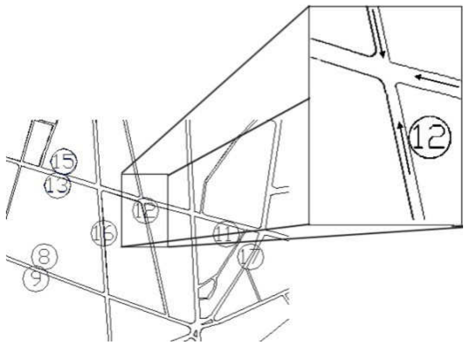

Fig. 3. Crossing of 4 roads

The basic idea was to test if a NN could use information on previous values of the variables associated with this intersection in order to provide an estimate for future values, of the variables involved. In the cases presented the variables considered were traffic flows, and the objective was to provide an estimate that could be of use in a subsequently decision at the traffic lights control level.

Different variables and their corresponding values at different instants of time were considered for the NN input. The output provided an estimated for the future value for the variables. The results presented were based on a network as represented in (Fig.4) and (Table1).

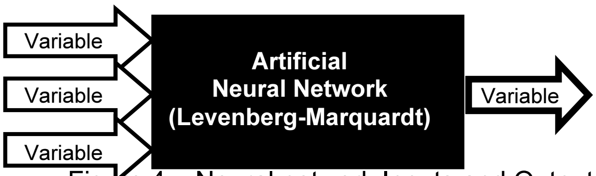

Figure 4 – Neural network Inputs and Output

Inputs	Output
Traffic flow at time t: F(t)	
Variation in traffic flow: F(t)-F(t-1)	Traffic flow at time t+1: F(t+1)
Traffic flow at time t-2: F(t-2)	

Table 1. Neural network Inputs and Output

Several neural network structures have been tried as a result of considering different values for the design parameters (i.e. number of hidden layers and nodes, number of iterations, input/output coding,…)., and also different selections of the training and testing data sets.

Having available data covering an entire month, tests were made using sets of data based on 1 day or more (i.e. 7 days, 24 days), and the entire month. This allowed comparing the performance of the NNs based on using different amounts of training/testing data.

The data collected was based on a 5 minutes interval. In order to verify the effect of reducing the discrete nature of the data associated with traffic flow, experiments were also made based on averaging the neural network output over 3 periods of time (i.e. 15 minutes).

From the high number of experiments tried it was verified that the NN estimates were following the desired values with an overall low error margin (4 vehicles/ 5 minutes). However in a few localised cases the error was significant (14 vehicles/ 5 minutes). Increasing the amount of data the results improved in overall, but not significantly at the localised cases. Using an average of 15 minutes produced better results (24 vehicles/15 minutes).

Error	Maximum [nº vehicles]	Minimum [nº vehicles]	Squared Mean Error
Training	21	-18	0,00651
Testing	24	-18	0,01394

Table 2. Localised extreme error values (15 min).

The graphs below present the results obtained on a training set (Fig. 5) and a testing set (Fig. 6).

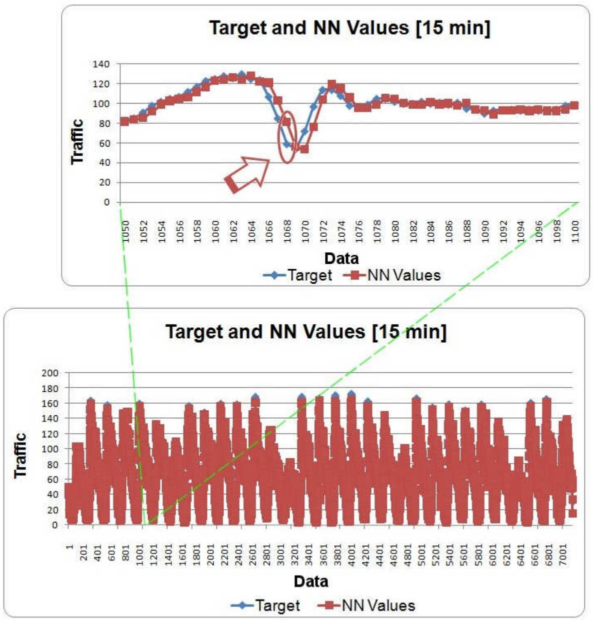

Fig. 5. Performance on a training set

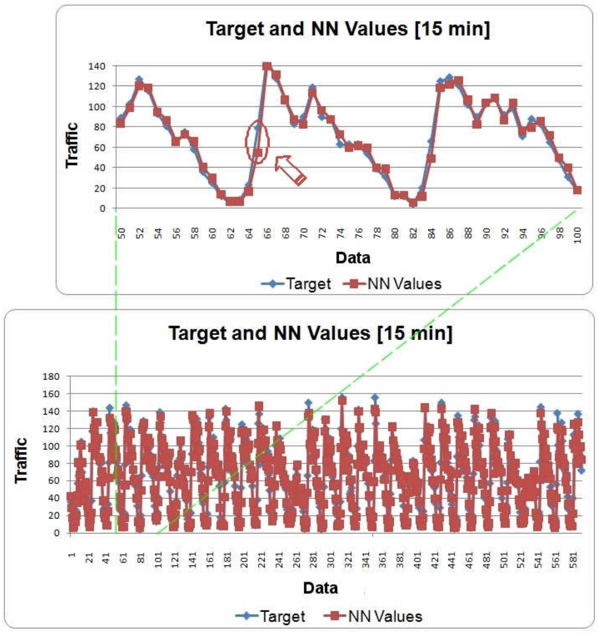

Fig. 6. Performance on a testing set

5. CONCLUSIONS AND FUTURE WORK

Traffic management considered at its various levels still offers opportunities for further improvements. We concentrate on a specific type of problems, which can be associated with the capability to recognise traffic conditions or states and on using a particular type of technique, Artificial Neural Networks (ANN) to approach the problem.

Based on real data available, related to crossroads in an urban area, we developed various Backpropagation type networks and used the Levenberg-Marquardt learning algorithm, to estimate future values for traffic flows. The results obtained showed that the discrete nature of the variables involved can be effectively modelled by the NN in what the overall trends are concerned. However it was not possible to reduce the error levels in some cases, which may limit the use of this information for short term (i.e. less than 5 min) decisions at the traffic lights control level.

It can therefore be foreseen that Neural Networks can be of use in a traffic management and control system, as a technique capable of providing information on the evolution of traffic parameters in a global level. In a more stringent time scale, associate with a micro-regulation of the traffic flow, as for example at the traffic lights level, we still have to verify whether the results obtained can be of use in the control strategy.

References

[1] J. P. Tavares, "Sistemas Centralizados de Controlo de Tráfego Urbano - Sua Avaliação: Aplicação do Caso na Cidade do Porto," in Dissertação de Mestrado em Transportes, IST, Lisboa, Portugal, 1994.

[2] Leoncio Zárate, Ademar Ferreira, and S. R. Augusto, "Um novo sistema de controle neuro-fuzzy para trafego de veículos." São Paulo, Brasil. 2002.

[3] W. Wei and M. Wang, "Traffic Signal Control Using Fuzzy And Neural Network," in Department of Road and Traffic Engineering, Changsha Communications University.

[4] M. Patel and N. Ranganathan, "IDUTC: An Intelligent Decision-Making System for Urban Traffic-Control Applications," 2001.

[5] D. A. Pomerleau, "Vision and Navigation: The CMU Navlab," Boston, MA: Kluwer, 1990.

[6] A. Niehaus and R. F. Steged, "An expert system for automated highway driving," IEEE Control Syst. Mag., Vol 11, pp. 53-61, 1991.

[7] M. Maskarinec, "An expert system accident avoidance system for an autonomous highway vehicle," in Proc. 6th IASTED Int. Symp., vol C4, pp.20-23, 1989.

[8] S. G. Ritchie and N. A. Prosser, "Real-time expert system approach to freeway incident management," Transportation Res. Rec. 1320, pp.7-16, 1993.

[9] M. I. Patel and N. Ranganathan, "An Intelligent System Architecture for Urban Traffic Control Applications," 1996.

[10] L. Prechelt, "A Set of Neural Network Benchmark Problems and Benchmarking Rules," Fakultat fur Informatik Universitat Karlsruhe Germany 1994.

[11] S. Russell and P. Norving, "Artificial Intelligence: A Modern Approach," in Prentice-Hall. New Jersey USA, 1995.

[12] E. Azoff, Neural Network Time Series Forecasting of Financial Markets. New York, USA: John Wiley & Sons, 1995.

[13] E. I. Vlahogianni, J.C. Golias, M. G. Karlaftis, Short-term Traffic Forecasting: Overview of Objectives and Methods. Transport Reviews, Vol. 24, Nº 5, 533-557, September, 2004.

[14] S. Peeta, A. K. Ziliaskopoulos, Foundations of Dynamic Traffic Assignement: The Past, the Present and the Future. Networks and Spatial Economics, 1: 2001, 233-265.

[15] M. Wiering, Jelle van Veenen, J. Vreeken, A. Koopman, Intelligent Traffic Light Control, technical report UU-CS-2004-029, www.cs.uu.nl].

[16] M. C. Choy, D. Srinivasan, R.L. Cheu, Cooperative, Hybrid Agent Architecture for Real-Time Traffic Signal Control. IEEE Transactions on Systems, Man, And Cybernetics-Part A: Systems and Humans, Vol.33, Nº5, September, 2003.

[17] J. Freeman, D. M. Skapura, Neural Networks, Algorithms, Applications and Programming Techniques. Addison-Wesley Publishing Company, 1992.

[18] J. L. McClelland, D. E. Rumelhart, Parallel Distributed Processing, Vol1. The MIT Press, 1986.

[19] J. Hertz, A. Krogh, R. Palmer, Introduction to the Theory of Neural Computation. Addison-Wesley Publishing Company, 1991.

[20] P. D. Wasserman, Advanced Methods in Neural Computing. Van Nostrand Reinhold, 1993.

[21] Hagan, M. T., and M. Menhaj, "Training feedforward networks with the Marquardt algorithm," IEEE Transactions on Neural Networks, vol. 5, no. 6, pp. 989-993, 1994.

FURNACE SCHEDULING IN A FOUNDRY

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Abstract: This paper presents a two-phase heuristic methodology to the production scheduling of a foundry. The first phase covers up a packing problem, in which is grouped together the set of orders, by the type of alloy in well defined dimension groups. On the second phase is solved a knapsack problem in a defined time horizon, where the furnaces set is processed in order to exhaust the daily capacity melting installed. A software tool was developed to implement the algorithm on Microsoft Office Excel 2007, using the VBA language. The results were very good and considerably better than those achieved in real production, for the same list of orders

Keywords: scheduling, software production, heuristics, production management, dynamic scheduling.

INTRODUCTION

This article presents a production planning problem in an iron and steel foundry. The production system consists in three sequential processes: molding, melting / casting and finishing. The planning of operations for the processing of orders is a problem of a high degree of complexity and its solution is not trivial. The orders must be divided by alloy types and grouped in sets of maximum size in order to minimize the production costs, which makes more difficult to accomplish delivery deadlines.

In this article is presented a heuristic methodology consisting in a two phase's algorithm. In the first phase the problem is shaped as a *Bin Packing Problem* to group the orders in *bins*. On the second phase the problem is shaped as a *Knapsack Problem*, to group the *bins* obtained in the previous phase. For both phases are presented two constructive algorithms, associated to a local search procedure. The methods of exact solution are not suitable for the treatment of this problem due to the size of the instances of the real problem and to the need of making frequent executions of the algorithm. This methodology will be included in a decision support system and it is crucial to obtain solutions quickly, so that the coordinator can make a planning and respond to the permanent request of new orders.

A software tool was developed on Microsoft Office Excel 2007, using the Visual Basic for Applications (VBA) language. This option was chosen because the company information system allows moving data into this format, each order being presented in each line. The data reading (orders) will be made line by line and the information will be processed in the form of the desired output, also in an Excel sheet.

The results were good and considerably better than those achieved in real production, for the same list of orders. The occupation of the melting was complete, with consumption of all the available molds, when the priority order does allow it. However, the algorithm differs most in the scheduling criterion: according to a well defined criterion, the program will consider first the priority orders.

PROBLEM DESCRIPTION

This section describes in detail the two processes of the production system identified as critical for scheduling, molding and melting, and the implications that generate on the production planning. The molding and melting processes were identified as the determinant points of the production and as the critical of planning, since the products arise to the finishing process, they are processed without major constraints. In the finishing process are included the final operations of dimensional correction and piece cleaning.

In molding, the molds are made of sand, with the format of the piece to produce, in the necessary amount to meet the production order. In the molding process there are three separate sectors, one automatic and two manuals, where the choice of molds to produce in each depends on its size and on its quantity. The automatic molding line is the one that most contributes to the amount of molds (72%) and metal weight (56%).

The line of automatic molding has a special characteristic that distinguishes its planning from the conventional machines of metallurgy, who usually works only with one tool at a time. In the molding line four different tools (wood molds-patterns) are used at the same time, with two half molds each. Figure 1 outlines the molding line process.

To illustrate the operation, consider four different tools (four different final products): 1, 2, 3 and 4. Knowing that each tool has two half molds (MM) the sequence of processing in the carousel circuit is the one illustrated in Figure1. Figure 1 shows three distinct areas of operation relating to the automatic molding machine. Areas 1 and 2 respectively represent the entry and exit of molds, and zone 3 is the area of processing. The molds move in circle, in zone 3, and are filled with sand under the mixer. The sand molds are removed from the wood molds in the roll-over. When the amount of molds needed to meet the production orders is reached the corresponding two half molds leave to zone 2 and two half molds of a new reference enter from zone 1. The selection of a new mold must comply with planning restrictions imposed by the subsequent operations (melting and casting).

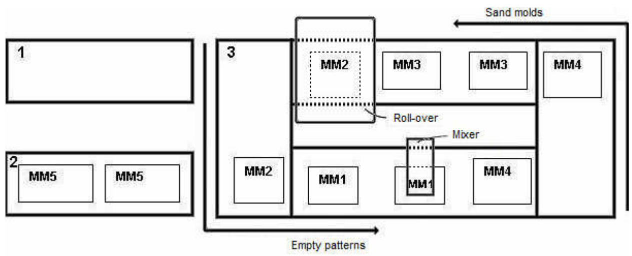

Fig. 1. Diagram of the automatic molding line

In the second process, melting, the metal is melted into an alloy of a known chemical composition. For the melting there are two furnaces with melting capacity of 500 kg and one with the capacity of 1500 kg. The melting timing of the 500 kg furnaces is about 1 hour and 10 minutes and on the 1500 kg furnaces is about 1 hour and 30 minutes. The scheduling of this study is focused only in the furnace of 1500 kg, furnace where is produced 89% of the metal, constituting quite a reasonable and important simplification to the model. The casting is the operation where the molds are filled with the metallic alloy. The casting operation is quite a fast operation when compared to the others. However, this operation implies the existence and availability of all the molds before it begins.

The production planning represents an exercise of high degree of difficulty because involves a huge quantity of references, mainly in the automatic molding line considered crucial to the progress of all the other production process. Only when the weight of the metal from the molding is justified, grouped by the type of alloy to melt in a certain furnace, is that the melting could be planned. Only pieces of the same alloy can be considered in the same melting batch. This fact requires a great coordination between these two sequential processes.

Summarizing, it is important to obtain an adequate planning of molding and melting processes, to ensure enough weight of metal to compose meltings and to respect the daily capacity of molding. The capabilities of molding and melting are known and established in terms of number of daily molds and daily number of meltings in each furnace, respectively.

RESOLUTION METHODOLOGY

The resolution methodology adopted is a two-phase algorithm, where the solutions obtained in a first phase determine the quality of solutions for the following phase. In the first phase is approached a packing problem and in the second phase is solved a problem as a knapsack problem. To shape the problem is considered the melting as early planning, where it is necessary to ensure the enough weight of alloy to melt. Actually, it is the molding process that introduces the manufacturing orders in production, assuming a decisive role in processing order, and melting is being scheduled as the molds are released from the first process. However, there may be profits with the anticipated scheduling of melting loads, with the balancing of metal weights per mold.

The aim of the first phase is to allocate orders, or part of them, to a certain melting (furnace) with some criterion of uniformity, in order to consider, orders of the same alloy, with delivery deadlines the closest as possible. A melting, or a furnace, is a *bin* in this packing problem.

An intuitive approach is to assign to a furnace the orders in descending order of priority, providing a constructive and very simple heuristic. The criterion of priority for each order is determined by a weighted sum of four parcels: days in advance, priority of the order, margin of the order and priority of the client.

Mathematically, given a set of orders $E = \{e_1, \dots, e_n\}$, of weights w_j, alloys a_j and criteria d_j and a set m of furnaces of capacity c, each order is attached to each furnace according to the following terms:

$$\mathrm{d}_{[1]} \geq \mathrm{d}_{[2]} \geq \cdots \geq \mathrm{d}_{[n]} \tag{1}$$

$$\text{s.a.} \quad \sum_{\mathrm{j}=1}^{\mathrm{k_i}<n} \mathrm{w}_{[\mathrm{j}]\mathrm{i}} \leq \mathrm{c},\ \mathrm{i}=1,\dots,\mathrm{m},\ \mathrm{j} \in \mathrm{E} \tag{2}$$

$$a_{[1]i} = a_{[2]i} = \cdots = a_{[j]i},\ i = 1,\dots,m,\ j \in E \tag{3}$$

The orders fitting in a certain furnace are allocated up to its capacity before moving to the next furnace. At the end of this assignment there are m_k furnaces filled with orders of the same alloy, which constitutes the starting point for the next phase.

