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FINITE RESOURCES MANAGEMENT IN COMPANIES

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Dissertation presented to ISEP – School of Engineering to fulfill the requirements necessary to obtain a master's degree in Mechanical Engineering, carried out under the guidance of Professor Susana Nicola.

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KEYWORDS

Resources management; companies; decision making problems; MCDM methods; AHP; TOPSIS; fuzzy sets; literature analysis.

ABSTRACT

The present work has as goal aiding decision makers, researchers, enterprises and practitioners by developing a proper literature review as a base for comparison among multiple-criteria decision making methods in finite resources management according to each of the most important areas of a business environment. Efficient resource management decision making in companies impacts its value creation capability and, therefore, its competitiveness and ultimate success.

The methodology for paper research follows the PRISMA flow diagram, for correct paper filtrations according to the set of criteria stablished in alignment with the thesis goal. The papers included in the study are any that employ multiple-criteria decision making methods in their pure forms, in combination with each other forming hybrids, or in combination with other mathematical techniques for solving decision making problems across five major areas of a company's body. The five major areas are: (1) Supply Chain Management and Logistics; (2) Environmental Management; (3) Business and Marketing Management; (4) Design, Engineering and Manufacturing Systems; and (5) Human Resources Management.

The 204 final papers are presented separated by their corresponding application areas, ordered by number of citations, which is used as a measure of their scientific community relevance. They are also classified by, author, nationality, journal, year, type of research and methods used. All collected data is used for quantitative statistical analysis, with which is possible to collect more in-depth information on the literature research. Focused comments on the main methods are also present in this work, with observations made on the many applications and variations each of them had throughout the articles in the research.

The AHP and TOPSIS approaches, either with their fuzzy set variations are by far the most popular methods in the referred applications. However, besides them other 51 MCDM or other mathematical techniques are employed in many different combinations and approaches, bringing a very interesting diversity to the study that is very useful for it to be used as a base for comparison among methods. A total number of 111 journals and authors and co-authors of 41 nationalities are involved in the publications between 2012 and 2018, with more than half of papers coming from either India, Turkey or Iran. Many other results are obtained, bringing the readers different perspectives on the subject.

This paper contributes to the body of knowledge with a great and insightful overview on MCDM methods application in aiding in challenges part of a business environment, so that companies can better manage their resources and be more prosperous. It is a vast database that allows many comparisons and evaluations, offering more analysis than the standard literature review articles.

PALAVRAS CHAVE

Gestão de recursos; empresas; problemas de tomada de decisão; Métodos MCDM; AHP; TOPSIS; conjuntos difusos; fuzzy; análise bibliográfica.

RESUMO

O presente trabalho tem como objetivo auxiliar os tomadores de decisão, pesquisadores e profissionais, ao desenvolver uma revisão bibliográfica adequada como base para comparação entre os métodos de decisão multicritério na gestão de recursos finitos de acordo com cada uma das áreas mais importantes de um ambiente de negócios. A tomada eficiente de decisões de gestão de recursos nas empresas afeta sua capacidade de criação de valor e, portanto, sua competitividade e sucesso finais.

A metodologia da investigação baseou-se na metodologia PRISMA, para a correta filtração das publicações de acordo com o conjunto de critérios estabelecidos, em alinhamento com o objetivo da tese. Os artigos incluídos no estudo são aqueles que apresentam métodos de decisão com critérios múltiplos em suas formas puras, em combinação uns com os outros ao formar híbridos, ou com outras técnicas matemáticas para resolver problemas em cinco áreas principais das empresas. As cinco áreas são: (1) Gestão da Cadeia de Suprimentos e Logística; (2) Gestão Ambiental; (3) Gestão de Negócios e Marketing; (4) Sistemas de Projeto, Engenharia e Manufatura; e (5) Gestão de Recursos Humanos.

Os 204 artigos finais são apresentados de acordo com as áreas de aplicação correspondentes, ordenadas por número de citações, que são usadas como uma medida de sua relevância na comunidade científica. Eles são, ainda, classificados por autor, nacionalidade, revista, ano, tipo de pesquisa e métodos utilizados. Todos os dados coletados são utilizados para análise estatística quantitativa, com a qual é possível recolher informações mais aprofundadas sobre a pesquisa bibliográfica. São realizados comentários sobre os principais métodos e as maneiras que foram apresentados ao longo do estudo de todos os artigos durante a pesquisa.

As abordagens AHP e TOPSIS, com suas variações em conjuntos difusos ou *fuzzy*, são de longe os métodos mais populares nas aplicações referidas. No entanto, além destes, outros 51 MCDM e outras técnicas são utilizadas em muitas combinações e abordagens, trazendo uma diversidade muito interessante para o estudo, servindo de base para comparação dos métodos. Um total de 111 revistas e autores e coautores de 41 nacionalidades estão envolvidos nas publicações entre 2012 e 2018, com mais de metade dos artigos provenientes da Índia, Turquia ou Irão. Estes e outros resultados levam aos leitores diferentes perspectivas sobre o assunto.

Este documento contribui para o estado da arte, com um conhecimento geral excelente e perspicaz sobre a aplicação de métodos MCDM para ajudar nos desafios de um ambiente de negócios, para que as empresas possam melhor gerenciar seus recursos e serem mais prósperas. É um vasto banco de dados que permite muitas comparações e avaliações, oferecendo mais análises do que os artigos de revisão de literatura padrão.

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

Abbreviation	Acronym
AHP	Analytic Hierarchy Process
AFP	Accounting-Based Financial Performance
ANP	Analytic Network Process
ARAS	Additive Ratio Assessment
BI	Business Intelligence
BSC	Balanced Score Card
BWM	Best Worst Methods
CEO	Chief Executive Officer
COPRAS	Complex Proportional Assessment
CRITIC	Criteria Importance Through Inter-Criteria Correlation
DEA	Data Envelopment Analysis
DEMATEL	Decision Making Trial and Evaluation Laboratory
DoE-TOPSIS	Design of Experiment and TOPSIS Hybrid
ECQFD	Environmentally Conscious Quality Function Deployment
ELECTRE	Elimination Et Choix Traduisant La Realité (Elimination and Choice Expressing Reality)
ERP software	Enterprise Resource Planning Software
ETL Software	Extract Transform and Load Software
Et al.	And others.
EW	Entropy Weight
FAD	Fuzzy Axiomatic Design
FCE	Fuzzy Comprehensive Evaluation
FCM	Fuzzy C-Means
FEW	Flexible Entropy Weighting
FIS	Fuzzy Inference System
FMS	Flexible Manufacturing System
FRBS	Fuzzy Rule Base System
fsQCA	Fuzzy-Set Qualitative Comparative Analysis
FWA	Fuzzy Weighted Average
GA	Generic Algorithm
GP	Goal Programming
GRA	Gray Relational Analysis
HR	Human Resources
IFAD	Intuitionistic Fuzzy Axiomatic Design
IFS	Intuitionistic Fuzzy Set

ISM	Interpretive Structural Model
KAU	King Abdulaziz University
KM	Knowledge Management
KME	Knowledge Management Enablers
MABAC	Multi-Attributive Border Approximation Area Comparison
MAFC	Multi-Agent Fuzzy Control
MATLAB	Matrix Laboratory, Software
MCDA	Multiple Criteria Decision Analysis
MCDM	Multiple Criteria Decision Making
MCGP	Multi-Choice Goal Programming
MODM	Multi-Objective Decision Making
MOLP	Multi-Objective Linear Programming
MOORA	Multi-Objective Optimization on The Basis of Ratio Analysis
MOPM	Multi-Objective Programming Model
NGT	Nominal Group Technique
OM-AHP	Orders-Of-Magnitude AHP
OR	Operations Research
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROMETHEE	The Preference Ranking Organization Method for Enrichment of Evaluations
QFD	Quality Function Deployment
ROC	Rank Order Centroid
SAW	Simple Additive Weighting
SC	Supply Chain
SCOR	Supply Chain Operations Reference
SEM	Structural Equation Modelling
SWARA	Step-Wise Weight Assessment Ratio Analysis
SWOT	Strengths, Weaknesses, Opportunities, Threats
TOPSIS	Technique for Order Of Preference By Similarity To Ideal Solution
TRIZ	Теория Решения Изобретательских Задач, Teoriya Resheniya Izobretatelskikh Zadatch (The Theory of Inventive Problem Solving)
VFP	Value-Based Financial Performance
VIKOR	Visekriterijumska Optimizacija I Kompromisno Resenje (Multicriteria Optimization and Compromise Solution)

List of symbols

Symbol	**Meaning**
R^2	Regression Coefficient

GLOSSARY OF TERMS

Name	Definition
Axiology	The study of the nature of value and valuation, and of the kinds of things that are valuable.
Business Management	The activities associated with running a company, such as controlling, leading, monitoring, organizing, and planning.
Chef Executive Officer	A chief executive officer, the highest-ranking person in a company or other institution, ultimately responsible for taking managerial decisions.
Cost Efficiency Maximization	Optimization of how effective or productive in relation to its cost.
downtime	Time during which a machine, especially a computer, is out of action or unavailable for use.
econometrics	The branch of economics concerned with the use of mathematical methods (especially statistics) in describing economic systems.
Environmental Management	Management of human impact on the environment, especially with the intention of preserving natural resources.
Epistemology	The theory of knowledge, especially with regard to its methods, validity, and scope, and the distinction between justified belief and opinion.
ERP	Enterprise resource planning, the management of all the information and resources involved in a company's operations by means of an integrated computer system.
Game Theory	Mathematical analysis of strategies for maximizing gains and minimizing losses, applied to games of strategic competition and to corporate, military, and other decision making problems.
Global Resources	They are what the industry, agriculture and service sectors need to operate and what people also need as human beings to continue their daily activities at work, at home, and in various institutions, organizations and groups they are engaged with. Example: water.
Human Resources	The personnel of a business or organization regarded as a significant asset in terms of skills and abilities.
Kano Model	To categorize the attributes of a product or service based on how well they are able to satisfy customer needs.
Knowledge Management	Efficient handling of information and resources within a commercial organization.
Logistics	The planning and implementing of the details of any operation.
Manufacturing	The making of articles on a large scale using machinery; industrial production.
Marketing	The action or business of promoting and selling products or services, including market research and advertising.
Outsourcing	To purchase (goods or services) from an outside supplier instead of producing (the same goods or services) internally.
Revenue	Income, especially when of an organization and of a substantial nature.
Semiotics	(Used with a singular verb) in philosophy, a theory of signs and symbols, especially as they are used in language.
shareholders	A person who owns stock in a business organization.
Stochastic	Having a random probability distribution or pattern that may be analyzed statistically but may not be predicted precisely.
Supply Chain	The sequence of processes involved in the production and distribution of a commodity.
World War	A war involving many large nations in all different parts of the world. The name is commonly given to the wars of 1914–18 and 1939–45, although only the second of these was truly global.

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INTRODUCTION

1 INTRODUCTION

1.1 GOALS AND CONTEXT

In recent centuries, the impact of human beings on the planet has grown massively [4], especially in the last decades with the great advance of knowledge in the areas of computing and electronics. This development has brought integration and interaction between countries and cultures as never before, creating, among other things, a market with global behavior that is increasingly affecting the lives of ordinary people in most countries in the world. Today, many of the structures of society look very different from what could be found in one hundred, fifty or even ten years ago [5].

The changes generated in this process have brought not only positive but also negative changes. The negative point most debated in the last decades is about the great impacts that men have caused all over nature. There are a number of issues in this debate, such as pollution of soils, air, rivers, lakes and seas, the extinction of many species of fauna and flora around the globe, the global warming theory [6] and, finally, the theme among which is most related to this work: the scarcity and probable end of the natural resources that are used to feed this human development [7].

The goal of the present work is to aid decision-makers, researchers, enterprises and practitioners by developing a proper literature review as a base for comparison among multiple-criteria decision making methods, bringing to light which are the most relevant and recommended applications in finite resources management according to different areas of a business environment.

On all sides of the market, many of the companies, especially the dominant ones in their niches, can have their ages measured in decades, and even centuries. To survive for so long in the business environment, they all had to be aware of all the mentioned and other past changes and their effects. They also had to be able to adapt themselves and change their decisions and attitude, which allowed them to survive as time progressed [8]. This is an important rule for every business, being it small or large. All of them must be able to adapt to the new needs and challenges of the market, society, politics, and so forth. But never has there been such a big challenge in front of all of us. Exponential change in the way the world works does not allow the experts to make as accurate predictions of how things will be in the long run as they once were. More and more often companies will need to reinvent themselves in order to prepare for what is to come, and be able to compete in their current niches, and in the new ones that will definitely emerge in the future [9]. What becomes clear is that the only things that remain the same over time are the constant changes. The enterprises that change accordingly to the tendencies and demands of the market, consumers and new regulations are the ones with the better chances of surviving when comparing to the ones that delay in doing so [10].

Still, many companies belong to the group of the ones that are alert and foresee the best strategies for the future. In this situation, how to edge this competition? For example, if a given firm is in the middle of those that are leading in terms of adapting and competing, then, this firm is acting mostly in the same manner as these others. Among these mentioned firms, the most efficient ones in all actions are the ones that ultimately are going to lead even the other companies that are also on alert [11]. These actions to be performed can involve many sides of a company, like having financial performance in the market, giving value and attention to its human capital [12], having profound studies on its supply chain management [13], working on its environmental issues [14], optimizing its logistics [15], developing its knowledge management [16], improving its manufacturing systems [17], while at the same time reducing its costs, waste and disappointment indexes among employees [18]. The companies that better manage these and many other matters, have the upper hand in competition. It is not only about doing what is needed anymore, it is about doing it efficiently, and making the best out of each decision.

There are many ways to work and build up on each of the mentioned areas of action, but almost always, for them to be best implemented and managed, must involve decision making processes [1]. One could think that decision making process for implementing new things, or for changing strategy of the business, or the way it works, is something that the CEO would take care of, or the president, or the senior manager, or all of them together, around a table, by simply exposing points, talking, discussing. The thing is, that even a group of people with the highest level of expertise in the subject, judgment and great impartiality in their discussions, relying only on reasoning and discussion, would be complete hostages of the human subjectivity, and maybe not evaluate correctly one or another point, or not be able to see all relations and impact one criteria has on another, or maybe a problem has just so many pros and cons for each change of variable, that it gets really hard to assess these decisions with complete clarity [19]. And, thinking about it this way now, and with millions of dollars at stake if something goes wrong in that decision, someone would probably prefer a more reliable and clear way, or method, to see the complete picture, and take the best decision. Here is where it becomes relevant the importance of multiple-criteria decision making methods [20].

Multiple-criteria decision making (MCDM), also called multiple-criteria decision analysis (MCDA) is a very expressive sub-area of operations research (OR). It has as goal designing mathematical and computational tools for supporting the subjective evaluation of a finite number of decision alternatives in relation to a finite number of performance criteria, that can be done by a single decision maker or by a group of them [21]. There are several different methods within this sub-discipline, each one with its own way of understanding and dealing with these kinds of problems, and there is no need to rely solely on one of them. As time progressed, researchers from all parts of the

world created ‘hybrid’ methods, that is, a method that combines two or more MCDM tools for solving a specific problem. Some hybrids became so useful for many applications that became commonsense and it is today very common to see them applied in different variations of decision making challenges.

Some of the most traditional MCDM methods are Analytic Hierarchy Process (AHP) [22], Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [23] and Analytic Network Process (ANP) [24]. There are some that are most recent, like the Serbian Visekriterijumska Optimizacija I Kompromisno Resenje (VIKOR), or Multicriteria Optimization and Compromise Solution, in the English language. All of them are among many others, each one of them being unique and useful in its own manners. Each method can have different variations and can be built on a more appropriate linguistic for a given problem, the most famous linguistic, or also called environment, is the fuzzy sets theory [25]. This theory goes a step further than the conventional ones and zeros of traditional programming, giving values in between these two extremes. The referred idea gives MCDM tools a fantastic advantage: the ability to evaluate and weight criteria based on the subjectivity and uncertainty of the human perspective. The three methods mentioned above, among other MCDM techniques, each with their possible variations and applications on fuzzy environment are among the main methods present in this work, but also many other useful and insightful methods will be seen.

Multiple-criteria decision making methods can help a company of any niche solve problems of the most diverse types. From strategic marketing decisions for a small sized firm [26] to choosing the new knowledge management system in a big corporation [27], the MCDM methods can help them all. Different companies, different sizes, different niches, different products, different environmental issues, and else. These methods can be applied to many kinds of challenges in the business environment. The scope is big indeed, but most of companies, in a way or another, share the same structure for operating, no matter the services they provide [28]. Most of them need to have an input of some material, knowledge, human workforce and turn it into something else with aggregated value over it, being it a product or service of any kind, as seen in [29]. This is the simple idea, but there is room to go further in it, and find some of the most common areas that companies rely on to be able to function, like human resources, manufacturing systems and marketing management, as well as new areas that appeared recently as a necessity to an enterprise to build due to new regulations and customer’s opinions, like environmental management and green initiatives, for the fight against the economic decrease [30].

Everything that the businesses, of any kind, deal with to create value and therefore, profit, will be ultimately finite. There is no company with infinite number of employees, or money, or material, or machines, or space [31]. So, managing these and other resources properly and in a smart way is of paramount importance for a company’s survival. Now, considering that everything that a company deals with is a resource and

is ultimately finite, even the decision-makers themselves, it becomes highlighted that all decision making problems in all areas of each company become very important. Each of them, if performed efficiently, will at least contribute slightly to the company's health and competitiveness, not only financially, but on every horizon. The management of these resources have a crucial financial aspect and importance for companies, but also it is very important nowadays to an enterprise that to be as more sustainable as it can be. Not only for the earth and nature, and people that work in these firms and others that somehow are affected by all the firm's work, but also for the company's own continuity in this ever changing world [14].

There are many applicable areas in companies, many different kinds and sizes of problems, challenges and decisions, and there are several MCDM methods that can be applied to them. Ironically, deciding which is the best method to use can become a huge decision problem itself.

1.2 THESIS STRUCTURE

This work is organized in 4 chapters. The present Chapter is an introduction to the subject, bringing the context of it, the main goals of the work and how it is structured. Chapter 2 presents a bibliographic review of decision making problems, based on multiple-criteria decision making methods, first in a general way, and later describing some of the most important specific methods. It also brings an overview of the most relevant and some of the most recent literature on standard enterprises. The papers review of MCDM methods applications in a company's environment is presented in Chapter 3. Firstly, all researched papers are presented and categorized. Secondly, a statistical analysis of all data takes place. Finally, in-depth commentaries of what was observed from methods during the study is made, followed by final discussions. Chapter 4 presents conclusions on the thesis and suggestions about possible future works.

STATE OF ART

2 STATE OF ART

The goal of the state of art is the study of the MCDM application in decision making problems, in a business environment, namely, problems on managing finite resources in companies in different fields. The author focuses on knowledge of business issues and theories that involve the relations and limitations between supply and demand in enterprises, the economic value creation, as well as the efficiency in the use of nonrenewable resources in processes. It also combines these with knowledge about the creation of different types of mathematical models, algorithms and computational programming tools to find the method or combination of methods that best frames decision making problems.

2.1 FIRST CONSIDERATIONS

To develop a successful bibliographic study on the subject, a schematic structure was developed in the shape of a mind map that correlates accurately the interrelations between the mentioned areas of knowledge and how they could contribute to achieve the goal of the project. The scheme, Figure 1, contributes to the reader's understanding of where each topic could be addressed in the state of the art.

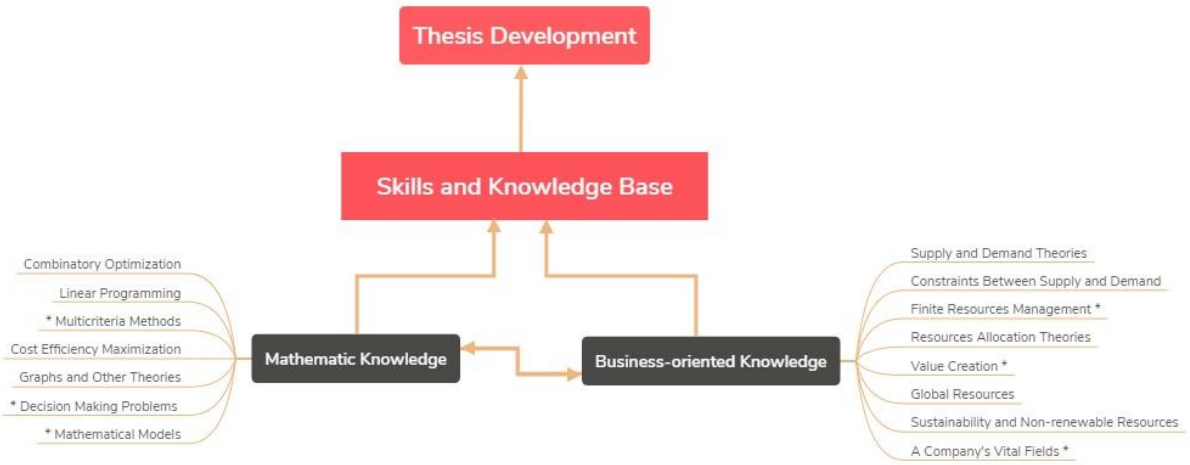

Figure 1: Knowledge Base

The development of the state-of-the-art is achieved by the interaction between mathematical and business-oriented knowledge after they are both explored. All sub-topics together represent the big scope of all that was investigated in the beginning of the thesis, both for mathematical and for business knowledge. The sub-topics that are marked represent the subjects that actually ended as part of the state of the art and contributed to the development of this work.

In Mathematical Knowledge, first it will be studied the basic notions in how mathematical optimization models should be built, and some of their insights. Afterwards, it will be seen a specific type of real-life situation that can be modelled: the decision making problems. Later, the major multiple criteria methods are presented as the focused choice of this work to better solve such problems in a business environment.

In Business Knowledge, it will be first seen how finite resources management can present itself inside companies as well as its relations with value creation. Further on, the specific concepts of value creation will be presented, as well as their importance to a company's survival. Finally, important fields for the operation of a standard company will be presented, each one facing their own challenges in the task of more efficiently managing their resources for helping enterprises being successful in their markets.

By establishing a detailed fundamental bibliographic knowledge base, it is possible to properly advance in the correct path towards the excellency in the development of the thesis on the multiple criteria decision making methods applicability in solving decision making problems inside the business environment.

2.2 MATHEMATICAL KNOWLEDGE

The current sub-chapter is devoted to present an overview on the existent scientific work on the pertinent topics for the proper development of this work. First, it is presented the beginnings on bringing real world problems to a mathematical environment, with a space for history, and later general and introductory rules on mathematical modelling are presented. Next, a specific modelling problem is presented, the decision making, with a general view on its existence and importance in the world, and principles for its solution in general and inside a company's environment. Finally, the multiple criteria decision making methods are presented, as a tool for aiding in their solution, along with some other mathematical fields that can work side by side with them.

2.2.1 COMPLEXITY BEHIND MODELS

Throughout history, as a way of dealing with the complexity of real problems faced every day in life, men always had the tendency of looking for creating metaphors that would help them better understand these situations and, therefore, better solve them, instead of dealing with them directly and without measuring consequences [32]. This development can be observed since the work of the great Greek thinkers two to three thousand years ago, with the mathematical way of thinking even in its simpler forms being almost always present in the process [33]. With time, many theories arouse with the goal of guiding through the best manners of creating a proper representation of real-world problems, a proper *model.*

The word model can have many different meanings, even when only speaking in the mathematical way. It comes from the Latin *modulus*, and when consulting the Oxford Dictionaries [34], one can find that a model is *"a simplified description, especially a mathematical one, of a system or process, to assist calculations and predictions".* It is crucial to see that it is not only a representation of a given problem or system in a smaller scale, but also a way of understanding and predicting its behavior, and "*this power behind a model, is what makes it desirable"* [3]. There are many aspects to consider for producing the most appropriate model, but for now a model can be described as:

"representations of the reality they preserve, for specific situations and focuses, an adequate equivalency." – [3].

Nevertheless, while the usage of a model is always helpful and makes it easier to understand and find best solutions for a complex and real problem, it is not always easy to create it. There are many different aspects that must be considered when the goal is creating a suitable, effective and realistic model, otherwise it may only give an illusion of correctly interpreting and solving the situation, when all it is doing doesn't really solve the real problem, because its variables and their impacts weren't rightly considered in the early stages.

According to Goldbarg & Luna [3], a model is "*a substitutive representation of reality and has a limited range"* and, therefore, has to be efficient in its modelling process. For a model to be efficient, it needs to have three abilities:

- **A Heuristic Focus:** is the ability to understand the impacts that the solution would bring to the real environment, and if later these impacts would bring problems that would end up annulling the contribution of the model.

- **An Eclectic Treatment of the Analysis Dimension:** the solution methods must be as most freely disposed as they can. Epistemology and Axiology must be complimentary. The construction of the model should consider both theory and deduction validity in practice.

- **An Adequate Translation:** it must have an adequate context translation. That means a correct isomorphism between the model and the real phenomena. It should simplify and structure the problem adequately. This is exemplified below, in Figure 2.

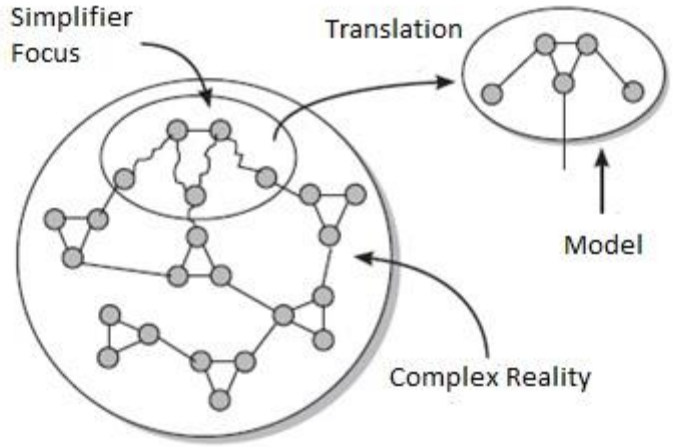

Figure 2: Translation Process from Reality to an Appropriate Model [3]

It is very important to expose the principle that often a problem that is difficult to adequately translate and represent, can be of easy solutions, while the opposite can also be true. This means that the difficulty in generating and representing the problem in an appropriate model and the one in solving the model itself are not necessarily related. This idea brings up the concept of *complexity* of models [3].

There are three different properties that can be observed in a model in order to evaluate its degree of complexity [3]. The first is its “permeability” in relation to the problem’s neighborhood environment. A simple model should have a simple and well-defined interference perimeter. The second property would be its “internal structure”. A simple model should have a homogeneous structure, a uniform morphology and a as reduced as possible number of variables. The last one would be the model’s “dynamics”, which is related to how much the internal structure changes through time. A simple model should have little or no changes in its structure with time, which means, be predictable. Figure 3 show the advance in the degree of complexity of a problem with these three properties represented by three different axes.

