Business and Economics Faculty

FINAL YEAR PROJECT

INTERNATIONAL PROGRAM OF BUSINESS ADMINISTRATION AND MANAGEMENT

SELECTION OF GLOBAL DELIVERY MODELS IN PROJECT MANAGEMENT. FUZZY EXPERT SYSTEM AS A MULTI-CRITERIA DECISION TOOL.

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ABSTRACT

The developments in Information and Technology (IT) have eliminated the physical boundaries for the exchange of information and have made possible the communication, interaction and collaboration of individuals regardless of their geographical location. As a result, projects that were traditionally performed by pure face-to-face teams are now being executed by virtual teams whose team members are distributed globally, thus, following a global delivery model. The world leader project management methodology, the Project Management Body of Knowledge (PMBOK) is already recommending the usage of multi-criteria decision tools to assist project managers with such complex decision making, however, there is a lack of guidance on specific tools or techniques to use. The purpose of this project is to propose a fuzzy expert system as the tool to assist project managers with selecting the most suitable global delivery model.

KEYWORDS

Fuzzy Expert Systems, Global Delivery Models, Virtual teams

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1. INTRODUCTION

1.1. Importance, motivation and objective

The dramatic technological changes occurring during the past century have revolutionized every aspect of life. The developments in Information and Technology (IT) and the expansion of the Internet have eliminated the physical boundaries for the exchange of information and have made the communication, interaction and collaboration of individuals possible regardless of their geographical location. The evolution of the Internet and IT has not only had an impact in the field of IT, but rather, it has influenced economics, culture and every other aspect of society (Leiner et al. 2009). Technology has allowed us to interact as a global society in many aspects of our lives, and has specifically facilitated the accomplishment of business across geographic boundaries (Martinelli, Rahschulte, and Waddell, 2010).

Narrowing the picture, as an indirect consequence of globalization and IT developments, the business landscape has changed (AIM Strategies 2010). The development of IT tools such as web-conferencing systems, instant communication, intranets, cloud systems, whiteboards and SAAS (Software as a Service) among others have allowed the appearance of virtual teams, which are made up of individuals in multiple locations working toward a common team goal or mission (Milhauser, 2012). Project management is evolving from traditional project work towards a global project management, projects that were traditionally performed by pure face-to-face teams are now being delivered across borders using virtual teams, organizations are now adopting global delivery models.

A global delivery model can be defined as the process of executing a project using a team that is distributed globally, that is, that the team resources are located at multiple sites across the globe. The amount of possible combinations of the number of geographic locations from where a project can be executed and the amount of team members allocated in each location is limitless, complexity is undoubtedly a relevant characteristic of today's project management reality.

Besides, several academic studies have been conducted in the field of virtual project management and they have identified the challenges associated with the use of virtual teams compared to the traditional face-to-face project teams (Berry, 2011; AIM Strategies, 2010; Chhay et al., 2013; Kirkman et al., 2002; Malhotra et al., 2007; Jarvenpaa, 1998;

Brake, 2006; Amir, 2010; Hunsaker et al., 2008; Pauleen, 2003). These numerous challenges present potential threats to project success and thus, the decision of the delivery model becomes of crucial importance and new criteria should be considered when making the decision to try to minimize the threats associated with using global delivery models through virtual teams.

An increasing number of organizations are implementing their business operations through projects (Kerzner, 2001). The Project Management Institute (2013) defines a project as "a temporary endeavor undertaken to create a unique product, service, or result". Several professional organizations have developed project management methodologies that define the principles, techniques, processes, guidelines and best practices used in order to manage a project and meet its requirements (PMI 2013). The project Management Body of Knowledge (PMBOK) remains the world leader in project management providing the most comprehensive framework (Errihani, Elfezazi and Benhida, 2015).

The results of several studies conducted (White and Fortune, 2002; Shenhar, Dvir et al., 2002a; Shenhar, Tishler et al., 2002b; Joslin and Müller, 2015) support the fact that using a project management methodology and the correct choice of tools, techniques, and processes are indeed factors that are significantly correlated to project success. However, are these project management methodologies adapted to the current reality of global project management described before? Do they provide support to project managers to select the appropriate global delivery model? The answer would be 'not really'.

The Project Management Body of Knowledge (PMBOK) is already recommending the use of multi-criteria decision tools to assist project managers with the selection of the team members and their location; nevertheless, there is a lack of guidance on specific tools or techniques to use.

The purpose of this work is to propose a fuzzy expert system as the tool to assist project managers with the selection of the most suitable global delivery model. For this purpose, I will provide an introduction to the basic concepts of fuzzy logic and I will explain through an example how I envisage a project manager would make use of a fuzzy expert system to select the global delivery model.

1.2. Contribution

This paper tries to fill an existing gap in project management methodologies by proposing a tool to help project managers to make a decision on which global delivery model to use. The application of a fuzzy expert system to help project managers to an example will allow making conclusions on the benefits and challenges resulting from the use of such tool in this decision making context.