The constructive heuristic used for the definition of meltings is similar to that used in the *bin packing* problems. The purpose of heuristic is to group, in an appropriate manner, the set of orders $E = \{e_1, \ldots, e_n\}$ to compose the furnaces (meltings) required $F = \{f_1, \ldots, f_m\}$. This scheduling is exclusive to the furnace of the 1500 kg, because it is the one with the higher income of melting, and it contributes prominently to the total amount meltd in the company. However, when the weight of a particular alloy is not enough to ensure a melting in this furnace, the orders are assigned to other existent furnaces, whose working decision belongs to the user, or, in case that the minimum amounts of melting are not reached (2/3 of the melting weight of the smaller furnaces) a list with the information of these orders is emitted, and the scheduling decision of the orders in that list will also belongs to the user.

The flowchart illustrated in Figure 2 schematizes the algorithm of furnaces definition (first phase), with the increases of the capacity restrictions adjusted to the reality of the company.

For the second phase of the methodology the resolution strategy for the scheduling is based on the resolution strategy of the knapsack problem. In this case, the furnaces to schedule will be the items to consider, and the days of planning will be the available knapsacks. The daily capacity of melting represents the knapsack of a well defined capacity. In this way, the knapsack problem could be used to shape the attribution of furnaces, builted in the previous phase, to the knapsacks, which constitute the planning days. As the assumption, the number of items (furnaces) is very superior to the available capacity in the several knapsacks (planning days) defined for the planning period.

Mathematically, given a set of furnaces $F = \{f_1, \ldots, f_m\}$, of weights $w_j = 1$ and criteria d_j and given a set of planning days /knapsacks $M = \{M_1, \ldots, M_k\}$ of capacity c, each furnaces are attached to each knapsack according to the following terms:

$$d_{[1]} \geq d_{[2]} \geq \cdots \geq d_{[m]} \tag{4}$$

$$s.a. \quad \sum_{j=1}^{n_i<m} w_{[j]i} \leq c\,,\ i = 1, \ldots, k,\ j \in F \tag{5}$$

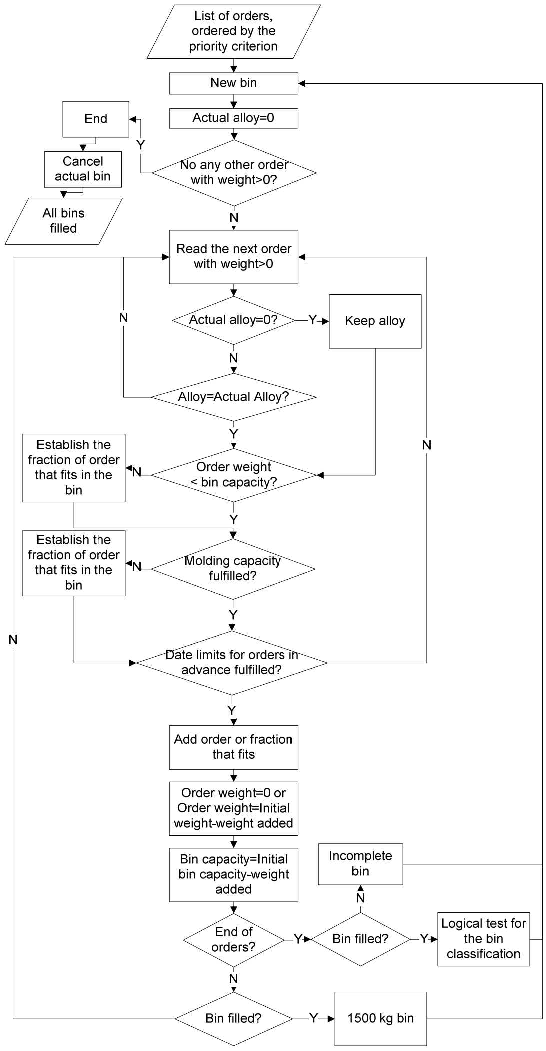

Fig. 2. Flowchart of the algorithm of furnaces definition

Note that each furnace has an individual weight $w_j = 1$, as each furnace occupies a unitary space in a capacity translated in number of furnaces/meltings.

At this phase must be taken into account the remaining restrictions of capacity. The molding capacities of each sector are known and must be kept. It is necessary to consider also the ability to process four tools simultaneously in the automatic molding line, constituting the usual processing situation.

The resolution will be done again with a constructive heuristic (filling of the knapsacks). Figure 3 shows a flowchart of the algorithm. It is considered that the set $F = \{f_1, \ldots, f_m\}$ generated in the previous phase is ordered by a well-defined criterion. For this purpose is used the criteria of the orders, already determined, with a balance based on the weight that each order represents in the whole furnace weight in which is assigned to $(peso_{enc.}/peso_{forno})$.

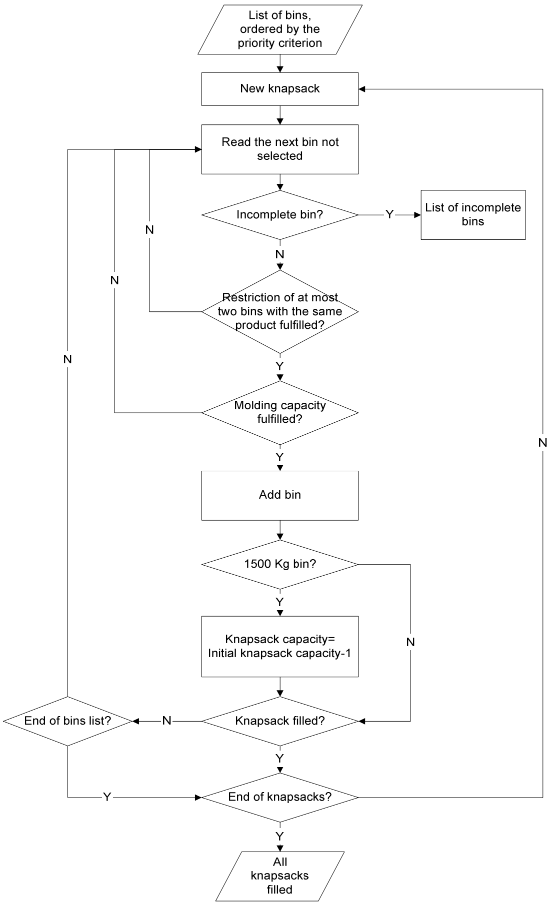

Fig. 3. Flowchart of the algorithm of furnaces scheduling

LOCAL SEARCH

In order to enhance the quality of the results obtained by the constructive algorithms was implemented a first iteration of a local search procedure. In a local search algorithm, starting from an initial complete solution, repeatedly, the aim will be to replace the current solution for a better solution that exists in a neighborhood of the current solution.

The original solution used, will be achieved through the use of constructive algorithms presented in the flowcharts of Figure 2 and Figure 3. From the current solution we start a process of transformation of this solution. The best solution of the neighborhood is assessed and it is taken as the current solution if it is better than the actual current solution.

To test the viability of a local search as a quality improvement mechanism of the solution achieved through constructive algorithms (phase 1 and 2), was developed an algorithm that enables a blind order (for the first phase) or furnace (for the second phase) in a given iteration, preventing their assignment and making them available for review in the following iterations. These occultations are made randomly in each iteration, providing small changes regarding the original solution and giving rise to the possibility of a different solution generated randomly.

COMPUTATIONAL EXPERIMENTS

In order to validate the methodology designed, computational experiments were carried out with real data from the company and these were compared with the company procedure in two different situations. An additional study for the scheduling of two months of production in two different formats has also been carried, allowing to observe some important lessons.

Thus, the results were assessed in the following situations:

1. Comparison of ten days of production (actual data obtained for comparable situations);
2. Comparison of a month of production with the 2007 worst and best month of real production;
3. Comparison of two months of planned production sequentially, deducting the orders planned in the first month in the list of orders of the second month;
4. Comparison of two months of production planned simultaneously.

The fulfilling obtained for the 1500 kg meltings, in the first phase of planning, demonstrated to be sufficiently good. The average was 98% of fulfilling and 76% of furnaces had a fulfilling above 94%.

In the second phase, for the purpose of comparison of the results obtained in the program with the real production in a ten working days, the real data was obtained between coating maintenances of the 1500 kg furnace (sinterizations), which prevents its normal work on two consecutive days, and in a date of molds stocks determined for this purpose.

For the same list of orders we found that the program results are rather better than the real ones. In the scheduling results the occupation of the melting capability of the 1500 kg furnace is total, unlike the actual production, and the consumption of molds generated in the three sectors of molding, on those ten days, is complete. In real production only took place 53 meltings (88%) of a total capacity of 60 meltings, all planned in the results of the program. In real production it took place, however, a greater use of one of the furnaces of 500 kg resulting in a higher number of total meltings ,than the one from the program (92 real versus 62 of the program) but with an inferior number of cast molds: in real production there were only casted 87% of the molds that the program results does allow to cast.

However, it was in the criterion of scheduling and in consideration of priority orders, that the program most stood out against the real scheduling. The program, within the possibilities determined by the restrictions of the model, considers the orders by their priority, established for the study. In real production, currently, there is not a well-defined scheduling criterion: orders with posterior delivery deadlines are processed before orders with a previous delivery deadline.

By comparison with the best and worst months of 2007 of the company, in terms of weight of metal cast, the result and conclusions are similar. The program ensures a better optimization of the melting, with a more uniform production than the real production. The main results, in terms of global indicators, are summarized in Table 1.

The results of the program have a greater number of cast molds, by the use of a better fulfilling of the capacity melting of the furnace of 1500 kg. As can be seen in Table 1 we can achieve a considerable improvement in average weight of cast metal a day using a greater number of meltings in the furnace of 1500 kg.

In the two months scheduling, it was found that with the new list of orders, for the second month of the sequential scheduling, the results have conducted to a low occupation of the melting capacity. For this month, with a list of orders obtained by discounting the orders considered in the first month, only 68% of the available meltings were planned. With the initial list of orders, for the first month, the occupation of melting, in terms of number of meltings, was 98%. This low occupation of the second month is due to two reasons. A first reason due to the lack of molds from the larger manual molding secto, corresponding to higher weight molds and higher contribution to the melting. This sector is underused due to the lack of references pre-established to produce there. This may represent an improvement to the presented tool. Each product may correspond, for default, to a particular sector molding, however, it should be possible the assignment it to another sector, if necessary, and when it's possible. Apart from this identified factor there is another reason: the planning of orders of metal weight per mold below the weights programmed for the first month. For a constant molding capacity, in terms of number of daily molds, the weight of melting obtained will be lower, because it results from the sum of the metal weights per molds, that are more reduced, and could constrain the ability to optimize the melting. This can also be an improvement for the developed tool.

	Program	Best mon.	Worst mon.
Nº of molds	**107,7**	**106,8**	**84,8**
Nº of pieces	**191,2**	**298,0**	**216,2**
Casted metal (kg)	**10119,9**	**7977,9**	**7100,0**
Nº meltings 1500 kg	**5,9**	**4,6**	**4,3**
Nº meltings 500 kg	**0,3**	**1,1**	**1,0**
Nº total meltings	**6,2**	**5,7**	**5,3**

Table 1. Comparison per day between the overall results obtained in the program and the real production for a month of work (the best and the worst month):

Through the combination of orders by weight of metal molded we can ensure or not the melting weight necessary. The weight of the metal has been identified by a daily average molding, for an optimum, between molding and melting, of 94 kg. In this way, in the present study we observed that, for the actual molding capacity, trough a daily average of metal weight per mold of 94 kg, we can obtain a full occupation of the molding capacity and the melting capacity and a balance between these two sequential processes.

In this study it is also verified that, for the molding and melting capacity studied, by the combination of weight of metal per mold, it may be the process of molding or the process of melting to strangle the production process. Therefore, trough scheduling orders of reduced metal weight per mold, we can easily exhaust all the capacity of molding, without achieving the necessary melting weight. For orders of higher metal weight per mold happens exactly the opposite, where they exhaust the capacity of melting, even with uncast molds, not being able to avoid the stock accumulation.

The local search mechanism, through a first iteration, has led to some improvement in the value of objective functions used for each of the phases. The tests were performed to 6 lists of different orders chosen randomly and for 2000 and 10000 iterations of transformation, in order to assess the influence of the size of the neighborhood set. It is not established that there is an improvement considering a larger neighborhood. For the first phase, the best improvement achieved was a 1,0% reduction in the number of bins (reduction of 4 bins in a total of 395). In the second phase, the improvement in the value of the objective function of the new solution was higher and reached 2,2% of the original solution.

However, for the overall results, through the influence of the best solution of the first phase in the quality of the solution of the second phase, the results were not enough to conclude the existence of a pattern of improvement. Through the generation of 2000 and 10000 possible alternative solutions of the original solution, it is observed that the results achieved through constructive algorithms are already quite reasonable. This observation was achieved for the existence of quite worst alternative solutions, obtained with only a slight transformation of the original solution.

CONCLUSIONS

The problem of production scheduling of a foundry company is very complex and of hard solution. The use of exact solution methods may be compromised in the resolution of instances of large scale projects. The alternative involves the use of heuristic methodologies.

The complexity of the problem suggests the implementation of the strategy of dividing the original problem into two sub-problems and implement, in each case, a specific methodology: in an initial phase the bin packing problem, for the assignment of the orders to the furnaces, and in a second phase, the knapsack problem methodology, for the assignment of these furnaces to processing days. It is known that this methodology is an approach methodology, but it appears that the simplicity of the model does not question the achievement of good quality solutions. In order to enhance the quality of the solutions of the problem we think that the implementation of procedures of local search is justified and will avoid the disadvantages arising from the use of two-phase strategy and constructive algorithms. The software tool developed through the application of algorithms identified under the form of VBA, in Microsoft Excel 2007 format, has proved to be very useful, with sufficiently efficiency and effectiveness for the uncertainties of real data that characterize this type of market. The results could be used for the early scheduling of production, according to well-defined criteria, and to achieve better results than the real production, for the same list of orders. There are many other studies and developments that could be made in the follow of this study, more specifically in the foundry industry, but also in other industries that are characterized by processes that depend on the production rate and release frequency of components from previous processes.

References

ALVIM, A. C. F. et al. – A hybrid improvement heuristic for the one-dimensional bin packing problem. Journal of Heuristics. 10 (2004), 205-229.

ARAUJO, S.A.- Modelos e métodos para o planejamento e programação da produção aplicados no setor de fundições. São Carlos: Universidade de São Paulo, 2003a. 125 p. Tese de Doutoramento.

ARAUJO, S. A; ARENALES, M. N.- Dimensionamento de lotes e programação do forno numa fundição automatizada de porte médio. Pesquisa Operacional. 23:3 (2003b), 403-420.

ARAUJO, S. A.; ARENALES, M. N.; CLARK, A. R. - Dimensionamento de lotes e programação do forno numa fundição de pequeno porte. Gestão & Produção. 11:2 (2004a),165-176.

ARAUJO, S. A; ARENALES, M. N.- Planejamento e programação da produção numa fundição cativa automatizada de grande porte. Investigação Operacional. 24 (2004b), 197-210.

ARAUJO, S. A.; AREALES, M. N.; CLARK, A. R. – Lot sizing and furnance scheduling in small foundries. Computers & Operations Research. 35:3 (2008), 916-932.

CHAN, F.T.S.; AU, K.C.; CHAN, P.L.Y. – A decision support system for production scheduling in an ion plating cell. Expert Systems with Applications. 30 (2006), 727-738.

COFFMAN, E. G.; GAREY, M. R.; JOHNSON, D. S. – Approximation algorithms for bin packing: a survey. In HOCHBAUM, D. (Ed.) – Approximation algorithms for NP-Hard problems. Boston: PWS Publishing, 1996. p. 46-93.

FINK, C. – A programação da produção em fundições de pequeno porte: modelagem matemática e métodos de solução. São Carlos: Universidade de São Paulo, 2007. 64 p. Tese de Mestrado.

FLESZAR, K.; HINDI, K.S. – New heuristics for one-dimensional bin packing. Computers & Operations Research. 29 (2002), 821-839.

GUPTA, J. N. D.; HO, J. C. – A new heuristic algorithm for the one-dimensional bin-packing problem. Production Planning & Control. 10:6 (1999), 598-603.

HEIZER, J.; RENDER, B. – Operations Management. 8th ed. Pearson Prentice Hall, 2006.

JUNIOR, R. F. T.; FERNANDES, F. C. F.; PEREIRA, N. A. – Sistema de apoio à decisão para programação da produção em fundições de mercado. Gestão & Produção. 13:2 (2006), 205-221.

KELLERER, H.; PFERSCHY, U.; PISINGER, D. – Knapsack Problems. Berlin: Springer, 2004.

MARTELLO, S.; TOTH, P. – Knapsack Problems: Algorithms and Computer Implementations. Chichester: John Wiley & Sons, 1990.

MICHIELS, W.; AARTS, E.; KORST, J. – Theoretical aspects of local search. EATCS monographs in Theoretical Computer Science. New York: Springer, 2007.

