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"SUPPORTING THE EMERGENCE OF KNOWLEDGE COMMUNITIES IN INDUSTRIAL ASSOCIATION GROUPS IN THE CONSTRUCTION SECTOR"

António Lucas Soares¹, Hugo Ferreira¹, Manuel Silva² and Dora Simões³

ABSTRACT

This paper describes the development of a knowledge community in the context of an industrial association group in the construction sector. This system is a result of the Know-Construct project which aimed at providing association sponsored SME communities of the construction sector with a sophisticated information management platform and community building tools for knowledge sharing and customer support. The paper begins by characterizing the so-called construction industry knowledge community (CIK). The generic architecture of the supporting system (Knowledge Community Support - KCS and Customer Needs Management - CNM) is described, in terms of information and knowledge management, community building facilities and semantic resources management. The Know-Construct project decided to re-use, as far as possible, existing ontologies, classification systems and other semantic resources to develop a system for the integration, management and reuse of the area specific knowledge. Part of the paper describes the approach followed, as well the lessons learned. The final part of the paper depicts the approach to the actual introduction of the system in the community.

KEY WORDS

Knowledge communities, semantic web, ontology engineering, industrial associations, SMEs

INTRODUCTION

Organizations in the construction sector have to renew themselves rapidly in order to adapt to a more competitive and changing environment, be much more flexible than in the past and also need more sophisticated ways of managing their knowledge assets. Most of knowledge management systems have emerged from document-centric approaches and are able to efficiently support, although only a fraction, of the whole knowledge cycle (classifying, storing, and retrieving knowledge). The Know-Construct project⁴ intends to improve the effectiveness of the Construction Industry (CI) SME's by enhancing and extending the relationship with their customers through an innovative support regarding information and knowledge about products, processes and associated issues. This is achieved through specifically developed tools, supporting in particular the formation and operation of SME's knowledge communities in the context of Industry Association Groups (IAG). More concretely these objectives are to:

- Provide a platform to support the creation and management of a community of CI SME's, coordinated by an association, fostering collaboration and knowledge sharing among its members. Knowledge to be shared includes, besides product and services information; companies' experience (e.g. best practices). This will lead to a wider and deeper technical

¹ INESC Porto and Faculty of Engineering University of Porto, Rua Dr. Roberto Frias, s/n 4200 Porto, Portugal, asoares@inescporto.pt, hmf@inescporto.pt

² ISCAP-IPP, INESC Porto, Porto, Portugal, mdsilva@iscap.ipp.pt

³ ISCA, Aveiro University, Aveiro, Portugal, dora.simoese@ua.pt

⁴ COLL-CT-2004-500276 KNOW-CONSTRUCT Internet Platform for Knowledge-based Customer Needs Management and Collaboration among SMEs in Construction Industry (2005-2007). Project co-funded by the European Community under the "Horizontal Research Activities Involving SMEs - Collective Research" Program.

and professional competence shared by the SME's community, fundamental in its ability to satisfy customer needs, obtained through closer co-operation and knowledge exchange.

- Provide problem-solving support to the individual IAG member's customers regarding the selection of products, their applications and processes, as well as addressing other related problems such as legislative issues, safety issues etc. This will be materialized as an internet-based platform that will offer the possibility to establish a "one to one" communications medium. Manufacturers and wholesalers (SME) may interact with their customers, advising them on specific topics relying also on knowledge created and maintained by a community of SME's mentioned in the previous point. KC system then designed to provide comprehensive services to their users regarding a large scope of construction issues, although centred in the SME knowledge community.

KNOWLEDGE COMMUNITIES AND INDUSTRIAL ASSOCIATION GROUPS

Based on the typology of virtual communities proposed by Porter (2004) where virtual communities are classified under two levels: *establishment* and *relationship orientation*, the CIK Community can be classified as an organization-sponsored community relatively to type of establishment and as commercial community relatively to the relationship orientation. This community will have key stakeholders and/or beneficiaries (ex. customers) that will play an important part in sponsoring the community's mission and goals. Being an organization-sponsored community, will foster relationships both among members (e.g. professionals belonging to the associations of the project partnership) and between individual members (e. g. customers) and the sponsoring organizations (associations of the project partnership).