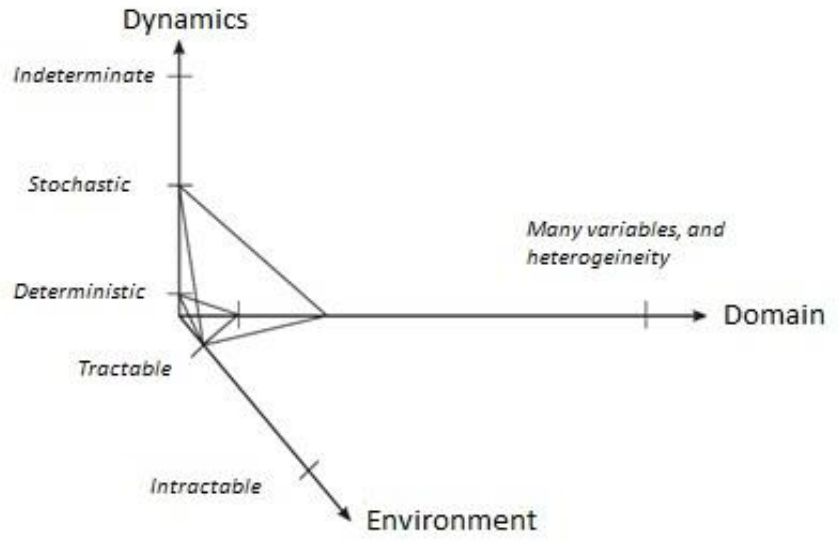

Figure 3: Viable Space for Applying Optimization Models [3]

The three delimitated planes represent the space that is more viable for the creation of optimization models. The area beyond these planes could represent large scale problems, like socioeconomic and government-wise.

A great translation of a given real life problem into a proper model should consider all the aspects mentioned above. Therefore, it is worth knowing that the translation process is normally something with some degree of complexity and can't be performed as a one step process. It is important to highlight that it is practically impossible to represent in a model every single characteristic, behavior and relation the way they work in a real system. What can be done is a translation of its most relevant relations and properties, aligned with the problem that is to be solved. This attitude also helps with simplifying the solution method applied [3].

The modeling process composition is about the usage of both technique and art, of both methods and intuition, and this makes it harder to create a step-by-step guide for some kind of "general modeling". However, according to Ackoff [35], there can be some partial systematization of this process. According to the author, there can be five patterns for building models:

- **Pattern 1:** when the system's (real life problem) structure is sufficiently simple and evident so that it can be understood easily via inspection. This doesn't necessarily mean that the solution for this modeling process will be easy as well. Depending on the case, the solution may be impossible.

- **Pattern 2:** when the system's structure is apparently simple, but its representation isn't so obvious. In this case, it is advisable to create an analog system with an already known structure.

- **Pattern 3:** when the system´s structure isn't of simple visualization, but a statistical analysis can fulfill what is desired.

- **Pattern 4:** when the system's structure isn't of simple visualization and a statistical analysis won't help isolate and understand its variables either. In this case, empirical experimentations are recommended to understand the some of the structures correlations and variables and then bring this case back to pattern 4.

- **Pattern 5:** when the same case as in pattern 4 happens, but the experimentation possibilities are limited and cannot achieve the desirable results. There are still some tools that can be used as the theory of conflict models and, if that still doesn't work, then there is room for some creative solutions, like using software simulations and others.

The patterns that better relate to what will be seen in this work go from Pattern 1 to Pattern 3, mostly.

In a more macro view of the modeling process, it can have its operational steps summarized by the flow chart represented next in Figure 4, suggested by [3].

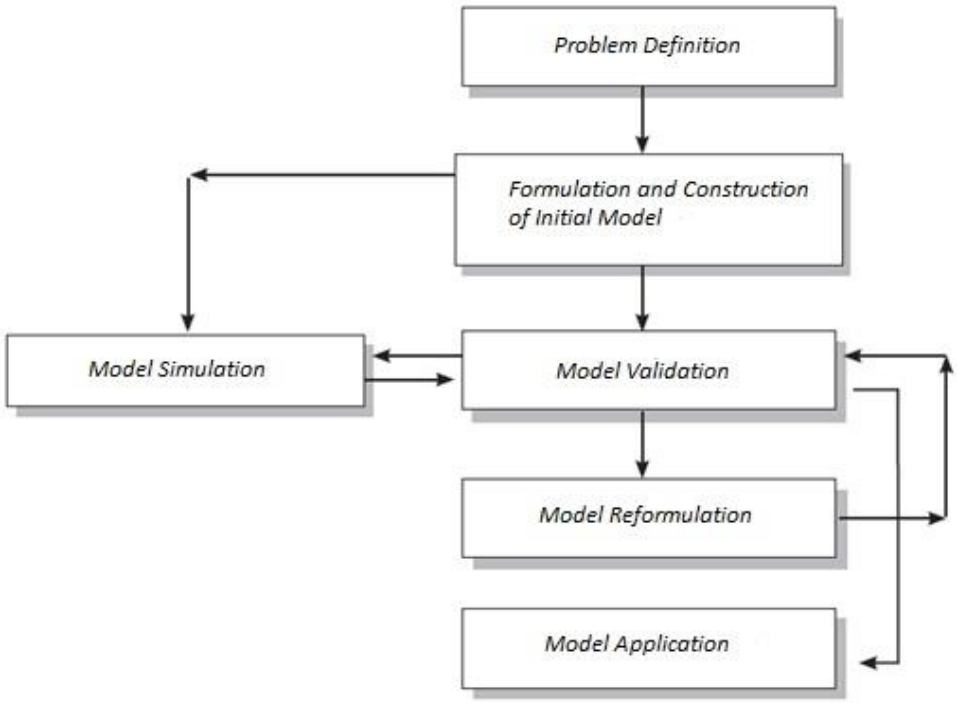

Figure 4: Operational Steps for the Modeling Process [3]

In the flow chart, it is possible to see that the first thing to do is to define the problem. This should be very detailed. If the problem isn't defined correctly, all other steps go wrong ultimately. It is important to clearly understand the objectives and focus of the problem, as well as its main variables and correlations. Once all of this is correctly assigned, then the formulation step becomes a little bit easier and the modeling process as a whole has more chances of being successful. When correctly assigned, the problem is then translated into the initial model that represents the real scale problem. The formulation step is crucial for the success of the model and depends both on knowledge of the techniques as on the perception and experience of the person that is elaborating the model. The given model should then be simulated and validated in parallel, so that the model can be readjusted along the way, and the simulated and validated once more, just to be readjusted again if necessary. This improvement cycle should remain until it gets to something satisfactory, and if it doesn't, the modeling process should be reviewed since its first step. When the model finally reaches its desirable degree of quality, then it can be applied [3].

Therefore, a modeling process is something that isn't fully achieved by merely following some generic steps, or one proven method. Depending on the problem, the way it should be formulated changes, and also which data to collect and how. This means that a portion of modeling relies upon something else, that is, the researcher's skills, intuition and experience. Even though, a person must be careful not to stray away from the correct path and get into uncontrollable parameters. It is important to have criteria when analyzing a problem and collecting its data. This rigor can be found in many already consecrated methods that were developed through the years and now are part of a larger area of knowledge. It focuses on modeling and solving models for most kinds of real scale system: this larger area is called Operations Research. The models present inside this field of knowledge are structured by logic and supported by mathematical ways of representation, with the clear objective of finding the best ways of functioning for the represented systems [3].

Operations Research is a wide branch of knowledge that has many important areas for problem-solving. It developed itself during World War I and II, to help solving decision making problems, planning and making strategies, and only in the decades after them that it expanded itself to a field widely used in many application areas ranging between business, industry and society, becoming an area of active academic and industrial research [36]. It kept expanding along with computational development throughout the years, and nowadays has many different methods and branches of applications.

Some of the most relevant techniques are, according to [37], simulation, queueing theories, mathematical optimization, econometric methods, neural networks, expert systems, decision analysis, and multiple-criteria decision making methods, like analytic hierarchy process. Most of the techniques used in operations research are based on

mathematical models constructed in alliance to computer technologies, what makes the area very close to computer sciences. The major topics in the modern operations research, as listed by the journal Operations Research, are:

- Computer and Information Technologies;
- Financial Engineering;
- Manufacturing, Service Sciences, and Supply Chain Management;
- Policy Modelling and Public Sector Work;
- Revenue Management;
- Simulation;
- Stochastic Models;
- Transportation.

Most of the disciplines listed are related to decision making problems in different environments, in a way or another. Decision are an unavoidable part of any problem to be solved. This work focuses specifically on decision making problems that are related to any activities performed inside the body of a company. Decision making problems and the main techniques used as tool to solve them are presented in the next sub-chapter.

2.2.2 DECISION MAKING PROBLEMS

Among the several kinds of problems that can be modeled around men's lives, there are the decision making problems. These problems must pass through a modelling process to apply the most efficient method in each situation. In a company's environment, it is a part of the routine of all managers and people responsible for important decisions, the so-called decision makers. In a business setting, decisions of any size always affect in a way or another in the company's efficiency in dealing with its resources, which results in the quantity of economic value created, that ends in ultimately determining how healthy and strong an enterprise is [38]. The current section concentrates its efforts in understanding the main concepts on decision making problems in businesses, its challenges and complexities.

One may think that it may not be necessary to need computer or mathematical aid when making decisions, but the truth is that making decisions isn't something easy and obvious as people may think, and it can become difficult in several occasions. Big decision making problems in businesses, industry or governments are normally solved by a group of people with expertise in the subject, this being called group decision making [1]. Even in these situations, when the goal is to decide, people can have different perceptions about what is preferred, either because they have different criteria or either because they weight them differently when they are the same. Also, it depends on the individuals' goals. Decision making can be very difficult depending either on the complexity of the problems or the people involved in them [38].

In the managerial world inside businesses and industries, decision making problems have possible classifications. As presented by Dessler [39], they can be either programmed or unprogrammed. Programmed decisions are the ones already faced by managers before, and every time they reappear there is already a set of policies to follow, as well as computations or a set of decision making guidelines. Unprogrammed decisions are the unexpected and unique ones, and they tend to happen more frequently than the programmed ones.

According to Boddy [2], decision making problems can also be categorized into strategic and operational, when concerning how big a decision and its implications are. Also, they can be classified into dependents and independents, relating to whether they are influenced by anteriorly made decisions or not. Boddy also works on the programmed and unprogrammed classification, suggesting that they change from one to another and can be in-between them depending on the context in which the decisions are made. They can vary among the contexts of certainty, risk, uncertainty and ambiguity. The mentioned relations are exposed in Figure 5.

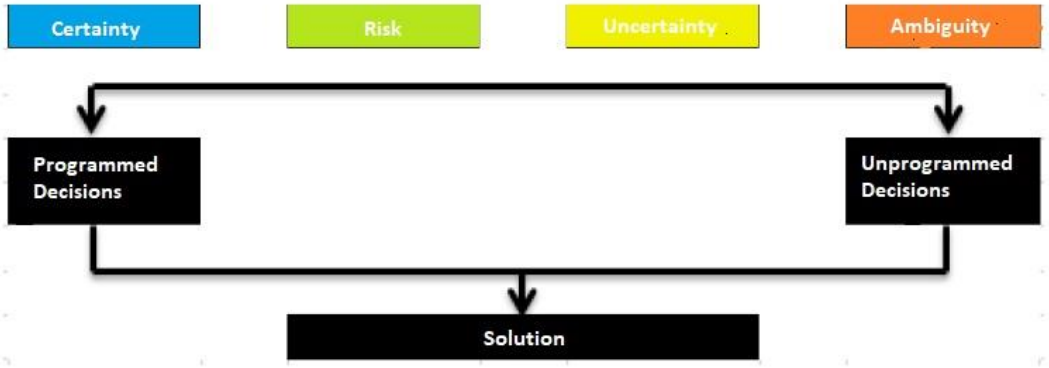

Figure 5: Relations Between Context and Decision Making [2]

No matter the type of decision to be performed, there are suggestions and directions to how a decision making process should be executed. In alignment with Rowe and Luecke [40], the process of decision making should start by the proper and clear establishment of the objectives, because the decision is being made in the pursuing of reaching those objectives. After that, the process of decision making involves a series of steps that include establishing a successful argument, collecting adequate information, having the existence of alternatives, evaluating the alternatives, and choosing the best alternatives.

However, some problems can occur during the process, because of the people involved. Sometimes they lack the vision or the motivation, or simply have different ways of solving these kinds of challenges. Marakas [41] suggests another series of steps: stimulation, definition of decision participants, problem definition, alternative selection, and finally, implementation. In the same study, the author also suggests a classification

on the different types of decision making responses depending on people's motivations and the way they work. Therefore, decision making can be a very complicated issue, and if it is not addressed with proper attention, it can generate negative consequences to a company [38].

Another important concept about the decision making process is that after all the described difficulties and the decision are finally passed through, it is still not the end. That happens because a decision result must be measured and monitored and, subsequently, no matter how good or bad the consequences are, they create situations in which more decisions must be made. Thus, it becomes a cycle [1]. Harrison describes this perspective and gives a representation of it, presented next in Figure 6.

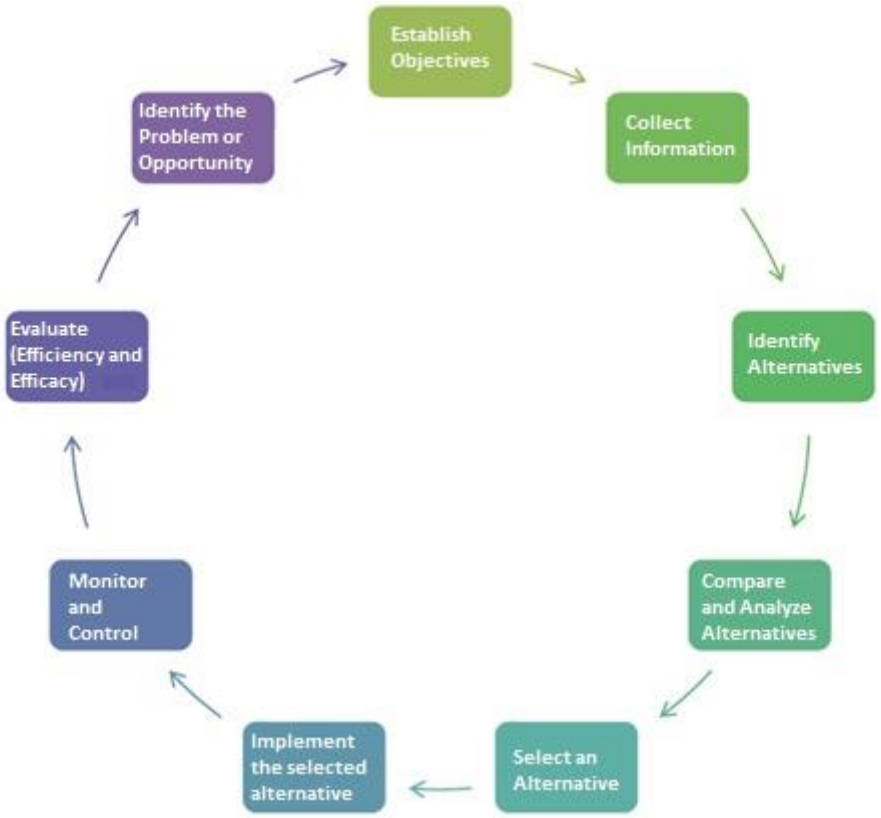

Figure 6: Decision Cycle [1]

First, the objectives must be established, which will determine the nature of the decision problem to be taken. Next, information should be collected to start de decision making process. The alternatives are then identified, compared and analyzed through one of the many available methods, and after it one of them is selected as the best. Then, after the decision making process is done, the selected alternative is implemented. After it, there comes the monitoring and controlling of the implemented alternative, and its efficiency, efficacy and other properties are evaluated. With the consequences of the implemented

alternative measured, opportunities and problems are observed, which motivate the establishment of new objectives, restarting the cycle.

Throughout history, many ways of solving decision making problems were developed, and still are. It's a very vast subject with a great number of alternatives to use as an aid. Many techniques were developed through the years, and many more have been created recently, especially because of the evolution in computer sciences. This work focuses its efforts in the multiple-criteria decision making methods, or multiple-criteria decision analysis methods, that create an advanced field in operations research, and are specialized in aiding in decision making problems and widely used in this sense, offering a very large range of options and ways of accurately dealing with this type of problem [42].

2.2.3 MULTIPLE-CRITERIA DECISION MAKING METHODS

In this section it will be first given attention to the most important and popular MCDM methods that will appear being employed in several problems presented in the next chapter. The methods presented here, their contributions and their limitations will relate to their general forms. Next, some other mathematical techniques that are also part of Operations Research (OR) and that can relate to MCDM methods in some of the decision making problems in companies will also be presented. Finally, a special and very popular relation existent between a non-MCDM technique and MCDM methods is presented with more depth: the fuzzy-MCDM relation.

2.2.3.1 Most Popular MCDM Methods

One advanced branch of operations research, multiple criteria decision making methods, or else MCDM methods, or either MCDA (multiple criteria decision analysis) methods, form the field of focus of this work. It provides many different methods specialized in aiding the solution of decision making problems, with each of them specialized in different aspects of these problems [20]. This field is devoted to the development and implementation of decision aiding tools to face difficult decisions with multiple criteria, goals, and / or objectives of conflicting nature [43].

In the multiple criteria methods review performed by Kahraman et al. [44], it is exposed the classification of MCDM methods between discrete and continuous. The discrete ones are problems where the decision makers have a finite set of alternatives to evaluate and rank. Continuous are the problems where there is an infinite number of alternatives. The first are present in the multi attribute decision making (MCDA) methods, while the second are addressed in multi objective decision making (MODM). This work focuses only on the discrete decision making methods and problems inside companies.

This section describes the main multiple-criteria decision making methods present in the papers review that will be presented in the next chapter. These are the methods that normally are cited as the most popular options when the subject is decision making problems. It does not necessarily mean that the methods not mentioned here and that will appear in part of the papers research are not as relevant for the field as a total. However, as in several occasions there will be methods that appear only once or twice next chapter, and it would be too excessive to introduce around half a hundred techniques in this section.

The Analytic Hierarchy Process – AHP

This multiple-criteria decision making method was first proposed by Saaty [45], with the aim of being a useful tool and structure for aiding in complex problems. It is one of the most popular methods of MCDM [46]. As observed by Kahraman [44], AHP organizes the decision making criteria as a hierarchy by giving them weights, and then quantifies priorities for an existent set of alternatives, all based in the decision makers pairwise judgments. According to the same author, AHP also emphasizes the consistency of the comparison of alternatives and has the capability of detecting and incorporating inconsistencies inherent in the decision making process.

This method has its advantages as well as defects criticized by the community. The main advantage of AHP is its ease of being used. The usage of pairwise comparisons allow decision makers to compare alternatives and weight criteria with relative ease. It also is a scalable method, that can easily adjust its size when adding or reducing the number of alternatives, due to its hierarchical structure [46]. But also, duo to the approach based on pairwise comparisons, it can have inconsistencies when measuring judgment and when ranking criteria. It does not allow that these terms be evaluated individually, but always on comparison. This makes it difficult to see an alternative's strengths and weaknesses [47]. However, this is not the main disadvantage of the method in its general form. Its most criticized matter it that AHP, in its general form, is susceptible to rank reversal. That is, the addition of alternatives late in the process can cause the final ranking to flip or to reverse, because of the pairwise comparisons used to form the rankings.

Analytic Network Process – ANP

This is a variation of the AHP method, in the sense of being a generalization of the former, and is also developed by Saaty [48]. As presented by its creator, the ANP method has as main difference the treatment of data by a non-linear network, instead of the linear hierarchy of AHP. It also divides alternatives into clusters, and it can understand dependencies between higher and lower level elements [49]. This all directs the method to be used in very advanced decision making problems, with complex relations among

elements. The relationship among elements that are in the same cluster is named inner dependency, while an outer dependency between two clusters is called feedback [48]. Its steps are three, and they are defined as: (1) structuring, where the problem is selected and the criteria is identified; (2) modeling, where questions that are based on pairwise comparison are asked to the experts in the specific subject; and (3) analyzing, where group judgments are calculated and priorities are found [44].

The ANP method can better relate interdependencies than the AHP method, being able to support a decision making problem that is complex and networked, with various intangible criteria [50]. The major disadvantage of the method, in addition to those that are consequence of pairwise comparisons, according to Wang et al. [51], is that "it ignores the different effects among clusters".

Technique for Order of Preference by Similarity to Ideal Solution - TOPSIS

This approach was first developed by Hwang and Yoon [52], and its major idea is to find the alternative of a given decision making problem that is in the closest distance to the positive-ideal solution and the furthest distance from the negative-ideal solution. For that to be accomplished, a similarity index, or also called relative closeness coefficient, is calculated for each alternative. This index indicates de distance the alternative is from the positive-ideal and the negative-ideal solutions. After the mentioned process, the best alternative is then selected [44]. It is a very popular method of MCDM, mostly because of its simplicity.

This is a method that offer a great number of advantages. It has, as described above, a simple process. It has an easy application, being also a easily programmable method [46]. The number of steps in its process are always the same, no matter the number of attributes [53]. All of this contributes to its popularity, even with it also having its disadvantages. Because of its use of Euclidean Distance, the correlations among attributes are never considered. Also, in this method it is difficult to be consistent in judgment when weighting criteria, especially when its necessary to add attributes. Therefore, it is common to see TOPSIS being used in partnership with another method specialized in weighting criteria [46].

Visekriterijumska Optimizacija I Kompromisno Resenje – VIKOR

This is a very recent method, that has been gaining popularity rapidly due to its ability to deal with complex problems. The Serbian name means Multicriteria Optimization and Compromise Solution in the English language. This method was developed by Opricovic [54]. It is a technique that can contain criteria with different units and that also are conflicting among each other. For example, it can consider financial, social and environmental criteria in the same analysis. The compromise solution is categorized as a ranking index over alternatives, that is based on the measure of closeness to the ideal

solution and also the agreement established by mutual concessions [55]. The way of obtaining the solution is close to the one used in TOPSIS.

Decision Making Trial and Evaluation Laboratory – DEMATEL

As reported by [44], this method in particular does not have only one creator. It was originally developed between the years 1972 and 1979 by the Science of Human Affairs Program of the Battelle Memorial Institute of Geneva, with the objective of studying and understanding the complex and intertwined problematic group, as described in [56] and in [57]. This approach has been acknowledged as one of the best tools to solve cause and effect relationships among evaluation criteria. It is formed by digraphs, that separates the criteria into cause groups and effect groups, and then it indicates and portrays their behavior, showing the strength of the influence one has on the other, and later turns all this information in a structured model of the real system [44]. DEMATEL can indicate the most important criteria regarding the effects caused in other criteria [58]. As it can be observed, this method focuses on a different direction if compared to the other described methods.

There are several other methods that will be present in solutions of decision making problems in the upcoming chapter, each of them with their own characteristics. Each of the methods focuses on different aspects of the decision making problems, and many of them can be complimentary. Most of the time they will appear in cooperation with one of the mentioned methods above. Among the other methods present in this work, including MCDM and non-MCDM techniques, there are PROMETHEE, ELECTRE, QFD, Delphi, MOORA, COPRAS, Goal Programming, Best Worst Method, Fuzzy Axiomatic Design and Shannon Entropy, and many others.

2.2.3.2 Related Techniques

There are other mathematical modelling techniques besides multicriteria decision making methods that can relate to MCDM to solve decision making problems. Asimov highlights the following methods [59]:

- **Classical Methods:** they are a part of operations research that have the quality of having an objective function, restrictions and an own domain. It can be divided into the large areas *Linear Programming* [60] and *Nonlinear Programming* [61], where functions and restrictions are linear and not linear, respectively. These methods can have many different applications in decision making problems. A common example of the application of linear programming is the optimization of which of its products a company should focus its production on, to maximize its profit. Besides production planning problems, both areas can be very useful for several other problems, like personnel planning, transportation planning,

assignment of people and activities, trim-loss problems and investment decisions.

- **Artificial Intelligence:** this is a fascinating field in which computers look for creating systems that imitate behaviors linked to human beings, like adaptation, perception, reasoning and learning. It can be divided into:

    - *Artificial Neural Networks:* it solves problems through artificial intelligence. It proposes circuit networks that are connected as if simulating the human brain, and they process information, recognize their mistakes, and learn by experience [62]. They have the advantage of identifying relation even in non-linear physical problems, because most of times it does not consider things physically, it just learns what it observes. It is a field in development, and it is still expanding its applications. It can be found from microbiology to science and industry applications. In industry, it has been employed in problems of pattern classification, prediction, financial analysis, control and optimization [63].

    - *Generic Algorithms:* it is a powerful optimization tool that solve problems by collecting the data and the criteria and then, by reproduction and mutation, it develops through as many generations as necessary until it gets to acceptable solution values [64]. It is a field in a consistent growth, and among its applications there are scheduling, optimization, multidimensional scaling, constraint handling, and feature selection and classification problems [65].

    - *Fuzzy Logic:* the leading technique in making alliances with MCDM methods for decision making problems. It was first introduced by Zadeh [66] and Klaua [67] in the 60's as a proposition of an extension of the classical view on mathematical sets. It is an extension of Boolean logic, by giving values in between the ones and zeros. This allows computers to read uncertainty and qualitative aspects, causing a revolution in the development of many different types of studies throughout science [68]. This feature fits perfectly in decision making problems solving, because decisions have one complicated point in common: uncertainty. The fuzzy theory can influence the creation of many fuzzy-oriented systems, like MCDM problems themselves, language programming, controllers, pattern classification, diagnosis in probabilistic environments, identification of structures, games, and catastrophes. Among fuzzy potential applications, according to Dubois [68], there are: (a) Artificial Intelligence and Robotics; (b) Image Processing and Speech Recognition; (c) Biological and Medical Sciences; (d) Control; (e) Applied Operations

Research; (f) Economics and Geographic; (g) Sociology; (h) Psychology; (i) Linguistics; (j) Semiotics, and (k) other different topics.

- **Chaos Theory:** the key concept of this theory is that it is never possible to foresee with complete certainty the future, in short, medium or long terms. Its systems are very sensible to any change, and it simulates thousands of possible outcomes for problems, identifying patters that can help in a strategic decision for a company, for example [69]. According to Thietart et al. [70], organizations present in a chaotic domain have the tendency of exhibiting qualitative properties of chaotic systems, and these properties lead to six propositions about the mentioned organizations: (1) Organizations are potentially chaotic, because of the coupling of counteracting forces among its structures; (2) The path for an organization to move from stability to chaos in discrete; (3) When an organization is in a chaotic domain, small changes can have big consequences in the long term that cannot be foreseen; (4) From chaos, new stabilities can emerge, because of strange attraction to specific configurations; (5) Similar patterns can be found in different scales; and (6) Between two different organizations or during one single organization life span, similar actions will never lead to the same result [70].