OSOGAMI, T.; OKANO, H. – Local search algorithms for the bin packing problem and their relationships to various construction heuristics. Journal of Heuristics. 9 (2003), 29-49.

SILVA, R. J.; MORABITO, R. – Otimização da programação de cargas de forno em uma fábrica de fundição em aço-inox. Gestão & Produção. 11:1 (2004), 135-151.

TONAKI, V. S. – Uma heurística para o problema de dimensionamento de lotes em fundições de mercado. São Carlos: Universidade de São Paulo, 2006. 89 p. Tese de Mestrado.

OPTIMIZING TRANSPORTATION PROCESSES IN URBAN WASTE COLLECTION SYSTEMS

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Keywords: Operations Research, Analytical Methods, Operations Planning.

INTRODUCTION

Waste collection and treatment in urban areas are a real concern of today local governments. Following this increasing ecological consciousness, individuals but also industrial companies are starting to look differently to their contribution. More and more often, they choose to divide their waste materials, putting them on dedicated containers. As a consequence, the number of such containers in our towns is becoming larger every day. Large amounts of these materials now go to recycling. This situation puts an increasing pressure on the recycling facilities, and forces the waste managers to better use their recycling capacities and control the flow of materials coming in and out. The equilibrium may be achieved through the use of optimization approaches applied to waste management processes.

An issue in waste management systems is related to waste handling and transportation. Important energy savings and reductions of emissions may be achieved by improving these processes. Furthermore, waste managers try to articulate the waste collecting process with the operation of their central recycling facilities. This context gives rise to new and interesting optimization problems that can be tackled using Operations Research models and techniques. In this paper, we analyze a problem that arises in such waste management systems. Given a set of operational requirements, we formulate it as a *Vehicle Routing Problem* with additional constraints.

Usually, the collecting vehicles used locally are identical in terms of their capacity and type of waste they can handle. Hence, the fleet is assumed to be homogeneous. Using the terminology related to vehicle routing problems, each waste collecting point can be seen as a client with a given load. Picking up these loads is not compulsory. A maximum level of waste is defined above which a container is considered to be full. Such containers must be picked up, while the others may not. A client with a load below that maximum level is visited only to fulfill the periodic needs of waste materials determined by the waste managers. Indeed, to improve both their storage and recycling capacity, the waste managers forecast what they consider to be the best level of materials to be collected in the next planning periods. These planning requirements may lead to vehicles leaving their depot only to collect a small amount of waste. Typically, this situation is not tolerated and, hence, a vehicle that leaves the depot must come back with a minimum amount of waste. This gives rise to an additional minimum filling constraint. The objective of the problem is to optimize the operation of the collecting vehicles by defining both the set of clients to visit and the routes that must be followed. The time required to complete a circuit is a minor concern in urban systems, and hence the global criteria to optimize consists in the total length of the routes. A related routing problem has been studied for example in [1]. Problems with minimum filling constraints have been tackled recently for example in [2].

In this paper, we use a column generation model to solve our practical problem. Column generation has its roots in Dantzig-Wolfe decomposition [3] which is a reformulation technique. These reformulations lead to models with an huge number of columns (variables) that can hardly be tackled simultaneously. Column generation allows the enumeration of columns to be done implicitly. Only the attractive columns are considered explicitly, while the others are left out since they can not improve the objective function. A column generation algorithm can be divided in two parts: the restricted master problem (RMP) is a common linear program that includes a subset of interesting variables; the pricing subproblems are used to identify those columns that do not belong to the RMP but that may improve it (negative reduced cost columns). The advantage of column generation models in the context of integer programming is the quality of the lower bounds they generate usually.

Despite the strength of column generation models, many exact algorithms fail in finding integer optimal solutions because of the large integrality gap that must be closed. Resorting to cutting planes techniques to improve the continuous bounds is not trivial, since by introducing cuts in the RMP, one may lose the structure of the subproblem and thus complicate the generation of new attractive columns. Recently, some authors proposed an original way of deriving strong cuts using dual-feasible functions [4,5,6]. In [4,5], the authors used these functions to derive valid inequalities for column generation models for cutting and packing problems. In this paper, we use dual-feasible functions to derive valid cutting planes from implicit constraints of our model.

An issue with column generation algorithms is its long tail convergence, which is due to the way the dual variables change along the iterations [7], and to primal degeneracy [8]. Stabilizing column generation has been a major topic of research in the integer programming field, and many contributions are given in the literature, some of them related to vehicle routing problems [9]. In this paper, we focus on a technique introduced recently in [10] that consists in adding valid dual cutting planes to the RMP. For many well known optimization problems, this technique leads to significant improvements in the convergence of column generation algorithms [10,11].

All the notation and terminology used throughout this paper is introduced in the next section. In Section “Mathematical Programming Model”, we describe the integer programming models that underly our approaches. In Section “Stabilization Strategies”, we show how to apply dynamic stabilization techniques to the column generation algorithm. In Section “Cutting Planes”, we discuss the cutting planes used to strengthen the model, and in Section “Branch-and-Bound” we describe the branch-and-bound algorithm used to find integer optimal solutions. Some preliminary computational results are discussed in Section “Preliminary Computational Results”.

PROBLEM DEFINITION AND NOTATION

Our routing problem is defined in a graph *G*=(*V,A*), where *V* represents the set of nodes in the graph and *A* the set of oriented arcs. The set of clients (collecting points) is represented by *N*={1,…,*n*}. The depot is denoted by *o* and *d*, representing respectively the beginning and the end of a vehicle route. Hence, we have that $V = N \cup \{o,d\}$. The graph is assumed to be complete: for every pair of nodes, there is an arc in *A* connecting them. Since the fleet is homogeneous, the graph is also unique. All the vehicles can visit the same set of clients, using the same set of arcs.

Each arc $(i,j) \in A$ has a cost c_{ij}, that is directly related to the distance between *i* and *j* and other eventual costs that may be incurred by traveling through it. These costs have the triangular inequality property, i.e., if there is a direct path between two nodes, it will never be worse than any indirect path. The optimization objective of the plan is to minimize the total cost of the vehicles routes.

The vehicles have a capacity *W*. A vehicle that leaves the depot must come back with at least $L_{\min}$ units of waste materials. This value is determined by the waste managers, and it may be set to 0 if such a constraint does not apply. The fleet of collecting vehicles is not unlimited. The number of available vehicles in the fleet is denoted by *K*, and the vehicles are indexed by *k* (*k=1,..,K*).

For each client $i \in N$, there is a corresponding amount of waste denoted by l_i stored in appropriate containers. If $l_i > w_{\max}$, the container is considered as full, forcing a vehicle to collect it in the next round. The set of clients with full containers is denoted by N_1, while the other clients are represented by the set N_2.

Finally, the minimum amount of waste material to be collected in the next planning period is denoted by $L^T_{\min}$.Again, this value is determined by the waste managers according to the operational requirements of the recycling plant.

MATHEMATICAL PROGRAMMING MODEL

An Original Network Flow Model

Our routing problem is a generalization of the standard *Vehicle Routing Problem* with capacity constraints. By setting appropriately some of its parameters, one can easily get an instance of the VRP. The problem can be modeled using a network flow model with binary variables representing a vehicle passing or not through a given arc. The model states as follows.

$$\min \sum_{k=1}^{K} \sum_{(i,j)\in A} c_{ij} x_{ij}^k \tag{1}$$

s.t

$$\sum_{k=1}^{K} \sum_{j\in N\cup\{d\}} x_{ij}^k = 1, \ \forall i \in N_1, \tag{2}$$

$$\sum_{k=1}^{K} \sum_{j \in N \cup \{d\}} x_{ij}^k \leq 1, \ \forall i \in N2, \quad (3)$$

$$\sum_{k=1}^{K} \sum_{j \in N} x_{o,j}^k \leq K, \quad (4)$$

$$\sum_{j \in N \cup \{d\}} x_{o,j}^k = 1, k = 1,...,K, \quad (5)$$

$$\sum_{i \in N \cup \{o\}} x_{ij}^k - \sum_{i \in N \cup \{d\}} x_{ji}^k = 0, k = 1,...,K, \forall j \in V \setminus \{o,d\} \quad (6)$$

$$\sum_{i \in N \cup \{o\}} x_{i,d}^k = 1, \ k = 1,...K, \quad (7)$$

$$\sum_{k=1}^{K} \sum_{i \in N_2} l_i \sum_{j \in N \cup \{d\}} x_{ij}^k \geq L_{\min}^T, \quad (8)$$

$$Q_i^k + l_i - Q_j^k \leq (1 - x_{ij}^k)W, k = 1,...,K, \ \forall (i,j) \in A, \quad (9)$$

$$l_i \leq Q_i^k \leq W, k = 1,..., K, \forall i \in V, \quad (10)$$

$$Q_d^k \geq \sum_{i \in N} x_{id}^k L_{\min}, k = 1,...,K, \forall i \in V, \quad (11)$$

$$x_{ij}^k \in \{0,1\}, k = 1,..., K, (i,j) \in A. \quad (12)$$

The model above is an arc-flow model. The decision variables are denoted by x_{ij}^k, *i* and *j* being respectively the origin and destination of the arc, and *k* a given vehicle. Forcing the visit on clients will full containers is enforced by constraints (2), while (3) state that the other clients may or may not be visited by a collecting vehicle. The limit on the maximum number of vehicles is defined by constraint (4). Constraints (5)-(7) are the flow conservation constraints. Constraint (8) forces the vehicles to pick up at least $L_{\min}^T$ units of waste material. The capacity constraints are defined by (9) and (10). The general integer variables Q_i^k represent the amount of waste collected by the vehicle *k* after leaving a client *i*. The minimum filling constraint on the vehicles is represented by constraint (11). Finally, the objective function (1) consists in minimizing the total cost of the vehicle routes. The size of model (1)-(12) is large even for medium-size instances.

Being a generalization of the VRP, our routing problem is NP-hard, and hence no polynomial solution scheme can be devised for it.

A Column Generation Model

Model (1)-(12) can be reformulated as a flow model over paths instead of arcs by applying a Dantzig-Wolfe decomposition. The result is a master problem whose variables represent feasible vehicle routes, and a pricing subproblem which is a shortest path problem with additional constraints. The following sections describe both these elements.

Master Problem

The master problem is defined by the constraints (2)-(4) and (8) of the previous model, while the remaining constraints define the pricing subproblem. The latter generates paths that start and end at the depot, passing through a subset of nodes so that all the operational constraints imposed to the vehicles are fulfilled. Let Ω denote the set of all the feasible routes. The master problem can be formulated as follows.

$$\min \quad \sum_{p \in \Omega} c_p \lambda_p \quad (13)$$

$$s.t.$$

$$\sum_{p \in \Omega} a_{ip} \lambda_p = 1, \ \forall i \in N_1 \quad (14)$$

$$\sum_{p \in \Omega} a_{ip} \lambda_p \leq 1, \ \forall i \in N_2 \quad (15)$$

$$\sum_{p \in \Omega} \lambda_p \leq K, \quad (16)$$

$$\sum_{p \in \Omega} l_p \lambda_p \geq L_{\min}^T, \quad (17)$$

$$\lambda_p \in \{0,1\}, \ \forall p \in \Omega \quad (18)$$

For the sake of brevity, we will not describe here all the steps involved in the decomposition process (for complete details, see [12]). The resulting model has variables that are flows over paths. The λ_p are binary valued, since the same path will never be used more than once. The cost of a path $p \in \Omega$, which is equal to the sum of the arc costs that define it, is denoted by c_p. Constraints (13) and (14) ensure that the clients will be visited according to their total amount of waste. Constraint (16) limits the number of used routes. Collecting the minimum amount of materials prescribed by the waste managers is guaranteed by constraint (17). Coefficient l_p stands for the total amount of waste picked up in route *p*. Model (13)-(18) can be seen as a set-partitioning model with additional constraints.

Each path in Ω visits a client only once (elementary paths). Enforcing this constraint in the subproblem increases its complexity. Hence, in our implementation, we allow the generation of paths with cycles. Given that the constraints that force a visit to a client with a full container are equalities, clearly, such columns will never belong to an optimal integer solution.

Model (16)-(18) has no symmetry. While in model (1)-(12), one can express the same in different ways by exchanging the indices *k*, in the former a feasible solution has a single representation. This is an important feature of the model, since symmetry may penalize significantly the convergence of branch-and-bound search schemes.

Pricing Subproblem

The pricing subproblem consists in *K* shortest path problems with capacity constraints (resource constraints, if one resorts to the general terminology). Since the fleet is homogeneous, these *K* problems are identical and hence only one shortest path problem is solved in practice. As alluded before, the paths should be acyclic. However, in routing problems under resource constraints, this constraint is usually relaxed when solving the linear programming relaxation. The quality of the model and the quality of the bounds of the relaxed problem decrease, but the corresponding subproblem is easier to solve. Although the relaxed problem remains NP-hard, it can be solved efficiently using pseudo-polynomial algorithms.

The subproblem has not the integrality property. As a consequence, the resulting decomposition may lead to lower bounds stronger than the continuous bounds given by the original network flow model.

The pricing subproblem can be formulated as follows.

$$\min \sum_{(i,j)\in A} c'_{ij}\chi_{ij} \tag{19}$$

$s.t.$

$$\sum_{j\in N\cup\{d\}} \chi_{o,j} = 1, \tag{20}$$

$$\sum_{j\in N\cup\{d\}} \chi_{ij} - \sum_{j\in N\cup\{d\}} \chi_{ji} = 0, \forall j \in V, \tag{21}$$

$$\sum_{j\in N\cup\{d\}} \chi_{i,d} = 1, \tag{22}$$

$$Q_i + l_i - Q_j \le (1-\chi_{ij})W,\ \forall (i,j)\in A, \tag{23}$$

$$l_i \le Q_i \le W,\ \forall i \in V \tag{24}$$

$$Q_d \ge L_{\min}, \tag{25}$$

$$\chi_{ij} \in \{0,1\},\ \forall (i,j)\in A \tag{26}$$

The paths generated by this subproblem must pass by at least one client. Hence, the minimum filling constraint (25) applies in every case. Indeed, the empty path consisting in leaving the depot and coming back to it immediately will never be attractive. Its reduced cost will always be equal to 0.

In column generation, the objective of the subproblems is to price the columns that are not explicitly in the RMP. In model (19)-(26), the objective function (19) consists in minimizing the total reduced cost of a path (columns in the RMP) by taking into account the individual contribution of each arc to that cost. Let $\pi_i, i \in N$, θ and δ , be the dual variables associated to the constraints (14)-(15), (16) and (17) of the master, respectively. The reduced cost c'p of a path $p \in \Omega$ is given by the following expression:

$$c'_p = c_p - \sum_{i\in N_1\cup N_2} a_{ip}\pi_i - l_p\delta - \theta.$$

By manipulating the terms of this equation, one can express it as a function of the arc costs. The final contribution of each arc is given next:

$$c'_{ij} = c_{ij} - \pi_i, \text{ if } i \in N_1,$$

$$c'_{ij} = c_{ij} - \pi_i - l_i\delta, \text{ if } i \in N_2,$$

$$c'_{ij} = c_{ij} - \theta, \text{ if } i = o \text{ and } j \in N,$$

$$c'_{ij} = c_{ij}, \text{ if } i = o \text{ and } j = d.$$

In our implementation, we solved this subproblem using a dynamic programming algorithm with pseudo-polynomial complexity [13].

Stabilization Strategies

Using the column generation model (13)-(18) to solve our practical routing problem has two main advantages. First, the model is stronger than the original arc-flow formulation. Second, it does not have symmetry. However, column generation procedures have an important drawback: convergence is usually slow. The value of the bounds improves significantly in the first stages, but then the improvements become increasingly smaller as the algorithm comes closer to the optimal solution value. This phenomenon is called the long tail convergence.

Many methods have been proposed in the literature to improve the convergence of column generation algorithms. Among the many contributions, the technique based on the introduction of dual cuts [10] is among the most promising. Recently, new results were derived leading to more sophisticated and stronger dual cuts [11]. As happens with common polyhedral cuts, dual cutting planes can be derived by taking into account the structure of the dual solutions.

Given a client $i \in N$, let S be a subset of clients such that $\sum_{j \in S} l_j = l_i$, and P be a path between all the clients of S. The cost of that path is denoted by cp. Let $c^1_{\min}$ and $c^2_{\min}$ be the first and the second smaller cost of arcs incident in i, respectively. Let a and b be the nodes at the extremities of P, and $d^1_{\max}$ and $d^2_{\max}$ be the higher costs among the arcs incident in a and b, respectively. If P is a circuit, pick the higher arc costs incident in two nodes of S. The following cut is valid in the dual space:

$$-\pi_i + \sum_{j \in S} \pi_j \le c_p - (c^1_{\min} + c^2_{\min}) + (d^1_{\max} + d^2_{\max}) \quad (27)$$

The columns in the primal related to (27) represent the possibility of exchanging clients in a route. The capacity of the vehicles is never exceeded. Hence, the primal is not relaxed, and the continuous bound remains unchanged. When the minimum filling constraint does not apply, one may relax the requisites on set S. In that case, S may be defined as a subset of clients such that $\sum_{j \in S} l_j \le l_i$.