Table 1 - Conceptualization of the CIK Community attributes

Purpose	To share professional knowledge aiming to provide a better individual service to company's customers.
Place	Virtual place where companies develop and maintain social and economic relationships, mostly virtual, but also physical (e.g., association meetings, customer contacts, etc.).
Platform	Synchronous and asynchronous communication (hybrid). Interactivity is multi-modal: co-presence based interaction through instant messaging; differed interaction through basic mechanisms such as forums or weblogs, and through complex tools such as content management tools, fostering coordination mechanisms (workflow).
Population	The IAG is both the context of interaction and an actor in it. Companies and individual professionals are actors. Individual professionals can assume both an individual role (the professional) or organizational role (company's representative). Customers can assume also the role of actor in the community. The motivation of the interaction is due to both individual interests and company orientated goals. Companies also look for enhanced reputation and improved levels in efficacy and efficiency. It is likely that the interaction patterns will be characterised by a mix of small group characteristics (where strong ties tend to dominate), and network characteristics (where weak ties are prominent and stressful ties are likely). Relationships are addressed by user needs, where small group and network attributes are blended.
Profit model	Revenue generation of individual companies in the construction sector. Although the CIK community will provide mainly intangible benefits, it is expected that by providing a better service to customers, individual companies will increase their revenues.

Departing from the classification of the CIK Community under the virtual community concept and the attributes commonly suggested in the literature to characterize virtual communities the key attributes that allow characterization of the CIK Community can be summarized (Table 1) as the Five Ps (Porter, 2004): *Purpose* (Content of Interaction), *Place* (Extent of Technology Mediation of Interaction), *Platform* (Design of Interaction), *Population* (Pattern of Interaction) and *Profit Model* (Return on Interaction).

To summarize, the CIK Community is defined as an aggregation of professionals and customers who interact around a specific shared interest of construction sector, sharing information and knowledge about products, services, techniques, legal aspects, experiences, etc, and where the interaction is totally supported and/or mediated by web technology and guided by some agreed protocols or norms.

A PLATFORM TO SUPPORT KNOWLEDGE COMMUNITIES IN THE CONSTRUCTION INDUSTRY

As mentioned before, the KC project has a very specific goal: to enable individual SME's to better solve the problems of their customers. Therefore, the KCS system is focused on pursuing this goal in the first place. Although a knowledge community encompasses, as stated before, mechanisms that surpass this simple instrumental goal, the initial vision of the KCS system was specifically conceived with this in mind. This means that the KCS system supports CIK community building in a broad sense, though focused fundamentally in generating wide ranging and detailed knowledge to be used in managing the SME's customers' relationship, particularly in problem solving. The operationalization of the KCS system is made through the use of mechanisms (Nabeth et al., 2002; Hearn et al., 2002; Simões and Soares, 2006) that will allow: (i) for the support the social processes (trust building, group formation and coordination), i.e., conditions for tacit knowledge exchange; (ii) for increased levels of interactivity and to stimulate the dynamic exchange of knowledge (collaborative content management systems); (iii) to support the personalization of user interaction (via the selection and presentation of content), maximize the impact of distributed knowledge and also to facilitate the development of new relationships between the users).

FUNCTIONAL ARCHITECTURE

Keeping in mind the basic idea that the KCS system should support the CIK Community building in a broad sense, but focused fundamentally in generating a knowledge base that is as comprehensive and detailed as possible to be used in managing the SME's customers' relationships, particularly in problem solving, this module has the following general functions:

Community building tools: this part of the KCS system supports the processes of community building by providing the instruments to foster professional interaction and socialization. Forums and weblogs are two such instruments and are tailored in KCS to be tightly integrated with the semantic structure supporting knowledge management in KC.