2.2.3.3 The Fuzzy Set Theory Application on MCDM

Fuzzy set theory is an extension of the classical set theory, allowing the solution of problems related to dealing the unprecise and uncertain data [71]. Its possible applications are very wide, and there are many developed methods with MCDM purposes that solely base themselves on this logic, to a point that fuzzy set theory can be considered a MCDM method itself by many [46]. The form in which fuzzy set theory presents itself the most in this work is as linguistic values represented by fuzzy numbers. These linguistic variables are used to evaluate the importance weights of criteria in other established MCDM methods, allowing them to deal with unprecise data and, therefore, making them be more effective [72]. A linguistic variable is variable that have as values words or sentences in a natural or artificial language [73]. This allows MCDM methods, like AHP or TOPSIS, to have more precise translation of the information given as input, that later will be used to weight the criteria or define the alternatives, resulting in a more accurate solution.

Fuzzy logic is applied in the AHP, ANP, TOPSIS, VIKOR, DEMATEL methods and many others, in cases where experts' judgments are uncertain and cannot be expressed with proper precision, and then fuzzy comes providing a mathematical strength to capture the uncertainties associated with the human cognitive process [74]. This affects the process of weighting, and positively improves the results of the methods.

According to Kahraman et al. [44], there are various proposals of fuzzy extension for AHP in the literature. Fuzzy ANP is also very popular, with a literature review on it using the software SCOPUS in 2015 giving 1,542 published papers, in all fields [44], with the number increasing drastically since 2009. Still according to Kahraman et al. [44], a literature review on Fuzzy TOPSIS using SCOPUS gives 4,010 published papers in total. The first application of fuzzy inputs in VIKOR method was presented in the year of 2012 [75]. Later, by Opricovic, a fuzzy extension was used to find a fuzzy compromise solution, that would change both criteria and weights of the problem to fuzzy numbers [76].

In the next chapter, when the number of times methods appear on the papers researched will be evaluated, it will be seen many times that the fuzzy variations of certain MCDM methods are more times employed then their general forms, such is the popularity of this theory in decision making problems.

2.3 COMPANIES, RESOURCES MANAGEMENT AND VALUE CREATION

In the modern world, companies need to stay sharp to guarantee that they can last through the upcoming decades. There are many aspects in which they can focus in to be able to improve, and in between many of them this project focus on a subject many times took for granted but that can cause real impacts in the way a company prospers: the economic value creation through optimized resource management [77]. First, this section concentrates on presenting how finite resources management is present in a company, then its relations and influence in value creation are exposed, as well as value creation itself and its importance to a business success. Later, the areas inside a company that are popular for application of MCDM techniques are presented, as the many fields for dealing more efficiently with resources inside an organization.

2.3.1 FINITE RESOURCES MANAGEMENT IN COMPANIES

Resources management is about allocating resources in the most effective way possible, according to Business Dictionary [292]:

"The process of using a company's resources in the most efficient way possible. These resources can include tangible resources such as goods and equipment, financial resources, and labor resources such as employees. Resource management can include ideas such as making sure one has enough physical resources for one's business, but not an overabundance so that products won't get used, or making sure that people are assigned to tasks that will keep them busy and not have too much downtime."

Thus, if resources management refers to allocation of resources, it is interesting to observe the definition of resource allocation, also given by Business Dictionary [291]:

"Analysis of how scarce resources ('factors of production') are distributed among producers, and how scarce goods and services are apportioned among consumers. This analysis takes into consideration the accounting cost, opportunity cost, and other costs of resources and goods and services. Allocation of resources is a central theme in economics (which is essentially a study of how resources are allocated) and is associated with economic efficiency and maximization of utility"

Therefore, managing resources affects every kind of 'factors of production', across the company's body. Resource allocation is not a field inside a company, but it embraces all areas, and is part of all areas, in the pursuing of making the business become more efficient and, consequently, more successful [77].

When observing recent articles on the allocation of resources, it is noticeable that the recent idea is that resource management shouldn't be something static or definitive, because external factors like demand growth, regulations, launches from competitors, and internal factors like changes in available talent, new processes and technologies surrounding the company's existence are in constant change, so resource allocation should be dynamic instead. According to a research made by American consultant giant McKinsey & Company, on their article *How Nimble Resource Allocation Can Double Your Company's Value* [288], constant and agile reallocation can increase profit, and also generate a raise in the financial market, increasing the company's share values, according to the study performed. That is crucial knowledge to a company's success.

In another study performed by the consultant giant, it is made a deep research through an enquiry that asked many top entrepreneurs about the decision making processes in their companies. It was identified that the most competitive businesses many times had five factors in common [290]. The factors are: (a) Tying budgets to strategic plans; (b) Evidence-based decision making; (c) Setting bottom-up performance goals; (d) Formally ranking investments; (e) Similarity of financial characteristics. At the end of the research, it was evidenced that when acting together, the factors would cause more impact on the organizations' competitiveness than when acting alone, but even when acting alone, they could also influence value creation and, therefore, influence the company's degree of competitiveness.

2.3.2 VALUE CREATION

The Business Dictionary also gives a proper definition for value creation [293]:

Value creation is the performance of actions that increase the worth of goods, services or even a business. Many business operators now focus on value creation both in the context of creating better value for customers purchasing its products and services, as well as for shareholders in the business who want to see their stake appreciate in value."

The creation of value not only refers to goods and services, but to the consequent increase in the company's actual value in influence, currency and stakes. Also, some ways of creating value are more useful than others, according to Peter Thiel in his book *Zero to One* [78], in which he states that unique activities create more value than the commonsense ones.

There is a general diagram that represents the generic and traditional way through which companies create value in the current modern era. The Harvard Business School Professor Michael Porter first introduced the ideas about Value Chain in his book *Competitive Advantage* [28]. Basically, it refers to how companies can take raw resources as an input and sell than as outputs in a way that the value created surpasses the costs to create such value. This is the fundamental principle through which companies exist in the first place.

Porter created a generic diagram of activities from which value is built within any company, and divided this structure into primary and support activities, as seen in Figure 7.

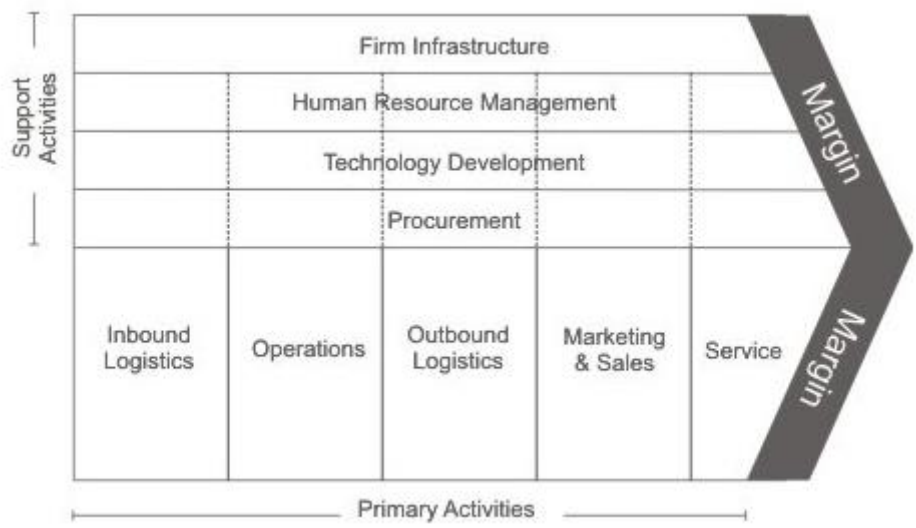

Figure 7: Porter's Generic Value Chain Diagram

As their category name indicate, support activities serve as base structure, resources and mechanisms through and from which the primary activities can be performed. Three of the four support activities are divided by dotted lines, meaning that each of them gives support to all primary activities, in different ways. A brief explanation on the activities can be given, according to Porter. First, primary activities:

- **Inbound logistics** – These are all the processes related to receiving, storing, and distributing inputs internally. The relationships with the suppliers are a key factor in creating value in this step.

- **Operations** – These are the transformation activities that change inputs into outputs, that later are sold to customers. Here, the operational systems create value.

- **Outbound logistics** – These activities are related to delivering the product or service to the customer, which can be the final one or another company. These are things like collection, storage, and distribution systems, and they may be internal or external to the organization.

- **Marketing and sales** – These are the processes used to persuade clients to purchase from one company instead of its competitors. The benefits offered, and how well they are communicated, are sources of value here.

- **Service** – These are the activities related to maintaining the value of the product or service to the customers with time, once it's been purchased.

Then there come the secondary activities:

- **Procurement (purchasing)** – This is what the organization does to get the resources it needs to operate. This includes finding vendors and negotiating best prices.

- **Human resource management** – This is how well a company recruits, hires, trains, motivates, rewards, and retains its workers. People are a significant source of value, so businesses can create a clear advantage with good HR practices.

- **Technological development** – These activities relate to managing and processing information, as well as protecting a company's knowledge base. Minimizing information technology costs, accompanying technological advances, and maintaining technical excellence are sources of value creation.

- **Infrastructure** – These are a company's support systems, and the functions that allow it to maintain daily operations. Accounting, legal, administrative, and general management are examples of necessary infrastructure that businesses can use to their advantage.

Support activities can determine how well primary activities are performed, and the better they perform, more value is created. More value offered to consumers means more satisfied customers and, therefore, they become more loyal and come in more quantity, and this also means the increase in the company’s share value. All is related.

After it is understood the way any company work, the important step is to identify opportunities in between these activities to increase value. It can be either by creating more small portions of value to the customer, or either by avoiding or minimizing losses. One way or another, it all involves the optimization of the efficiency of decisions made inside the businesses.

About how the future on value creation looks for enterprises, Jack Hughes article in the Harvard Business Review on *What Value Creation Will Look Like in the Future (Evergreen)* [289]. Value is no more only created through cost efficiency maximization, operational improvements and large scale sales. Nowadays, more and more, creativity and customer customization are assuming the lead in value creation.

Into the future, value will be created manly through creativity, but it reaches its maximum efficiency only after the way the companies organize themselves, allocate resources, and everything in this sense is fully optimized. Hence, the improvement and optimal functioning of all the mechanisms inside a company, including resource allocation, are and still will be extremely important for ultimate success of all creative solutions that now and tomorrow will be offered by these companies and startups [289].

2.3.3 COMPANIES' BODY OF APPLICATION

As seen above, a business chance of success is directly related to the value that is created by it, being that the value created depends of the efficiency of resources management, and given that such efficiency is achieved by more effective and clear decision making processes. It all comes towards deciding for the right tool to aid in decision making processes, inside all spheres of a business.

The methods that will be focused in this work are already introduced, but the areas in which they are applied in recent literature are not. As it is going to be presented in the beginning of the next chapter, the understanding and the knowledge of what are the kinds of problems in which MCDM methods are applied inside a company's structure took some time. It was an iteration process between searching new papers and determining new areas and sub-areas, until the final areas in which the approaches are applied were finally defined. The areas align with the work of Behzadian [79], in which TOPSIS and other MCDM tools were divided in all areas of applications they have. Of the nine areas proposed by the author, five were related to a business environment. The areas proposed by the author and that are also utilized in this work are the following:

- **Supply Chain Management and Logistics:** applications in supplier selection, supply chain management and logistics and outsourcing in companies.

- **Design, Engineering and Manufacturing Systems:** applications in engineering decisions and challenges, product development, materials and quality management and manufacturing systems.

- **Business and Marketing Management:** concentrates in several kinds of performance evaluation of enterprises, knowledge management, strategic and investment decision and also marketing challenges.

- **Health, Safety and Environment Management**: applications in sustainable management in companies, impact reduction, reverse logistics, green supply chain selections and evaluations and eco development of new products or facilities.

- **Human Resources Management:** focuses on staff selection problems, products and ergonomic relations and care of the human resources that businesses have.

These areas are later defined as the major areas of MCDM methods application in this work, because they align very well with the applications of all work related to a company's environment encountered in the papers research.

THESIS DEVELOPMENT

3 THESIS DEVELOPMENT

In pursuing of properly bringing a clear and wide view on all possible MCDM applications to help solving different types of problems present in the business setting, all the efforts are first dedicated in a vast papers research. It helps the readers understand what the most recent and relevant work in different areas of a company's environment are. Important statistics evaluations are made to make data even clearer and more explored. Following the literature review and data analysis, a deeper analysis is on the main methods take place, commenting on the many ways each of them appeared throughout the papers reviewed. These comments bring a more in-depth and technical insight of how each of the main method is applied in the studied areas. Finally, final discussions on results are made, as a way of summarizing the study. All analysis made should further help readers in their searching for the appropriate method for decision making problems in an enterprise setting.

3.1 MCDM PAPERS REVIEW

This section is divided into Research Methodology and Research Results. The first one presents all the criteria and the formation of the framework of research before it starts, and then shows how the research proceeded and application areas were developed. The second one is where the presentation of all researched papers happens, in a proper classification.

As seen in the state of art, multiple-criteria decision making methods have been developed for a long time now. Each method was created with the objective of first solving one specific problem their creator was facing or had in mind, that was very important for that time in history. But time passes, and with it the nature of problems faced by the world, including the ones faced by enterprises. Hence, multiple-criteria methods had to adapt over time, and new ones had to be created to meet the needs of new problems, and new combinations between methods. This phenomenon created a wide variety of options when the subject on the managers meeting is to choose the most appropriate MCDM method for helping to solve that one specific decision making problem.

Sometimes that problem is very specific, with its own set of criteria and a unique objective, with all sorts of complications, configuring a problem never seen before. Then the creativity of experts must be put to work and its needed to find the patterns and which methods could be combined to better model that problem. However, this is not the rule anymore. The probability is that the main problems faced in the firms' routines already existed somewhere else, and already there are some perfected ways of solving them. And this is the focus of this dissertation. The idea is to help decision-makers by covering all main areas of standard companies with a literature research of most recent and relevant work in them regarding the usage of the main multiple-criteria decision

making tools. Therefore, these most recurrent problems faced by standard companies all over the world constitute what is the aim of this work. However, this database could also serve as guidance to decision makers seeking a way to solve a new and unique problem.

3.1.1 RESEARCH METHODOLOGY

3.1.1.1 Defining the Framework of Research

The literature review was undertaken to identify the most relevant and top-leading works in most recent years, from beginning of 2012 to the end of 2018. It focuses first on the most important and popular MCDM methods for decision making problems in standard companies, including their many variations, especially the ones that include fuzzy set theory. Also, any paper that has a not-as-popular multiple criteria methods that is applied in combination or in comparison with the main ones to solve certain problems are included. Some specific papers that have the sole presence of multiple criteria methods or new methods, not mentioned in the state of the art, are kept, to provide even more options and insights for researchers and practitioners.

Works that solve problems not related to a company's decisions, plans and other activities are discarded from the papers review, for example, government decisions or university projects decision making problems. Regarding the types of scientific work included in this literature review, they are solely composed by article publications in respected journals and papers proceeding through conferences. PhD, Doctoral dissertations, Master's theses, textbooks and unpublished working papers are thus excluded from it.

There are specific database platforms that are chosen to properly proceed with the research of relevant work on the subject. The platforms of research selected are Google Scholar, ScienceDirect, Taylor and Francis, IEEExplore and Scielo, essentially because they offer so many good papers and works with so little financial barriers for researchers. The research for a determined combination of terms follows the exact order of platforms as how they were mentioned: first on Scholar, collecting all related articles from pages 1 to 5, classified by order of relevance, then to ScienceDirect and its first 50 results also sorted by relevance, and so on. In all platforms, with all terms used for research, always it is filtered for only articles, from 2012 to 2018, in journals related to the business setting, including environmental issues, considering at least the first 50 results in each platform and with each research tag.

The found articles are analyzed, one by one, and are then categorized and distributed among the five bigger application areas that complement each other in the decision making subject, mentioned in last chapter [79], to constitute the scope of a business

setting, and in seventeen sub-areas inside of them. Including going through this distribution, the targeted papers are coded and classified according to several categories, in the following order: application area, sub-area, authors, involved institutes' countries, year of publication, title, number of citations, journal, type of research, methods involved, and commentaries on the paper, with the last one involving a synopsis and observations made.

All classifications allow a good diversification of characteristics in the form of analyzable data, that will be part of the statistical analysis and comparison sub-chapters that will take place further on.

The scope of this literature research as mentioned above, including the manner MCDM/MCDA methods are going to be organized and divided in this literature review, as well as their different approaches and their different areas of applicability, is not the way the research is planned from the beginning. A development of these areas and concepts occurs during the research process, as it is going to be mentioned below.

3.1.1.2 The Development of the Research

The research work starts in a narrow mindset, thinking only about the allocation of resources inside business, that is the core and raw idea behind this work. Therefore, the research tags used in the first step include the words: AHP; TOPSIS; Fuzzy; MCDM; and Resource Allocation. These words are combined in different ways and ordinations across all mentioned platforms, respecting all mentioned criteria. The results that are obtained in this first step already show something interesting. Many decision making problems do appear involving the need of allocating resources in companies, but not explicitly. Problems involving the selection of suppliers, or the selection of personnel, or the decisions for inside logistics, or even the ones about expanding the companies' territories, are all found with much more ease and relevance, and in a much bigger proportion than the ones explicitly talking about resource allocation problems. The resource allocation specific articles end up being rare, and the ones found under this kind of title and abstract talk about very specific technical problems in electronic and information technology systems most of times.

This setback pushes the research to be reinvented. All other problems found under the allocation resources tag ended up ultimately being about the correct allocation of money, time, people and materials of a standard enterprise, among others, as mentioned in the introductory parts of the present work. So, after this, sub-application areas are created inside the initial resource allocation big application area. These sub-areas are created according to the areas of the articles found under the old tags.

New tags are created with new words being combined, specific groups of words at each time: AHP, TOPSIS, Fuzzy, MCDM, Supplier Selection, Sustainability, Facility Location,

Logistics, Business Management. In all tags the words 'MCDM', 'AHP', 'TOPSIS' and 'Fuzzy' are included, one way or another, always combined with one of the others that are related to sub-application areas. As it happened before, every new tag used brings also results of other areas not mentioned before that are still related to the business environment, continuing the cycle and causing the creation of new areas, and subsequently, new tags, and so on. Figure 8 shows the algorithm that represents the process.

Figure 8: Scheme representing the development of application areas

After some time, part of the application areas classification proposed by Behzadian in [79] are adopted as the five application areas inside which all papers found would be classified. The areas created according to the algorithm exposed in Figure 8 are allocated as sub-areas of the five major fields. The other four areas proposed by the mentioned author as of MCDM application areas are not adopted in this work because they are not part of a company's environment. The final application areas and their sub-areas are finally divided as follows in Table 1.

Table 1: Categorization of Application Areas and their divisions

Application Area	*Sub-Area*
Supply Chain Management	Supplier Selection and Assessment
	Chain Management
	Logistics Management and Outsourcing
Environmental Management	Sustainable Management
	Impact Reduction and Reverse Logistics
	Green Supply Chain Selections
	Eco Design
Business and Marketing Management	Performance Evaluation
	Strategic and Investment Decisions
	Knowledge Management
	Marketing Management
Design, Engineering and Manufacturing Systems	Engineering Challenges
	Modern Manufacturing Systems
	Material and Quality Engineering
	Product Development
Human Resources Management	Staff Selection
	Products and Ergonomics
	Human Capital

With all applications areas, and consequently, all tags developed, the complete research can take place in the determined time for it, and the appropriate filtering can happen through it. In the research process, besides the filter settings when performing the search in the platforms, articles are selected to download according to the content of their titles and their keywords. Even under specific tags, a lot of papers not related to the focus of this work appear in the most relevant lists of searches. Later, even after the carefulness of the correct search and all the filtering, there are still some of the downloaded papers that do not relate to the interested application areas or methods, that are out of the interested timeframe – are from before 2012, or that end up being duplicates of other already downloaded papers. The PRISMA Flow Diagram [80] is used to show the systematic of this process in Figure 9, next.

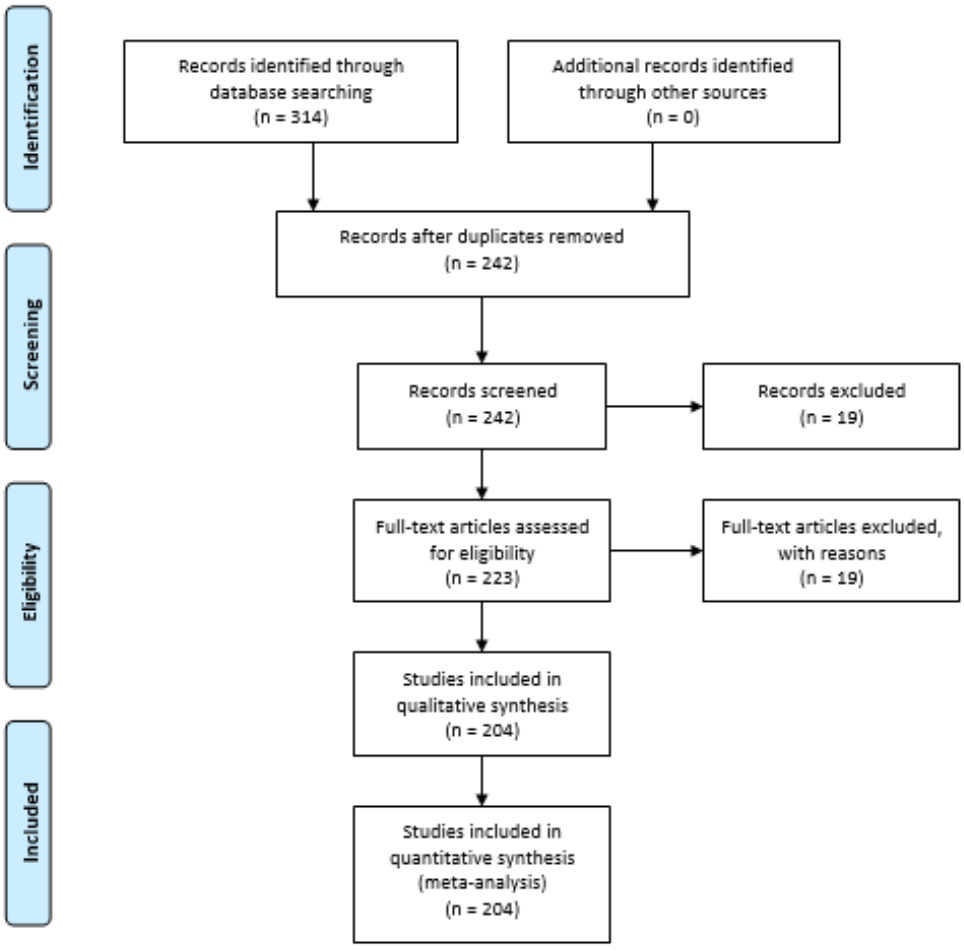

Figure 9: PRISMA of the presented literature review

Before the filtering process, all articles encountered through the papers research form a total of 314 publications. No records are found through other source that aren't the determined database. The first filtering process is the removal of duplicates existent among the papers found. A total of 72 duplicates are removed, leaving 242 eligible articles. Next, the remaining papers are screened, that is, opened for reading, and 19 are excluded for being published before 2012. Later, the papers were read and other 19 are removed for being out of topic. Finally, after all exclusions, 204 papers remain to be presented in this work. The remaining 204 eligible and selected papers are divided among all mentioned classification, and are ready for being presented and, further on, analyzed statistically.

3.1.2 RESEARCH PRESENTATION

3.1.2.1 General Considerations

This section is responsible for presenting all papers elected in the subject, divided them in the five major application areas. Each application area is going to be presented individually, for proportionating a better understanding from the reader by offering a

clearer and more focused disposal of the selected articles for the papers review, showing more evidently the similarities and differences.

The papers' types of researches vary among application, comparison, review and development. Most of the papers only embrace one approach, while some others combine two of them in a special work. Application papers are the ones that use a method or combination of methods (hybrid) in a practical example. Comparison ones evaluate one method against another, comparing either their approaches or their results. Review papers are the ones that perform literature review of related methods inside any of the focused areas. Development ones are rare, and represent the creation of a new tool for solving specific decision making methods.

The presentation of the research papers in all areas will always follow the same pattern, where each one is classified by author's name, year, title, type of research, methods involved and number of citations. They are ordered by number of citations. All not mentioned classifications, like nationalities and journals, will only be relevant in the next sub-chapter. Below is presented Table 2 as the concept table that will be used to present the work of all application areas.

Table 2: Example table for presentation of papers in each field

Main Author	Year	Title	Type	Methods	Citations
XXX, xx *et al*	2045	.....	Comparison	AHP, TOPSIS	200
...					
...					

All research papers presented in this sub-chapter are directly linked to their respective references in the end of this work, for further reading and researching by the readers. The presentation of this review is as detailed as seem necessary to better help readers, researchers and practitioners have a general view of what can be found in each application field, as well as a glance on specific examples, to get a better feel of each topic present in this literature research.

3.1.2.2 Supply Chain Management and Logistics

Together with Environmental Management, this is the application area with most papers relating multiple-criteria decision making methods to decision making problems. It covers several topics, divided into the sub-areas Supplier Selection and Assessment, Chain Management and Logistics Management and Outsourcing.

In Supplier Selection and Assessment, papers found treat mostly about problems related to selecting the best alternative supplier, while others are about evaluating the performance of the current supplier or also about supplier segmentation. For supplier

selection, Junior et al. [81] proposed a comparison between methods Fuzzy AHP and Fuzzy TOPSIS, and Fuzzy AHP rank reversal problem is pointed out, as well as its limitations with the increase in number of criteria, while Fuzzy TOPSIS shows more consistency and versatility, not taking much more time complexity than Fuzzy AHP for these decision making problems. On the other hand, Deng et al. [82] suggested a supplier selection method with usage of AHP extended by D numbers, that are there as an extension of fuzzy preference relation, perfecting the AHP method in order that it would help in the representing of the decision matrix of pairwise comparisons. Chai et al [83] offered a big review on decision making methods for supplier selection problems, presenting many MCDM methods as well as broadening the research by presenting other genres of decision making methods like Artificial Intelligence.

In Chain Management, decision making problems involve several different types of challenges involving the management of a supply chain in a company, like assessing its risks, modelling its coordination and adopting knowledge management in it. Regarding this last topic, Patil et al. [84] proposed a fuzzy AHP-TOPSIS framework to identify and prioritize the solutions of Knowledge Management (KM) adoption in Supply Chain (SC) to overcome its barriers. In the same year, Samdevi et al [85] offerred an integration between Fuzzy AHP and Fuzzy TOPSIS in order to weight the criteria and then rank risks in a Supply Chain according to the referred criteria, with the criteria weighting being made by Fuzzy AHP and the risks ranking by Fuzzy TOPSIS. A great and very popular combination between the two methods.

In Logistics Management and Outsourcing, the topics involve selection of warehouse location, logistics outsourcing, transport vehicle selection and third-part logistics assessment and selection. Ashrafzadeh et al. [86] presented the application of Fuzzy TOPSIS method for the selection of a warehouse location, It was used to aggregate scores and rank the best location alternative, having as contribution cutting costs and reducing risk in these decisions. In transportation vehicle selection, Baykasoglu et al [87] offered a hybrid that integrates Fuzzy DEMATEL with Fuzzy TOPSIS for an appropriate truck selection.