The introduction of these cuts in the RMP can be done in two ways. A large set of cuts can be generated once before column generation starts. This strategy has been largely used [10,11]. The cuts can be generated dynamically, as the other columns. In this particular routing problem, to dynamically generate the cuts (27) using dynamic programming for example, we have to keep track of the head and tail of the path to correctly account for the cost at the right hand side of (27). The state space becomes larger, but given that the capacity constraint is determined by the load of client i, which is typically much smaller than W, generating paths of medium cardinality can be done efficiently.

CUTTING PLANES

Improving the convergence of the column generation helps in getting the bound of the model faster. Increasing this bound by adding cutting planes, for example, accelerates the convergence to integer optimal solutions. Combining cutting planes procedure with column generation algorithms is far from being trivial. Typically, the cuts change the structure of the subproblems making them harder to solve. Given that the most efficient column generation algorithms are those that allow the subproblem to be solved repeatedly and quickly, the cuts should be chosen so as to be compatible with the structure of the subproblem.

Recently, new cuts have been described in the literature [4,6,14]. They were used to strengthen column generation models for cutting and packing problems. These cuts are based on dual-feasible functions which can be formally defined as follows.

Definition 1: A function $f : [0,1] \to [0,1]$ is said to be dual-feasible if for any finite set S of real numbers, the following applies

$$\sum_{x \in S} x \le 1 \Rightarrow \sum_{x \in S} f(x) \le 1.$$

In [5], the authors showed that dual-feasible functions can be used to derive valid inequalities for integer programs. The coefficients of the cutting planes are defined by applying the dual-feasible function to the coefficients of a generating constraint, which is also valid for the problem.

In our routing problem, we can apply these principles by considering the following valid constraint for (13)-(18):

$$\sum_{p \in \Omega} f_p \lambda_p \le K \times W - L^T_{\min},$$

with fp denoting the free space in a vehicle that goes through route p. This constraint is redundant in (13)-(18), and so it is not considered explicitly in that model. However, it can be very useful for deriving cutting planes.

Note that the cutting planes will be stronger for smaller values of K. Since K can be updated with the value of the incumbent during the course of the algorithm, the strength of the cuts will be expectably better as the algorithm reaches improved solutions.

BRANCH AND BOUND

Model (13)-(18) does not have the integrality property, and hence solving its linear relaxation may result in solutions with fractional values. To search for integer optimal solutions, we resort to branch-and-bound. When column generation is applied at each node of the branching tree, the global method is called branch-and-price.

Branching on the variables of the master problem should not be done. Forcing a column to be equal to 1 is trivial (we just have to remove the clients visited in the corresponding route and update other values at the right hand side of the constraints), but trying to exclude a column from the RMP is much more complicated. What happens is that the forbidden column will be regenerated if nothing is done to avoid it. The only way to avoid regeneration is to reformulate the pricing subproblem. That usually leads to very complicated subproblems.

In our implementation, we considered branching on the variables x_{ij} of the network flow model. If the solution of a linear relaxation is fractional, two branching nodes are created with the following branching constraints: x_{ij} =1 and x_{ij} =0. These constraints are easily enforced in the RMP. For that purpose, one has to keep the definition of the paths related to each column in the RMP.

PRELIMINARY COMPUTATIONAL RESULTS

The exact branch-and-price-and-cut algorithm presented above was coded in C++. For some of the optimization subroutines, we used the CPLEX 10.2 Callable Library [15]. The tests were performed on a PC with a 2.20 GHz Intel Core Duo processor, and 2GB of RAM.

We conducted some preliminary computational experiments on a set of random instances with up to 50 clients. We used instances with 15, 25 and 50 clients. The loads, distances and other parameters of the problem were generated using an uniform distribution.

Expectably, the performance of the algorithm relies heavily on the sizes of the instances. The two parameters determined by the waste managers ($L_{\min}$ and $L^{T}_{\min}$) also impacts on the overall performance of our optimization procedures.

For the sake of brevity, we do not list here the list of computational results obtained. The complete list and a deeper discussion of these results is left for the long version of the paper. In summary, instances with up to 25 clients are usually solved in less than 5 minutes, by searching usually in no more than 1000 branching nodes. For the instances with 50 clients, we usually converge to a small optimality gap in a reasonable amount of time. Even when the algorithm does not find an optimal integer solution within the time limit (we used 15 minutes in our experiments), it can always be used as a good heuristic by aborting its execution whenever the optimality gap is below an acceptable value.

CONCLUSIONS

In this paper, a routing problem arising in an urban waste management system was analyzed. The motivation for studying this problem comes from the necessity in harmonizing the flow of materials coming in the recycling facilities with both the quality of service provided to the municipality and some economic criteria. Our approach is analytical. After stating formally all the elements that define the problem, we defined an exact optimization algorithm for it. Our method is based on efficient integer programming techniques, namely column generation, branch-and-bound and cutting planes. Combining these methods in a single robust algorithm is well known to be a hard task. The advantage lies on the quality of the associated models.

Forthcoming research will lead to the exploration of new families of cutting planes based on dual-feasible functions, and on efficient rounding schemes that allow to quickly improve the incumbent in the branching tree.

References

[1] Alves, C., Valério de Carvalho, J. M., Planeamento de rotas num sistema de recolha de desperdícios de madeira. Investigação Operacional, 24:21-43, 2004.

[2] Bettinelli, A., Ceselli, A., Righini, G., A branch-and-price algorithm for the variable size bin packing problem with minimum filling constraint. submitted to Annals of Operations Research, 2008.

[3] Dantzig, G. B., Wolfe, P., Decomposition principle for linear programs. Operations Research, 8:101-111, 1960.

[4] Alves, C., Valério de Carvalho, J. M., A branch-and-price-and-cut algorithm for the pattern minimization problem. RAIRO Operations Research (in press), 2008.

[5] Clautiaux, F., Alves, C., Valério de Carvalho, J. M., A survey of dual-feasible and superadditive functions. Annals of Operations Research (accepted), 2008.

[6] Baldacci, R., Boschetti, M., A cutting plane approach for the two-dimensional orthogonal non guillotine cutting stock problem. European Journal of Operational Research, 183:1136-1149, 2007.

[7] Merle, O. du, Villeneuve, D., Desrosiers, J., Hansen, P., Stabilized column generation. Discrete Mathematics, 194:229-237, 1999.

[8] Luebbecke, M., Desrosiers, J., Selected topics in column generation. Operations Research, 53:1007-1023, 2005.

[9] Kallehauge, B., Larsen, J., Madsen, O., Lagrangean duality applied on vehicle routing with time windows. Computers and Operations Research, 33(5):1464-1487, 2006.

[10] Valério de Carvalho, J. M., Using extra dual cuts to accelerate column generation. INFORMS Journal on Computing, 17(2):175-182, 2005.

[11] Clautiaux, F., Alves, C., Valério de Carvalho, J. M., New stabilization procedures for the cutting stock problem. submitted, 2007.

[12] Alves, C., Planeamento de rotas de veículos em sistemas de recolha/distribuição. Master's thesis,

Dissertação de Mestrado em Engenharia Industrial, Especialidade de Logística e Distribuição, Universidade do Minho, 2000.

[13] Ahuja, R., Magnanti, T., Orlin, J., Network flows: Theory, algorithms and applications. Prentice-Hall, 1993.

[14] Vanderbeck, F., Exact algorithm for minimizing the number of setups in the one-dimensional cutting stock problem. Operations Research, 46(6):915-926, 2000.

[15] Ilog. Ilog CPLEX 10.0 Reference Manual. 9, rue de Verdun, BP 85, F-92453, Gentilly, France, 2006.

MAKESPAN MINIMIZATION IN THE FLOW-SHOP SCHEDULING PROBLEM WITH SEQUENCE DEPENDENT SETUP TIMES

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Keywords: Flow shop scheduling, sequence-dependent setup times, exact algorithm, Makespan

1. INTRODUCTION

In this paper, we address the problem of finding a permutation schedule of n jobs in an m machine flow-shop environment that minimizes the maximum completion time C_{max} (Makespan) of all jobs. The jobs are available at time zero and have sequence-dependent setup times on each machine. All parameters, such as processing and setup times, are assumed to be known with certainty. This problem is classified in the scheduling literature as the sequence-dependent setup time flow-shop (SDST flow shop) . It is easy to see that the SDST flow shop scheduling problem to minimize the Makespan is NP-hard in the strong sense, since the problem is equivalent to the extensively studied and computationally intractable travelling salesman problem (TSP) when m=1 [1]. Further, when sequence dependent setups are present on all machines of a flow shop, Gupta and Darrow [3] showed that permutation schedules (where the sequence of job on all stages is identical) are not always optimal even for the two-machine case.

Applications of sequence-dependent setup time scheduling are commonly found in most manufacturing environments. In printing industry, for example, presses must be cleaned and settings changed when ink color, paper size or type differ from one job to the next. Setup times are strongly dependent on the job order. In the container manufacturing industry machines must be adjusted whenever the dimensions of the containers are changed, while in printed circuit board assembly, rearranging and restocking component inventories on the magazine rack is required between batches. In each of these situations, sequence-dependent setup times play a major role and must be considered explicitly when modelling the problem.

This is the case of the real problem addressed in this work – the manufacturing of natural wood doors. In this industry, the doors in different sizes, wood species and panels, create the need to adjust the machines every time one of these parameters changes, and the setup times are strongly dependent on the job order.

In this work, we develop an exact algorithm for solving a real flow-shop scheduling problem. First, we give a general integer programming formulation (IP) for the problem. Then, taking advantage of the special structure and properties of the real system, we show how this problem can be reduced it to a single machine.

The success of the method is mainly due to the excellent balance between the model simplicity and the correct level of real system representation. Although many system variables were relaxed, the results obtained show that we were able to keep the relevant system variables in the model.

This solution was validated against the real system and the results obtained show that the approach is capable of solving problems of large size to optimality within reasonable computational time.

This paper is organized as follows. In next section, we describe the problem. In section 3 we formulate our problem, describe the simplification approach and present the simplified model. Next, in section 4, we describe the computational experiments, and report the results. Finally, in section 5, we conclude the paper.

2. PROBLEM DESCRIPTION

The production process under study is a flow shop with permutation, processing large quantities of wood panels coated, machined and packaged (more than 5.000 doors per day). The production orders are obtained through the current planning system (*ERP*) and comprehend the following information: product type, quantity, and production date.

Product families are defined according to the characteristics of coating, size and structure. Thus, the setup time is the time needed to adjust the machine to process a sequence of two different jobs belonging to two different families. If two consecutive jobs to be processed belong to the same family, setup time is considered to be equal to zero. These setup times are heavily dependent on the type of operation and on the family of products.

The *ERP* (APO) establishes the production schedule for the first work station (stage) through a heuristic process, taking in account the delivery date and machine setups. This process will not be considered in our study as it is a "*blackbox*" and company management don't want to change it, for several reasons. Subsequent work stations follow a FIFO rule. The FIFO rule is justified by the wood panels lot size and weight; it takes a lot of effort to move it out of the sequential position.

The production managers claim that this approach is far from being efficient as setup times are important and are not formally considered. Our study will focus on these work stations with the objective to improve its overall efficiency.

In the flow shop environment, a set of n independent jobs $N=\{1, 2, \ldots, n\}$ must be scheduled on a set of m machines $M=\{1, 2, \ldots, m\}$, where each job has the same routing, that is, they have to be processed first on machine 1, then on machine 2, and so on. Therefore, without loss of generality, we assume that the machines are ordered according to how they are visited by each job. After completion on one machine, a job joins the queue at the next machine. If the queues operate under the *first in first out* (*FIFO*) discipline, the flow shop is referred as a *permutation* flow shop.

Each job j consists of m operations O_{ij} (i =1,…, m) which have to be processed in the order $O_{1j} \rightarrow O_{2j} \rightarrow \ldots \rightarrow O_{mj}$. Operation O_{ij} has to be processed on machine M_i without preemption for $p_{ij} \geq 0$ time units. Each machine can only process one job at a time.

We suppose that each job is available at time zero. We also assume that there is a setup time which is sequence dependent so that, for every machine i, a setup time must precede the start of a given operation that depends on both the job to be processed (k) and the job that immediately precedes it (j) - a sequence dependent setup time is incurred whenever jobs are from different families of products. The setup time on machine i is denoted by s_{ijk} and is assumed to be *symmetric*, i.e., $s_{ijk} = s_{ikj}$. After the last job has been processed on a given machine, the machine is brought back to an acceptable "ending" state. We assume that this last operation can be done instantaneously because we are interested in job completion time rather than machine completion time.

As the buffers have high capacity (more than 4 hours) and work in-process is, typically, less than that, it is reasonable to assume that there's no machine idle time and buffers have unlimited capacity.

Our objective is to minimize the time at which the last job in the sequence finishes processing on the last machine, that is, completion time *Cmax* (Makespan) of all jobs.

All the parameters are deterministic nonnegative integers.

In the literature [2] this problem is denoted by $Fm|s_{ijk}, prmu|Cmax$ or *SDST flow shop*.

3. PROBLEM FORMULATION

In this chapter, first we will present a general formulation for the flow shop *SDST* problem. Then, we will describe the process followed to simplify it and present the final mathematical model.

3.1 Flow Shop Integer Programming Formulation

A standard flow shop scheduling problem can be formally stated as follows: A set $N=\{1,2, \ \ , n\}$ of n jobs is to be processed on m stages sequentially. There is one machine at each stage. All machines are continuously available. A job is to be processed on one machine at a time without preemption and a machine processes no more than one job at a time. The objective is to schedule the jobs so as to minimize some performance measure such as the Makespan, total completion time, maximum tardiness, total tardiness, weighted tardiness, and weighted sum of earliness and tardiness, among others.

The formulation presented here is an adaptation from [2] and is based on the following assumptions:

- All n jobs are independent and available for processing at the initial time.
- The production work station has sufficient capacity to store and manage the work-in-process (WIP) inventory generated during the execution of the complete set of jobs. That is, we suppose infinite storage capacity at each stage.
- One machine can process only one job at a time and one job can be processed by only one machine at any time.
- The ready times for all machines (times when the machines become available to process the set of jobs to be scheduled) are known.
- For all the jobs, the processing times at each stage are known and deterministic.

- Job set-up times are sequence-dependent.
- Travel time between consecutive stages is negligible. In instances where this assumption does not hold true, inter-stage travel can be treated as a processing step with the process time equal to the travel time.
- Pre-emption is not allowed, that is no interruption of a job processing is allowed.

To present the mathematical, the following notation is needed:

x_{jk} : a binary variable that is equal to 1 if job j is the kth job in the sequence, 0 otherwise;

I_{ik} : an auxiliary variable which denotes the idle time on machine i between the processing of the jobs in the kth position and (k+1) position;

W_{ik} : an auxiliary variable which denotes the waiting time of the job in the kth position in between machines i and i+1:

p_{ij} : the processing time on machine i of the job j;

s_{ijl} : setup time on machine i if job l is processed immediately after job j.

The problem can now be formulated as:

$$(1)\ \min\ C_{\max}$$

$$(2)\ \sum_{j=1}^{n} x_{jk} = 1, k = 1,\cdots,n$$

$$(3)\ \sum_{k=1}^{n} x_{jk} = 1, j = 1,\cdots,n$$

$$(4)\ I_{ik} + \sum_{j=1}^{n} x_{j,k+1} p_{ij} + \sum_{j=1}^{n}\sum_{l=1}^{n}\left(x_{lk}.x_{j,k+1}\right).s_{ijl} + W_{i,k+1}$$
$$- I_{i+1,k} - \sum_{j=1}^{n} x_{jk} p_{i+1,j} - \sum_{j=1}^{n}\sum_{l=1}^{n}\left(x_{jk}.x_{l,k+1}\right).s_{ijl} - W_{ik} = 0,$$
$$k = 1,\cdots,n-1, i = 1,\cdots,m-1$$

$$(5)\ C_{\max} = \left(\sum_{i=1}^{m-1}\ \sum_{j=1}^{n} x_{j1} p_{ij} + \sum_{j=1}^{n-1} I_{mj}\right)$$

$$(6)\ x_{jk} \in \{0,1\}, I_{ik} \geq 0, W_{ik} \geq 0, j = 1,\cdots,n$$
$$k = 1,\cdots,n, i = 1,\cdots,m$$

The cost function (1) minimizes the Makespan which is equivalent to minimize the total idle time on last machine m – equation (5). The first set of constraints (2) specifies that exactly one job has to be assigned to position k, for any k. The second set of constraints (3) specifies that job j has to be assigned to exactly one position. The third set of constraints (4) relate the decision variables with the physical constraints which enforce the necessary relationships between the idle time variables and the waiting time variables. Equation (5) defines the Makespan. Constraints (6) impose binary integrality for decision variables and non negative values for auxiliary variables.

This is a large-scale integer programming problem which is not easy to solve because it involves a nonlinear expression (4).

3.2 Simplified Flow Shop Integer Programming Formulation

The detailed study of the production system revealed some opportunities to simplify the formulation presented in (3.1):

- As the buffers have high capacity (more than 4 hours) and the production system initial condition is always with WIP (not empty), we can assume that machine idle time is equal to zero.
- Once a processing sequence is defined for a production batch, the FIFO rule is to be followed for all the stages. This is equivalent to say that that initial machine setup configuration is equal for all the stages.
- As there is no machine idle time, machine setup time during idle time is not applied.
- Processing times are constant for all the stages, that is, do not depend on the job sequence. Therefore, minimizing the total production batch setup times is equivalent to minimize the Makespan.