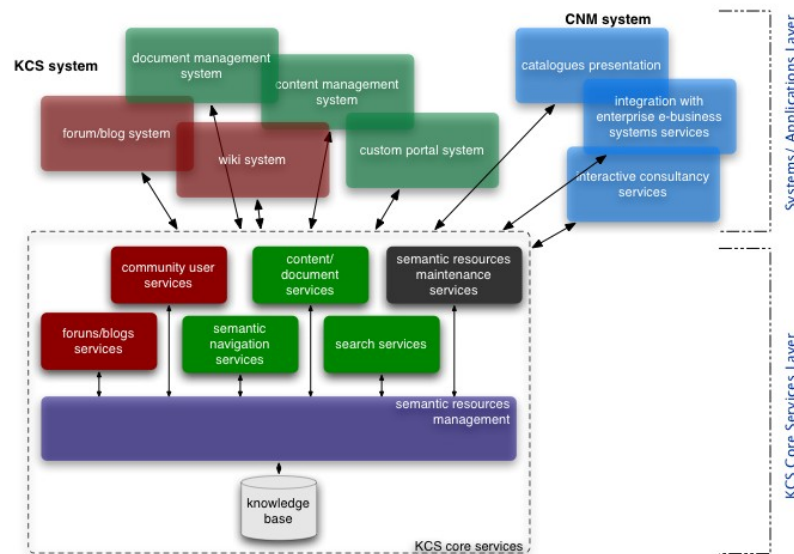
Semantic resources management: this is the infrastructure and corresponding set of functionalities that support information and knowledge acquisition, organization and storage in KCS system. More specifically, they enable the (i) management of classifications, thesauri and vocabulary, (ii) the acquisition of knowledge from digital content (including forums and weblogs entries, web pages, etc.) both internal to the CIK and from external sources, (iii) the maintenance of an ontology which is the base of knowledge representation, access and storage.

Knowledge resources access: creating, searching and updating knowledge resources is a fundamental set of functionalities in KCS. Although much of the community's information/knowledge will be created in communication/interaction processes (forums, weblogs), there will be also the need to create/access knowledge in a more structured way. Digital

content management and document management are the natural approaches regarding this issue.

This generic architecture is decomposed in two layers: KCS Core Services layer and Systems/Applications layer. KCS Core Services layer provide a set of services centered in the semantic resources management of KC. The basic architectural idea of KCS is to have a set of services to be used by specific, adaptable and, eventually, off-the-shelf systems/applications. The rationale is to take advantage of as great a number of open source systems/applications as possible that already provide the end user functionalities required in a knowledge community.

Figure 1 - KC general architecture



For example, a content management system (CMS) can be used, providing off-the-shelf functionalities to organize reports, data sheets, legal documents, and to publish web pages related with some community topic. The CMS is configured and extended to use content/document services, search services and semantic navigation services in order to provide value added knowledge management to the community. The KCS core services are divided into a Semantic Resource Management layer and a set of functionalities that provide the systems/applications with access to the semantic resources as described below.

SEMANTIC ARCHITECTURE

The identification and selection of existing knowledge sources was the first step to building the semantic resources structure of KCS system. Multiple different sources like terminologies, ontologies, international classifications, standards, norms and regulations, national classifications were analysed. The difficulty of this task is well known (Lima *et al.*, 2004), since the different sources are usually designed using different theoretical grounds, design principles and serve different purposes.

According to ISO 12006-2 (ISO, 2001) the most widely used classifications are work sections (mainly for specifications) and elements (mainly for cost analysis). They are also the most varied, not only in their itemization and structure but also in the range of other purposes to which they are put. As a result of the research, several other classifications were identified, potentially just as important, which have not yet been used to the same degree, e.g. construction products and properties/characteristics.