All researched papers in the referred Supply Chain Management and Logistics field and sub-fields can be consulted in Table 3, next.

Table 3: Literature in Supply Chain Management and Logistics

SUB-AREA	AUTHOR	YEAR	TITLE	TYPE	METHODS	CITATIONS
Supplier Selection and Assessment	KUMAR, Sanjay et al [88]	2018	Supplier selection using fuzzy TOPSIS multi criteria model for a small scale steel manufacturing unit	Application	Fuzzy TOPSIS	new
	KUMAR, Rajnish et al [89]	2018	Supplier Selection of an Indian Heavy Locomotive Manufacturer: An Integrated Approach using Taguchi Loss Function, TOPSIS, and AHP	Application	Taguchi Loss Function, TOPSIS, AHP	new
	CHAI, Junyi et al [83]	2013	Application of decision-making techniques in supplier selection: A systematic review of literature	Review	MCDM, MP and AI Techniques	517
	JUNIOR, Francisco Rodrigues Lima et al [81]	2014	A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection	Comparison	Fuzzy AHP and Fuzzy TOPSIS	306
	DENG, Xinyang et al [82]	2013	Supplier selection using AHP methodology extended by D numbers	Application	D numbers, AHP	280
	ZOUGGARI, Akram et al [90]	2012	Simulation based fuzzy TOPSIS approach for group multi-criteria supplier selection problem	Application	Fuzzy AHP, Fuzzy TOPSIS	176
	REZAEI, Jafar et al [91]	2013	Multi-criteria supplier segmentation using a fuzzy preference relations based AHP	Application	Fuzzy AHP	135
	AYHAN , Mustafa Batuhan [92]	2013	A Fuzzy AHP Approach For Supplier Selection Problem: A Case Study In A Gearmotor Company	Application, Review	Fuzzy AHP	101
	DURSUN, Mehtap et al [93]	2012	A QFD-based fuzzy MCDM approach for supplier selection	Application	QFD, Fuzzy Weighted Average (FWA)	95
	KARSAK, E. Ertugrul et al [94]	2015	An integrated fuzzy MCDM approach for supplier evaluation and selection	Application	QFD, Fuzzy Information and 2-tuple linguistic representation model	86
	DARGI, Ahmad et al [95]	2014	Supplier Selection: A Fuzzy-ANP Approach	Application	Fuzzy ANP	73
	KARSAK, E. Ertugrul et al [96]	2014	An integrated supplier selection methodology incorporating QFD and DEA with imprecise data	Application	QFD, FWA, DEA	73
	ROUYENDEGH, Babak Daneshvar et al [97]	2013	Supplier selection using integrated fuzzy TOPSIS and MCGP: a case study	Application	Fuzzy TOPSIS, MCGP	70
	ROSHANDEL, Jinus et al [98]	2013	Evaluating and selecting the supplier in detergent production industry using hierarchical fuzzy TOPSIS	Application	Hierarchical fuzzy TOPSIS	70
	BEIKKHAKHIAN, Yokabed et al [99]	2015	The application of ISM model in evaluating agile suppliers selection criteria and ranking suppliers using fuzzy TOPSIS-AHP methods	Application	ISM, AHP, Fuzzy TOPSIS	69
	REZAEI, Jafar et al [100]	2013	Supplier segmentation using fuzzy logic	Application, Development	New Fuzzy rule-based system	56
	GHORBANI, Mazaher [101]	2013	A novel approach for supplier selection based on the Kano model and fuzzy MCDM	Application	Fuzzy KANO, Fuzzy AHP, Fuzzy TOPSIS	43
	LI, Ye et al [102]	2012	Supplier selection using axiomatic fuzzy set and TOPSIS methodology in supply chain management	Application	AFS, Fuzzy AHP, TOPSIS	41
	BUYUKOZKAN, Gülçin et al [103]	2017	Application of a new combined intuitionistic fuzzy MCDM approach based on axiomatic design methodology for the supplier selection problem	Application	IFS, IFAD, IFAHP	41
	JUNIOR, Francisco Rodrigues Lima et al [104]	2016	Combining SCORs model and fuzzy TOPSIS for supplier evaluation and management	Application	Fuzzy TOPSIS, SCOR model	40
	WU, Chung-Min et al [105]	2013	A Hybrid Multiple Criteria Decision Making Model for Supplier Selection	Application	Fuzzy Delphi, ANP, TOPSIS	40
	LEE, Jaehun et al [106]	2015	Assessing business impacts of agility criterion and order allocation strategy in multi-criteria supplier selection	Application	Fuzzy AHP, Fuzzy TOPSIS	38
	GALANKASHI, Masoud Rahiminezhad et al [107]	2016	Supplier selection in automobile industry: A mixed balanced scorecard–fuzzy AHP approach	Application	BSC, Fuzzy AHP	35

	JAIN, Vipul et al [108]	2018	Supplier selection using fuzzy AHP and TOPSIS: a case study in the Indian automotive industry	Application	Fuzzy AHP, Fuzzy TOPSIS	31
	JUNIOR, Francisco Rodrigues Lima et al [109]	2016	A multicriteria approach based on fuzzy QFD for choosing criteria for supplier selection	Application	Fuzzy QFD	30
	HALDAR, Anupam et al [110]	2017	Resilient supplier selection under a fuzzy environment	Application	Fuzzy TOPSIS, aggregate fuzzy weight method	29
	HALDAR, Anupam et al [111]	2012	A hybrid MCDM model for resilient supplier selection	Application	Topsis, AHP, AHP-QFD	27
	WOOD, David A. [112]	2016	Supplier selection for development of petroleum industry facilities, applying multi-criteria decision making techniques including fuzzy and intuitionistic fuzzy TOPSIS with flexible entropy weighting	Application	Fuzzy TOPSIS, Intuitionistic fuzzy TOPSIS, Flexible entropy weighting	27
	WU, Chong et al [113]	2013	Partner selection in agile supply chains: a fuzzy intelligent approach	Application	fuzzy set theory, artificial neural network	25
	GHORABAEE, Mehdi Keshavarz et al [114]	2017	Supplier evaluation and selection in fuzzy environments: a review of MADM approaches	Review	MADM approaches	23
	SANTOS, Luiz Felipe de Oliveira Moura et al [115]	2017	A model based on 2-tuple fuzzy linguistic representation and Analytic Hierarchy Process for supplier segmentation using qualitative and quantitative criteria	Application	AHP, 2-tuple linguistic representatio n model	18
	SIMIC, Dragan et al [116]	2017	50 years of fuzzy set theory and models for supplier assessment and selection: A literature review	Review	hybrid solutions based on fuzzy	14
	AZIZI, Amir et al [117]	2015	A Fuzzy TOPSIS Model to Rank Automotive Suppliers	Application	Fuzzy TOPSIS	7
	GORENER, Ali et al [118]	2017	A hybrid type-2 fuzzy based supplier performance evaluation methodology: The Turkish Airlines technic case.	Application	Interval type-2 fuzzy AHP, Interval type-2 fuzzy TOPSIS	6
	PRAMANIK, Dipika et al [119]	2016	Resilient supplier selection using AHP-TOPSIS-QFD under a fuzzy environment	Application	Fuzzy AHP, Fuzzy TOPSIS, Fuzzy QFD	5
	SUREEYATANAPAS, Panitas et al [120]	2018	Supplier selection towards uncertain and unavailable information: An extension of TOPSIS method	Application	TOPSIS, Rank Order Centroid (ROC)	2
	TYAGI, Mohit et al [121]	2018	Assessment of CSR based supply chain performance system using an integrated fuzzy AHP-TOPSIS approach	Application	Fuzzy AHP, Fuzzy TOPSIS	new
Chain Management	PATIL, Sachin K. et al [84]	2013	A fuzzy AHP-TOPSIS framework for ranking the solutions of Knowledge Management adoption in Supply Chain to overcome its barriers	Application	Fuzzy AHP, Fuzzy TOPSIS	181
	SAMDEVI, Avinash et al [85]	2013	Quantifying risks in a supply chain through integration of fuzzy AHP and fuzzy TOPSIS	Application	Fuzzy AHP, Fuzzy TOPSIS	123
	PATIL, Sachin K. et al [122]	2014	A hybrid approach based on fuzzy DEMATEL and FMCDM to predict success of knowledge management adoption in supply chain	Application	Fuzzy DEMATEL, FMCDM	83
	JAKHAR, Suresh Kumar et al [123]	2013	An integrated model of supply chain performance evaluation and decision-making using structural equation modelling and fuzzy AHP	Application	Estructural Equation Modelling (SEM), Fuzzy AHP	40
	DONG, Qingxing et al [124]	2016	An orders-of-magnitude AHP supply chain risk assessment framework	Application, Development	OM-AHP	28
	SHUKLA, Rajendra Kumar et al [125]	2014	An integrated approach of Fuzzy AHP and Fuzzy TOPSIS in modeling supply chain coordination	Application	Fuzzy AHP, Fuzzy TOPSIS	23
	TRAMARICO, Claudemir Leif et al [126]	2015	Analytic Hierarchy Process and Supply Chain Management: a bibliometric study	Review	AHP	13
	MAVI, Reza Kiani et al [127]	2016	Supplier selection with Shannon entropy and fuzzy TOPSIS in the context of supply chain risk management	Application	Fuzzy TOPSIS, Shannon Entropy	13
	GOVINDAN, Kannan et al [128]	2015	Prioritising indicators in improving supply chain performance using fuzzy AHP:	Application	Fuzzy AHP	12

			insights from the case example of four Indian manufacturing companies			
	TAMOSAITIENE, Jolanta et al [129]	2017	A novel hybrid MCDM approach for complicated supply chain management problems in construction	Application	AHP, ARAS, Multiplicative Utility, Hovanov	6
	SINGH, Rajesh Kr et al [130]	2018	Selection of warehouse location for a global supply chain: A case study	Application	Fuzzy AHP	new
Logistics Management and Outsourcing	AGUEZZOUL, Aicha [131]	2014	Third-party logistics selection problem: A literature review on criteria and methods	Review	MCDM Methods and others	154
	BAYKASOGLU, Adil et al [87]	2013	Integrating fuzzy DEMATEL and fuzzy hierarchical TOPSIS methods for truck selection	Application	Fuzzy TOPSIS, Fuzzy DEMATEL	136
	HO, William et al [132]	2012	Strategic logistics outsourcing: An integrated QFD and fuzzy AHP approach	Application	QFD, Fuzzy AHP	120
	ASHRAFZADEH, Maysam et al [86]	2012	Application of fuzzy TOPSIS method for the selection of Warehouse Location: A Case Study	Application	Fuzzy TOPSIS.	78
	UYGUN, Özer et al [133]	2015	An integrated DEMATEL and Fuzzy ANP techniques for evaluation and selection of outsourcing provider for a telecommunication company	Application	DEMATEL, Fuzzy ANP	56
	ŻAK, Jacek et al [134]	2014	The selection of the logistics center location based on MCDM/A methodology	Application	Electre III/IV	48
	BUYUKOZKAN, Gülçin et al [135]	2012	Logistics tool selection with two-phase fuzzy multi criteria decision making: A case study for personal digital assistant selection	Application	FAD, Fuzzy AHP, Fuzzy TOPSIS	43
	PERÇIN, Selçuk et al [136]	2013	A hybrid quality function deployment and fuzzy decision-making methodology for the optimal selection of third-party logistics service providers	Application	QFD, Fuzzy Linear Regression	39
	GOVINDAN, Kannan et al [137]	2016	Interrelationships of risks faced by third party logistics service providers: A DEMATEL based approach	Application	DEMATEL	32
	SAHU, Nitin Kumar et al [138]	2015	Appraisement and benchmarking of third-party logistic service provider by exploration of risk-based approach	Application	Fuzzy AHP	15
	DEY, Balaram [139]	2016	Warehouse location selection by fuzzy multi-criteria decision making methodologies based on subjective and objective criteria	Application	Fuzzy TOPSIS, Fuzzy SAW, Fuzzy MOORA	14
	RAMIREZ-FLÓREZ, Giselle [140]	2017	Fuzzy AHP for 3PL supplier's performance evaluation considering risk	Application	Fuzzy AHP	1

3.1.2.3 Environmental Management

The research works in this area are plentiful, and the way they are encountered is divided into Sustainable Management, Impact Reduction and Reverse Logistics, Green Supply Chain Selections, and finally, Eco Design.

Sustainable Management's papers consist on presenting application of MCDM methods for solving problems related to diverse management and risk assessments throughout the whole company's body. The analysis created by Wang et al. [141] offered a two-stage fuzzy-AHP model for risk assessment of implementing green initiatives in a company in the fashion segment, with the method dealing with certain and uncertain criteria. Also, this author's work has great business insights. Singla et al. [142] proposed an analysis of Technology Push Strategies affecting sustainable development in

manufacturing industries by comparing the multiple-criteria methods TOPSIS and VIKOR, with both achieving very similar results in the rankings.

In Impact Reduction and Reverse Logistics, works are directed towards recycling, performance evaluation of reverse logistics, selection of reverse logistics provider and channels and ranking of barriers in these subjects. An integrated Fuzzy AHP with TOPSIS is suggested by Vinodh et al. [143] for selecting the best recycling method in a practical application. Prakash et al. [144] proposed the usage of the combination Fuzzy AHP and Fuzzy TOPSIS for prioritizing the solutions of reverse logistics adoption to overcome its barriers in a general view, with Fuzzy AHP being applied to generate weights for the barriers as criteria by pairwise comparison, and final ranking of the solutions of Reverse Logistics adoption obtained through fuzzy TOPSIS.

Green Supply Chain Selection sub-area is constituted by papers related to the selection of green suppliers, that is, selection of suppliers for companies by considering partially or completely sustainable aspects as criteria. Also, there are papers with the objective of assessing green suppliers, of segmenting them, allocating and also other focused on the management or risk analysis of the green supply chain. Govindan et al. [145] offers a vast literature review on the application of MCDA methods for the green supplier evaluation and selection problems, by analyzing researches in international scientific journals and international conference proceedings, also criticizing the limited range of green supplier options for companies in comparison to standard ones. An application with comparison among three variations of Fuzzy TOPSIS is offered by Kannan, et al. [146], where the methods are employed in green supplier selection based on GSCM practices, and their results showed good correlation.

Eco Design gathers research works with the purpose of using MCDM methods for decision making problems involving eco designs and concepts as alternatives for a product, location or management, sustainable ranking of materials and materials selection regarding green criteria. Vinodh et al. [147] proposes a unique hybrid in the literature review when combining eco-QFD, TRIS and AHP for innovative and sustainable product development, where eco-QFD is a theory for inventive problem solving. On the other hand, Bakhoum et al. [148] proposes another hybrid, by combining AHP, TOPSIS and Shannon in for performing a sustainable ranking of sustainable materials.

The complete list of research works related to Environmental Management is presented in Table 4, below.

Table 4: Literature in Environmental Management

SUB-AREA	AUTHOR	YEAR	TITLE	TYPE	METHODS	CITATIONS
Sustainable Management	SINGLA, Anuj et al [142]	2018	Comparative Analysis of Technology Push Strategies Influencing Sustainable Development In Manufacturing Industries Using Topsis And Vikor Technique	Application, Comparison	TOPSIS and VIKOR	new
	GUPTA, Himanshu et al [149]	2018	Assessing organizations performance on the basis of GHRM practices using BWM and Fuzzy TOPSIS	Application	Best Worst Method (BWM), Fuzzy TOPSIS	new
	GUPTA, Himanshu et al [150]	2018	A framework to overcome barriers to green innovation in SMEs using BWM and Fuzzy TOPSIS	Application	BWM, Fuzzy TOPSIS	new
	WANG, Xiaojun et al [141]	2012	A two-stage fuzzy-AHP model for risk assessment of implementing green initiatives in the fashion supply chain	Application	Fuzzy AHP	192
	WATROBSKI, Jarosław et al [151]	2016	Outline of multicriteria decision-making in green logistics	Comparison	MCDM Methods that apply in green logistics	2
Impact Reduction and Reverse Logistics	WANG, Han et al [152]	2018	A Demands-Matching Multi-Criteria Decision-Making Method for Reverse Logistics	Application	AHP, EW, MABAC	new
	PRAKASH, Chandra et al [144]	2015	Integration of AHP-TOPSIS method for prioritizing the solutions of reverse logistics adoption to overcome its barriers under fuzzy environment	Application	Fuzzy AHP, Fuzzy TOPSIS	91
	BOUZON, Marina et al [153]	2016	Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP	Application	Fuzzy Delphi, AHP	56
	JAYANT, A. et al [154]	2014	TOPSIS-AHP Based Approach for Selection of Reverse Logistics Service Provider: A Case Study of Mobile Phone Industry	Application	AHP, TOPSIS	54
	VINODH, S. et al [143]	2014	Integrated Fuzzy AHP–TOPSIS for selecting the best plastic recycling method: A case study	Application	Fuzzy AHP, TOPSIS	53
	BESKESE, Ahmet et al [155]	2015	Landfill site selection using fuzzy AHP and fuzzy TOPSIS: a case study for Istanbul	Application	Fuzzy AHP, Fuzzy TOPSIS	50
	PRAKASH, Chandra et al [156]	2016	A combined MCDM approach for evaluation and selection of third-party reverse logistics partner for Indian electronics industry	Application	Fuzzy AHP, VIKOR	35
	SENTHIL, S. et al [157]	2012	A decision making methodology for the selection of reverse logistics operating channels	Application	Fuzzy AHP, Fuzzy TOPSIS	35
	REZAEI, Jafar et al [158]	2015	A systematic review of multi-criteria decision-making applications in reverse logistics	Review	MCDM Methods	17
	PRAKASH, Chandra et al [159]	2016	A Multi-criteria Decision-making Approach for Prioritizing Reverse Logistics Adoption Barriers under Fuzzy Environment: Case of Indian Electronics Industry	Application	Fuzzy AHP	14
	WICHAPA, Narong et al [160]	2017	Solving multi-objective facility location problem using the fuzzy analytical hierarchy process and goal programming: a case study on infectious waste disposal centers	Application	Fuzzy AHP + GP	6
	HAN, Hui et al [161]	2018	A fuzzy TOPSIS method for performance evaluation of reverse logistics in social commerce platforms	Application	Fuzzy TOPSIS	4
	SIRISAWAT, Pornwasin et al [162]	2018	Fuzzy AHP-TOPSIS approaches to prioritizing solutions for reverse logistics barriers	Application	Fuzzy AHP, Fuzzy TOPSIS	4
	GNANAVELB ABU, A. et al [163]	2018	Ranking of MUDA using AHP and Fuzzy AHP algorithm	Application, Comparison	AHP, Fuzzy AHP	1
Green Supply Chain Selections	MOHAMMED , Ahmed et al [164]	2018	Evaluating Green and Resilient Supplier Performance: AHP-Fuzzy Topsis Decision-Making Approach	Application	AHP, Fuzzy Topsis	new
	MOHAMMED , Ahmed et al [165]	2018	An integrated methodology for a sustainable two-stage supplier selection and order allocation problem	Application	Fuzzy AHP, Fuzzy TOPSIS, MOPM (Multi-Objective Programming Model), TOPSIS	new

SHAW, Krishnendu et al [166]	2012	Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain	Application	Fuzzy MOLP, Fuzzy AHP	425
GOVINDAN, Kannan et al [145]	2013	Multi criteria decision making approaches for green supplier evaluation and selection: a literature review	Review	MCDA for Green Suppliers	418
GOVINDAN, Kannan et al [167]	2013	A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach	Application	Fuzzy TOPSIS	406
KANNAN, Devikan et al [168]	2013	Integrated fuzzy multi criteria decision making method and multiobjective programming approach for supplier selection and order allocation in a green supply chain	Application	Fuzzy AHP + Fuzzy Topsis + MOLP	317
LIN, Ru-Jen [169]	2013	Using fuzzy DEMATEL to evaluate the green supply chain management practices	Application	Fuzzy set theory, DEMATEL	284
KANNAN, Devika et al [146]	2013	Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company	Application, Comparison	3 types of Fuzzy TOPSIS	282
GOVINDAN, Kannan et al [170]	2014	Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process	Application	AHP	274
SHEN, Lixin et al [171]	2013	A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences	Application	Fuzzy TOPSIS	237
HASHEMI, Seyed Hamid et al [172]	2015	An integrated green supplier selection approach with analytic network process and improved Grey relational analysis	Application	ANP, Gray Relational Analysis (GRA)	166
KANNAN, Devikan et al [173]	2015	Fuzzy Axiomatic Design approach based green supplier selection: a case study from Singapore	Application	FAD (Fuzzy Axiomatic Design), Fuzzy MOPM	131
GOVINDAN, Kannan et al [174]	2015	Intuitionistic fuzzy based DEMATEL method for developing green practices and performances in a green supply chain	Application	DEMATEL, Intuitionistic Fuzzy Set (IFS)	131
MANGLA, Sachin Kumar et al [175]	2015	Risk analysis in green supply chain using fuzzy AHP approach: A case study	Application	Fuzzy AHP	107
LUTHRA, Sunil et al [176]	2017	An integrated framework for sustainable supplier selection and evaluation in supply chains	Application	AHP, VIKOR	89
AKMAN, Gulsen [177]	2014	Evaluating suppliers to include green supplier development programs via fuzzy c-means and VIKOR methods	Application	Fuzzy c-means clustering, VIKOR	82
SU, Chun-Mei et al [178]	2016	Improving sustainable supply chain management using a novel hierarchical grey-DEMATEL approach	Application	Grey Theory, DEMATEL	81
AWASTHI, Anjali et al [179]	2015	Green supplier development program selection using NGT and VIKOR under fuzzy environment	Application	Fuzzy numbers, NGT, VIKOR	78
WANG, Xiaojun et al [180]	2013	A hierarchical fuzzy TOPSIS approach to assess improvement areas when implementing green supply chain initiatives	Application	Fuzzy TOPSIS	78
BANAEIAN, Narges et al [181]	2016	Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry	Application, Comparison	Fuzzy TOPSIS, Fuzzy VIKOR and Fuzzy GRA	63
YAZDANI, Morteza et al [182]	2017	Integrated QFD-MCDM framework for green supplier selection	Application	DEMATEL, QFD, COPRAS	58
GUPTA, Himanshu et al [183]	2017	Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS	Application	BWM, Fuzzy TOPSIS	47
LUTHRA, Sunil et al [184]	2016	Using AHP to evaluate barriers in adopting sustainable consumption and production initiatives in a supply chain	Application	AHP	47
UYGUN, Özer et al [185]	2016	Performance evaluation of green supply chain management using integrated fuzzy multi-criteria decision making techniques	Application	Fuzzy DEMATEL, Fuzzy ANP, Fuzzy TOPSIS	46

	VISWANADHAM, N. et al [186]	2013	Supplier selection based on supply chain ecosystem, performance and risk criteria	Application	Fuzzy AHP, Fuzzy TOPSIS	43
	HAMDAN, Sadeque et al [187]	2016	Supplier selection and order allocation with green criteria: An MCDM and multi-objective optimization approach	Application	Fuzzy TOPSIS, AHP	39
	GALANKASHI, Masoud Rahiminezhad et al [188]	2015	Prioritizing Green Supplier Selection Criteria using Fuzzy Analytical Network Process	Application	ANP	36
	PAKSOY, Turan et al [189]	2012	Fuzzy Multi-Objective Optimization of a Green Supply Chain Network with Risk Management that Includes Environmental Hazards	Application, Comparison	AHP, Fuzzy AHP, Fuzzy TOPSIS	26
	KUMAR, Divesh et al [190]	2017	A fuzzy AHP and fuzzy multi-objective linear programming model for order allocation in a sustainable supply chain: A case study	Application	Fuzzy AHP, Fuzzy MOLP	24
	MURALIDHAR, P. et al [191]	2012	Evaluation of Green Supply Chain Management Strategies Using Fuzzy AHP and TOPSIS	Application	Fuzzy AHP, Fuzzy TOPSIS	17
	NAZAM, Muhammad et al [192]	2015	A fuzzy AHP-TOPSIS framework for the risk assessment of green supply chain implementation in the textile industry	Application	Fuzzy AHP, Fuzzy TOPSIS	14
	LIN, Kuo-Ping et al [193]	2018	Sustainable supply chain management using approximate fuzzy DEMATEL method	Application	Approximate Fuzzy DEMATEL, Fuzzy Cause and Effect Relationships	9
	ROSTAMZADEH, Reza et al [194]	2018	Evaluation of sustainable supply chain risk management using an integrated fuzzy TOPSIS- CRITIC approach	Application	Fuzzy TOPSIS, CRITIC	8
	MOUSAKHANI, Saeed et al [195]	2017	A novel interval type-2 fuzzy evaluation model based group decision analysis for green supplier selection problems: A case study of battery industry	Application	type-2 fuzzy TOPSIS	4
	BAI, Chunguang et al [196]	2017	Multicriteria Green Supplier Segmentation	Application	Rough Set Theory, VIKOR, Fuzzy C-Means	3
	SEN, Dilip Kumar et al [197]	2017	Dominance based fuzzy decision support framework for g-resilient (ecosilient) supplier selection: an empirical modelling	Application, Comparison	Fuzzy set theory vs Fuzzy TOPSIS and Fuzzy VIKOR	1
Eco Design	VINODH, S. et al [147]	2014	Integration of ECQFD, TRIZ, and AHP for innovative and sustainable product development	Application	ECQFD-TRIZ-AHP	38
	MAYYAS, Ahmad et al [198]	2016	Eco-material selection using fuzzy TOPSIS method	Application	Fuzzy TOPSIS	13
	VINODH, S. et al [199]	2013	Sustainable concept selection using modified fuzzy TOPSIS: a case study	Application	Fuzzy TOPSIS	12
	BAKHOUM, Emad S. et al [148]	2012	A hybrid approach using AHP–TOPSIS–entropy methods for sustainable ranking of structural materials	Application	AHP, TOPSIS, Shannon	11
	NG, Chun Yu et al [200]	2012	Evaluation of Eco design alternatives by integrating AHP and TOPSIS methodology under a fuzzy environment	Application	Fuzzy AHP, Fuzzy TOPSIS	8
	TU, Jui-Che et al [201]	2015	Fuzzy AHP and fuzzy TOPSIS integrated multicriteria decision-making scheme employing Chinese environmental esthetics for facility layout design evaluation	Application	Fuzzy AHP, Fuzzy TOPSIS	1

3.1.2.4 Business and Marketing Management

A good amount of research works brought to light in the current research are on the subjects related to Business and Marketing Management. On the business side of things, topics on strategic and investment decisions, performance evaluation and knowledge management are the most addressed. Researches on the application of MCDM methods for marketing management also appear, in a more limited scope.