Based on these assumptions, the problem can be reduced to a single stage (machine) formulation with the objective to minimize the total setup times. This formulation is equivalent to the traveling salesman problem (TSP).

To formulate the single machine (stage) SDST model, the following notation is needed:

x_{jk} : a binary variable that is equal to 1 if job k is processed immediately after job, 0 otherwise;

x_{0k} : a binary variable that is equal to 1 if job k is the first job to be processed in the production sequence, 0 otherwise;

x_{j0} : a binary variable that is equal to 1 if job j is the last job to be processed in the production sequence, 0 otherwise;

s_{jk} : total setup time for all m stages if job k is processed immediately after job j, in the production sequence;

s_{0k} : total setup time (for all m stages) if job k is the first job to be processed in the production sequence;

s_{j0}=0;

The simplified formulation is:

$$(7)\ \min \sum_{j=0}^{n}\sum_{k=1}^{n} s_{jk}x_{jk}$$

$$(8)\ \sum_{k=0|k\neq j}^{n} x_{jk} = 1, j = 0,\cdots,n$$

$$(9)\ \sum_{k=0|k\neq j}^{n} x_{jk} = \sum_{k=0|k\neq j}^{n} x_{kj}, j = 1,\cdots,n$$

$$(10)\ x_{jk} \in \{0,1\}, j = 0,\cdots,n, k = 0,\cdots,n$$

The cost function (7) minimizes the total sum of setup times. The first set of constraints (8) specifies that each job is processed exactly once. The set of equations (9) are flow conservation constraints. Constraints (10) impose binary integrality for decision variables.

4. COMPUTATIONAL IMPLEMENTATION AND RESULTS

In this section, we describe the method to obtain the test instances and we report the computational results.

All the algorithms involved were coded in Microsoft Excel and the Lingo package was used to solve the linear programming problems. The computational tests were performed on a desktop computer with a 2.6 GHz Pentium IV processor and 512 Mb of RAM.

4.1 Test Problems

The test problems were generated as follows:

- Selection of product families with significant setup times between them (there are about 37 product families);
- Planning Horizon: one work day which is equivalent to approximately 12 families (jobs) of products (n = 12).
- For these 12 families, it was determined the total setup time (for all stages) matrix.
- Number of test instances: 10 (randomly selected)

4.2. Test Results

From the 10 instances tested we can conclude the following:

- This algorithm is able to solve one day size problems in less than 40 seconds in average;
- The schedules generated were analyzed by production management and considered correct according to their knowledge and experience;
- Production management considered this approach is valid and shows a clear improvement from the actual situation.

5. CONCLUSIONS

In this work, we develop an exact algorithm for solving a real flow-shop scheduling problem. First, we presented a general integer programming formulation (IP) for the problem. Then, taking advantage of the special structure and properties of the real system, we reduced it to a single machine problem.

The success of the method is mainly due to the excellent balance between the model simplicity and the correct level of real system representation.

All the algorithms involved were coded in Microsoft Excel and the Lingo package was used to solve the linear programming problems.

Ten test instances were generated based on the real system. The test results show this algorithm is able to solve one day size problems in less than 40 seconds in average.

The schedules generated by the algorithm were validated by production management against the real system and. They also considered that this approach represents a clear improvement from the actual situation.

References

[1] B Chen, C N Potts and Woeginger G.J. , *A review of machine scheduling: Complexity, algorighms and approximability* in D.-Z. Du and P. Pardalos (ed.)*Handbook of Combinatorial Optimization*, Kluwer Academic Publishers, **3** 21-169 (1998)

[2] PINEDO, M., (1995), "*Scheduling: Theory, Algorithms, and Systems*", Prentice Hall.

[3] Gupta, J. (1988). "*Two stage hybrid flow shop scheduling problem*". *Journal of the Operations Research Society*, *38*, 359–364

CASE STUDY: CONTINUOUS IMPROVEMENT IN A SEMICONDUCTOR ASSEMBLY FAB

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Abstract: Semiconductors industrial companies have a specially interest in exploring the business opportunities for competitive advantage that can be gained by reinforcing production efficiency through continuous improvement with business sustainability practices. The present case study addresses this continuous need of improvement in order to ensure the long-term viability and sustainability of the business. The practices presented on this case study are classified by the company managers as a major example of best practices to be copied by other actors in the company's supply chain network.

Keywords: management; continuous improvements, evaluation process; enterprise resources

INTRODUCTION

The ability to quickly react to changes and continuously improve are becoming key factors for the survival and the success of any enterprise operating in today's competitive and globalized markets. Specially, semiconductors companies have to face completely new challenges such as world-wide availability, quick response to markets changes, product quality, delivery reliability and long term business sustainability.

Furthermore, there is in the semiconductors industrial sector, an increased interest in exploring the business opportunities for competitive advantage that can be gained by reinforcing production efficiency through continuous improvement with business sustainability practices [1].

Business Sustainability can be defined as a pro-active approach to ensure the long-term viability and integrity of the business by optimizing resource needs, reducing environmental, energy or social impacts, and managing resources efficiently while not compromising profitability [2].

The work presented in this paper reports to a case study on Qimonda Portugal an Assembly Fab of the Qimonda AG semiconductor supply chain located at Vila do Conde.

PROCESS DESCRIPTION

The manufacturing of semiconductor devices from base silicon "wafers" is a highly complex process which has been described as perhaps the world most difficult scheduling and process management problem. The process involves four main steps:

1. Wafer fabrication – the layers of the silicon chip are built up in an ultra-clean environment of a wafer fab. Many individual circuits are made on a single wafer. This involves very precise, expensive and unreliable equipment, through which the wafer must flow many times. At a certain load the cycle time through a wafer fab may typically be around 40 days. However, due to queuing caused by the complex re-entrant flow paths, this cycle time could be longer. Wafer fabrication requires highly skilled operators. Therefore the supply of such skilled labour is a major determinant in the location of the wafer fabs.
2. Probe test – the individual circuits in the wafer are tested using a testing machine attached to a probe, which indexes around the wafer and detects faulty circuits.
3. Assembly – each wafer is cut into individual circuits, known as die, which are then bond to connecters and sealed in packages to become the familiar silicon chips. This stage normally involves highly levels of labour with abundant types of specialized equipment.

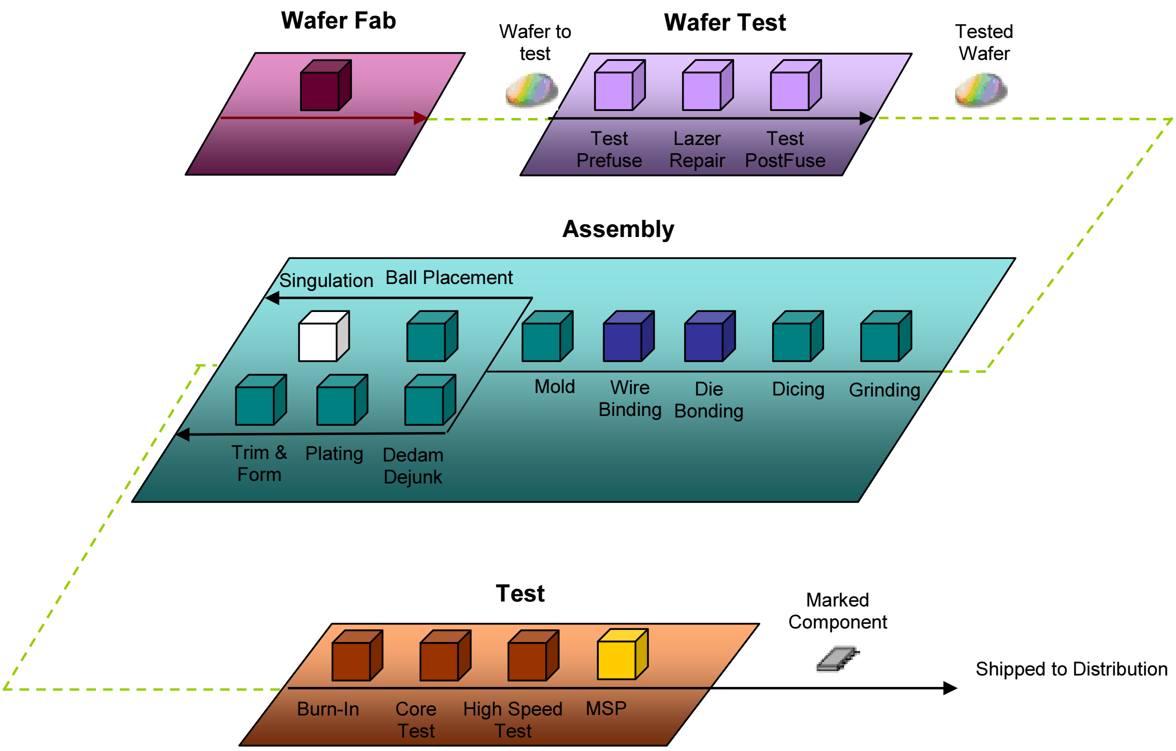

Fig. 1. Semiconductor process flow

4. Final Test – the individual chips are loaded into a handler attached to a test machine and fully tested. These testing machines are very expensive equipments and in larger sites with a restricted product range, they normally use dedicated testing machines to probe and final test.

The figure 1 presents the four main steps in Qimonda's semiconductor memory chip fabrication.

Specifically on Qimonda's Portuguese factory as an Assembly fab, the wafers arrive directly to the wafer test step in order to identify the dies to be assembly in the following processes. This wafer conformity mapping in the past was achieved through ink spots on the faulty circuits. Presently this identification is accomplished with memory chips attached to the wafers that store the location of the nonconformity.

After this first step, starts the core process behind Vila do Conde Qimonda's factory and the main focus of this case study, the Assembly phase. The first operation corresponds to grinding, which is a thinning operation on the surface of the wafer before cut. Afterwards there's the dicing operation in which the wafer is cut in its small devices known as dies. From this point on the flow is separated in two distinct families' product:

- Lead-Frame known as TSOP, which are standard memories packages that have a plurality of connection terminals extending from the device. A lead frame is disposed adjacent to the packages, positioned medially of the air space and having a plurality of connection terminals in registration with and in electric contact with the plurality of TSOP connection terminals.
- Substrate know as BOC, (board-on-chip) semiconductor package includes a semiconductor die having die contacts, a substrate bonded circuit side down to the die, and an adhesive layer bonding the substrate to the die. The substrate includes a circuit side having a pattern of conductors and wire bonding sites, and a back side having an array of external contacts in electrical communication with the conductors.

In the Die Bonding, the dies collected from the wafer are placed on the Lead-Frames or the Substrates depending if the products are TSOP or BOC. Afterwards the die is connected to the Lead-Frame or the Substrate through gold wire on the Wire Bonding operation. Then the package is molded with resin to seal the die and the wire bonded connections in the Mold operation.

From this stage on the flow is physically divided. For TSOP family products we have the leads separation in Dedam Dejunk, then lead protection with a protective layer on plating, and finally the Trim & Form to form and individualize the leads.

In the case of BOC family products we have two operations: Ball Placement which consists in the placement of small balls of solder on the surface of the substrate and bond with it; and Singulation which a saw operation of the substrate in individual packages.

Afterwards, in the last stage of the process, the memories packages are fully tested, identified according to their performance and behavior in specialized testing equipments. After that the products are laser marked, packed and sent to the distribution center.

This paper presents the “ongoing work” of continuous improvement; scrap reduction; efficient use of resources and materials in order to achieve business sustainability of the engineering process at Vila do Conde Qimonda’s factory. Specially addresses the studies performed in the Singulation operation of the BOC family products.

2. Substrates orientation checking – a camera identifies the product and orientation in order to prepare the placement of the substrate;
3. Sawing substrates placement – in the Dicer (the sawing part of the Singulation machine occurs a cutting mechanical process through two disk thin blades. The substrate is placed in a chuck table that fixes the substrate to the table though vacuum;
4. Cutted substrate scrap removable – this is achieved through water jets directed to the sawing area combined with contact velocity from the cutting blades;
5. Substrate wash – already singularized units are removed from the dicer and placed in the washing station to clean any impurities;
6. Substrate dry – prior to the final inspection the individual units are dried through hot air;
7. Ball vision inspection – through a camera, a visual inspection to singularized units is made in order to evaluate their conformity;
8. Turn table – on this phase automated arms pick and place upside down the singularized units in order to the following inspection;

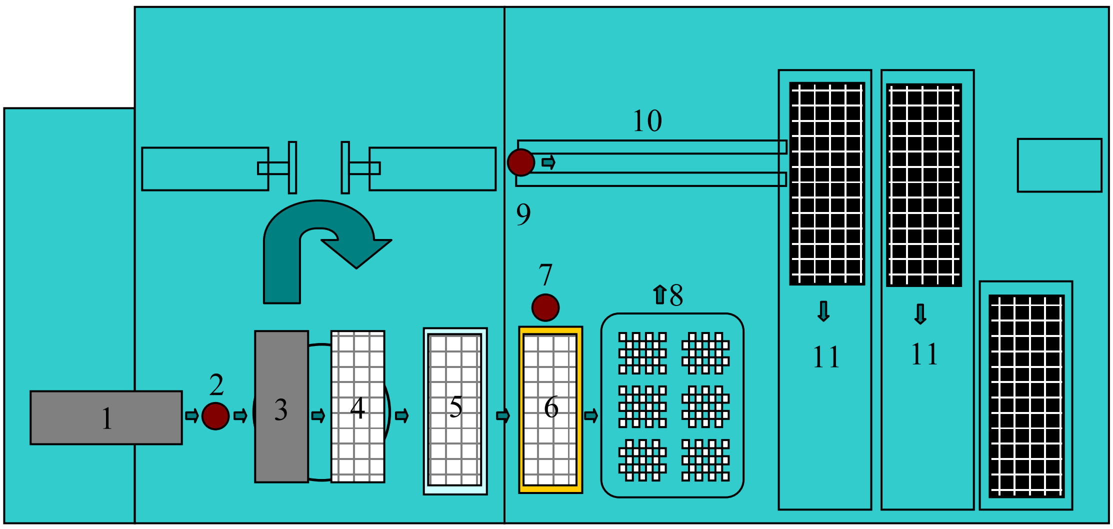

Fig. 2. Singulation process machine

The Singulation process occurs in special automated machines that saw substrates (BOC) into individual packages memory units setting them into trays through the following steps as presented in the figure 2:

1. Input magazine sets – the feed of the individual singulation machines are made through magazines containing sets of substrates, this substrates are then placed in a entrance guide;

9. Mark vision inspection – a third camera inspects the bottom side of each unit in order to detect nonconformities;
10. Pick and place individual packages – two automated arms move the inspected units to the turntable trays to final positioning;
11. Tray positioning – last operation that places the singularized units in custom made transportation trays to finalize the Singulation process.

Figure 3 presents a final product of the Singulation operation.

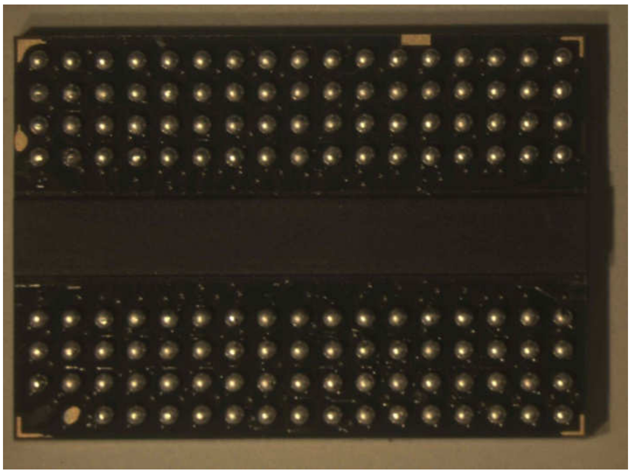

Fig. 4. Singularized BOP unit

USE CASE FOCUS

In order to maintain “Business Sustainability” in Qimonda’s supply chain, engineering process teams were formed and started working with a common objective in mind, a continuous improvement on every process phase. This particular paper addresses and presents the work and results obtained so far in the Singulation phase of the Assembly fab process at Vila do Conde Quimonda’s factory.

The main concern at Singulation process to the process engineers is related with the continuous effort to minimize the numbers of defective product units quantified through ppm (parts per million) process numbers. The statistical studies have shown that the major types of nonconformities are:

1. Ball Pad removed – this type of nonconformity occurs when in a particularly place where should be a ball, they are totally or partially removed along with the ball pad (the place where it should be weld to the substrate). Examples of this nonconformity on figures 4 and 5.

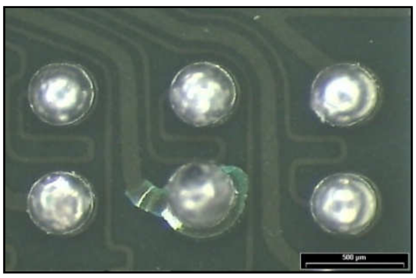

Fig. 4. Ball Pad partially removed

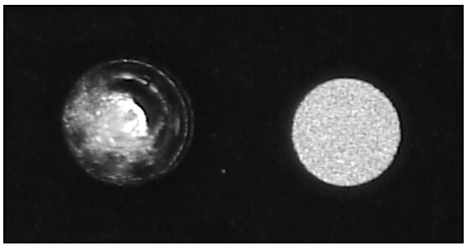

Fig. 3. Ball Pad totally removed

2. Ball Pad – this type of nonconformity occurs when the welding area are 100% grey without any contamination. This means that the ball didn’t weld with the ball pad and the ball was removed during the Singulation wash phase. Example of grey pad nonconformity on figure 6.