KC project is, along with the necessary development of classifications and taxonomies that answer the project needs, re-using/integrating as far as possible existing ontologies, classification systems and terminologies in order to develop a system that may, in the future, contribute to standards. The initial interaction of the KC project with standards issues will be to assure full compliance of the developed solution components with the current legal and de-facto standards in the targeted building sector and in relevant ICT domains.

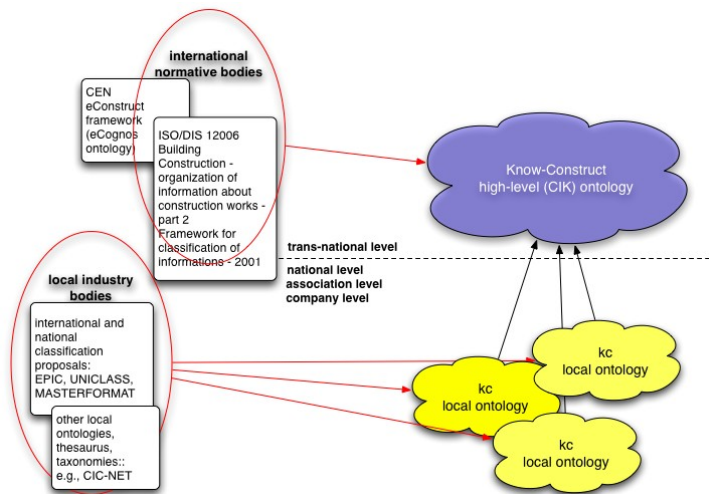
Besides CI online sites and other sources, some of the most relevant ontologies and classifications identified were: *e-Cognos* ontology; *e-Construct* ontology; *EPIC – European Product Information Co-Operation*; *UNICLASS – Unified Classification for the Construction Industry*; *IFC Model – Industry Foundation Classes*; *ICIS LexiCon*. The identification of these sources lead to conclude that part of the existing information has some common principles and structures, mostly because they result from European or governmental projects which also aim to contribute to harmonization and standardization. But, its diversity, nevertheless, posed the problem of how to test and adapt the selected resources according to the KC project purposes and scope and the industry consortium predefined needs, taking also into consideration the specific cultural and professional context of the ontology's development and use, the target-audience(s) and the previously defined scenarios. In order to choose the knowledge sources, a complex set of multi-criteria referring to different aspects were established. An analysis framework was elaborated in order to evaluate the candidate knowledge sources in what concerns their suitability to the KC system and methodology (Silva *et al.*, 2006).

Along with these criteria, subject field specialists were consulted to analyse both the methodologies and the resulting ontology. After this identification and evaluation process, and taking in consideration the general view expressed in the CWA 15142 – European eConstruction Ontology (EeO), from the candidate sources, those which, at the moment, presented the best solutions for the purpose of reuse and integration of information and for the development of Know-Construct high-level ontology are: *LexiCon*, *bcBuildingDefinitions*, *eCognos*, *IFC model and ISO 12006 – 2*. From these, *eCognos* ontology and *ISO 12006 – 2* were the main building blocks of the CIK ontology.

During the analysis described above, a perception gained strength - to deal with the very concrete reality of the SMEs of each country and with each Construction Industry Knowledge (CIK) Community of KCS, the KC system would need to have a local ontology that would answer the KC partners' particular professional and cultural needs and attend to its social context of use. This meant the need to construct not one, but more than one ontology. KC has decided to take this fact into account and look at this possibility as part of the standardised way to develop ontologies in the sector, but in such a way as to keep a common central ontological content (structure, attributes, relations, etc.) from where to derive the more specific ontologies. The development of this more specific ontology will, thus, be based on the larger, upper level ontology – the CIK ontology, where all the central concepts of the Construction area are structured. Therefore the solution resulted in an inter-organizational KM system for CIK Communities, built upon distributed ontologies locally managed and centrally integrated, as described in the figure 2 (see also Silva *et al.*, 2006).