In the sub-area Performance Evaluation, articles proposing multiple criteria applications on the evaluation, measurement and improvement of financial and intellectual performance of companies, in many different niches, and most of times showing how to compare one enterprise to a portion of other similar ones. In this sub-area, it is offered by Yalcin et al. [202] an application of Fuzzy AHP for weighting obtained criteria from classic AFP and modern VFP financial indicators, and then these inputs are used either by TOPSIS and VIKOR in ranking Turkish manufacturing industries according to their performances and, then, their results are compared. TOPSIS and VIKOR were able to obtain very similar results. Gorener et al. [203] suggest the application of the SWOT method alongside with AHP, so that the MCDM method would work as an extension of the former, expanding its capabilities in evaluate a company's strengths, weaknesses, opportunities and threats.

Papers inside the sub-field Strategic and Investment Decisions bring up subjects such as investment decisions, innovation research, risk assessment and strategic decision making. Taylan et al. [204] proposes the combined applications of Fuzzy AHP and Fuzzy TOPSIS in a hybrid with the goal of aiding in construction project selection and risk assessment. The study covers identifying the key risk criteria of construction projects at King Abdulaziz University (KAU), and assessing the criteria by the integrated hybrid methodologies. It is proposed by Rouhani et al. [205] the application of Fuzzy TOPSIS method in the weighting and ranking of criteria in fuzzy environment to help companies choose the best investment when buying enterprise systems. This method measures their business intelligence.

Another portion of articles found in the present field related to Knowledge Management decision making problems, with Wu et al. [206] proposing the employment of Fuzzy DEMATEL in segmenting the factors that are crucial for a successful knowledge management implementation in companies, by ranking the already called critical factors for implementing KM, to help companies go further in their strategic thinking in this area.

In Marketing Management, Parkoy et al. [207] suggests the usage of a hybrid combining Fuzzy AHP and Fuzzy Hierarchical TOPSIS in ranking the best out of five organizational strategies for distribution channel.

The list presented in Table 5, next, is with all research papers involving the application, comparison and review of MCDM/MCDA methods applied to Business and Marketing Management.

Table 5: Literature in Business and Marketing Management

SUB-AREA	AUTHOR	YEAR	TITLE	TYPE	METHODS	CITATIONS
Performance Evaluation	MAHTANI, Umesh S. et al [208]	2018	An analysis of key factors of financial distress in airline companies in India using fuzzy AHP framework	Application	Fuzzy AHP	new
	YALCIN, Nesse et al [202]	2012	Application of fuzzy multi-criteria decision making methods for financial performance evaluation of Turkish manufacturing industries	Application, Comparison	Fuzzy AHP, TOPSIS vs. VIKOR	159
	GORENER, Ali et al [203]	2012	Application of Combined SWOT and AHP: A Case Study for a Manufacturing Firm	Application	SWOT, AHP	103
	BULGURCU, Berna (Kiran) [209]	2012	Application of TOPSIS Technique for Financial Performance Evaluation of Technology Firms in Istanbul Stock Exchange Market	Application	TOPSIS	74
	GLYKAS, Michael et al [210]	2013	Fuzzy cognitive strategic maps in business process performance measurement	Application	Fuzzy Cognitive Maps	72
	AKKOÇ, Soner et al [211]	2013	Fuzzy Performance Evaluation with AHP and Topsis Methods: Evidence from Turkish Banking Sector after the Global Financial Crisis	Application	Fuzzy AHP, Fuzzy TOPSIS	55
	BAI, Chunguang et al [212]	2014	Integrating Fuzzy C-Means and TOPSIS for performance evaluation: An application and comparative analysis	Application	Fuzzy C-Means (FCM), TOPSIS	53
	REZAIE, Kamran et al [213]	2014	Evaluating performance of Iranian cement firms using na integrated fuzzy AHP–VIKOR method	Application	Fuzzy AHP, VIKOR	49
	WANG, Yu-Jie et al [214]	2014	The evaluation of financial performance for Taiwan containershipping companies by fuzzy TOPSIS	Application	Fuzzy TOPSIS	47
	EZZABADI, Jamal Hosseini et al [215]	2015	Implementing Fuzzy Logic and AHP into the EFQM model forperformance improvement: A case study	Application	Fuzzy AHP, Operation s Research Model	32
	SHAVERDI, Meysam et al [216]	2014	Application of Fuzzy AHP Approach for Financial Performance Evaluation of Iranian Petrochemical Sector	Application	Fuzzy AHP	31
	IÇ, Yusuf Tansel [217]	2014	A TOPSIS based design of experiment approach to assess company ranking	Application	DoE-TOPSIS	17
	GLYKAS, Michael et al [218]	2012	Performance measurement scenarios with fuzzy cognitive strategic maps	Application	Fuzzy Cognitive Maps	16
	HACIOGLU, Umit et al [219]	2015	A Comparative Performance Evaluation on Bipolar Risks in Emerging Capital Markets Using Fuzzy AHP-TOPSIS and VIKOR Approaches	Application, Comparison	Fuzzy AHP-TOPSIS vs. Fuzzy AHP-VIKOR	9
	ARVAN, Meysam et al [220]	2016	Intellectual capital evaluation using fuzzy cognitive maps: A scenario-based development planning	Application	Fuzzy Cognitive Maps	8
	ARSLAN, Muhammed et al [221]	2012	Performance Evaluation of Sugar Plants by Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS)	Application	Fuzzy TOPSIS	7
Strategic and Investment Decisions	DURMUSOGLU , Zeynep Didem Unutmaz et al [222]	2018	Assessment of techno-entrepreneurship projects by using Analytical Hierarchy Process (AHP)	Application	AHP	new
	TAYLAN, Osman et al [204]	2014	Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies	Application	Fuzzy AHP, Fuzzy TOPSIS	212
	ROUHANI, Saeed et al [205]	2012	Evaluation model of business intelligence for enterprise systems using fuzzy TOPSIS	Application	Fuzzy TOPSIS	154
	GÖRENER, Ali et al [223]	2012	Comparing AHP and ANP: An Application of Strategic Decisions Making in a Manufacturing Company	Application, Comparison	AHP, ANP	73
	GARCÍA, J.L. et al [224]	2014	Multi-attribute evaluation and selection of sites for agricultural product warehouses based on an Analytic Hierarchy Process	Application	AHP	66
	HANINE, Mohamed et al [225]	2016	Application of an integrated multi-criteria decision making AHP-TOPSIS methodology for ETL software selection	Application	AHP, TOPSIS	26
	SEKHAR, Chandra et al [226]	2015	A Delphi-AHP-TOPSIS based framework for the prioritization of intellectual capital indicators: A SMEs perspective	Application	Delphi, AHP, TOPSIS	21
	KRAUS, Sascha et al [227]	2017	Fuzzy-set qualitative comparative analysis (fsQCA) in entrepreneurship and innovation research - The rise of a method	Review	fsQCA	18

	SUDER, Asli et al [228]	2015	Multiattribute Evaluation Of Organic And Inorganic Agricultural Food Investments Using Fuzzy Topsis	Application	Fuzzy TOPSIS	1
Knowledge Management	WU, Wei-Wen et al [206]	2012	Segmenting critical factors for successful knowledge management implementation using the fuzzy DEMATEL method	Application	Fuzzy DEMATEL	120
	LI, ming et al [229]	2014	A new MCDM method combining QFD with TOPSIS for knowledge management system selection from the user's perspective in intuitionistic fuzzy environment	Application	QFD, Fuzzy TOPSIS	75
	WANG, Jun et al [230]	2016	A synthetic method for knowledge management performance evaluation based on triangular fuzzy number and group support systems	Application	Triangular Fuzzy Numbers	33
	ANAND, A. et al [231]	2012	Knowledge Management Implementation: A predictive Model Using an Analytical Hierarchical Process	Application	AHP	18
Marketing Management	PAKSOY, Turan et al [207]	2012	Organizational strategy development in distribution channel management using fuzzy AHP and hierarchical fuzzy TOPSIS	Application	Fuzzy AHP, Fuzzy TOPSIS	95
	KABIR, Golam et al [232]	2012	Framework for benchmarking online retailing performance using fuzzy AHP and TOPSIS method	Application	Fuzzy AHP-TOPSIS	22
	MASUDIN, I. et al [233]	2015	Evaluation of B2C website based on the usability factors by using fuzzy AHP & hierarchical fuzzy TOPSIS	Application, Comparison	Fuzzy AHP vs. Fuzzy TOPSIS	4
	SALE, Martha Lair et al [234]	2015	USING AHP TO DEVELOP A MESURE OF WEBPAGE PRESENCE	Application	AHP	1

3.1.2.5 Design, Engineering and Manufacturing Systems

Another group of research papers that refer to the usage of multiple-criteria methods in a company's setting are associated with the manufacturing operations inside a company, being here gathered in Design, Engineering and Manufacturing Systems field This group is further divided in the sub-groups Engineering Challenges, Modern Manufacturing Systems, Product Development, and finally Material and Quality Engineering.

The articles grouped in Engineering Challenges allude to the subject of many different technical problems of diverse natures faced by different companies. Efe et al. [235] proposes the employment of a hybrid with Fuzzy AHP and Fuzzy TOPSIS for ERP software selection in an electronic firm.

The ones gathered in Modern Manufacturing Systems are associated with production and manufacturing challenges, like tooling, machine and process selection and improvement. Many problems can be found in this area, and Subramanian et al. [236] proposes a literature review on the applications of AHP method in operations management problems. A combination between Fuzzy AHP and PROMETHEE is offered by Taha et al. [237] for machine tool selection in flexible manufacturing cell, with fuzzy AHP method performance via the mathematical software MATLAB.

In relation to Product development, Zhu et al. [238] uses rough numbers as base for the application of the hybrid of AHP and VIKOR in design concept evaluation for a new product.

Fewer papers were encountered under Material and Quality Engineering, with Chang et al. [239] applying in the proposed research Fuzzy ANP for evaluating quality management in project being one of them.

The complete list of research papers in this application areas is next, inside Table 6.

Table 6: Literature in Design, Engineering and Manufacturing Systems

SUB-AREA	AUTHOR	YEAR	TITLE	TYPE	METHODS	CITATIONS
Engineering Challenges	WUHIB, Fetahi et al [240]	2012	Dynamic Resource Allocation with Management Objectives— Implementation for an OpenStack Cloud	Application	Performance Manager Arquitecture	111
	EFE, Burak [235]	2015	An integrated fuzzy multi criteria group decision making approach for ERP system selection	Application	Hybrid Fuzzy AHP + Fuzzy TOPSIS	47
	GHUNG, When-chin, et al [241]	2012	An Intelligent Priority Resource Allocation Scheme for LTE-A Downlink Systems	Application	Fuzzy Inference System (FIS)	29
	RAHMAN, Atta-ur et al [242]	2012	Adaptive Resource Allocation in OFDM Systems Using GA and Fuzzy Rule Base System	Application	FRBS + GA	24
	MINAROLLI, Dorian et al [243]	2013	Virtual Machine Resource Allocation in Cloud Computing via Multi-Agent Fuzzy Control	Application	Multi-Agent Fuzzy Control (MAFC)	19
	YARI, M. et al [244]	2013	Selecting the Most Suitable Blasting Pattern Using AHP–TOPSIS Method: Sungun Copper Mine	Application	AHP, TOPSIS	11
	CHU, Wangwei et al [245]	2014	A manufacturing resource allocation method with knowledge-based fuzzy comprehensive valuation for aircraft structural parts	Application	FCE	9
	CHEN, Wang [246]	2016	Optimal Selection of a Longwall Mining Method for a Thin Coal SeamWorking Face	Application	AHP, TOPSIS	5
Modern Manufacturing Systems	KAZANCOGLU, Yigit et al [247]	2018	Integrated framework of disassembly line balancing with Green and business objectives using a mixed MCDM	Application	Fuzzy AHP, Fuzzy MOORA	new
	SUBRAMANIAN, Nachiappan et al [236]	2012	A review of applications of Analytic Hierarchy Process in operations management	Review	AHP	364
	TAHA, Zahari et al [237]	2012	A hybrid fuzzy AHP-PROMETHEE decision support system for machine tool selection in flexible manufacturing cell	Application	Fuzzy AHP, PROMETHEE	86
	AYAG, Zeki et al [248]	2012	Evaluating machine tool alternatives through modified TOPSIS and alpha-cut based fuzzy ANP	Application, Comparison	Fuzzy ANP vs. ANP, AHP and modiified TOPSIS	76
	IC, Yusuf Tansel et al [249]	2012	Development of a component-based machining centre selection model using AHP	Application	AHP	30
	THOR, Jureen et al [250]	2013	Comparison of Multi Criteria Decision Making Methods from The Maintenance Alternative Selection Perspective	Review, Comparison	MCDM techniques	33
	KARIM, Rubayet et al [251]	2016	Machine Selection by AHP and TOPSIS Methods	Application	AHP, TOPSIS	25
	KUMAR, Sanjay et al [252]	2015	Identification and evaluation of critical factors to technology transfer using AHP approach	Application	AHP, TOPSIS	21
	RUDNIK, Katarzyna et al [253]	2017	Fuzzy TOPSIS method with ordered fuzzy numbers for flow control ina manufacturing system	Application	Fuzzy TOPSIS, Flexible manufacturing system (FMS)	19
	VATANSEVER, Kemal et al [254]	2014	Integrated Usage of Fuzzy Multi Criteria Decision Making Techniques for Machine Selection Problems and an Application	Application	Fuzzy AHP, Fuzzy MOORA	11
	BHATT, Nisha [255]	2017	Forecasting the Implementation Success of AMT in SMEs using an Integrated AHP-TOPSIS Approach	Application	AHP, TOPSIS	0
Material and Quality Engineering	SINGH, Tej et al [256]	2013	Development and Optimization of Hybrid Friction Materials Consisting of Nanoclay and Carbon Nanotubes by using Analytical Hierarchy Process (AHP) and Technique for	Application	Fuzzy AHP, Fuzzy TOPSIS	20

			Order Preference by Similarity to Ideal Solution (TOPSIS) under Fuzzy Atmosphere			
	BANWET, D. K. et al [257]	2014	Comparative analysis of AHP-TOPSIS and GA-TOPSIS methods for selection of raw materials in textile industries	Application, Comparison	AHP-TOPSIS, GA-TOPSIS	17
	CHANG, Yao-Feng et al [239]	2013	Fuzzy Multiple Criteria Decision Making Approach to assess the Project Quality Management in Project	Application	Fuzzy ANP	7
	GUL, Muhammet et al [258]	2018	A fuzzy logic based PROMETHEE method for material selection problems	Application	Fuzzy PROMETHEE, Trapezoidal fuzzy interval numbers, VIKOR	6
Product Development	ZHU, Guo-Niu et al [238]	2015	An integrated AHP and VIKOR for design concept evaluation based on rough number	Application	Rough Number, VIKOR, AHP	77
	BUYUKOZKAN, Gülçin et al [259]	2016	A new integrated intuitionistic fuzzy group decision making approach for product development partner selection	Application	Intuitionistic Fuzzy AHP, Fuzzy TOPSIS	20
	ZHANG, Wei ai et al [260]	2013	Seeking the Important Nodes of Complex Networks in Product R&D Team Based on Fuzzy AHP and TOPSIS	Application	Fuzzy AHP, Fuzzy TOPSIS	13
	YAN, Hong-Bin et al [261]	2015	A fuzzy group decision making approach to new product concept screening at the fuzzy front end	Application	Fuzzy group-decision approach	11
	CHAKRABORTY, Kaustov et al [262]	2017	Analysis of product design characteristics for remanufacturing using Fuzzy AHP and Axiomatic Design	Application	Fuzzy AHP, Axiomatic Design	3
	PARVEZ, Md. Shohel et al [263]	2016	Optimisation of product design through QFD, AHP, Entropy and TOPSIS method: a case study of a Bathtub	Application	QFD, AHP, TOPSIS	0
	RAJHANS, Neela Ravindra et al [264]	2017	IDEATION SELECTION OF A NEW PRODUCT USING FUZZY MULTI CRITERIA DECISION MAKING AND PROMETHEE	Application	Fuzzy PROMETHEEE, AHP	0
	RAZIKIN, Mohd Azroy Mohd et al [265]	2013	THE USE OF ANALYTICAL HIERARCHY PROCESS (AHP) IN PRODUCT DEVELOPMENT PROCESS	Review	AHP	0

3.1.2.6 Human Resources Management

The gathering of papers associated with Human Resources Management have as goals Staff Selection, Products and Ergonomics, and Human Capital.

As part of Staff Selection proposed works, the example of Zolfani et al. [266] performs quality control manager selection with the employment of methods AHP and COPRAS-G, with the former weighting criteria and the later ranking the alternatives.

In Products and Ergonomics, Maldonado-Macias et al. [267] proposes the usage of Fuzzy AHP and Fuzzy TOPSIS for ergonomic compatibility evaluation of advanced manufacturing technology.

Human Capital sub-area consists on paper researches that focus on paying attention to the human aspects around production and manufacturing, providing solutions. Chiu et al. proposes a method that helps in analyzing latent human error in aviation maintenance tasks, and gives efficient improvement strategies by using Fuzzy TOPSIS. In the mentioned work, the human errors are defined by employing the methods HFACS and RCA.

All work related to Human Resources Management can be found in Table 7, below.

Table 7: Literature in Human Resources Management

SUB-AREA	AUTHOR	YEAR	TITLE	TYPE	METHODS	CITATIONS
Staff Selection	ZOLFANI, Sarfaraz Hashemkhani et al [266]	2012	QUALITY CONTROL MANAGER SELECTION BASED ON AHP- COPRAS-G METHODS: A CASE IN IRAN	Application	AHP, COPRAS-G	55
	KUSUMAWARDANI, Renny Pradina et al [268]	2015	Application of Fuzzy AHP-TOPSIS Method for Decision Making in Human Resource Manager Selection Process	Application	Fuzzy AHP, Fuzzy TOPSIS	25
	ROY, Bijoyeta et al [269]	2012	An Integrated DEMATEL and AHP Approach for Personnel Estimation	Application	DEMATEL, AHP	14
	KABIR, Golam et al [270]	2014	Integrating fuzzy analytic hierarchy process with PROMETHEE method for total quality management consultant selection	Application	Fuzzy AHP, PROMETHEE	12
	ASUQUO, Daniel E. et al [271]	2016	A Fuzzy AHP Model for Selection of University Academic Staff	Application	Fuzzy AHP	2
	ESMAILI-DOOKI, Ayda et al [272]	2017	An Integrated Fuzzy AHP and Fuzzy TOPSIS Approach for Ranking and Selecting the Chief Inspectors Of Bank: A Case Study	Application	Hybrid Fuzzy AHP + Fuzzy TOPSIS	2
Products and Ergonomics	MOHANTY, Pragyan Paramita et al [273]	2018	A novel multi-attribute decision making approach for selection of appropriate product conforming ergonomic considerations	Application, Development	TOPSIS, VIKOR, PROMETHEE	new
	MALDONADO-MACÍAS, Aide et al [267]	2013	Intuitionistic fuzzy TOPSIS for ergonomic compatibility evaluation of advanced manufacturing technology	Application	Fuzzy AHP, Fuzzy TOPSIS	32
	ZOLFANI, Sarfaraz Hashem khani et al [274]	2014	PERSONNEL SELECTION BASED ON A NOVEL MODEL OF GAME THEORY AND MCDM APPROACHES	Application, Development	SWARA, Game Theory	30
	BASAHEL, A. et al [275]	2016	USING FUZZY AHP AND FUZZY TOPSIS APPROACHES FOR ASSESSING SAFETY CONDITIONS AT WORKSITES IN CONSTRUCTION INDUSTRY	Application	Fuzzy AHP, Fuzzy TOPSIS	3
	BHATTACHARJEE, Pijush Kanti et al [276]	2012	Analysis of Noise Emitted from Electrical Machines Using TOPSIS Technique	Application	TOPSIS	1
	HOQUE, A.S.M. Mojahidul et al [277]	2015	TOPSIS BASED ERGONOMIC ANALYSIS ON WORK RELATED MUSCULOSKELETAL DISORDERS OF SEWING MACHINE OPERATORS	Application	TOPSIS	0
Human Capital	DENAVI, Hasan Dehghan et al [278]	2018	Ranking of Leagility Factors Based on Job Satisfaction through a Combinatory Model of Fuzzy TOPSIS and AHP (Case Study: M.R.I Hospital, Shiraz, Iran)	Application	Fuzzy AHP, Fuzzy TOPSIS	new
	ABDULLAH, Lazim et al [279]	2015	Integration of fuzzy AHP and interval type-2 fuzzy DEMATEL: Na application to human resource management	Application	Fuzzy AHP, Fuzzy DEMATEL, Interval type-2 fuzzy sets	82
	CHIU, Ming-Chuan et al [280]	2016	Latent human error analysis and efficient improvement strategies by fuzzy TOPSIS in aviation maintenance tasks	Application	Fuzzy TOPSIS	18
	AVAZPOUR, Reza et al [281]	2013	A 360 Degree Feedback Model for Performance Appraisal Based on Fuzzy AHP and TOPSIS	Application	Fuzzy AHP, Fuzzy TOPSIS	12
	SHAKERIAN, Hamed et al [282]	2016	The implementation of the hybrid model SWOT-TOPSIS by fuzzy approach to evaluate and rank the human resources and business strategies in organizations (case study: road and urban development organization in Yazd)	Application	SWOT Analysis, Fuzzy TOPSIS	7
	MALMIR, Ameneh et al [283]	2012	Classifying the Effective Factors on Productivity of Human Resources by Using AHP and TOPSIS Methods	Application	AHP, TOPSIS	6

All research papers presented in this sub-chapter are directed linked to their respective references in the end of this work, for further reading and researching by the readers. The presentations of this review are as detailed as seem fit to help readers, researchers and practitioners have a general view of what can be found in each application field, as well as a glance on specific examples, to get a better feel of each topic present in this literature research.

3.2 RESEARCH STATISTICAL ANALYSIS

The goal of the present section is to properly analyze all collected data in the most profound way possible, in pursuing of giving an in-depth quantitative and statistical analysis of the papers review, to help even further the reader in identifying patterns and most relevant information not observed at first when in the last sector.

Statistical analysis will be divided in two parts: Focused Analysis, determined to identify behaviors and statistics in each of the application fields at disposal; General Analysis, focused on analyzing aspects from all researched papers together and not distinguishing them by field of application;

3.2.1 FOCUSED ANALYSIS

This section devotes itself to a quantitative statistical analysis of collected data for each of the major areas, to help readers with an even deeper insight on the details about the present literature research.

3.2.1.1 Supply Chain Management and Logistics

Field Progress

The first analysis made in all areas is on the progression of the major field and its sub-fields over time, which can be seen for Supply Chain Management and Logistics next, in Table 8.

Table 8: Number of published papers per year in each sub-area and in the whole Supply Chain Management and Logistics area

Supply Chain Management and Logistics				
Year	*Supplier Selection and Assessment*	*Chain Management*	*Logistics Management and Outsourcing*	*Total*
2012	4	0	3	7
2013	10	3	2	15
2014	3	2	2	7
2015	5	2	2	9
2016	5	2	2	9
2017	6	1	1	8
2018	4	1	1	6
Total	**37**	**11**	**13**	**61**

Each column shows the number publications by each sub-field by year, and the last column presents the total number of publications of the major field in that year. The last line shows the total amount of publications by each sub-field and also the major field. It can be observed that *Supplier Selection and Assessment* is the sub-area that contributed the most to the progression the present application area, with 37 out of the 61 total published papers in the field. *Chain Management* is the field that produced less papers, being the only one that didn't produce any for a year, in 2012. The sub-field most successful in number of publications in a single year was again *Supplier Selection and Assessment*, with 10 published papers in 2013. The most successful year for the major field in terms of publications was also 2013, with 15 publications.

Relevant Authors

The authors present in this major area are classified in two measures, first accordingly to the number of papers published in Supply Chain Management and Logistics by each of them, and later by the total number of citations each author has in the sum of all their published papers in the area. This analysis helps readers understand which are the most important author that they can look for in this area. Table 9 presents the classification of main authors in the area according to their number of papers published in the current major area.

Table 9: Classification of Most Relevant Authors by Number of Papers Published in Supply Chain Management and Logistics

Main Author	Number of Papers in Area
JUNIOR, Francisco Rodrigues Lima *et al*	3
PATIL, Sachin K. *et al*	2
REZAEI, Jafar *et al*	2
KARSAK, E. Ertugrul *et al*	2
BEIKKHAKHIAN, Yokabed *et al*	2
BUYUKOZKAN, Gülçin *et al*	2
HALDAR, Anupam *et al*	2
GOVINDAN, Kannan *et al*	2
KUMAR, Sanjay *et al*	2
Others	42 (1 each)

The Brazilian author Junior is the author with the greatest number of publications in the area, with a total of 3 papers. Other seven authors have 2 papers each in the area, while all other 40 authors existent have 1 publication each.

For the analysis of authors' relevance to be more complete, Table 10 offers the classification of them according to the sum of citations they have, with all their papers in the area combined.

Table 10: Classification of Authors by Sum of Citations in Supply Chain Management and Logistics

Main Author	Total Number of Citations
CHAI, Junyi *et al*	517
JUNIOR, Francisco Rodrigues Lima *et al*	376
DENG, Xinyang *et al*	280
PATIL, Sachin K. *et al*	264
REZAEI, Jafar *et al*	191
ZOUGGARI, Akram *et al*	176
KARSAK, E. Ertugrul *et al*	159
AGUEZZOUL, Aicha	154
BEIKKHAKHIAN, Yokabed *et al*	138
BAYKASOGLU, Adil *et al*	136
SAMDEVI, Avinash *et al*	123
HO, William *et al*	120
AYHAN , Mustafa Batuhan	101
DURSUN, Mehtap *et al*	95
BUYUKOZKAN, Gülçin *et al*	84
ASHRAFZADEH, Maysam *et al*	78
DARGI, Ahmad *et al*	73
ROUYENDEGH, Babak Daneshvar *et al*	70
ROSHANDEL, Jinus *et al*	70
UYGUN, Özer *et al*	56
HALDAR, Anupam *et al*	56
ŻAK, Jacek *et al*	48
GOVINDAN, Kannan *et al*	44
GHORBANI, Mazaher	43
LI, Ye *et al*	41
WU, Chung-Min *et al*	40
JAKHAR, Suresh Kumar *et al*	40
PERÇIN, Selçuk *et al*	39
LEE, Jaehun *et al*	38
GALANKASHI, Masoud Rahiminezhad *et al*	35
JAIN, Vipul *et al*	31
DONG, Qingxing *et al*	28
WOOD, David A.	27
WU, Chong *et al*	25
GHORABAEE, Mehdi Keshavarz *et al*	23
SHUKLA, Rajendra Kumar *et al*	23
SANTOS, Luiz Felipe de Oliveira Moura *et al*	18
SAHU, Nitin Kumar *et al*	15
SIMIC, Dragan *et al*	14
DEY, Balaram	14
TRAMARICO, Claudemir Leif *et al*	13
MAVI, Reza Kiani *et al*	13
AZIZI, Amir *et al*	7
GORENER, Ali *et al*	6

TAMOSAITIENE, Jolanta *et al*	6
PRAMANIK, Dipika *et al*	5
SUREEYATANAPAS, Panitas *et al*	2
RAMIREZ-FLÓREZ, Giselle	1
KUMAR, Sanjay *et al*	new
TYAGI, Mohit *et al*	new
SINGH, Rajesh Kr *et al*	new

In the table, it can be observed that some new authors' names appeared among the ones that were highlighted before. That happens because these authors, even though having only one publication in the field, had a very relevant work, with many citations. Chai et al., appears as the leading author in terms of number of citations, with only one published paper in the area, but with an impressive number of 517 citations. Kumar et al., goes to the bottom of the present table because both his publications are from 2018 and still have no citations.