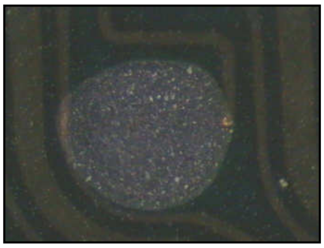

Fig. 6. Grey Pad

The initial studies (early 2006) addressed and evaluated the influence of the Singulation process in missing ball pad failure for the critical products of the process namely 256 GT11M and 512M T1184 products. The studies were conducted in the two types of singulation machines (Intercon and Hanmi) in order to determine if it exists any equipment correlation with the levels of missing ball pad failure.

During these studies it was possible to statistically map the positions of the nonconformities with respect to the substrate. In the figure 7 it is possible to observe the final results of this statistical analysis. The number of defectives in each position grows from minimum values represented in white color to the maximum values in red.

These statistical results have shown that: the last mold CAP doesn’t have any grey pads and 64% of grey pads failures are in third line. Also on unit mapping: around 60% of grey pads failures are in column 1; more than 70 % of grey pads failures are in the first part of units and 40% of grey pads failures are in line 1.

Looking to the Singulation process and according with the previous studies, two main potential causes were identified for grey pad and ball pad removable nonconformities:

- Water jets;
- Scrap "flying" due to sawing operation.

In order to evaluate the two main potential causes for defective units a series of experiences were prepared and executed for each potential cause.

With respect to water jets, the procedure to evaluate this cause involved the use of previously tested substrates. These substrates were afterwards subject to intensive water jets projection for several hundred passages on each direction in order to evaluate if the water jets have sufficient impact force to remove the substrate balls. The experiment demonstrated that the water jets didn't have sufficient force independently of the water flow speed to remove any balls.

The second set of experiments evaluated the scrap "flying" effect against balls. To accomplish these experiments some modifications were tested, the first one consists in the reorientation of the substrates by 180º degrees and the second, the installation of a high speed camera inside the singulation machine to check scrap trajectories.

For the first part of the experiment the results demonstrated that when rotated, the grey pads nonconformities changes position (follows rotation), clearly shows a correlation to dicing process. Figure 8 presents these results.

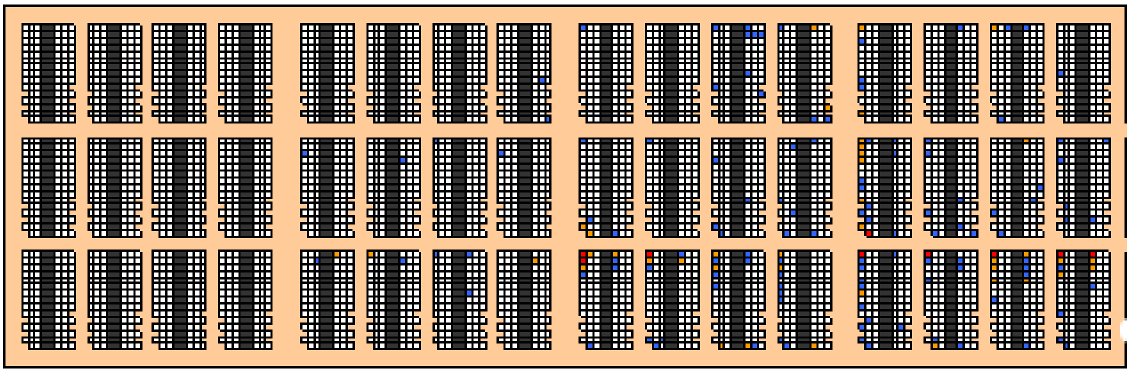

Fig.7. Failure mapping of the substrate

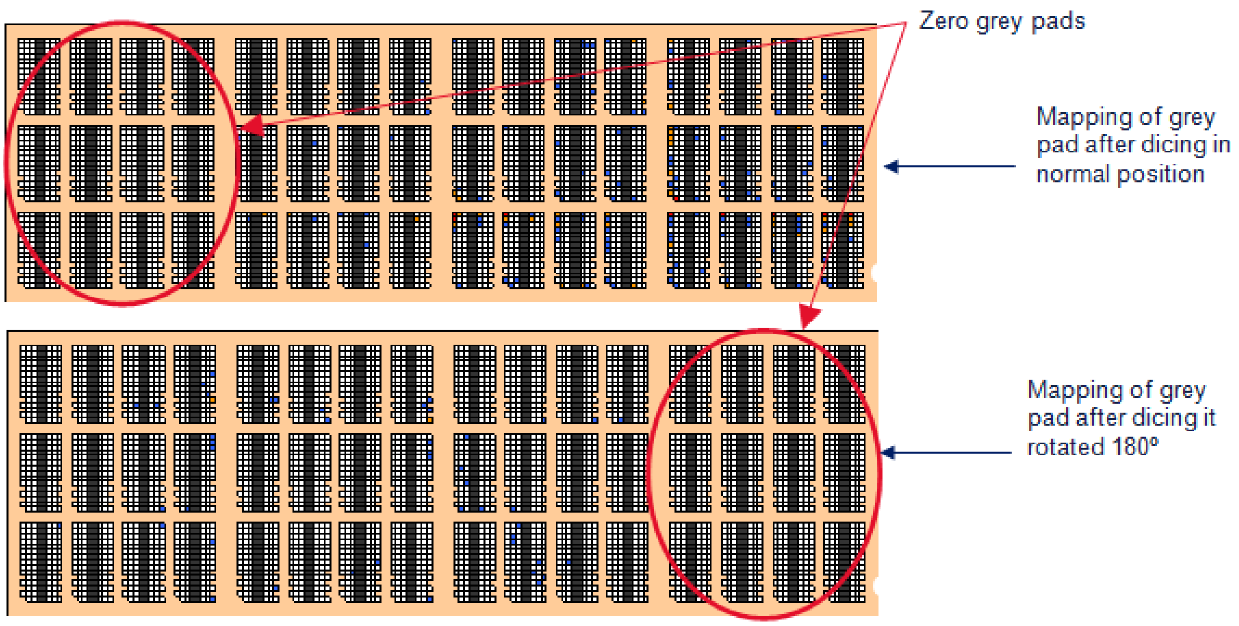

Fig. 8. Failure mapping of the substrate with 180º reorientation

Fig. 5. Failure mapping of the substrate

In the second part of the experiment based with the use of a high speed video camera to check scrap if scrap hits the balls, the video showed that sometimes, scrap is thrown against the substrate, consequently hitting the balls and potentially damaging them. The last cut mold cap is not affected since only the furthest mold caps are hit by the scrap. This validates the grey pad statistically mapping showed before.

two different equipments namely Hanmi model 6340 and Towa Intercon model 6361 (equipments with similar specifications) were used on a intensive test during a week to check for any correlation between fails and equipments families types. The statistical results have shown there wasn't any correlation between Hanmi e Towa Intercon equipments and the quantities or types of nonconformities. On other hand the

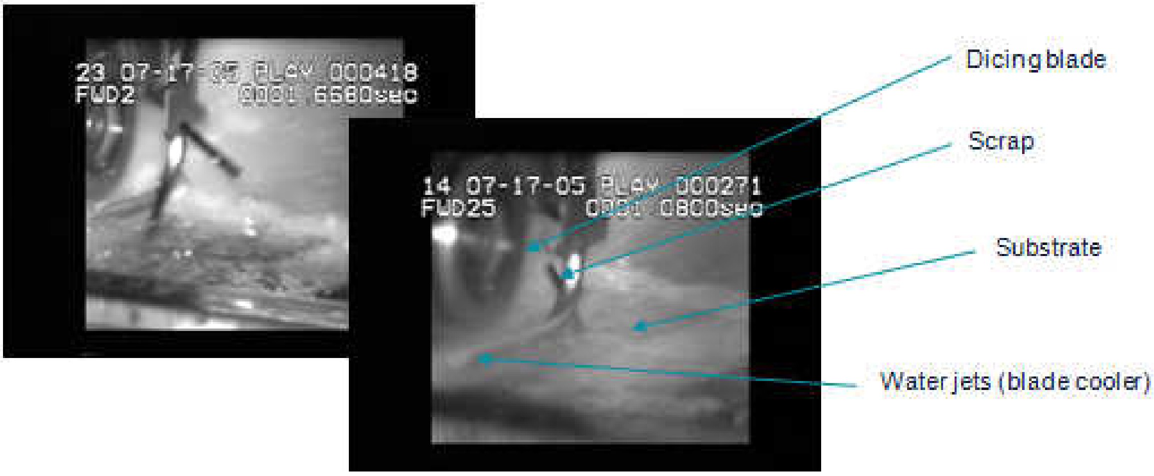

Fig. 9. High speed camera pictures

An immediate conclusion of these tests was that there is a direct relation between missing ball pad failure and the Singulation process namely with the scrap "flying" effect against balls.

Another complementary experiment involved the determination of a possible fail cause resulting from the use of two types of equipment families. In order to evaluate this possible cause,

same study have identified, that there was different levels of defects between the universe of equipments, namely in Hanmi types of equipment with special water jet sprinklers. This later study is summarized with the graph in the figure 10.

These later results have point out to a specific design problem represented in figure 11 and 12.

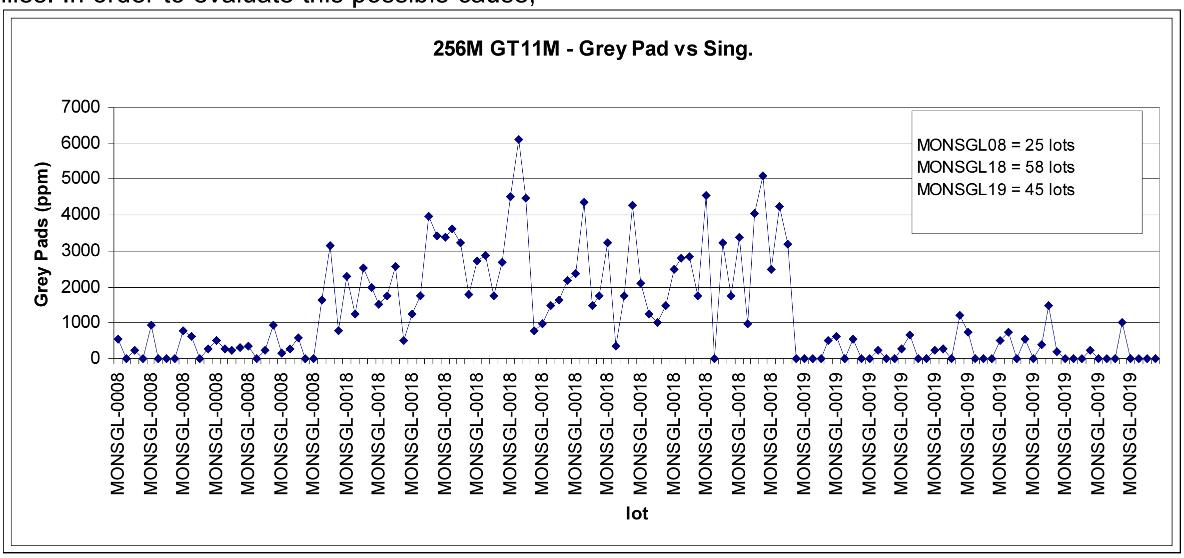

Fig. 10. Hanmi family defects quantity graph

According with the data production collected from the different equipments was possible to demonstrate that the equipments with water jets sprinklers inclined have much larger numbers of defective parts that can reach 4 to 5 times ppm than the equipments with horizontal jets sprinklers, possible due to the less efficient jet removable of the scrap and more damaging trajectory to the substrate.

As a result of these first equipment processing studies, an immediate management decision was made: to replace on all Singulation machines the jet sprinklers with the horizontal configuration. These replacements have proved later on, after their installation on very singulation machine, that the study assumptions were correct.

Fig. 11. Water jets sprinklers inclined

Fig. 12. Water jets sprinklers horizontal

Another important finding on these studies was that the cutting routes of the blades have relevant effect on the number of defects. This was demonstrated by the positions of the damaged and removed balls of the substrate. To proceed with the effort of “continuous improvement” a second set of studies were initiated to deal with the cutting routes from the blade on the substrate.

In this second phase of the studies, it was necessary to evaluate the critical parameters involved with the singulation cutting procedure. From all the variables present in the cutting process: cut sequence; cut speed, cutting blade height, water flow and air pressure were select due to their impact of the cutting process.

The cutting sequence which involves the sequence definition of columns and rows cutting routes has direct impact of scrap collisions with substrates, since longer cutting routes have tendency to project bigger scrap elements.

The cutting speed is a critical variable limited to a maximum of 250 mm/s. As long the as the air speed grows, it also increases the force that scrap hits the substrates; on the other hand, as long as speed is diminished it reduces the performance of the machine, the UPH (units per hour) that the equipment can process.

The third critical variable is the cutting blade height which has direct impact of the forces transmitted to the substrate during the cut. This variable spans from the minimum height at the chuck table (that creates the largest forces into the substrate) and a maximum value that still accomplish the cut of the substrate. Values larger than the maximum result in nonconformities due to lack of slashed borders of the packages.

The water flow is another relevant parameter since it influences the cooling of the blade. Lower levels of water flow provoke premature weariness of the blade or cut quality problems.

Related with the water flow is the air pressure parameter. This variable is critical in the correct distribution of the water in the cutting areas. Insufficient air pressure cause premature weariness of the blade or cut quality problems.

With all of these parameters present in the process, a set of experiments were constructed. These experiments have to be set in a controlled environment in order to establish the direct impact of each parameter in the process and evaluate the best feasible scenario to cope with the objective of reducing the number of defective units in the singulation process. Also by recurring to the statistical tool analysis of variance (ANOVA) [3] it was possible to study the different explanatory variables in this problem and establish the following set of experiments:

- The first set of experiments dealt with the cutting blade height, water flow and air pressure. The purpose was to determine the admissible intervals for these variables that don’t condition the two more relevant variables: cut sequence and cut speed. This was accomplished due to the vast experience of the engineering process of the area.

- The second set of experiments dealt specially with the cut sequence since the final objective was along with the minimization of nonconformities; maximize the flow output of the process (UPH - units per hour). And in order to achieve this maximization the goal was necessary to construct working scenarios with the cutting speed set at maximum or near de maximum.

Due to previous practices the standard cutting sequence was established according table 1 and figure 13.

CH	L S	L E	Item
2	1	1	x
2	24	24	
2	8	9	x
2	16	17	
1	1	1	x
1	7	7	
1	2	4	x
1	5	6	
2	2	7	x
2	18	23	
2	10	12	x
2	13	15	

Table 1 - Standard cutting sequence

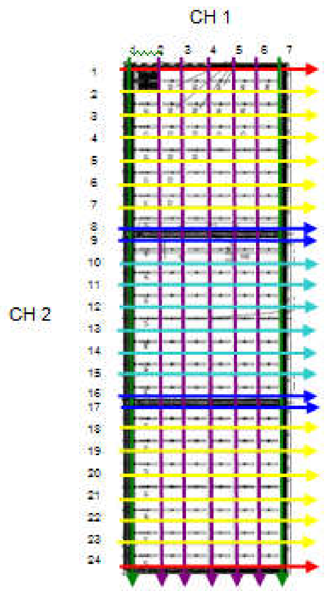

Fig. 13. Standard cutting sequence routes

The CH represents the cut direction, with the CH1 meaning the cut along the length side and CH2 the cut along the width side. LS means the start line and LE means the end line for each channel. The item selection indicates that both blades are cutting; and the absence of item selection indicates one blade cut.

This standard cutting sequence has demonstrated some degree of damaging impacts due to scrap release during the cut. So the next step was to minimize the dimension of the scrap. This concept lead to the following cut set of sequences represented in the table 2 and figure 14.

Solution 1 at is conception did appear very promising because it was constructed with the objective of minimizing scrap dimensions and avoid the warp deformation of the substrate resulting of the cutting heat and pressure. Nevertheless this solution was abandoned due to is tendency to bend the blade and provoke damaged products.

CH	L S	L E	Item
2	1	1	X
2	24	24	
2	5	5	X
2	9	9	
1	1	1	X
1	7	7	
2	2	4	X
2	14	16	
2	6	8	X
2	17	19	
2	10	13	X
2	20	23	
1	2	4	X
1	5	6	

Table 2 - Solution 1 cutting sequence

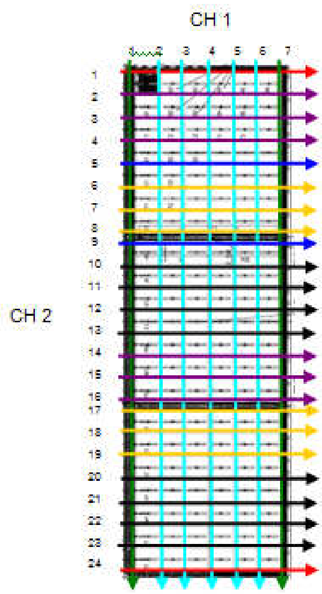

Fig. 14. Solution 1 cutting sequence routes

Finally after a number of iterations, a new cutting sequence was design taking into account the previous results. This final solution is presented in table 3 and figure 15.