An ontology merging process was used to build the CIK ontology from the *eCognos* ontology, the ISO 12006 and EPIC that cover similar and/or overlapping domains in the Construction area. From the requirements analysis it was concluded that different countries (or even different associations) need to use local classifications, thesauri or ontologies.

Figure 2 - KC ontologies structure



As different countries have different local ontologies, the best process to “plug-in” a local ontology into the CIK ontology is to align both ontologies. This has the advantage of being easier to maintain and evolve the ontologies. In practical terms the option for ontologies integration can be a lot more difficult when managing the ontologies and its evolution process, for example to discover the part of the integrated ontology that will suffer changes.

The resulting CIK Ontology that defines the domain of the CI can be summarized in the following sentence: The Construction Industry involves a set of resources (*Construction Resource*) that follow certain conditions (*Technical Topic*) which are used or required in a process (*Construction Process*) that leads to results (*Construction Result*). As such, the proposed taxonomy includes four major domains to classify these major concepts: Construction Resource; Construction Process; Construction Result; Technical Topic. As it is perceptible the first three domains coincide with the major themes in the ISO 12006-2 standard. The other domain (Technical Topic) is the result of the integration of an e-COGNOS module, further developed so as to include issues related to the CI that are not covered by the e-COGNOS ontology and IFC model. All domains integrate modules from eCognos ontology.

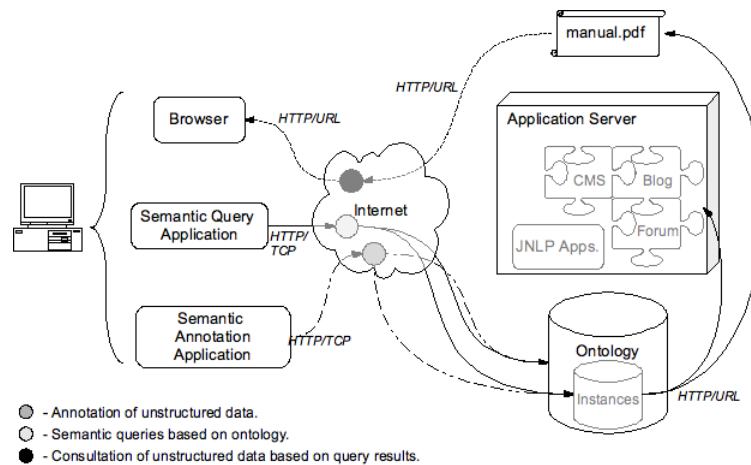
SEMANTIC WEB IMPLEMENTATION

The KC system applications based on the components described in Figure 3 supports two primary processes: a) allowing users to annotate unstructured data using the concepts and relationships defined in the KC ontology and b) searching for unstructured data based on the KC ontology. Unstructured data here refers to any data source that can be referred to by a Uniform Resource Locator (URL). This includes downloadable documents, web-pages, blog entries and forum posts. Such data sources may either be located within the KC system itself or any other system within the Internet. All unstructured data maintained by the KC system is managed via the use of a Content Management System (CMS) as is depicted by Figure 3. Currently we have also opted to make the KC system applications available via the Internet using the Java Network launching Protocol (JNLP). This means that all resources, whether they be applications, elements of the ontology or the annotated data sources, are access remotely via the Internet. Assuming the ontology will not change, annotation begins by first selecting a data source to be tagged, then identifying the relevant concepts and relationships required to annotate it and finally generating data instances that will describe the document and its contents.