Methods Involved

Moving forward with the analysis on the present major area, Table 11 presents the classification of number of appearances of methods in the related papers, showing the popularity of each of them in these sorts of problems.

Table 11: Classification of Methods Popularity in Supply Chain Management and Logistics

Supply Chain Management and Logistics	
Method	**Appearances in the 61 Papers**
Fuzzy TOPSIS	24
Fuzzy AHP	21
AHP	8
QFD	6
TOPSIS	5
MCDM	4
FWA	2
2-tuple linguistic representation model	2
Fuzzy ANP	2
ISM	2
Fuzzy QFD	2
fuzzy set theory	2
Fuzzy DEMATEL	2
DEMATEL	2
Fuzzy KANO	1
ROC	1
D numbers	1
BSC	1
AFS	1
MCGP	1
Taguchi Loss Function	1
Intuitionistic fuzzy TOPSIS	1
Flexible entropy weighting	1
DEA	1
Interval type-2 fuzzy AHP	1
Interval type-2 fuzzy TOPSIS	1

SCOR	1
Fuzzy rule-based system for supplier segmentation	1
aggregate fuzzy weight method	1
artificial neural network	1
IFS	1
IFAD	1
IF-AHP	1
Fuzzy Delphi	1
ANP	1
ARAS	1
Multiplicative Utility	1
Hovanov	1
SEM	1
FAD	1
OM-AHP	1
Shannon Entropy	1
Electre III/IV	1
Fuzzy SAW	1
Fuzzy MOORA	1
Fuzzy Linear Regression	1

Every method used in their standard form is separated from their fuzzy forms, to create a clearer view for the reader. One column shows the name of methods that appear in the related papers, while the other shows the number of times each of them appear inside the 61 papers of the major area Supply Chain Management and Logistics. Fuzzy TOPSIS and Fuzzy AHP are the most popular methods, with their presence in 24 and 21 papers, respectively. They are followed by AHP in its normal form, QFD and TOPSIS. The method represented by 'MCDM', right below TOPSIS, refers to papers that present a review of all MCDM methods for a certain application. Also, the term 'fuzzy set theory', with 2 appearances, refers to when fuzzy theory was used in combination with new and experimental methods or with non-MCDM methods.

Journals

The next topic for in-depth analysis of this application area is the journals and conferences that comported more publications of related papers between 2012 and 2018. Table 12 offers the classification of most relevant journals and conferences in this sense.

Table 12: Classification of Most Popular Journals and Conferences in Supply Chain Management and Logistics

Supply Chain Management and Logistics	
Journal	**Number of Papers in Area**
Expert Systems with Applications	11
Applied Soft Computing	4
International Journal of Management Science and Engineering Management	4
Computers & Industrial Engineering	3
Production Planning & Control	3
International Journal of Production Research	2
Applied Mathematical Modelling	2
IIMB Management Review	2
Information Technology and Quantitative Management	2
Int. J. Production Economics	2
International Journal of Managing Value and Supply Chains	1
2nd International Materials, Industrial, and Manufacturing Eng Conference	1
Operations Research Perspectives	1
Alexandria Engineering Journal	1
Neural Comput & Applic	1
European Journal of Operational Research	1
Fuzzy Optim Decis Making	1
5th World Conference on Educational Sciences	1
Journal of Natural Gas Science and Engineering	1
International Conference on Robotics and Smart Manufacturing	1
Industrial Marketing Management	1
Economic Research-Ekonomska Istraživanja	1
Engineering Applications of Artificial Intelligence	1
Journal of Applied Logic	1
Mathematical Problems in Engineering	1
Production & Manufacturing Research	1
Modern Building Materials, Structures and Techniques	1
International journal of logistics: research and applications	1
12th International Strategic Management Conference, ISMC	1
Omega	1
Cogent Business & Management	1
Transportation Research Procedia	1
Transportation Research Part E	1
Interdisciplinary journal of contemporary research in business	1
International Journal of Logistics Research and Applications	1
Revista Facultad de Ingeniería	1

Some of the journals and conferences names are abbreviated in the way they appear on papers themselves, or sometimes conferences names are abbreviated in order to fit the table. In the present area, all first eleven positions are occupied by journals, Expert Systems with Applications being the most popular, with 11 publications about supplier selections, assessment, supply chain management and logistics.

Countries

The last factor for analysis in Supply Chain Management and Logistics is the participation of countries institutes in the development of each research, by analyzing which countries are the most participant in such publications. The countries of all authors in each paper are considered, and not only the country of the main author. Table 13

presents the most relevant countries in publications in the studied major field of application.

Table 13: Classification of Countries Participation in Paper Production in Supply Chain Management and Logistics

Supply Chain Management and Logistics	
Country	**Number of Participations**
India	16
Turkey	11
Iran	7
Brazil	5
China	5
Lithuania	5
USA	4
Malaysia	3
Hong Kong	3
United Kingdom	3
The Netherlands	2
France	2
Denmark	2
Thailand	1
New Zealand	1
Republic of Korea	1
Serbia	1
Taiwan	1
Australia	1
Belgium	1
Poland	1
Colombia	1

The countries that participated the most in papers in the area are India, Turkey and Iran, with participations in 16, 11 and 7 publications, respectively. Brazil is the strongest representant of Latin America, while United Kingdom, Netherlands, France and Denmark are among the Europeans.

3.2.1.2 Environmental Management

Field Progress

Next field to be analyzed in depth is Environmental Management. The progression of the number of publications by year in this area and its sub-areas can be observed in Table 14, below.

Table 14: Number of published papers per year in each sub-area and in the whole Environmental Management area

Environmental Management					
Year	*Sustainable Management*	*Impact Reduction and Reverse Logistics*	*Green Supply Chain Selections*	*Eco Design*	*Total*
2012	1	1	3	2	7
2013	0	0	8	1	9
2014	0	2	2	1	5
2015	0	3	7	1	11
2016	1	3	5	1	10
2017	0	1	7	0	8
2018	3	4	4	0	11
Total	**5**	**14**	**36**	**6**	**61**

The structure of the table is the same as for Supply Chain Management and Logistics, and it can be seen that 2018 is the most successful year for Environmental Management so far in terms of number of publications, considering that the year isn't finished yet. The total numbers of published papers per area, showed in the last line, brings to light the contribution of each of them, making it clear that *Green Supply Chain Selections* is the sub-area with the biggest contribution by far, with 36 out of the 61 total papers published by the major area between 2012 and 2018. As well as in the major field analyzed in the last sections, it is here evidenced that that production of works around supply chain management is high, no matter if it's with standard or green approaches. It is also the only sub-area with publications every single year, while *Impact Reduction and Reverse Logistics*, being the second most important sub-field in terms of publications number, fails to publish in 2013, *Eco Design* fails in 2017 and 2018, and *Sustainable Management* has no found publications between 2013 and 2015, and also in 2017, having only 5 publications in total. The sub-field with most publications in a year is also *Green Supply Chain Selections*, with 7 published papers in either 2015 and 2017.

Relevant Authors

Following the same purpose as in the last section, a study on the authors was performed in order to understand which are the most relevant either in number of papers published in the main area as well as in the sum of citations each of them has in the area. Table 15 presents the main authors with the greatest number of published papers in Environmental Management.

Table 15: Classification of Most Relevant Authors by Number of Papers Published in Environmental Management

Main Authors	Number of Papers in Area
GOVINDAN, Kannan *et al*	4
KANNAN, Devikan *et al*	3
PRAKASH, Chandra *et al*	3
VINODH, S. *et al*	3
GUPTA, Himanshu *et al*	3
WANG, Xiaojun *et al*	2
LUTHRA, Sunil *et al*	2
MOHAMMED, Ahmed *et al*	2
Others	39 (1 each)

It is noticed that Govindan leads the area with number of published papers, and many other authors have either three or two publications in it. Next table, Table 16, presents the sum of citations all authors in the area have, to help the reader measure the relevance of each of them in the knowledge of application of MCDM methods in Environmental Management.

Table 16: Classification of Authors by Sum of Citations in Environmental Management

Main Authors	Respective Sum of Citations
GOVINDAN, Kannan *et al*	1229
KANNAN, Devikan *et al*	730
SHAW, Krishnendu *et al*	425
LIN, Ru-Jen	284
WANG, Xiaojun *et al*	270
SHEN, Lixin *et al*	237
HASHEMI, Seyed Hamid *et al*	166
PRAKASH, Chandra *et al*	140
LUTHRA, Sunil *et al*	136
MANGLA, Sachin Kumar *et al*	107
VINODH, S. *et al*	103
AKMAN, Gulsen	82
SU, Chun-Mei *et al*	81
AWASTHI, Anjali *et al*	78
BANAEIAN, Narges *et al*	63
YAZDANI, Morteza *et al*	58
BOUZON, Marina *et al*	56
JAYANT, A. *et al*	54
BESKESE, Ahmet *et al*	50
GUPTA, Himanshu *et al*	47
UYGUN, Özer *et al*	46
VISWANADHAM, N. *et al*	43
HAMDAN, Sadeque *et al*	39
GALANKASHI, Masoud Rahiminezhad *et al*	36
SENTHIL, S. *et al*	35
PAKSOY, Turan *et al*	26
KUMAR, Divesh *et al*	24
REZAEI, Jafar *et al*	17
MURALIDHAR, P. *et al*	17
NAZAM, Muhammad *et al*	14
MAYYAS, Ahmad *et al*	13
BAKHOUM, Emad S. *et al*	11
LIN, Kuo-Ping *et al*	9
ROSTAMZADEH, Reza *et al*	8
NG, Chun Yu *et al*	8
WICHAPA, Narong *et al*	6
HAN, Hui *et al*	4
SIRISAWAT, Pornwasin *et al*	4
MOUSAKHANI, Saeed *et al*	4
BAI, Chunguang *et al*	3
WATROBSKI, Jarosław *et al*	2
GNANAVELBABU, A. *et al*	1
SEN, Dilip Kumar *et al*	1
TU, Jui-Che *et al*	1
WANG, Han *et al*	new
SINGLA, Anuj *et al*	new
MOHAMMED, Ahmed *et al*	new

With the new analysis, it can be observed that the order of leading authors changes in most positions. Many of them that only had one publication had very relevant ones, with many citations, like Shaw et al., for example, with 425 citations in one published paper in the area. Govindan et al. keeps being the most relevant author in terms of citations, while Mohammed et al. goes all the way down in the table, because this author's work is new and still have no citations, what does not mean that it has little relevance.

Methods Involved

Moving forward with the analysis on the present major area, Table 17 presents the classification of number of appearances of methods in the related papers, showing the popularity of each of them in these sorts of problems.

Table 17: Classification of Methods Popularity in Environmental Management

Environmental Management	
Method	**Appearances in the 61 Papers**
Fuzzy TOPSIS	30
Fuzzy AHP	21
AHP	12
VIKOR	6
TOPSIS	5
DEMATEL	4
BWM	3
MCDM	3
Fuzzy set theory	3
Fuzzy VIKOR	2
Fuzzy c-means clustering	2
ANP	2
Fuzzy MOLP	2
GP	1
Fuzzy Delphi	1
MABAC	1
EW	1
Fuzzy GRA	1
NGT	1
MOLP	1
GRA	1
MOPM	1
Fuzzy MOPM	1
FAD	1
Rough Numbers	1
Fuzzy DEMATEL	1
Fuzzy ANP	1
IFS	1
QFD	1
COPRAS	1
Grey Theory	1
Fuzzy Cause and Effect Relationships	1
Approximate Fuzzy DEMATEL	1
CRITIC	1
type-2 fuzzy TOPSIS	1
Shannon	1
ECQFD	1
TRIZ	1

Following the same pattern as encountered in the last analyzed major area, Fuzzy TOPSIS and Fuzzy AHP are the most popular methods in Environmental Management papers, with 30 and 21 appearances, respectively, in 61 related articles. AHP and TOPSIS in their standard forms appear subsequently, and new methods appear with more relevance: VIKOR, DEMATEL and BWM, with 6, 4 and 3 appearances, in the same order.

Journals

The next topic for in-depth analysis of this application area is the journals and conferences that comported more publications of related papers between 2012 and 2018. Table 18 offers the classification of most relevant journals and conferences in this sense.

Table 18: Classification of Most Popular Journals and Conferences in Environmental Management

Environmental Management	
Journal	**Number of Papers in Area**
Journal of Cleaner Production	12
Int. J. Production Economics	4
Resources, Conservation and Recycling	4
Computers & Industrial Engineering	4
International Journal of Sustainable Engineering	4
Expert Systems with Applications	3
Applied Mathematical Modelling	2
Computers and Operations Research	2
International Journal of Production Research	2
Journal of Environmental Management	1
Science of the Total Environment	1
2nd International Conference "Green Cities - Green Logistics for Greener Cities"	1
Operations Research Perspectives	1
International Conference on Materials Manufacturing and Modelling	1
Journal of Manufacturing Systems	1
Procedia Engineering	1
51st CIRP Conference on Manufacturing Systems	1
18th Euro Working Group on Transportation	1
Sustainable Production and Consumption	1
Global Business Review	1
International Conference on Modeling, Optimization and Computing	1
Environmental Earth Sciences	1
7th International Conference on Operations Research and Enterprise Systems	1
European Journal of Operational Research	1
Human and Ecological Risk Assessment: An International Journal	1
IEEE Transactions on Engineering Management	1
12th Global Conference on Sustainable Manufacturing	1
IOSR Journal of Engineering	1
International Journal of Computer Integrated Manufacturing	1
International Journal of Supply and Operations Management	1
International Journal of Management Science and Engineering Management	1
Journal of Industrial and Production Engineering	1
International Journal for Quality Research	1

In relation to papers that approach environmental issues and solutions, Journal of Cleaner Production is the leading journal in publications, with a total of 12 of the 61 published papers in the area. Other journals that emphasize cleaner and greener measures also appear with relevance: Resources, Conservation and Recycling; and International Journal of Sustainable Engineering.

Countries

As before, the last factor for analysis in Environmental Management is the participation of countries institutes in the development of each research, by analyzing which countries are the most participant in such publications. Table 19 presents the most relevant countries in publications in the studied major field of application.

Table 19: Classification of Countries Participation in Paper Production in Environmental Management

Environmental Management	
Country	**Number of Participations**
India	24
Denmark	13
Iran	9
USA	8
United Kingdom	6
China	5
United Arab Emirates	5
Turkey	4
Taiwan	4
Hong Kong	3
The Netherlands	2
Thailand	2
Spain	2
Brazil	2
Poland	1
Australia	1
Canada	1
Germany	1
Lithuania	1
Malaysia	1
Philippines	1
Pakistan	1
Egypt	1
Jordan	1

As well as before, India appears as the most relevant country in terms of number of publications developed in the area. Denmark should be highlighted in the current area, with 13 publications. Iran and Turkey also appear among the most relevant ones, as well as China and USA.

3.2.1.3 Business and Marketing Management

Field Progress

The analysis of the present major field starts with its progress in terms of number of publications by year, also divided by sub-area, that is presented next, in Table 20.

Table 20: Number of published papers per year in each sub-area and in the whole Business and Marketing Management area

Business and Marketing Management					
Year	*Performance Evaluation*	*Strategic and Investment Decisions*	*Knowledge Management*	*Marketing Management*	*Total*
2012	5	2	2	2	11
2013	2	0	0	0	2
2014	5	2	1	0	8
2015	2	2	0	2	6
2016	1	1	1	0	3
2017	0	1	0	0	1
2018	1	1	0	0	2
Total	**16**	**9**	**4**	**4**	**33**

The table is presented in the same structure as in the two previous major areas of application. The most influential sub-area of the field is *Performance Evaluation*, with a total of 16 out of the 33 total publications of the major field between 2012 and 2018, that is, half of all publications. *Strategic and Investment Decisions*, that gather several types of problems, is the second, with 9 publications in total. *Knowledge Management* and *Marketing Management* are the ones with least influence, with 4 publications in total each. The sub-area with the most publications in a single year is *Performance Evaluation*, with 5 publications in 2012. The year of most publications in the major field was also 2012, with 11 publications in total.

Relevant Authors

In an analog manner as in the previous two major application areas, an attempt in measuring the relevance of authors in Business and Marketing Management is made to help practitioners in their research on the usage of MCDM methods in decision making problems in the area. First, Table 21 presents the main authors categorized accordingly to the number of published papers in the area.

Table 21: Classification of Most Relevant Authors by Number of Papers Published in Business and Marketing Management

Main Authors	Number of Papers in Area
GLYKAS, Michael *et al*	2
Others	31 (1 each)

In the current area, only one author has more than one publication. Glykas et al. has two publications, and all other 31 papers are proposed by 31 different main authors. In this

case, the next manner of classifying the authors brings a better perspective. Table 22 offers a categorization of the authors in the present major application area according to the sum of citations in all published papers they have in it.

Table 22: Classification of Authors by Sum of Citations in Business and Marketing Management

Main Authors	Respective Sum of Citations
TAYLAN, Osman *et al*	212
YALCIN, Nesse *et al*	159
ROUHANI, Saeed *et al*	154
WU, Wei-Wen *et al*	120
GORENER, Ali *et al*	103
PAKSOY, Turan *et al*	95
GLYKAS, Michael *et al*	88
LI, ming *et al*	75
BULGURCU, Berna (Kiran)	74
GÖRENER, Ali *et al*	73
GARCÍA, J.L. *et al*	66
AKKOÇ, Soner *et al*	55
BAI, Chunguang *et al*	53
REZAIE, Kamran *et al*	49
WANG, Yu-Jie *et al*	47
WANG, Jun *et al*	33
EZZABADI, Jamal Hosseini *et al*	32
SHAVERDI, Meysam *et al*	31
HANINE, Mohamed *et al*	26
KABIR, Golam *et al*	22
SEKHAR, Chandra *et al*	21
KRAUS, Sascha *et al*	18
ANAND, A. *et al*	18
IÇ, Yusuf Tansel	17
HACIOGLU, Umit *et al*	9
ARVAN, Meysam *et al*	8
ARSLAN, Muhammed *et al*	7
MASUDIN, I. *et al*	4
SUDER, Asli *et al*	1
SALE, Martha Lair *et al*	1
MAHTANI, Umesh S. *et al*	new
DURMUSOGLU, Zeynep Didem Unutmaz *et al*	new

With the current analysis, Glykas et al. is not the leading author in citations in the area, with 88, despite having two published papers in it. Other six main authors come before him, with Taylan et al., leading the area with a total number of citations of 212. Mahtani et al. and Durmusoglu et al. have published papers this year, having no citations yet.

Methods Involved

The analysis continues with classification of most popular methods used in the area. Table 23 shows which are the most used ones.

Table 23: Classification of Methods Popularity in Business and Marketing Management

Business and Marketing Management	
Method	**Appearances in the 33 Papers**
Fuzzy AHP	11
Fuzzy TOPSIS	11
AHP	8
TOPSIS	5
Fuzzy Cognitive Maps	3
VIKOR	3
Operations Research Model	1
FCM	1
DoE-TOPSIS	1
SWOT	1
ANP	1
fsQCA	1
Delphi	1
Triangular Fuzzy Numbers	1
Fuzzy DEMATEL	1
QFD	1

Fuzzy AHP and Fuzzy TOPSIS are tied as the most used methods in the area, with 11 appearances in publications for each of them. They are followed by the same methods without fuzzy set theories, and after that, VIKOR and Fuzzy Cognitive Maps methods appear with more relevance.

Journals

The journals and conferences in which the papers of the area were most popular in are presented next in Table 24.

Table 24: Classification of Most Popular Journals and Conferences in Business and Marketing Management

Business and Marketing Management	
Journal	**Number of Papers in Area**
Expert Systems with Applications	6
Applied Soft Computing	6
Procedia - Social and Behavioral Sciences	1
Applied Mathematical Modelling	1
Cybernetics and Systems	1
International Journal of Information Management	1
Transportation Research Part A	1
Information Technology and Quantitative Management	1
Applied Mathematics and Computation	1
8th International Strategic Management Conference	1
Inzinerine Ekonomika-Engineering Economics	1
Eurasian Journal of Business and Economics	1
International Journal of Business and Social Science	1
Technological and Economic Development of Economy	1
Technology in Society	1
International Entrepreneurship and Management Journal	1
XVIII Annual International Conference of the Society of Operations Management	1

Computers and Electronics in Agriculture	1
SpringerPlus	1
J Knowl Econ	1
IOP Conf. Series: Materials Science and Engineering	1
International Journal of Industrial Engineering Computations	1
Electronic Business Journal	1

The most relevant sources in which to find papers related to the subject of decision making problems in this area are Expert Systems with Applications and Applied Soft Computing. Both have 6 publications in the current major area.

Countries

The countries that participated the most in the development of the work related to Business and Marketing Management are ranked next, in Table 25.

Table 25: Classification of Countries Participation in Paper Production in Business and Marketing Management

Business and Marketing Management	
Country	**Number of Participations**
Turkey	11
Iran	4
China	3
USA	3
India	3
Greece	2
Taiwan	2
Spain	2
Australia	1
Liechtenstein	1
Saudi Arabia	1
Mexico	1
Morocco	1
Hong Kong	1
Indonesia	1
Canada	1
Bangladesh	1

This is the first area in which India does not appear as one of the most relevant, leaving the first spot open for Turkey to take its place, with participations in 11 out of 33 publications. Iran, 4, China, 4, and USA, 3, follow the rankings. Greece and Liechtenstein appear for the first time, with 2 and 1 involvements, respectively.

3.2.1.4 Design, Engineering and Manufacturing Systems

Field Progress

The progress in publications throughout the years for *Design, Engineering and Manufacturing Systems* is showed next, in Table 26.

Table 26: Number of published papers per year in each sub-area and in the whole Design, Engineering and Manufacturing Systems area

Design, Engineering and Manufacturing Systems					
Year	*Engineering Challenges*	*Modern Manufacturing Systems*	*Material and Quality Engineering*	*Product Development*	*Total*
2012	3	4	0	0	7
2013	2	1	2	2	7
2014	1	1	1	0	3
2015	1	1	0	2	4
2016	1	1	0	2	4
2017	0	2	0	2	4
2018	0	1	1	0	2
Total	**8**	**11**	**4**	**8**	**31**

The structure of the table is the same as for the last 3 sections. It can be observed that the most influential area of the field is *Modern Manufacturing Systems*, with 11 published papers in total out of the 31 of the major field, publishing every year from 2012 to 2018. *Engineering Challenges* and *Product Development* both had 8 publications each, in total. *Material and Quality Engineering* was the least influential sub-area, with 4 papers in total, publishing only in 2013, 2014 and 2018. The most successful years in terms of number of publications for the major area were 2012 and 2013, with 7 publications in both years.

Relevant Authors

In relation to the authors presence in this area, all of them have only one publication each in it, even though some of them, like Kumar et al. and also Singh et al. have publications in other of the already mentioned areas. Table 27 presents, then, the order of relevance of these authors accordingly to the number of citations their works have.

Table 27: Classification of Authors by Sum of Citations in Design, Engineering and Manufacturing Systems

Main Authors	Respective Sum of Citations
SUBRAMANIAN, Nachiappan *et al*	364
WUHIB, Fetahi *et al*	111
TAHA, Zahari *et al*	86
ZHU, Guo-Niu *et al*	77
AYAG, Zeki *et al*	76
EFE, Burak	47
THOR, Jureen *et al*	33
IC, Yusuf Tansel *et al*	30
GHUNG, When-chin, *et al*	29
KARIM, Rubayet *et al*	25
RAHMAN, Atta-ur *et al*	24
KUMAR, Sanjay *et al*	21
SINGH, Tej *et al*	20
BUYUKOZKAN, Gülçin *et al*	20
MINAROLLI, Dorian *et al*	19
RUDNIK, Katarzyna *et al*	19
BANWET, D. K. *et al*	17

ZHANG, Wei ai *et al*	13
YARI, M. *et al*	11
VATANSEVER, Kemal *et al*	11
YAN, Hong-Bin *et al*	11
CHU, Wangwei *et al*	9
CHANG, Yao-Feng *et al*	7
GUL, Muhammet *et al*	6
CHEN, Wang	5
CHAKRABORTY, Kaustov *et al*	3
BHATT, Nisha	0
PARVEZ, Md. Shohel *et al*	0
RAJHANS, Neela Ravindra *et al*	0
RAZIKIN, Mohd Azroy Mohd *et al*	0
KAZANCOGLU, Yigit *et al*	new

The author by far with most citations in the area is Subramanian et al., with 364 citations, followed by Wuhib, with 111. The difference between the authors with zero citations and the ones with a 'new' assigned to them, is that the 'new' ones have been published in the present year, whereas the others have been published before 2018.

Methods Involved

It is offered in Table 28 the rankings of the most popular methods employed in the area.

Table 28: Classification of Methods Popularity in Design, Engineering and Manufacturing Systems

Design, Engineering and Manufacturing Systems	
Method	**Appearances in the 31 Papers**
AHP	12
Fuzzy AHP	7
TOPSIS	7
Fuzzy TOPSIS	4
Fuzzy MOORA	2
Fuzzy ANP	2
Fuzzy PROMETHEE	2
VIKOR	2
GA	2
ANP	1
FCE	1
MAFC	1
FRBS	1
FIS	1
Performance Manager Arquitecture	1
FMS	1
Modified TOPSIS	1
MCDM	1
PROMETHEE	1
Trapezoidal fuzzy interval numbers	1
Fuzzy group-decision approach	1
FAD	1
Intuitionistic Fuzzy AHP	1
Intuitionistic Fuzzy TOPSIS	1
Rough Numbers	1
QFD	1

The method AHP in its pure form takes the leading place as the most used method to solve the MCDM problems in the area, with 12 presences, instead of its fuzzy variation, that in its turn comes in second place, with 7. TOPSIS follows the same pattern, with its standard version (7 usages) being more used than the one in fuzzy linguistics (4 usages). Other new methods also appear with relevance, like fuzzy MOORA and fuzzy PROMETHEE.

Journals

Table 29 presents the most popular journals and conferences in the area.