CH	L S	L E	Item
1	4	4	
2	8	9	x
2	16	17	
2	1	1	x
2	24	24	
1	1	3	x
1	5	7	
2	2	7	x
2	18	23	
2	10	12	x
2	13	15	

Table 3 - Solution 2 cutting sequence

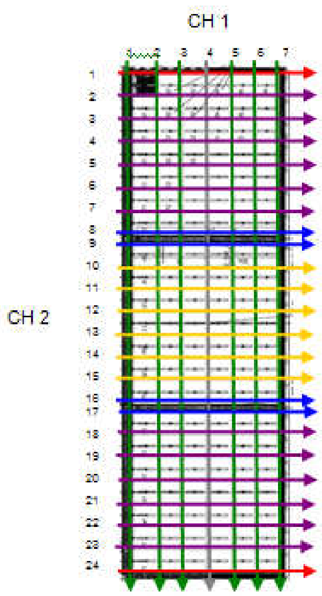

Fig. 15. Solution 2 cutting sequence routes

With the presented solution 2 was possible to resolve the blade bending problems and simultaneously achieve a sufficiently reduced scrap dimension on channel 2 which was demonstrated as the most critical channel for the cutting sequences.

USE CASE RESULTS

The solution 2 sequence was introduced in a two of the Hanmi singulation machines for a test period and later on after its preliminary results extended to the rest of the machines.

After a significant period of time using this new solution 2 cutting sequence, the results achieved were very optimistic. The final results are summarized on the following table 4:

Nonconformity	Grey Pad	Ball Pad Removed
Average ppm reduction	76%	97%

Table 4 - Solution 2 average ppm reduction

With these new validated results, the next phase of this team effort of “continuous improvement” to achieve business sustainability proceed to the next phase, the dissemination of this project findings on similar plants of the enterprise group.

CONCLUSIONS

The first commentary that arises from this use case work is that in order to a process “continuously improve” it has to have the commitment of all human elements involved with it in the pursuit of the business sustainability. Their collective knowledge is fundamental to overcome technological or process difficulties. Companies like Qimonda values this collective knowledge based on the sum of each individual experiences and provide means to its dissemination.

Another important aspect that this use case description portraits quite well is the constant need of improvement. Even after the first phase of the project accomplished very interesting results, still then, the efforts for bigger improvements haven’t stopped. This enterprise attitude is very well suitable with the concept of continuous innovation and improvement that are substantiated in the new paradigms of world class enterprises.

References

[1] Dilworth, J.B., Operations Management, Editor. McGraw Hill International Editions, 1992, p. 221-239.
[2] Smukowsk, D., Center for Innovation and Entrepreneurship – Workshop presentation - bschool.washington.edu/cie/PDF/Business_Sustainability.ppt - 2006
[3] Guimarães, R.C., Estatística. McGraw Hill, 1997. p. 427-483.

THE EXCELLENCE IN METROLOGY

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Abstract: The excellence in Quality is possible… but only if theirs supports are excellences also. A Portuguese legal definition of Quality (in Decreto-Lei 142/2007) is: «Quality is the set of attributes and characteristics of an entity or product that determine their suitability to meet reach needs and expectations of society». It is important to note that what we want, it is no more to please the client or the customer, but to please the entire society. But, if the society needs Quality, an important item for the society satisfaction, so the society needs good supports of Quality. These supports are: Qualification; Standardization; and Metrology.

We believe that Metrology is the special one support! Why we say that? Because the Metrology is the support of Quality with the complete structure and better international organization! In this paper we make to note the importance of the traceability concept and postulate that without good traceability it is not possible excellence in Metrology. And, without excellence in Metrology, there we will never have excellence in Quality. By this path – Quality, Qualification, Standardization and Metrology – we, the society, could expect the excellence!

Keywords: quality; metrology; qualification, standardization, traceability, pillars of the traceability.

1. INTRODUCTION

The excellence is something that we search, but that we never achieve. It can be assumed that this is a perfect target - always searching. Indeed excellence is a way to perfection and therefore unattainable.

In the field of quality, the quest for perfection needs also a quest for perfection in all three pillars of quality: the qualification, the standardization and the metrology. These three pillars are presented in Portugal, by a law which, in the definition of quality, pointed a goal - to satisfy the society and not just the client.

It is made clear that quality only can be done if, in organizations, there is a credible and robust Metrological process. So, it is necessary that the metrology ensures a complete traceability and to be evidenced by a set of four pillars that ensure the six items of the traceability. By this, measurements will be reliable and internationally comparable.

Finally, due to the definition of traceability and complete expression of the result of a measurement, shows that there is not complete measuring without the estimation of uncertainty.

By the proposed work we want to clarify that the items and the pillars of traceability as well as the uncertainty of measurement, are absolutely essential in order the way to the excellence. Consequently the quality and the society can trust in metrology.

2. WHAT EXCELLENCE MEANS

In the Sermon on the Mount, Jesus encouraged the people to be perfect. He did not say «give your best» or «try to be the best», nor said «demand the perfection». He said «be perfect as your Father which is in heaven is perfect». At first we can think that this doesn’t make sense! Nobody can expect be perfect like God! If Jesus is a God, He could not say that! But, precisely because Jesus was a very sapient person, he knew very well what the excellence means, and today, it means the same than 2000 years ago. Yes, it was excellence that Jesus talked about!

Jesus pointed a perfect goal! It is not possible to achieve it! So it is a Path...The Excellence is not a PLACE; it is a WAY! The excellence is continual improvement! Like in everything appended, in Metrology it is not possible to be achieved the Excellence, but looking for it is desirable.

3. THE QUALITY SUPPORTS

Several authors have defined the term quality, however, in Portugal we have a legal definition of Quality that we should fellow because is quite complete and actual. «Quality» is the set of attributes and characteristics of an entity or product that determine their suitability to meet needs and expectations of society [1]. This is an interesting definition: Who we want to please is no more the client, but the society!

According to the Portuguese law [1], that specify the Portuguese Quality System the quality supports are the following:

- qualification
- standardization and
- metrology

We can say that the Metrology is the main pillar because all of the others appeal to the metrology. Moreover, the metrology is strongly structured. It is constituted by people, equipment, places and systems, and it have a very good international organization.

About measurement, Abbagnano, an Italian philosopher said: "Galileu reduced the nature to the measurable objectivity and he have conduced the actual science to the maturity". And Lord Kelvin, about measurement, said “When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind.”

After that, we have no doubts that the measurement is an important Quality support subject.

However, It is usual to say that measuring is a simple matter... because the Metrology is so logic! So, to manage a measuring system should be common-sense only! This is a danger affirmation, because the common-sense is very unstable - it changes from person to person...We will see in next chapter that Metrology is a complex system and needs special cares.

4. BETTER METROLOGY IMPLIES BETTER TRACEABILITY

Metrological traceability is defined by [2] as “property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty”. As an important note, metrological traceability requires an established calibration hierarchy [2].

In a classical view of traceability we can see a pyramid linking the current measurement to the top of International System of the Unities (figure 1).

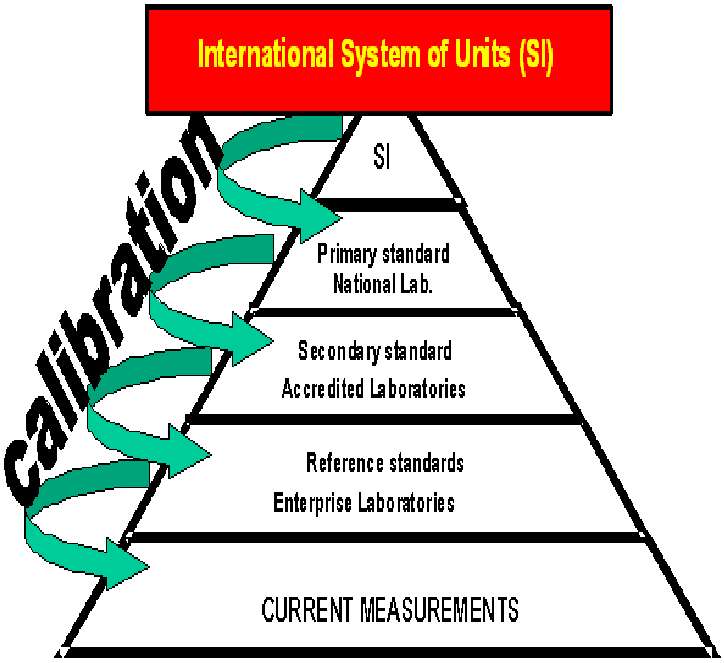

Fig. 1. Conventional pyramid of traceability.

Sometimes industrial technicians say that it is not necessary that calibrations can be held in not accreditation laboratories. Indeed analyzing what is said on ISO 9001 [3] and ISO 17025 [4], nowhere is said that the calibrations can only be made in accreditation laboratories. The common requirement for all standards is that it must be ensured the traceability.

It is here that enter the concept of excellence in metrology - is that traceability is not something that can be defined as white or black, or an on-off system. This subject has been widely discussed in international organizations that are concerned with issues of quality.

Among others, there is a document published by EA in 1995 [5] where are clearly mentioned the minimum requirements to achieve the completeness traceability.

We must remember the six items referred in [5] for the complete traceability (figure 2).

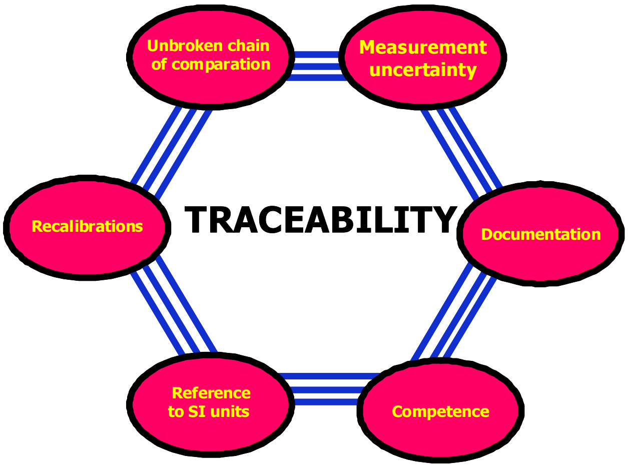

Fig. 2. The six items for complete traceability.

Linking the items referred in the figure 2 with the pyramid of traceability, we obtain the concept of the traceability pillars (see figure 3):

- Human resources;
- Material resources;
- Places and;
- Quality systems.

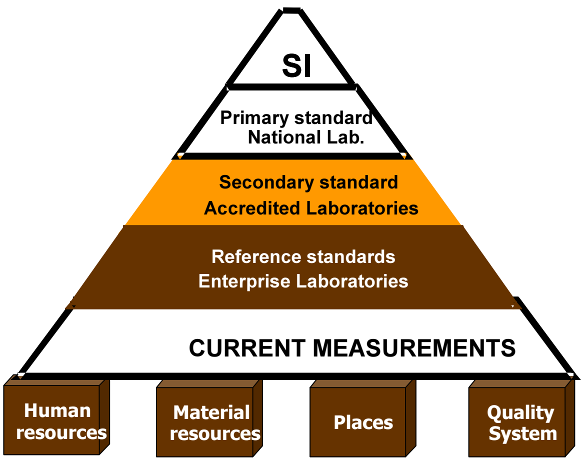

Fig. 3. The four pillars of the traceability.

If one of these pillars fails, we have not performed a complete measurement and we are not leading de Control improvements. The same pillars are necessary to link two consecutive steps of our pyramid (see figure 4).

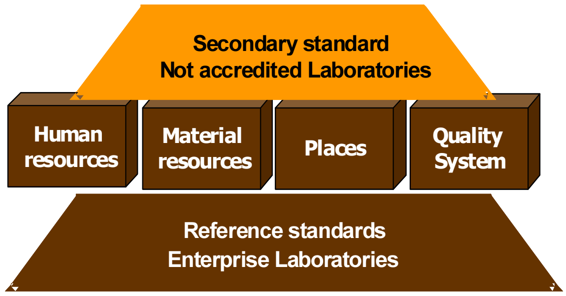

Fig. 4. The four pillars between two steps of the traceability.

The complete statement result of measurement (y') it is represented by the following expression:

$$y' = y \pm U$$

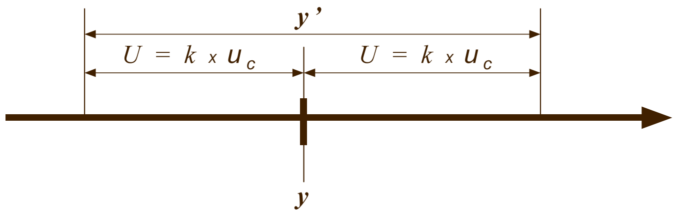

Fig. 5 Complete expression of the result of a measurement, y' [6,7].

Where [8]:

U – expanded measurement uncertainty

uc – combined standard uncertainty

k – coverage factor

y - complete statement result of measurement

y – result of measurement

So, for a general concept for good measurements is need: uncertainty! This statement is supported as a logical analysis but is mainly supported by the traceability definition, as we referred before. Through this manner we can affirm that we are in the way of Excellence and not using the common sense.

The two steps for a good way are:

First step is ensuring that the complete traceability is performed;

Second step is ensuring a total measurement management system.

How to ensure the complete Traceability?

To perform calibrations in accredited laboratories calibration (better) or auditing the Laboratories if they are not accredited by National Body of Accreditation, that means, second part audit (doubtful).

And how to ensure the total measurement management system?

The ISO 9001:2000 [3] recommends the implementation of this measurement system, suggesting ISO 10012:2003 Measurement Management Systems - Requirements for Measurement Processes and Measuring Equipment [9], like guidance.

Applying the ISO 10012, an effective measurement management system ensures that measuring equipment and measurement processes are fit for their intended use and is important in achieved product quality objectives and managing the risk of incorrect measurement results. The objective of a measurement management system is to manage the risk that measuring equipment and measurement processes could produce incorrect [9].

5. CONCLUSION

The main requirements to attend a quality assurance in measurement are considered in this standard:

1 – Good measuring instruments are need;

2 – Skill technician is necessary;

3 – Places (environmental conditions);

4 – Management of measurement systems with rules of quality is essential.

As a final conclusion we can say that there are no real measurements without estimation of uncertainty, and so the quality can trust the metrology and the society also!

References

[1] Decreto-Lei nº 142/2007 Sistema Português da Qualidade, de 27 de Abril.
[2] Joint Committee for Guides in Metrology, JCGM, 200:2008 – International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)
[3] NP EN ISO 9001:2000. Quality Management Systems – Requirements.
[4] NP EN ISO/IEC 17025:2005. General Requirements for the Competence of Testing and Calibration Laboratories.
[5] Document EA*-4/07 - Traceability of Measuring and Test Equipment to National Standards (previously EAL-G12) – NOV 1995.
[6] Sousa, C. (2008) Cadernos Técnicos Carlos Sousa, Erros - Conceitos Elementares, CATIM. Retrieved from: http://www.catim.pt/Catim/PDFS/erros-conceitos-elementares.pdf.
[7] ISO 14253-1:1998 – Geometrical product specifications (GPS) – Inspection by Measurement of work piece and Measuring Equipment.
[8] Guide to the Expression of Uncertainty in Measurement (GUM), BIPM, IEC, IFCC, ISO, IUPAC, PAP, IOIML, 1995.
[9] ISO 10012:2003 - Measurement management systems - Requirements for measurement processes and measuring equipment.

OPTIMIZATION OF THE QUALITY PLAN IN SAINT-GOBAIN MONDEGO, SA - A CASE STUDY

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Abstract: The quality plan is one of the most important documents into the quality management systems. It brings to the system how the quality control should be done in order to assure the product quality and the customer's satisfaction. Nowadays the production systems have to continue to improve its performance in order to be more competitive and the quality plan has to follow this trend too. In this work we will present a case study developed in Saint-Gobain Mondego, SA, whose goal was to improve the quality plan in order to reduce the product non conformities and simultaneously the costs associated with the quality.

The present work makes firstly a presentation of the enterprise production process and an overview of how the quality controls it is performed during the process. After that, we will characterize the problem that Saint-Gobain proposes to study; our propose to decrease the problem; the tests effectuated and the analysis of the results; and the final conclusions about this case. How we will see, there are strong signs that the proposal tested will bring quality improvement associated with a cost reduction and consequently better satisfaction for the customer.

Keywords: quality improvement; quality plan; quality costs reduction; customer satisfaction continuous improvement.

1. INTRODUCTION

The Saint-Gobain group was born in France by order of the King Luís XIV in 1665. It was created by Colbert, with the goal to produce the mirrors of the Versalhes Palace. Since that, the company has developed others activities and has been implemented in several countries. Nowadays the Saint-Gobain is a multinational group that produces and distributes materials of high technology in the area of the glasses. In Portugal, the Saint-Gobain Mondego, since 1987, dedicates to the production and commercialization of package glass (e.g., bottles) in the following colours: amber, white, cinnamon and green.

As a quality certified enterprise by NP EN ISO 9001:2000, beyond others certifications[1], Saint-Gobain interprets adequately the principle of the continuous quality improvement as it is described in the NP EN ISO 9000:2005 [1]: "consists in increase the probability of customers satisfaction and other interested parts". Not only described into its mission of integrated politics, but also in quotidian worries and actions, as this case study will demonstrate.

The work proposed into the case study has a goal to promote the improvement of the quality plan, more concretely into the phases where the quality control is manual and not automatic, i.e., the final control quality, in order to evaluate the frequency of this control.