Because the ontology itself is large (consisting of approximately 600 classes and 30 properties), and many of the terms and words used in the data source do not have a direct correspondence with the language used in the ontology, the user therefore needs to browse and explore the

ontology itself. This first phase may require several iterations before all relevant concepts and relationships have been identified (depicted in the figure 3 as a large ellipse). In order to facilitate this task simple string searches based on localised text can be used to find concepts and properties that may be of most interest. The string searching uses meta-data that is associated with all elements of the ontology. In a second phase instance data and its corresponding properties are created and stored in the ontology. This will allow one to describe the data source itself (for example an installation manual made available at a manufacturers web-site), the products the manual refers to (anything from building material to electrical wiring) and the process that is being described (in this case the on-site process of installation).

Figure 3 Components of the KC system implementation



At this point the implicit meaning embedded within unstructured data have been effectively structured and formalized. Symbolic reasoning, based on description logics, may now be brought to bear in order to efficiently extract interesting information. This is the second primary process supported by the KC system. To be able to find the relevant unstructured data a user first needs to construct a query. Just as in the case of the annotation, the first phase of this process is also iterative. A query begins by first identifying the relevant concepts. This may be done using the localised string search functionality as was described above. A user may then identify instances of the concepts. Upon inspection of the instances the user will identify additional properties and instances that can also be used to construct more complex and refined queries. Query refinement is done by simply adding class properties to the selection criteria. For example a Portuguese user is interested in finding product catalogues on taps, performs a simple text search of “*torneira*” that will point to the concept class “*tap*”. A selection of instances of this class shows that all products have a relationship with “document elements”. Upon further investigation the user can use the concept “document element” to identify documents describing a given tap. Note that all element of the graphical user interface are localized so all concept and relation names will only appear in the users language.

The KC project foresees that the majority of the users of the system will simply use it for query and document retrieval. The user population in this case also includes the less sophisticated and knowledgeable user population. In order to better support these users the query interface has been simplified. It allows for three basic levels of query sophistication: simple, advanced and predefined. In the case of the simple version only text bases concept searches and instance retrieval an be performed. This is not particularly useful but will allow user to explore the ontology by identify some instances data and their respective properties. The advanced search allows a user to add properties as query filters. Selections may therefore be refined in or-

der to select specific instance data. The predefined query option is much like the advanced query option only now the user is provided with a set of classes that represent the most representative class groups or categories in order to facilitate searching.

KCS SYSTEM INTRODUCTION, TRAINING AND EVALUATION

Enterprise sponsored virtual communities (ESVC) are complex socio-technical systems, difficult to design and maintain, needing multi-disciplinary approaches for their development. In order to assure its functioning and to assure a highly productive usage of the system by end-users it is of utmost importance to organise optimal adoption of the system by them. In addition to participation of end users in the system concept creation and testing, what assured an initial creation of awareness on system characteristics, a final training was organised for familiarization of the end-user with the full system functionalities and advantages to be achieved through its usage (Pereira *et al.* 2007).

AN ACTION-RESEARCH APPROACH

Empirical studies regarding the company's adoption and use of information systems based on advanced semantic infrastructures are scarce in the literature. Particularly when it comes to ESVC, our knowledge about the context, conditions and actual use of such type of systems is almost inexistent (as much as the authors are aware). In this project it was decided to go further in the development of the Know-Construct system, taking advantage of prototype testing in realistic organizational situations to research the adoption and use of semantic enabled information systems in ESVCs.

A first technical prototype of the KCS system was developed in two modules: (i) a minimally configured Content Management System providing basic content management, and basic community building functionalities i.e., a forum and a weblog application, and (ii) semantic functionalities module providing classification and ontology browsing, semantic searching, and content annotation. Two IAGs were selected to implement the first socio-technical KC prototype. Besides the IAG management unit, six companies in each IAG were chosen for the prototype testing and study. In each of these companies a set of people was selected to form the KC testing groups. During a training day they were introduced to the CIK community concept and to the use of the KCS system.

The general research questions can be formulated as the following: (i) how do workers in SMEs adopt and accept collaborative information management strategies, and (ii) how do workers belonging to SMEs participating in some form of network apprehend and appropriate the concept of enterprise sponsored virtual community. These research questions can be detailed in more specific topics (see Table 2).