Table 29: Classification of Most Popular Journals and Conferences in Desing, Engineering and Manufacturing Systems

Design, Engineering and Manufacturing Systems	
Journal	**Number of Papers in Area**
International Journal of Production Research	3
Applied Soft Computing	2
Int. J. Production Economics	2
International Journal of Industrial Engineering	2
IEEE Third International Conference on Cloud and Green Computing	1
World Applied Sciences Journal	1
IEEE WIRELESS COMMUNICATIONS LETTERS	1
8th International Conference on Network and Service Management	1
Arab Journal of Science and Engineering	1
Journal of Mining Science	1
Journal of Cleaner Production	1
Global Journal of Enterprise Information System	1
INTERNATIONAL STRATEGIC MANAGEMENT REVIEW	1
Machine Selection by AHP and TOPSIS Methods	1
International Journal of Business and Social Science	1
Journal of Intelligent Manufacturing	1
The International Journal Of Engineering And Science	1
Beni-Suef University Journal of Basic and Applied Sciences	1
17th International Conference in Knowledge Based and Intelligent Information and Engineering Systems	1
International Conference on Industrial Engineering and Operations Management	1
Walailak J Science & Technology	1
Journal of Engineering Design	1
Computers & Industrial Engineering	1
Advanced Engineering Informatics	1
Mathematical Problems in Engineering	1
Proceedings of the International Symposium on the Analytic Hierarchy Process	1

The leading journal is International Journal of Production Research, with 3 published papers in it related to the area. Its much less publications than the leading ones in the other areas. This more wide and flat distribution of papers among journals can be justified by the wide range of topics and problems encountered to be solved in this area.

Countries

Table 30 ranks the countries presence in the development of papers in the area.

Table 30: Classification of Countries Participation in Paper Production in Design, Engineering and Manufacturing Systems

Design, Engineering and Manufacturing Systems	
Country	**Number of Participations**
China	7
Turkey	6
India	6
Malaysia	3
Bangladesh	2
Germany	1
Pakistan	1
Sweden	1
Turkey	1
Iran	1
Poland	1
United Kingdom	1
Japan	1
Norway	1

China leads the charts with 7 participations, with Turkey and India tied in second place, with 6 publications each.

3.2.1.5 Human Resources Management

Field Progress

Human Resources Management is the last field of application. Its focused analysis starts with the correspondent field progress of publication per years, as it is given below, in Table 31.

Table 31: Number of published papers per year in each sub-area and in the whole Human Resources Management area

Human Resources Management				
Year	*Staff Selection*	*Products and Ergonomics*	*Human Capital*	*Total*
2012	2	1	1	4
2013	0	1	1	2
2014	1	1	0	2
2015	1	1	1	3
2016	1	1	2	4
2017	1	0	0	1
2018	0	1	1	2
Total	**6**	**6**	**6**	**18**

It follows the same table structure as the other major fields, and it can be seen that all three sub-fields are equal in publications-wise importance, with 6 publications each between 2012 and 2018. However, they had different behavior throughout the years. *Products and Ergonomics* had only one year without any publications, in 2017, while published 1 paper each year in all other years. *Staff Selection* had 2 publications in 2012, no publications in the following year, and then four consecutive years with 1 published paper per year, having no publications in 2018 yet. *Human Capital* had 1 publication in either 2012 and 2013, no papers in 2014, 1 in 2015, 2 in the following year, none in 2017, and has 1 currently this year. The most successful years in number of publications for the major area were 2012 and 2016, with 4 publication in each.

Relevant Authors

The present area has only one author with more than 1 published paper found in the literature research, as presented in Table 32.

Table 32: Classification of Most Relevant Authors by Number of Papers Published in Human Resources Management

Main Authors	Papers in the Area
ZOLFANI, Sarfaraz Hashemkhani *et al*	2
Others	16 (1 each)

As well as Govindan et al. in Environmental Management, Zolfani et al. leads the current application area in either number of published papers as well as in number of citations, as it is seen in Table 33.

Table 33: Classification of Authors by Sum of Citations in Human Resources Management

Main Authors	Respective Sum of Citations
ZOLFANI, Sarfaraz Hashemkhani *et al*	85
ABDULLAH, Lazim *et al*	82
MALDONADO-MACÍAS, Aide *et al*	32
KUSUMAWARDANI, Renny Pradina *et al*	25
CHIU, Ming-Chuan *et al*	18
ROY, Bijoyeta *et al*	14
KABIR, Golam *et al*	12
AVAZPOUR, Reza *et al*	12
SHAKERIAN, Hamed *et al*	7
MALMIR, Ameneh *et al*	6
BASAHEL, A. *et al*	3
ASUQUO, Daniel E. *et al*	2
ESMAILI-DOOKI, Ayda *et al*	2
BHATTACHARJEE, Pijush Kanti *et al*	1
HOQUE, A.S.M. Mojahidul *et al*	0
MOHANTY, Pragyan Paramita *et al*	new
DENAVI, Hasan Dehghan *et al*	new

The leading author in this area keeps being the same in this area with the new study, however it should be noticed the big number of citations obtained by Abdullah et al. with only one publication, being very close to both papers of Zolfani et al. combined, in

these terms. Both authors have a great lead advantage to the third main author, with 88, 82 and 32 being their respective number of citations.

Methods Involved

The analysis of the most popular methods employed is also performed for this area. Table 34 presents the results of the analysis.

Table 34: Classification of Methods Popularity in Human Resources Management

Human Resources Management	
Method	**Appearances in the 18 Papers**
Fuzzy AHP	9
Fuzzy TOPSIS	8
TOPSIS	4
AHP	3
PROMETHEE	2
DEMATEL	1
COPRAS-G	1
VIKOR	1
SWARA	1
Game Theory	1
SWOT	1
Fuzzy DEMATEL	1
Interval type-2 fuzzy sets	1

The popularity of methods follows the same pattern as most areas, with fuzzy AHP and fuzzy TOPSIS being the most relevant, with 9 and 8 appearances, respectively.

Journals

The most popular journals in which there are publication in the area are presented next, in Table 35.

Table 35: Classification of Most Popular Journals and Conferences in Human Resources Management

Human Resources Management	
Journal	**Number of Papers in Area**
International Journal of Computer Applications	1
Journal of Applied Research on Industrial Engineering	1
Production & Manufacturing Research	1
International Journal of Computer Science and Information Technology & Security	1
Ekonomska istraživanja (Economic Research - Croatian)	1
The Third Information Systems International Conference	1
Operations Research Perspectives	1
International Journal of Environmental Science and Development	1
8th International Scientific Conference “Business and Management 2014	1
International Journal of Advanced Manufacturing Technologies	1
International Journal of Advances in Engineering & Technology	1
International Journal of Safety and Security Engineering	1
Applied Ergonomics	1
3rdInternational Conference on New Challenges in Management and Organization: Organization and Leadership	1

Expert Systems with Applications	1
International Journal of Economy, Management and Social Sciences	1
Open Journal of Business and Management	1
Kuwait Chapter of Arabian Journal of Business and Management Review	1

No journal nor conference distinguish itself as more popular for the publications in the subject. All journals have one publication each.

Countries

Table 36 presents the distribution of countries popularity for the publications in Human Resources Management, and is presented next.

Table 36: Classification of Countries Participation in Paper Production in Human Resources Management

Human Resources Management	
Country	**Number of Participations**
Iran	7
India	3
Bangladesh	2
Nigeria	1
Canada	1
Indonesia	1
Mexico	1
Saudi Arabia	1
Taiwan	1
Malaysia	1

The most relevant country in these publications is Iran, with 7, between 2012 and 2018. India and Bangladesh are the only other two countries with more than one publication each, with 3 and 2, respectively. All other countries have only one publication each.

All data observed helped readers have a in-depth overview of how the scenario is for each application area in a business environment. All information collected added up to the general analysis, relating to the whole papers research, that will be presented next.

3.2.2 GENERAL ANALYSIS

The present section presents quantitative analyses of data of all areas together, to help understand relevancies in a macro view, regarding a business as a whole. Some of the

evaluations made are the number of published papers by field, the number of published papers by type of research, the techniques that appear in the biggest number of papers, the papers with more citations, the number of publications by country, the number of publications by year, and the journals that have more publications. In some of these analyses, the power law is applied for their more profound study.

3.2.2.1 Papers Distribution by Field

Starting with the distribution of research papers found by application area, some of these areas showed themselves to be more popular and with more easily found papers than others. Below, in Table 37, it is presented the distribution of papers by field.

Table 37: Distributions of papers published by field

Application Area	Sub-Area	Sub-Areas Sums	Sub-Areas %	Areas Sums	Areas %
Supply Chain Management	Supplier Selection and Assessment	37	18,14	61	29,90
	Chain Management	11	5,39		
	Logistics Management and Outsourcing	13	6,37		
Environmental Management	Sustainable Management	5	2,45	61	29,90
	Impact Reduction and Reverse Logistics	14	6,86		
	Green Supply Chain Selections	36	17,65		
	Eco Design	6	2,94		
Business and Marketing Management	Performance Evaluation	16	7,84	33	16,18
	Strategic and Investment Decisions	9	4,41		
	Knowledge Management	4	1,96		
	Marketing Management	4	1,96		
Design, Engineering and Manufacturing Systems	Engineering Challenges	8	3,92	31	15,20
	Modern Manufacturing Systems	11	5,39		
	Material and Quality Engineering	4	1,96		
	Product Development	8	3,92		
Human Resources Management	Staff Selection	6	2,94	18	8,82
	Products and Ergonomics	6	2,94		
	Human Capital	6	2,94		
Total		204	100,00	204	100,00

The Table 37 is divided by all application areas and sub-areas. The first column of results shows the number of papers published in each sub-area, while the next one represents the percentage of this number in relation to the total amount of published papers. The next two columns follow the same pattern, but this time in relation to the corresponding major areas of application. Results show that both *Supply Chain Management and Logistics* an *Environmental Management* have the same amount of published papers, that means they are equally relevant when talking about MCDM methods publications in a business environment, combining to have approximately 60% of all publications. *Business and Marketing Management* and *Design, Engineering and Manufacturing Systems* are similar major areas to each other as well, having both around half the number of publications if compared to each of the former leading areas. At the same time, *Human Resources Management* is the least expressive areas, with 8,8% of all

published papers. Among the analyzed sub-areas *Supplier Selection and Assessment* and *Green Supply Chain Selection* are highlighted as the most popular ones, with approximately 18% each. This can explain why their correspondent major areas became the leading ones. *Performance Evaluation* of businesses, *Logistics Management and Outsourcing, Chain Management, Impact Reduction and Reverse Logistics* and *Modern Manufacturing Systems* also deserve attention as areas with many publications between 2012 and 2018.

3.2.2.2 Type of Research Distribution

Regarding the number of research papers existent in the literature review by type of application, Table 38 draws how this distribution occurs.

Table 38: Distribution of published papers by type of research

Type of Research	Number of Appearances	Corresponding %
Application	191	93,63
Comparison	16	7,84
Review	12	5,88
Development	4	1,96
Total (number / %) of Papers	**204**	**100,00**
Total (number / %) of Appearances	**223**	**109,31**

It is important to notice that the sum of the number of appearances or of the corresponding percentages do not match the total number of papers published, but exceed them. It happens because there are papers that combine more than one type of research in them. This way, the total number of appearances of the types of researches in Table 38 exceed the number of papers. For example, a paper can be of Application and Comparison at the same time, thus, the same paper counts for both “Application” and “Comparison” categories. *Application* is by far the most popular type of research encountered in the literature review, with 191 appearances in the 204 papers. There never was a combination of more than two types of researches.

3.2.2.3 Most relevant Papers and Authors

The 12 most relevant papers and authors from all fields, being most of them from the major area *Environmental Management,* in Table 39, next.

Table 39: Most relevant papers and authors of all areas

AUTHOR	YEAR	TITLE	TYPE	METHODS	CITATIONS
CHAI, Junyi et al	2013	Application of decision-making techniques in supplier selection: A systematic review of literature	Review	MCDM, MP and AI Techniques	517
GOVINDAN, Kannan et al	2013	Multi criteria decision making approaches for green supplier evaluation and selection: a literature review	Review	MCDA for Green Suppliers	418
GOVINDAN, Kannan et al	2013	A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach	Application	Fuzzy TOPSIS	406
SUBRAMANIA, Nachiappan et al	2012	A review of applications of Analytic Hierarchy Process in operations management	Review	AHP	364
KANNAN, Devikan et al	2013	Integrated fuzzy multi criteria decision making method and multiobjective programming approach for supplier selection and order allocation in a green supply chain	Application	Fuzzy AHP, Fuzzy Topsis, MOLP	317
JUNIOR, Francisco Rodrigues Lima et al	2014	A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection	Comparison	Fuzzy AHP and Fuzzy TOPSIS	306
LIN, Ru-Jen	2013	Using fuzzy DEMATEL to evaluate the green supply chain management practices	Application	Fuzzy set theory, DEMATEL	284
KANNAN, Devika et al	2013	Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company	Application, Comparison	3 types of Fuzzy TOPSIS	282
DENG, Xinyang et al	2013	Supplier selection using AHP methodology extended by D numbers	Application	D numbers, AHP	280
GOVINDAN, Kannan et al	2014	Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process	Application	AHP	274
SHEN, Lixin et al	2013	A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences	Application	Fuzzy TOPSIS	237
TAYLAN, Osman et al	2014	Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies	Application	Fuzzy AHP, Fuzzy TOPSIS	212

By observing the titles of the papers in Table 39, of the 12 papers presented as the more relevant, 10 involve supplier selection problems, either in traditional or green form of evaluation. Also, among the 4 more relevant papers, 3 are *Review* papers, despite the great majority of *Application* ones. None of them are from a more recent year than 2014. *Govindan* is the most relevant author, with 3 publications among the top 12 and 1098 citations, being the author of the most relevant *Application* paper of the entire literature review. This author is followed by *Kannan,* that has 2 publications among the top 12 with 599 citations. When analyzing the methods, AHP and TOPSIS, with their variations, are the most relevant with only one of the top 12 papers not mentioning any of both.

3.2.2.4 Methods Popularity Distribution

As well as the distribution by type of research, it is also performed the distribution of reviewed papers by type of methods that were applied in them, so that it is possible to understand which MCDM methods are the most used in the focused decision making problems. This analysis ins presented in Table 40. As well as in the last-mentioned analysis, if a paper involves two or more different methods, all methods are counted separately. Thus, the sum of methods appearances does not match the total number of published papers and, because of that, the sum of 'correspondent %' also does not

match 100%. The percentage is not in relation to the total number of appearances, but to the total number of papers.

Table 40: Methods Distribution of Appearances in the 204 Papers

Method	Number of Appearances	Correspondent %
Fuzzy TOPSIS	77	37,75
Fuzzy AHP	69	33,82
AHP	43	21,08
TOPSIS	26	12,75
VIKOR	12	5,88
QFD	9	4,41
DEMATEL	7	3,43
fuzzy set theory	5	2,45
Fuzzy DEMATEL	5	2,45
Fuzzy ANP	5	2,45
ANP	5	2,45
FAD	3	1,47
Fuzzy MOORA	3	1,47
PROMETHEE	3	1,47
Fuzzy Cognitive Maps	3	1,47
Fuzzy c-means	3	1,47
BWM	3	1,47
FWA	2	0,98
2-tuple linguistic representation model	2	0,98
ISM	2	0,98
Fuzzy QFD	2	0,98
Interval type-2 fuzzy TOPSIS	2	0,98
Intuitionistic fuzzy TOPSIS	2	0,98
Intuitionistic fuzzy AHP	2	0,98
Intuitionistic fuzzy sets	2	0,98
Fuzzy Delphi	2	0,98
Shannon Entropy	2	0,98
Fuzzy PROMETHEE	2	0,98
GA	2	0,98
Rough Numbers	2	0,98
Fuzzy MOLP	2	0,98
fuzzy VIKOR	2	0,98
SWOT	2	0,98
Fuzzy KANO	1	0,49
ROC	1	0,49
D numbers	1	0,49
BSC	1	0,49
AFS	1	0,49
MCGP	1	0,49
Taguchi Loss Function	1	0,49
Flexible entropy weighting	1	0,49
DEA	1	0,49
Interval type-2 fuzzy AHP	1	0,49
Interval type-2 fuzzy sets	1	0,49
SCOR	1	0,49
Fuzzy rule-based system for supplier segmentation	1	0,49
aggregate fuzzy weight method	1	0,49
artificial neural network	1	0,49
IFAD	1	0,49
ARAS	1	0,49

Multiplicative Utility	1	0,49
Hovanov	1	0,49
SEM	1	0,49
OM-AHP	1	0,49
Electre III/IV	1	0,49
Fuzzy SAW	1	0,49
Fuzzy Linear Regression	1	0,49
FCE	1	0,49
MAFC	1	0,49
FRBS	1	0,49
FIS	1	0,49
Performance Manager Arquitecture	1	0,49
FMS	1	0,49
Modified TOPSIS	1	0,49
Trapezoidal fuzzy interval numbers	1	0,49
Fuzzy group-decision approach	1	0,49
Operations Research Model	1	0,49
DoE-TOPSIS	1	0,49
fsQCA	1	0,49
Delphi	1	0,49
Triangular Fuzzy Numbers	1	0,49
GP	1	0,49
MABAC	1	0,49
EW	1	0,49
NGT	1	0,49
MOLP	1	0,49
GRA	1	0,49
Fuzzy GRA	1	0,49
MOPM	1	0,49
Fuzzy MOPM	1	0,49
COPRAS	1	0,49
COPRAS-G	1	0,49
Grey Theory	1	0,49
Fuzzy Cause and Effect Relationships	1	0,49
Approximate Fuzzy DEMATEL	1	0,49
CRITIC	1	0,49
ECQFD	1	0,49
TRIZ	1	0,49
SWARA	1	0,49
Game Theory	1	0,49
Total Number of Papers	**204**	**100,00**
Total Number of Appearances	**370**	**185,29**

When observing the table, Fuzzy TOPSIS is the most popular method employed in all papers, with 77 appearances in the 204 published papers, corresponding to 37,75% of all papers. Fuzzy AHP is the second most popular method, with a total of 69 appearances, a number that corresponds to a presence in 33,82% of all papers. AHP and TOPSIS in their pure forms are the third and fourth most popular applications, with 43 and 26 appearances, respectively. It is very interesting to observe the relevance of the relatively new VIKOR method, positioned in fifth place, with 12 appearances in its pure form. DEMATEL and ANP, in either their pure and fuzzy forms, also appear in a relevant position. Other methods that had applications in special cases with some relevance were QFD, Promethee, MOORA, FAD, Fuzzy Cognitive Maps and Fuzzy C-Means.

It is very noticeable the amount of appearances that belong solely to Fuzzy TOPSIS, Fuzzy AHP, TOPSIS and AHP methods. The number of their appearances together is 215, which is already more than the total number of papers present in the research. At the same time, all other methods together make a total of 155 appearances in the papers. This great impact made by a small portion of the methods takes us to the Pareto Law [284]. This law has many developed possible applications, and started when Pareto presented a distribution to describe income, where it was demonstrated that the relative number of individuals with an annual income larger than a certain value *x* was proportional to a certain value of *x* [285]. This tells us that the size of an event is inversely proportional to the frequency in which it happens. Pareto explained that 80% of all income in the society he analyzed was in the hands of 20% of all people [284].

Detecting the existence of this behavior in natural or human-made systems can be difficult. Power law (PL) distributions, or either Pareto-like laws, or Zipf-like laws, or even heavy tail distributions, are employed to demonstrate the mentioned behavior. Therefore, they use a log-log plot of the quantities of these events and verify if a straight line is obtained [285]. The closer the curve generated from the data is to a straight line, than the closer its regression coefficient is to the value of 1,00. The regression coefficient (R^2) measures the change in X for the unit change in Y. If its value is 1,00, it means that they change in the same proportion, thus generating a straight line. Consequently, it can mean that the studied data has the behavior stated by the Pareto Law, if the angular coefficient allows the increase in X values to cause decrease in Y values, and vice-versa. The described behavior represents that the event size and its frequency are inversely proportional.

The Power law distribution for the methods popularity is presented in Figure 10, with the discussed event size being the number of appearances of a method in the papers. It was created via Excel software. The *x* axis represents the ranking of the methods in a logarithmic scale, that is, a relative weight is given to each rank. The sum of the present methods (90) is set as the parameter, with a weight of 1. This way, the last ranked method, the 90^{th}, has a weight of 1. The 89^{th} method is divided by the parameter, to get a relative weight lower than one. This happens to all methods, and they all have correspondent values between zero and one. The method ranked in first is the closest to 0 in the *x* axis. The *y* axis represents the number of appearances of each method in a logarithmic, that is, relative scale. The method with most number of appearances is set as the parameter, with a weight of 1. All other method's number of appearances are divided by it and have a logarithmic value below 1. The less appearances a method has, the closer its *y* axis value is to zero. The total number of methods and their number of appearances were translated into logarithmic values, and then the graph was generated.

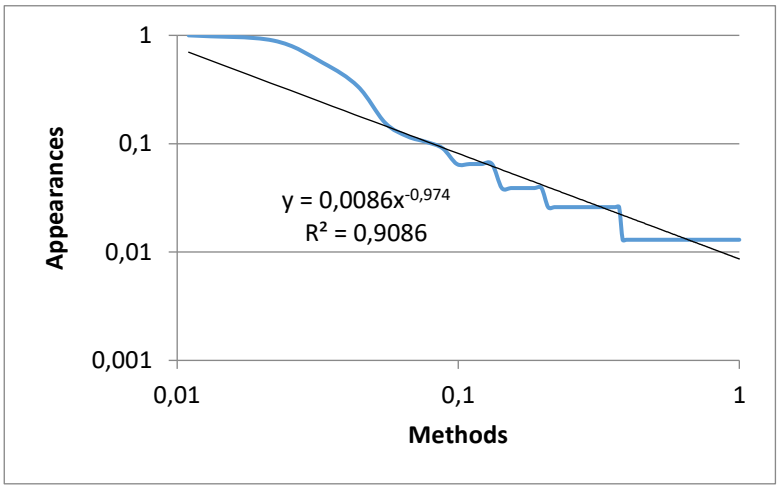

Figure 10: Power Law Distribution of Methods Appearances in Papers

By observing the PL distribution of methods appearances, the data generated curve is not a straight line, but has a behavior that is close to it. Its regression coefficient is 0,9086, which indicates its closeness to a straight line form. Since it does not create a perfect straight line, it can be concluded that the data acts very close to the behavior described by Pareto Law, but not entirely. There are 90 methods in total. By taking the leading 20% of them, that is, the first 18 methods, the number of appearances is a sum of 283. The total number of all methods appearances in the papers is 370. That means that the top 20% methods are responsible for 76,49% of all appearances, and not 80%. The data do not follow the 80/20 rule, but follow closely a Power law distribution.

3.2.2.5 Countries Participation Distribution

The general analysis for countries distribution represents the participation of researches from different countries in all the 204 publications. Many times, there were more than one country being represented in a paper. This means that the sum of countries researchers' appearances is superior than the number of papers, as it happened with the methods analysis. Therefore, the sum of 'Correspondent %' is not 100% too. The distribution of researchers' countries is represented next, in Table 41.

Table 41: Countries presence in reviewed papers

Country of Research	Number of Papers Participation	Correspondent %
India	52	25,5
Turkey	33	16,2
Iran	28	13,7
China	20	9,8
USA	15	7,4
Denmark	15	7,4
Malaysia	8	3,9
Taiwan	8	3,9
Brazil	7	3,4

Hong Kong	7	3,4
Lithuania	6	2,9
Bangladesh	5	2,5
United Arab Emirates	5	2,5
United Kingdom	4	2,0
Spain	4	2,0
Thailand	3	1,5
The Netherlands	3	1,5
Australia	3	1,5
Poland	3	1,5
Canada	3	1,5
France	2	1,0
Germany	2	1,0
Pakistan	2	1,0
Greece	2	1,0
Saudi Arabia	2	1,0
Mexico	2	1,0
Indonesia	2	1,0
New Zealand	1	0,5
Republic of Korea	1	0,5
Serbia	1	0,5
Belgium	1	0,5
Colombia	1	0,5
Sweden	1	0,5
Japan	1	0,5
Norway	1	0,5
Liechtenstein	1	0,5
Morocco	1	0,5
Philippines	1	0,5
Egypt	1	0,5
Jordan	1	0,5
Nigeria	1	0,5
Total Number of Papers	**204**	**100**
Total Number of Appearances	**260**	**127,5**

India is the country with more participations in publications, with 52 in the 204 papers, which means a presence in 25,5% of all papers published. Turkey, Iran and China are three other strong countries in this subject, with 33, 28 and 20 participations each, respectively. The first two countries to appear that are not part of the Middle East nor Asia are the USA and Denmark, with presence in the development of 15 papers each. Denmark's publications come mostly from Govindan et al. [128] [137] [145] [167] [170] [174] and Kannan et al. [146] [168] [173], that are very present in the analysis of last sector, having combined 5 publications among the 12 most relevant papers of this research.

The behavior demonstrated by the leading countries constitutes the approximate idea proposed by the Pareto Law. Therefore, the Power law distribution can be applied to this data set too. The intention of the analysis is to observe the relation between the quantity of countries and the number of participations in papers, in a logarithmic scale. The Power law distribution for countries researchers' participations is presented next, in Figure 11.

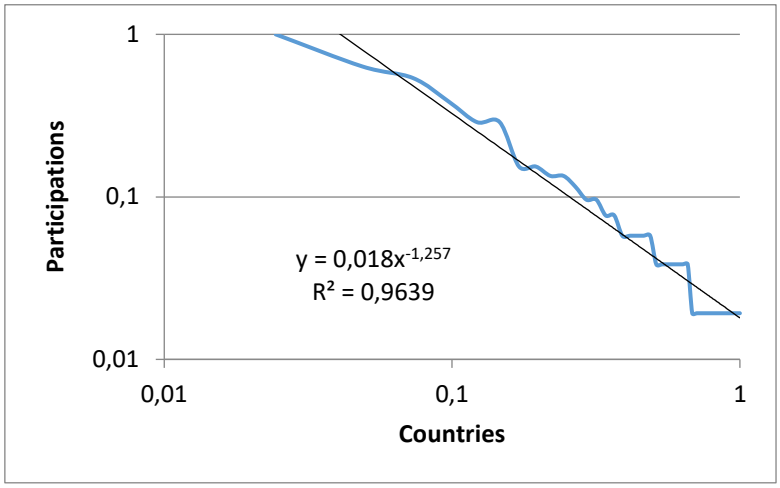

Figure 11: Power Law Distribution of Countries Participations in Papers

The observations on the generated Power law distribution shows that the data curve is closer to the behavior of a straight line if compared to the one generated by the methods appearances. The same is indicated when observing the value of the regression coefficient (R^2) also closer to 1,00 than before. The regression coefficient value now is of 0,9639. It can be concluded that the analyzed data by Power law distribution is very close to the behavior stated by the Pareto law. There is a total number of 260 researchers' participations in the 204 papers, and 41 countries in total. When taking the leading 20% countries, that is, the first 9 countries (the correct value is 8,2), it is seen that together they are responsible for 186 participations in papers, which corresponds to 71,54% of all appearances. The obtained result is very interesting. Even with a power law distribution closer to a straight line than the methods analysis done before, the actual percentage of participation related to the top 20% is lower. This can be explained by the number of events, or samples, in each case. The methods distribution had 90 events, while the countries distribution has 41. In order to observe a perfect Power law behavior, in the sense of a perfect 80/20 rule, more data is needed. Needless, is to say, that reality is not perfect, and all the examples considered here follow a Power law distribution, as can be observed by the graphs and by the corresponding regression coefficients.