2. PRODUCTION PROCESS AND QUALITY CONTROL

A schematic description of the production process and quality control is illustrated in figure 1. Soon after, we will resort to the figure to explain globally its process flux. We are in the presence of a continuous production system, or line production, that is reconfigured (setting up) when the product changes.

After the reception of the raw materials (point 1 of the figure) and its quality control (paragraph a of the figure), the production process begins with the preparation of the composition or vitrified mixture (point 1 of the figure), composed essentially by sand, limestone, oxide of sodium and broken glass, into the mixer machine (*preparation of the composition activity*).

Secondly the composition is driven until the continuous fusion stove (point 2 of the figure), at approximately 1500^{o}c, where will be produced the glass in fusion state (*fusion activity*). During this

[1] Environment certification by NP EN ISO 14001:1999; Security certification by OHSAS 18001:1999; EMAS registration according to the CE 761/2001 regulation.

phase components will be added to give the colour and opaque degree of the glass and the process is controlled (paragraph b of the figure).

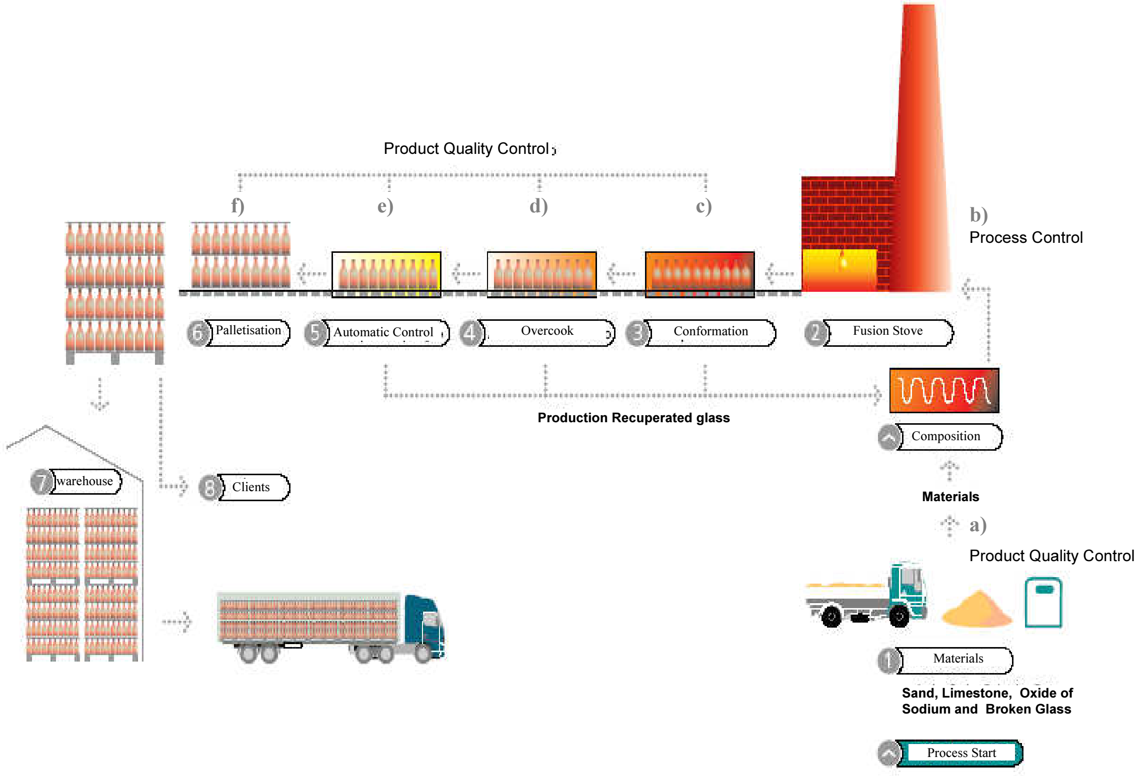

Fig. 1. Saint-Gobain production process [2].

Then, this glass is empty trough the feeders, in a drop form, to the conformation machines (point 3 of the figure). Where with an automatic process, involving flows of air and compression we got the final form of the desired product (*conformation activity*). Immediately at this phase the product is target of a dimension control (interior and exterior) of the type pass or not pass trough the use of gauge (paragraph c of the figure).

Afterwards, the product is overcooked (*overcooked activity*) to permit the slowly cooling until the ambient temperature into overcooked ark of the type of tunnel (point 4 of the figure). It permits to alleviate the tensions. The products are heated until the temperature of tensions relaxation, maintained at this temperature during the necessary time and cooling controllably until the room temperature. Immediately at this phase the samples of the product are collected and submitted to physic essay in the laboratory in order to evaluate the capacity, the minimal thickness and overcooked degree (paragraph d of the figure).

In the next step all the products pass trough several automatic control machines (point 5 of the figure) in order to proceed at the control of several product characteristics susceptible of being controlled automatically (*automatic control activity*).

However, because of other characteristics of the product it could not be automatic controlled and because this control needs, for each type of product, to be adjusted during the production process, during the palletization (point 6 of the figure) there is a final control of the product. This control is manual and it depends substantially of the controller experience and is made by sampling control methodology according to the dimension of the lot production.

Then the product is ready to go to the warehouse (point 7 of the figure) or to go directly to the clients (point 8 of the figure).

3. PROBLEM CARACTERIZATION AND FORMULATION OF PROPOSALS OF IMPROVMENTS

Of course, as we said before in the introduction chapter, the principal Saint-Gobain input to develop the study that we will present, it was to look for the continuous improvement inside its production system (pro-active attitude). However, it is necessary to analyse the production data and to identify an opportunity and then perform the cycle PDCA (Plan, Do, Check and Act). We can say that: at this point of our work we were in the phase Plan.

So, first we have analysed the following data[2], related with the client satisfaction degree:

- the deterioration commercial index sense 2004;
- the number of clients complaints, sense 2004, distributed by a set of motives or non conformities;

With this data we could verify that there was some stability in spite of the number of reclamations related with critic non conformities has decrease significantly sense 2004 until 2007.

Secondly we have analysed the data referring with the production results for:

- The process revenue (quantity of good units produced / quantity of units launched to the production) by the set of colours.

In this analysis we have identified that the products of white colour were the worst in process revenue.

Thirdly we have analysed the:

- revenue of the products class A for the white colour, resulted from the Pareto analysis considering the tax of production during two campaigns of the stove producing the white colour;
- tax of production for each class A products of white colour.

We have verified that doesn't exist a correlation between the process revenue and the tax production, It means, that the products that we produce more have not necessarily the best revenue. Otherwise, most of the products have almost the same revenue, i.e., the dispersion of the values of the revenue is small.

Fourthly we have analysed the:

- the quality control plans for products class A;
- the registers of the controls results (namely the final control);
- the verification on the field (plant production) the activities of control.

After that we have concluded the following:

1. The control plan for each product it was been well applied, i.e., the plan was accomplished by the controllers;
2. The final control it is a sampling control and is defined according to the Military Standard 105D [3] and according to the acceptance or specifications of the client;
3. The frequency of the final control (sampling control) is at least once a turn (turn of 8 hours) and we have verified that: (1) if the acceptance criterion are satisfied, the next sampling is performed only in the next turn; (2) If the lot is not accepted, all the lots produced since the last final control are rejected and until the next lot is accepted, all of the lots produced have to be controlled; after that is repeated the first proceeding.
4. During each turn are produced 200 to 400 lots of products (depending of course of the product type), with 500 to 1500 units of products (depending of the product too);
5. During the initial phase of the production of one product, so and so corresponding at the production of the first 20 lots of products, the process is in phase of adjustments in order to setup adequately the production process (including the automatic control);
6. In the initial phase of the production (referred in the previous point) we have verified that the final control was realised only one time per turn, save if the first control do not accepted the lot. However, in several cases the lots were not controlled sequentially, but with intervals between them.
7. When happens the existence of production intervals between the final production control, referred into sixth point, the feedback of the final controller to the production is too late because during that period we could have produced without quality, even maintaining the others controls. As a note, we cannot forget that the automatic control is adjusted for each type of product and for that it needs production time. On the other hand not all the product characteristics can be automatic controlled.

After the detailed analysis presented before we have questioned the following: Have we margin to promote an alteration to the final control of the quality plan? Our answer was affirmative and we have proposed to test the following:

- *During the first 20 lots produced (the identified as critic for the set up production) in the beginning of one product production can we obtain better results than those we got now if we make a continuous sampling control?*

Of course that when we talk about better results we should think about two kinds of performance measures: the production performance and the cost performance [4]. The second one means the evaluation of the amortization investment. The first one, the improvement of the production performance, only makes sense if investment made is amortized in useful time.

[2] This data could not be presented because it was classified as confidential information of Saint-Gobain enterprise.

4. EXPERIMENT AND RESULTS ANALISYS

"The continuous improvement should be based into analysis of facts" [5]. To implement that it is necessary to define performance parameters, quantify them, to define new objectives, to plan, implement and to control the actions that permit to get the objectives and further to compare the results obtained with the objectives. Based on this statement, that is consensual in our days, but more correctly/easily interpleaded by enterprises with quality certification, we advance to the experimental phase with a single restriction: It was impossible to wait for the products class A of colour white because we could have to wait a year or more, to develop the experimental phase.

So, we have decided to advance to the production of one mouth and analyse the results. It was precisely what we did. During a mouth we follow the first twenty production lots in the final control and recorded the total of lots rejected to compare with the previously lots rejection without the frequency of the final controls proposed in this work.

During a month we analysed 12 different types of final products produced in one of the two lines of Saint-Gobain Mondego production and compared the lots rejections, before and with our final control change proposed. The values were collected in a format of the table 1, whose data are concerning simply for one of the products studied.

Product Model: Bord. Elite 75		
Last Four Productions Dates	**Machine:**	**Lots Rejected**
09-06-2006	23	0
17-11-2006	23	0
02-04-2007	21	2
02-04-2007	13B	2
Average of lots rejection during the last four productions:		**1**
Ours lots rejection 03-01-2008	21	**7**

Table. 1. The Average of historic lots rejection and our lots rejection with the final control alteration proposed [6].

For the previous historic results we have calculated the average for the data of the four last productions for each product. In some cases we had to obtain the values sense 2004, but for the majority of them it was sufficient the data from 2006 (case of the product of table 1). It is important to refer that for the products analysed the data collected doesn't show a tendency (decrease or increase), the values are quite at random.

For all the products data, Figure 2 shows the quantities of lots rejection, for the two situations, in order to permit a better comparison.

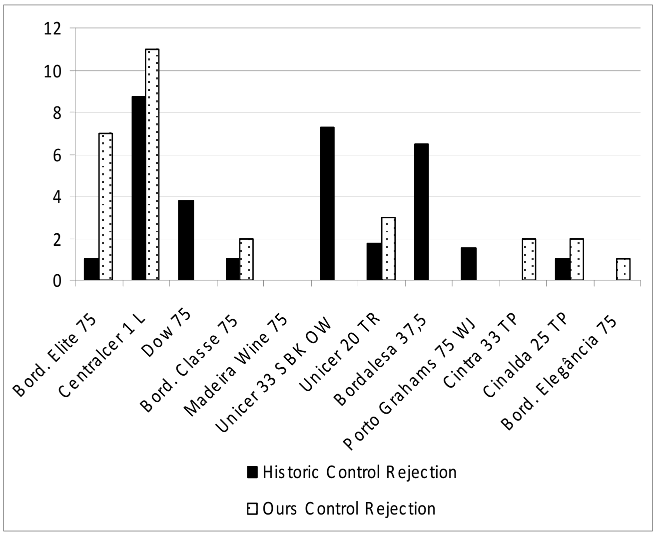

Fig. 2. Comparison of the lots rejection per product, before and during the experimentation for all the products produced during a month [6].

Analysing the collected data we have verified that:

- The final results are not positive for all the products. There were previous productions that never had a lot rejection in the first twenty lots produced but now they did;
- The opposite is also true. It is a good indicative because we infer that when the controls are more frequent, the defects are detected earlier and the process can be corrected earlier, avoiding so the rejection of lots produced;
- However as is possible to verify in the figure 3, that contains the final average values of the results, for our control we obtained a rejection value bellow the anterior standard, almost 0,4 lots rejection less per product during the first 20 lots produced.

At this point of our study, we could say that the production performance had good signs to be validated, i.e., with the experimentation we had verified less lots rejection. Nevertheless, we had to verify the cost performance, as we said at the beginning of this chapter. It was what we did with the direct production costs involved in our experience. We evaluated the direct labour costs of the final control and compared with the costs[2] reduction of the production (resulted from the difference of the lots rejection) and verified that the last ones covered the first ones.

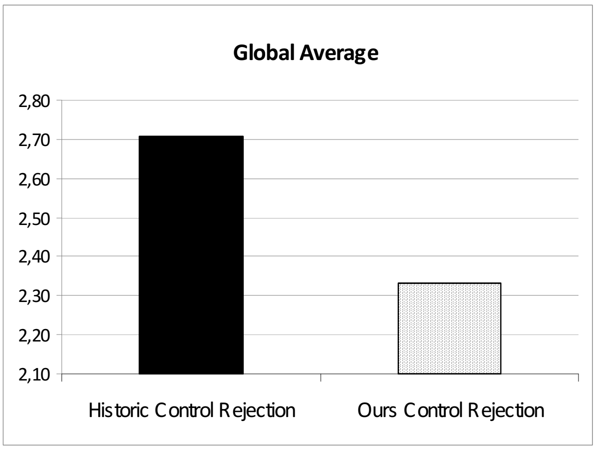

Fig. 3. Comparison of the lots rejection average, before and during the experimentation [6].

After the previous performance analysis we could say that our proposal has good signs to be implemented, but we proposed more. We picked the historic claims associated with the products tested, resumed in table 1, and verified that in a

total of 8 claims received until now (the last productions will could still have any claim) 5 of them (written in bold in table 2) can be associated with a deficient final control. Of course that when we say can be, it means that there is a strong probability, but we know that there is some subjectivity, beyond that we know the claims content and performed its analyses.

Product Model	Claim	Production Date	Claim Reason
Bord. Elite 75	No		
Centralcer 1L	Yes	07-08-2007	Palette downfall
Dow 75	No		
Bord. Classe	No		
Madeira Wine	**Yes**	**31-01-2006**	**Error in the labels and rupture in the filling up line**
Unicer 33 SBK OW	**Yes**	**28-11-2006**	**Rupture in the filling up line**
	Yes	**16-08-2007**	**Rupture in the filling up line and palette downfall**
Unicer 20 TR	Yes	31-05-2006	Palette mixture from other model
Bordalesa 37,5	**Yes**	**12-02-2007**	**Rupture by infused**
Porto Grahams 75 WJ	**Yes**	**08-02-2006**	**Bad engraver of the heraldic bearing and error in the labels**
Cintra 33 TP	Yes	06-09-2005	Model changed
Cinalda 25 TP	No		
Bord. Elegância 75	No		

Table. 2. Historic claims associated with the priors products productions [6].

We expect that with the increase of the final control during the first twenty lots production, the clients claims would decrease. If it happens, what we believe, the costs associated with the non quality can decrease. One part of these costs can be quantifiable, but the other part, related to the client satisfaction could not. It is true that the opposite is valid too. For that reason, our cost performance can achieve better results and simultaneously our production performance too.

In spite of this we weren't able to make the analysis of the potential claims of our production controls, because it needs some mouth until Saint-Gobain receive the claims, it will be useful to compare with the previous claims, and establish a comparison. Of course that we believe that the number of the claims will be less than in the past, but is something that the enterprise should be pay attention to the next mouths.

5. CONCLUSION AND FURTHER WORK

Trough the previous figures showed in the last chapter and from the analysis made, it is possible to verify that in global terms there is a reduction of the number of rejected palette, from 2,71 to 2,34 and less risks in the future to receive claims respecting the products production of our study. Besides, this is a matter that the enterprise should follow in the next mouth to establish a comparison more truthful between the previous claims and that ones that could appear.

After that the enterprise should test the the alteration of the control plan to other production products, more precisely to the products class A of the white colour, where we expect that the results will be still more significant.

Also, with this work we show that there are forms to promote the continuing improvement, even inside multinational groups enterprises, since they are interested, which is the case of Saint-Gobain Mondego.

As a final conclusion we have verified that there are strong signs that in the future the enterprise passes to control all the final lots through the sampling plans defined for each product, during the stating phase of the production process (normally the 20 first lots) and not the maintenance of the actual procedure, once per turn.

References

[1] NP EN ISO 9000:2005. Quality Management Systems – Fundamentals and Vocabulary.
[2] Saint-Gobain (2007) *Environment Declaration of 2007*.
[3] Military Standard 105D
[4] Ávila P. (2006). Methodology of Analyses and Improvement of the Production Process, *Lesson of the Concourse of Coordinator Professor*, Superior Institute of Engineering of Porto.
[5] NP EN ISO 9001:2005. Quality Management Systems – Requirements.
[6] Contente, J. (2008) Optimization of the Quality Control Plan in Saint-Gobain – *Traineeship Report,* Technologic school of Vale de Cambra.

THANKS

We would like to thank Saint-Gobain for all of its interest and support to perform this work inside its facilities.

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ISBN 978-972-8692-48-3
ISBN 978-989-95907-1-7