Table 2. Specific topics to research through the KC prototype testing

Semantic resources related	ESVC related
cognitive apprehension of the ontology and classification schemes	use of content shared within the community; trust and perceived importance of the information
Intended and effective use of the ontology	intention to share information according a "community" worldview; actual uploading of content; quality of the shared information
contextual factors of ontology adoption: country, type of association, type of company	intention to use community building tools (forums, weblogs, wikis); actual use of community building tools

TRAINING

An appropriate planning, including the training methods selection and training materials creation is crucial for the success of training. Thus a training plan and training sessions were devised, which aimed at (i) assuring maximal acceptance of the Know-Construct system through creation of a full awareness on the system characteristics and advantages it will bring to the end user companies; (ii) ensuring that all the SMEs fully understand the concepts involved with KC methodology and ICT system; (iii) providing familiarization of the future system users with all related aspects, primarily related to knowledge gathering, structuring within the system and presentation; (iv) assuring, through common "hands on" training sessions for the groups of users for all involved employees in SMEs and Associations, an efficient deployment of the future system for all planned functionalities.

The methods used for the training were adapted to the needs of training on the KC Methodology and System. The approaches included introductory lectures, coached "hands-on" training and application of e-learning tools. The training courses were carried out through the following forms (i) in IAGs for groups of belonging SMEs as courses organised and coached by the system experts; (ii) in individual SMEs as courses organised and coached by the system experts; and (iii) in individual SMEs as e-learning courses.

Within the ESVC presented context and for the correct implementation of KC system it was vital to understand the cognitive processes that underlie users' learning and acquisition methods when training and interacting with new knowledge management approaches based on semantically enabled knowledge technologies in a collaborative learning/working environment, in order to correctly assess the evolution of individual's knowledge, and thoughts about the new technology working/sharing environment and to access the technology itself.

CONCLUSIONS AND FURTHER WORK

The Know-Construct project established an ambitious, albeit risky, goal: to create a tool that combined effectively a structural and a social process view of knowledge management at the service of the construction sector SMEs and their sectorial associations. Ambitious because it tried to reuse and integrate generic construction industry knowledge structures from several sources, but maintaining the possibility to adapt local knowledge structures, specific to each of the countries or even to specific IAGs. Risky because it adopts collaboration as the cornerstone for an improved form of work within the construction sector SMEs. It is well known that a big part of the European construction industry SMEs have a lack of cooperation and collaboration tradition, then sharing knowledge can be no more than an academic dream. Knowledge communities imply advanced forms of collaboration, and no IT tool alone, as much as sophisticated as it can be, will put people collaborating. A socio-technical approach is mandatory to take all advantages of the web 2.0 technologies.

There are a lot of aspects to improve regarding the semantic web implementation of the system. The current status of the available technology is far from mature, but some aspects of our system can be already improved. In regards to the annotation and query applications future work will include better support for the searching and identification of concept by using additional meta-data. String search may also be enhanced by excluding stop-words from searches, taking stemming into account, checking for spelling mistakes, matching on similar words and using lexical databases in order to support search by synonyms for example. Use of profiling has also been considered as a means to provide recommendations during the tagging and searching of similar documents using natural language processing techniques and automated recommender based strategies.

As a CIK community member, professionals in the construction sector will have a place for continual professional development that gives them individualized, flexible and easy access to a

coherent and up to date knowledge domain, a range of opportunities to interact with like-minded persons and a range of opportunities to develop and exploit the knowledge domain. Our premise is that the membership of professionals of an online knowledge community has positive effects on their continuing development, expressed not only in competences like knowledge, skills, experiences and attitude, but also in the acquisition of organizational knowledge assets expressed in the growth and elaboration of professional knowledge, applicability of knowledge and legitimacy of knowledge.

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