3.2.2.6 Total Publications per Year During the Period

The distribution of total publication by year is presented next, in Figure 12.

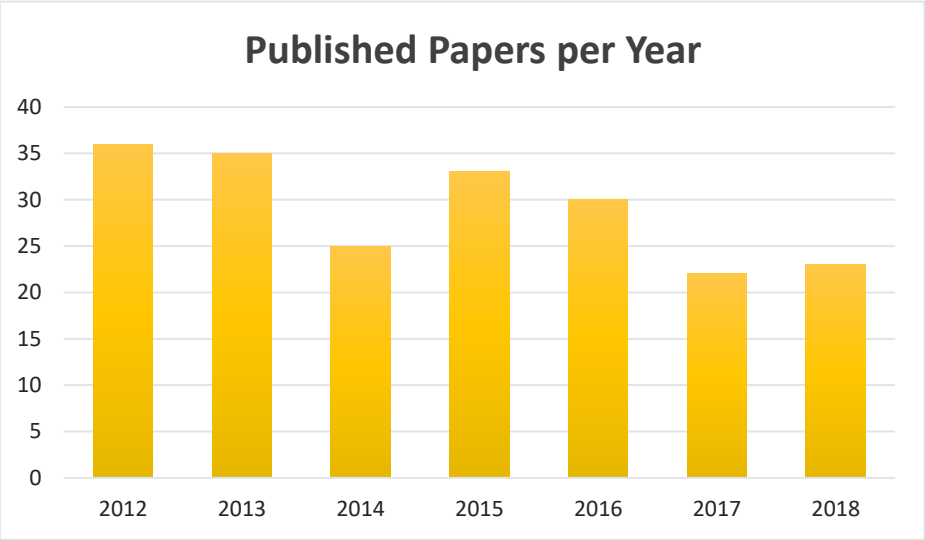

Figure 12: Distribution of the number of published papers present in the literature review, per each year

It is interesting to observe that the number of publications per year oscillates so much from time to time. The year 2014 can be observed as low on publications, because the years before and after it had almost ten publications more. However, the weakest year according to these indications is 2017, with 2018 already in front of it, even though it is still far from ended.

3.2.2.7 Journals and Conferences Choice Distribution

The table with the number of articles per journal help identifying the most relevant journals regarding their presence in the field of interest. Journal distribution analysis can be observed next, in Table 42.

Table 42: Distribution of papers through the different sources they were found

Source	Number of Papers	Corresponding %
Expert Systems with Applications	21	10,3
Journal of Cleaner Production	13	6,4
Applied Soft Computing	12	5,9
Computers & Industrial Engineering	8	3,9
International Journal of Production Research	7	3,4
Int. J. Production Economics	6	2,9
International Journal of Management Science and Engineering Management	5	2,5
Applied Mathematical Modelling	5	2,5
Resources, Conservation and Recycling	4	2,0
International Journal of Sustainable Engineering	4	2,0
Operations Research Perspectives	3	1,5
Information Technology and Quantitative Management	3	1,5
Production Planning & Control	3	1,5
Transportation Research	3	1,5
International Journal of Industrial Engineering	3	1,5

European Journal of Operational Research	2	1,0
IIMB Management Review	2	1,0
Economic Research (Ekonomska Istraživanja)	2	1,0
Mathematical Problems in Engineering	2	1,0
Production & Manufacturing Research	2	1,0
International Journal of Business and Social Science	2	1,0
Int. J. Production Economics	2	1,0
Computers and Operations Research	2	1,0
Other Sources	87	42,6

The most present journal for publications of MCDM methods in the business environment was by far *Expert Systems with Applications*, with 21 papers in it, corresponding to 10,3% of all papers in the literature research. *Journal of Cleaner Production* and *Applied Soft Computing* are the runners-up 6,4% and 5,9%, respectively. Beyond all more relevant results, 87 journals (42,6%) published only one paper in the subject. All other 87 sources have 1 publication each, and are listed in the end pages of this work in Annex 1.

3.3 OVERALL RESULTS

The present sub-chapter first consists on comments and observation on the different ways the techniques were used in the many decision making problems present in the papers review. These comments serve as observations of the methods, their applications, variations and comparisons. The goal of these commentaries is to enrich the reader with additional views on the tools available. The comments are divided by methods, and the methods are organized by the order of popularity (appearances) they had in the research.

After the comments, a final discussion on the results of the study is performed by highlighting all analysis made.

3.3.1 MAIN METHODS COMMENTARY

This section treats the main MCDM methods appearances in their pure or variated forms.

3.3.1.1 AHP

This multicriteria decision making method is the one that had the greatest number of appearances in publications, when summing all its variations as well as its pure form applications.

Its pure version made some useful appearances, as in the application research proposed by Iç et al. [249], where the method was utilized to weight criteria with its pairwise comparisons, to later evaluate and rank alternatives of machine-center components. The author highlights the possible inaccuracy of input values given by the decision makers, and suggest that this action is performed by a group of experts instead of a single person. Another example of AHP method's application in its pure form is the study presented by Anand et al. [231], being used to rank KME's (knowledge management enablers) given by experts, so that a company would know where to start when implementing Knowledge Management. The results obtained are compared to a survey that was performed simultaneously, and turn out with identical results. However, fuzzy logic is suggested for more accuracy in the input of information.

The original version of the Analytic Hierarchy Process also worked in combination with other methods. In the application work of Jayant et al. [154], it was used in combination with TOPSIS to select a reverse logistics service provider in the mobile phone industry. AHP would weight criteria through its pairwise comparisons, so that TOPSIS would analyze and rank alternatives with its own proceedings. The authors end up very satisfied with the combination between the two methods, but also suggest improvements, with the usage of ANP for studying the influences of each criteria on the others. Deng et al. [82] implemented the method in combination with D numbers, that are used as an extension of fuzzy preference relation to represent the decision matrix of pairwise comparisons given by the experts on the subject. Beikkhakhian et al [99] used AHP in cooperation with ISM (Interpretive structural model) and Fuzzy TOPSIS. AHP was used to measure the weight of the criteria and, this way, increase the efficiency of results of Fuzzy TOPSIS method, which ranked the suppliers accordingly to the criteria. The ISM method is used to analyze the influence of criteria in agile suppliers. The results of both AHP and ISM in relation to the criteria confirm each other. It is suggested the usage of fuzzy in ISM analysis for future works.

The extension of the AHP method using fuzzy set theory is widely used throughout the literature research, as observed by the number of appearances in the statistical analysis, in Table 40. Rezaei et al. [91] proposes an application research, in which Fuzzy AHP is used alone to rank and segment suppliers of broiler company, with fuzzy logic evidently helping make the results more precise and reliable. Li et al. [102] uses Fuzzy AHP in alliance with AFS and TOPSIS, where AFS is designated with the function of dividing criteria into clusters, Fuzzy AHP is used to weight the criteria, and TOPSIS to rank the alternatives. Hacioglu et al. [219] presents an application plus comparison research, where the hybrid Fuzzy AHP-TOPSIS is compared to Fuzzy AHP-VIKOR in evaluating bipolar risks in emerging capital markets. In both applications, AHP was used to weight criteria with input given in fuzzy logic, so that TOPSIS and VIKOR would evaluate and rank alternatives. Both hybrids achieved very similar results.

It is observed that even when having its limitations, the AHP methods is still very useful and popular in MCDM applications, especially when weighting criteria for other methods that are not too good in it, like TOPSIS and VIKOR. Also, it shows it is a very versatile method in the sense that it can combine with many techniques to create a several number of hybrids, and it also can have variations in the linguistics used for its inputs, like the examples given with fuzzy set and with D numbers, beside others not mentioned in the section. All these characteristics combine to make AHP conquer the place of most popular method in the MCDM applications in a company's environment.

3.3.1.2 TOPSIS

The Fuzzy TOPSIS variation of this method is the most popular technique in the papers review. Considering all its forms of appearance, the TOPSIS is the second most popular method, very close to AHP, and very far from the rest. It has different applications in problems than AHP, as it will be observed next.

In the present papers research, TOPSIS applications in its original form, with no combinations with other methods, is very narrow. Bulgurcu [209] applies the method in its pure form for financial performance evaluation of technology firms in Istanbul Stock Exchange Market. TOPSIS is applied to rank the 30 companies for a 3-year period, from 2009 to 2011. Its results are compared to the real data of their stock value rankings in the end of the years. The TOPSIS method had similar results to the real stock values when evaluating the companies with most consistent performances, but failed in ranking brand new companies to the stock market. The conclusion of the author is that TOPSIS method alone is not enough for predicting financial market behavior of companies, and it is proposed the creation of hybrids for more accuracy in future works. Bhattacharjee et al. [276] presents the application of TOPSIS for the ranking of the noise annoyance of different electrical equipment in relation to criteria constituted by technical sound parameters. Tests were conducted a data collected. The results are satisfactory, and the method is suggested to be used in the analysis of other different equipment. Singla et al. [142] compares the application of TOPSIS with the more recent VIKOR method for analysis of technology push strategies influencing sustainable development in companies. The results obtained are exactly the same.

TOPSIS has many hybrid applications in several different problems. Sekhar et al. [226] offers a Delphi-AHP-TOPSIS hybrid for the prioritization of intellectual capital indicators in small and medium-sized enterprises. The Delphi method is applied in the first phase of the work, in the brainstorming for the correct definition of input information. AHP is employed for weighting the generated criteria, and TOPSIS is used for ranking the available alternatives. Hanine et al. [225] offers an example of application that many times happens with TOPSIS, that is, its combination with AHP for weighting its required criteria. They are combined for the selection of ETL (Extract, Transform and Load) software, very important for Business Intelligence (BI). The results are satisfactory.

However, pairwise comparisons of AHP for capturing experts' judgments is acknowledged to be imprecise. Thus, fuzzy environment is suggested for future works. Wu et al. [105] offers a fuzzy Delphi-ANP-TOPSIS hybrid for supplier selection problem. Fuzzy Delphi is used for better criteria selection and, for considering the interdependence among criteria ANP is used to obtain their weights. TOPSIS finally is used for ranking the alternatives. The author recognizes that ANP and TOPSIS do not use fuzzy environment during the decision making process, and suggests that this should happen in future works.

The variation of TOPSIS with fuzzy environment is by far its most popular application, either alone or in hybrids. Rouyendegh et al. [97] proposes supplier selection with the combination between Fuzzy TOPSIS and MCGP (Multi-Choice Goal Programming). Fuzzy TOPSIS is used to express decision makers judgments by triangular fuzzy numbers. The objectives are to define the final supplier selection and the order allocation. With two goals wanted, MCGP is employed. The correct answers for both objectives are obtained by integrating the closeness coefficients of TOPSIS to the MCGP model. Junior et al. [104] creates a new model when combining the SCOR (Supply Chain Operations Reference) model with Fuzzy TOPSIS for supplier evaluation and management. SCOR is used to evaluate suppliers in the dimensions cost and delivery performance. It combines two Fuzzy TOPSIS models for categorizing the suppliers into four groups depending on their performance evaluation. The model brings the advantage of facilitating the integration between performance evaluation of suppliers and supply chain (SC). Fuzzy TOPSIS also does not limit the number of alternatives simultaneously evaluated and does not generate rank reversal problem when a new supplier is included in the evaluation process.

It can be noticed that TOPSIS applications in decision making problems are of a different nature than the AHP's. Its purpose in the problems is most of times related to the ranking of alternatives, normally according to criteria already weighted by another method, especially AHP. But many other methods also appear in hybrids with TOPSIS, most of times because of its limitations in weighting criteria. The method's fuzzy variation is more common than its pure form application, being used in several different problems. Despite working in a different way than the AHP method, TOPSIS also have the qualities of simplicity and versatility, which make it one of the most popular MCDM methods employed in decision making problems in a business setting.

3.3.1.3 VIKOR

After AHP, TOPSIS and their variations in the fuzzy environment, VIKOR is the most popular method employed in the problems presented in the studied papers, despite being a relatively new method.

Its pure form is always applied in combination or comparison with other methods. One great example is the work proposed by Zhu et al. [238], already mentioned in this work, that uses rough numbers as base for the application of the AHP-VIKOR hybrid in a design concept evaluation for a new product. Rough numbers is an alternative to fuzzy numbers in dealing with vagueness in judgements and preferences. AHP and VIKOR are both applied based in this environment. AHP weights the criteria and VIKOR ranks the design concept alternatives. Validation shows that the proposed decision making method can effectively enhance the objectivity in design concept evaluation under a subjective environment. Prakash et al. [156] proposes a combined method between Fuzzy AHP and VIKOR for evaluation and selection of third-party reverse logistic partner. AHP under fuzzy environment is able to deal with uncertainty in judgment and opinions of experts for weighting the criteria. Later, VIKOR is employed for evaluating and ranking the alternative partners. The hybrid AHP-VIKOR is proposed for evaluation and selection of green supplier by Luthra et al. [176], where the first is used to weight criteria by pairwise comparisons and the other to rank the alternatives.

In respect to fuzzy environment application, Awasthi et al. [179] proposes the usage of NGT (Nominal Group Technique) and VIKOR to evaluate green supplier development programs under it. NGT is employed to identify criteria, fuzzy theory is used to address qualitative linguistic rating to either criteria and alternatives, and finally VIKOR is applied in ranking and recommending the best program for implementation. In another study, Akman [177] offers the combination between VIKOR and fuzzy c-means to determine and evaluate the environmental performance of suppliers and determine which of them need to improve in this sense. Fuzzy c-means can separate data into clusters. First, all available suppliers were clustered according to standard performance criteria. The best suppliers of the first phase were re-clustered now according to green criteria. The evaluated suppliers were divided into three groups according to their green performance – good, medium, bad. Finally, the suppliers in the worst group were sequenced from worst to best by VIKOR in order to implement green supplier development programs. According to the authors, the method is easily and rapidly adaptable to other sectors and firms. Also, more advanced segmentation methods are suggested, as well as the TOPSIS method, for comparison.

The VIKOR method has been developed since the 80's by Opricovic [286], but its international recognition as a MCDM methods is very recent, since 2004 [287]. Even so, it is the most popular method in application in this research besides AHP and TOPSIS. This method also carries the characteristics of being of simple and versatile applications, allowing researcher from many places, in many subjects, employ it in their problematics. Its function in a decision making problem is very similar to the one proposed by TOPSIS. In all the comparations found in during the research between these two methods, being it in their pure forms or under fuzzy environment, the results were always close.

3.3.1.4 Other Methods

Among other popular techniques applied, Junior et al. [109] proposes the usage of fuzzy QFD for choosing criteria for supplier selection, while Karsak et al. [96] proposes and integrated supplier selection methodology with QFD, DEA and Fuzzy Weighted Average. Kraus et al. [227] proposed a review observing the rise of the method fuzzy-set qualitative comparative analysis (fsQCA) applied in business and management research on the fields of entrepreneurship and innovation research. The method is a very good to understand correlations and discover paths and patterns in complex environments or organizations, relating quantitative values to a qualitative viewpoint.

3.3.2 DISCUSSION OF THE RESULTS

Since de beginning of the work, the aim was to give more than just a simple presentation of the papers available on the subject of MCDM applications in a company's environment. The objective was always to give as much depth as possible as well as a wide perspective on the subject. With this purpose, many analyses were performed on many different aspects of the collected data. The efforts were concentrated either on focused and detailed analysis on the aspects of each sub-areas as well as on the general perspective of the papers research.

The presentation of the papers researched was divided into five tables, being them Table 3, Table 4, Table 5, Table 6 and Table 7, with the purpose of a clearer and more objective view of the published papers. Along with the tables, commentaries were performed on each of the fields sub-fields with exemplifications, with the aim of bringing more of the context of applications to the readers.

The focused analysis on each of the five major application areas brought to readers deeper insights on: (a) each field and sub-field progress in the number of publications per year; (b) the lists of the most relevant authors in each major area by two criteria – the number of publications and the number of citations each of them had in the respective areas; (c) the rankings of the most popular methods in each area; (d) the rankings of the most chosen journals and conferences for the papers published in each area; and finally (e) the ranking of the countries with most participations in the development of the researches in each of these major areas. These analyses should guide readers in an in-depth and detailed view and understanding of each area, properly aiding them in the particular problems that they are interested in.

The general analysis brought all information of the focused results together to give a very important overview of the papers research to the readers.

The first topic analyzed in general analysis was the distribution of publications over all fields and sub-fields of the study, presented by Table 31. In this analysis, it could be observed which were the most popular enterprise-related topics (the ones with bigger

percentage) for MCDM methods applications. *Supply Chain Management and Logistics* and *Environmental Management* were evidenced as the most dominant of the five major areas in this analysis, with each one of them holding 29,9% of all publications. The biggest sub-fields in each of these major areas were the ones that involved supplier selection problems.

The second topic analyzed in general analysis was the distribution of type of research developed by the studied authors. The options were *Application, Comparison, Review* and *Development* papers. Some papers had more than one type of research at the same time. The great majority of papers were, as observed in Table 38, of the *Application* type (appearing in 93,63% of papers), which consists in the researches where MCDM methods were applied to solve either a practical or an illustrative problem.

The third analysis performed was the classification of authors and of papers by relevance. The factor considered as the parameter to measure the relevance of papers and authors was their number of citations. If authors had more than one publication, their citation numbers would be summed. Table 39 presents the 12 most relevant publication in the totality of the papers review. It is highlighted that 10 of these 12 most relevant papers are related to the subject of supplier selection, a fact that shows the popularity of this specific type of problem. The most relevant publication of all 204 papers is *Application of decision-making techniques in supplier selection: A systematic review of literature*, from Chai et al. [83], with 517 citations. The most relevant author is *GOVINDAN, Kannan* with a total number of 1098 citations from 7 publications.

The fourth performed analysis was on the most popular methods in the totality of the 204 papers, as presented by Table 40. This distribution presented the ranking of the methods that appeared the most in the publications. Fuzzy TOPSIS and fuzzy AHP were the most popular methods with 77 and 69 appearances, respectively. In this analysis it is observed that a small portion of all methods is responsible for the majority of the appearances, while many methods are responsible for the minority of appearances. The Power law distribution analysis, Figure 10, is performed to evaluate how close the behavior of the data was to the 80/20 Pareto rule. The data do not follow the 80/20 rule, but follow closely a Power law distribution.

Next, it was analyzed the participation of countries in the research, with countries from Middle East and Asia dominating the number of appearances in the development of new publications. As observed in Table 41, India, Turkey, Iran and China are the countries with the strongest representations, with 52, 33, 28 and 20 appearances each, respectively. A similar behavior to the one observed in the methods distribution is noticed in the countries' data as well. The Power law distribution analysis is performed on this data, as seen in Figure 11. In order to observe a perfect Power law behavior, in the sense of a perfect 80/20 rule, more data is needed. Needless, is to say, that reality

is not perfect, and the two examples considered follow a Power law distribution, as could be observed by the graphs and by the corresponding regression coefficients.

Finally, additional information is brought through the analysis of the number of publications by year, showed in Figure 12, and the distribution of most chosen journals and conferences for publishing the papers, in Table 42. *Expert Systems with Applications* was the most popular journal, with 21 (10,3%) papers.

Later on, in the present sub-chapter, commentaries and observations with the perspective of each of the main methods were developed, to aid the readers in better understanding the different variations and combinations on the applications of such methods throughout the studied papers.

All this information put together gives a complete, deep and wide overview to researchers, students, practitioners, enterprises and other interested parties on the most relevant applications of the MCDM methods in solving decision making problems in a company's environment.

CONCLUSIONS

4 CONCLUSIONS AND PROPOSALS OF FUTURE WORKS

4.1 CONCLUSIONS

The aim of the present work is to ultimately help researchers, practitioners, enterprises, students and any other interested in solving decision making problems with MCDM methods in a company's environment. It should contribute with giving them a proper overview of methods and areas of application allocated to each problem.

The methodology of research applied, is limited only in areas related to companies' environment, focusing com MCDM methods applications, comparisons, reviews and developments. The literature research followed the criteria suggested by the PRISMA methods, and after filtration, ended up with 204 research papers on the interested subject. The papers were divided in five major areas of applications, and many sub-areas inside of them, so that it would become easier for the reader to identify specific papers and identify patterns in the usage of the methods.

A quantitative analysis was performed, developing a statistical analysis bringing in-depth understanding of many important information not seen at first with the presented list of papers. AHP and TOPSIS, with their variations, are appointed as the most popular and relevant methods in this scenario, and therefore highly recommended due to their versatility and applicability. Counting their pure forms and fuzzy variations, together both methods appear 215 times in the 204 papers. VIKOR is a relatively new method that is also relevant for its simplicity and versatility and is very popular. The Asian and Middle East countries like India, China and Iran, as well as Turkey are the most relevant in these paper productions. Together they appear 133 times in the 204 papers. The journal most times chosen for publications is Expert Systems with Applications, with 10,3% of all publications. A percentage of 93,6% of papers researched is of the application type. The most relevant areas in a company's environment in terms of publications were *Supply Chain Management and Logistics* and *Environmental Management*, with 61 papers present in each of them, from 2012 to 2018. Both methods and countries final distributions had a behavior close to the 80/20 rule of Pareto, exposed by Power law distributions.

Many applications could be seen for each method, either in their pure or in many of their variated forms, in different combinations, forming different hybrid methods. This characteristic of the papers encountered allied with the diversification of areas of application, has as consequence the offering of a vast range of examples for readers, researchers and practitioners, becoming a very useful manual for aiding in several types of decision making problems that can be faced by them in the future, as well as serving as a source for making comparisons.

Among other contributions, this work adds up to the current body of knowledge of MCDM methods applications in the business environment, with the already mentioned

vast range of presented methods, a diverse number of combinations among them, and many application areas. This study was also very important for me, the author, opening my horizons for business areas and actions once unknown, creating for me a more wide and complete understanding of the business environment.

4.2 PROPOSALS OF FUTURE WORKS

As with every kind of work ever created, in many ways there could be improvements in the current work, that may be stated as suggestions and proposals for future projects. The database is something that always can be improved, either in better delineated definition of areas or methods researched, as well as in a bigger number of publications present in the papers research. The areas also could be expanded to branches like entrepreneurship or information technologies, and methods could be expanded beyond MCDM techniques, to make the work become an ever more complete manual for comparison and reference in decision making problems. All the data collected in this work could as well be used for creating a new combination of methods, that is, a new hybrid. Also, further study could be done in how to measure papers and authors' relevance, by combining number of citations with journals importance weights. For the purpose of being a true and deep guide for readers, the work could also have in the state of art an in depth presentation of all featured methods, and not only the main ones. In the same way, the final commentaries on the different applications of each method could be broadened to the less popular methods that also appeared in the study.

Another interesting tone that the work could have would be the usage of one decision making method for deciding which of the reviewed methods is the best according to a specific given problem, like green supplier selection, for example. Going even further, with the purpose of making this content useful and agile in the companies' environment, a software could be created, in which the type of problem is expressed as an input by the company's employee, and then it chooses the most suitable methods for the given problem by using the presented database. As an extension, the same software could also provide the option of applying the chosen method or methods, solving the problem right away.

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ANNEXES

6.1 ANNEX 1

6 ANNEXES

6.1 ANNEX 1

List of Journals and Conferences with only 1 Publication
2nd International Materials, Industrial, and Manufacturing Engineering Conference
Alexandria Engineering Journal
Neural Computing & Applications
Fuzzy Optim Decis Making
5th World Conference on Educational Sciences
Journal of Natural Gas Science and Engineering
International Conference on Robotics and Smart Manufacturing
Industrial Marketing Management
Engineering Applications of Artificial Intelligence
Journal of Applied Logic
Modern Building Materials, Structures and Techniques
INTERNATIONAL JOURNAL OF LOGISTICS: RESEARCH AND APPLICATIONS
12th International Strategic Management Conference, ISMC
Omega
Cogent Business & Management
INTERDISCIPLINARY JOURNAL OF CONTEMPORARY RESEARCH IN BUSINESS
International Journal of Logistics Research and Applications
Revista Facultad de Ingeniería
Third International Conference on Cloud and Green Computing
World Applied Sciences Journal
WIRELESS COMMUNICATIONS LETTERS
8th International Conference on Network and Service Management
Arab Journal of Science and Engineering
Journal of Mining Science
Global Journal of Enterprise Information System
INTERNATIONAL STRATEGIC MANAGEMENT REVIEW
Journal of Intelligent Manufacturing
The International Journal Of Engineering And Science
Beni-Suef University Journal of Basic and Applied Sciences
17th International Conference in Knowledge Based and Intelligent Information and Engineering Systems
International Conference on Industrial Engineering and Operations Management
Walailak J Science & Technology
Journal of Engineering Design
Advanced Engineering Informatics
Proceedings of the International Symposium on the Analytic Hierarchy Process
Social and Behavioral Sciences
Cybernetics and Systems
International Journal of Information Management
Applied Mathematics and Computation
8th International Strategic Management Conference
Eurasian Journal of Business and Economics
Technological and Economic Development of Economy
Technology in Society
International Entrepreneurship and Management Journal
XVIII Annual International Conference of the Society of Operations Management
Computers and Electronics in Agriculture
SpringerPlus
Journal of Knowledge Economy
IOP Conf. Series: Materials Science and Engineering
Electronic Business Journal
International Journal for Quality Research
Journal of Environmental Management
Science of the Total Environment
2nd International Conference "Green Cities - Green Logistics for Greener Cities"
International Conference on Materials Manufacturing and Modelling
Journal of Manufacturing Systems

Procedia Engineering
51st CIRP Conference on Manufacturing Systems
18th Euro Working Group on Transportation
Sustainable Production and Consumption
Global Business Review
International Conference on Modeling, Optimization and Computing
Environmental Earth Sciences
7th International Conference on Operations Research and Enterprise Systems
Human and Ecological Risk Assessment: An International Journal
IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT
12th Global Conference on Sustainable Manufacturing
IOSR Journal of Engineering
International Journal of Computer Integrated Manufacturing
International Journal of Supply and Operations Management
Journal of Industrial and Production Engineering,
International Journal of Computer Applications
Journal of Applied Research on Industrial Engineering
International Journal of Computer Science and Information Technology & Security
The Third Information Systems International Conference
International Journal of Environmental Science and Development
8th International Scientific Conference “Business and Management 2014
International Journal of Advances in Engineering & Technology
Intertnational Journal of Advanced Manufacturing Technologies
International Journal of Safety and Security Engineering
Applied Ergonomics
3rdInternational Conference on New Challenges in Management and Organization: Organization and Leadership
International Journal of Economy, Management and Social Sciences
Open Journal of Business and Management
Kuwait Chapter of Arabian Journal of Business and Management Review
Inzinerine Ekonomika-Engineering Economics
International Journal of Managing Value and Supply Chains