The idea that drives this project came from my experience as an intern during the last semester of my degree. My internship took place in Everis, a multinational consulting company with offices and high performance centers in 15 countries across Europe, USA and Latin America. I was located in the office in Brussels and I was part of a team developing a project for the European Commission, part of the team was working from the office in Brussels with me, but another part was being delivered by the office from Barcelona. During my experience I became aware that ours was not a unique case, many of the projects that were performed in the office also had their team members distributed across the world in other offices. After discussing with project managers I realized that there was not a standardized procedure or method to follow in order to choose which offices would be involved in the delivery of each project, that is, the delivery model. From a practical perspective, this research is expected to contribute to the delivery model selection process of Everis and other multinational companies who have to face this decision.

The rest of the project is structured as follows: Section 2 presents the theoretical framework: the state of art of the project management field of study and more specifically the PMBOK methodology; in Section 3, I describe the changing project management reality and in Section 4, I provide an overview of the need for a multi-criteria decision tool, with an accompanying proposition. Section 5 contains the proposed tool: a fuzzy expert system, the theoretical basis behind it and an implementation will be found within the section. Discussion of the findings, conclusion and future research are presented at the end of the document.

2. THEORETICAL FRAMEWORK

A thorough review of the literature was performed in order to gain a better understanding of the theoretical context surrounding the topic of project management.

In this section I will explain the main concepts regarding project management and I will present an overview of the most widely recognized project management methodology PMBOK.

2.1. Project management, generalities and state of the art

2.1.1. Project Definition

An increasing number of organizations are implementing their business operations through projects (Kerzner, 2001). The British Standards Institution (2000) defines a project as "a unique process, consisting of a set of coordinated and controlled activities with start and end date, aiming to complete a goal according to specific requirements". The Project Management Institute (2013) defines a project as "a temporary endeavor undertaken to create a unique product, service, or result." Temporary means that projects has a definite beginning and end, while unique implies that the outcome of the project is different from other projects in some distinguishing way even if there are repetitive deliverables within the project.

2.1.2. Project Management and Project Management Schools

Project management is described as the application of knowledge, tools, skills and techniques to project activities to meet the project requirements (PMI, 2013). In order to meet these project requirements, project managers have to plan, organize, direct, and control company resources and balance the competing project constraints: time, cost, performance and customer relations (Kerzner, 2009). Figure 1 is a representation of project management.

Figure 1: Project management. Source: (Kerzner, 2009)

The project manager is the person assigned by the performing organization to lead the team that is responsible and accountable for the planning and performance of the project and for achieving the project objectives (PMI, 2013).

Today, the concept behind project management is being applied in such diverse industries and organizations as defense, construction, pharmaceuticals, chemicals, banking, hospitals, accounting, advertising, law, state and local governments, and the United Nations. (Kerzner, 2009)

Following the increasing use of project management across these various sectors, several institutions and project management schools have emerged with the purpose of establishing standards, guidelines and certifications to improve project management practices.

Among the best known organizations, some of which have been referenced along this document, there is IPMA (International Project Management Association), APM Group (association for project management), AFITEP (Francophone Association for Project Management), and the PMI (Project Management Institute). This last one is the most important and active among these organizations (Errihani et al., 2015).

2.1.3. Project Management Methodologies

A project management methodology is defined by the Project Management Institute (2013) as a set of methods, techniques, procedures, rules, templates, and best practices used on a project. Other definitions do not differ significantly, Charvat (2003) defines it as a set of guidelines and principles that can be tailored and applied to specific project.

Institutes and professional project management associations have developed project management methodologies in order to improve project effectiveness and increase project success rates (Vaskimo, 2011).

Project success is one of the most researched fields in project management. Success is a multidimensional construct that is measured by project quality, timeliness, budget and specification compliance, degree of customer satisfaction and potential for future work (PMI, 2013; Kerzner 2009). The results of several studies conducted (White and Fortune (2002); Shenhar, Dvir et al., 2002a; Shenhar, Tishler et al., 2002b; Joslin and Müller, 2015) support the fact that the experience of using a project management methodology and the correct choice of tools, techniques, and processes are indeed factors that are significantly correlated to project success. Authors like Charvat (2009) and Joslin and Müller (2015) recognize in their work the need for a formal, comprehensive and appropriate project methodology to lead the work of all team members throughout the life cycle of a project.

The Project Management Institute aforementioned developed the Project Management Body of Knowledge (PMBOK), which is a methodology that incorporates standards, methods, processes and practices established and it remains the world leader in the project management field (Errihani, et al., 2015). The PMP certification (Project Management Professional) from the PMI whose content is based on the PMBOK is among the most recognized and appreciated certifications (Errihani, et al., 2015). Besides, most research conducted in the field of project management such as the ones referenced herein and even books such as "Project Management : A Systems Approach to Planning, Scheduling, and Controlling" by Harold Herzner are based on the structure of PMBOK.

In light of the above, due to its extensive recognition and usage among both professionals and researchers I have selected the PMBOK methodology to be the theoretical basis for this study. In the following section I will introduce such methodology and its main components.

2.2. Project Management Body of Knowledge: PMBOK

According to the Project Management Institute (2013), "Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements." Effective project management is accomplished through the appropriate application and integration of project management processes.

A process is "a set of interrelated actions and activities performed to create a pre-specified product, service, or result" (PMI, 2013). Each process is characterized by its inputs, the tools and techniques that can be applied, and the resulting outputs.

In this methodology, 47 project management processes are grouped into five categories known as Project Management Process Groups (or Process Groups):

- **Initiating**: processes to obtain authorization to start the project
- **Planning**: processes aimed to define the scope, objectives, and course of action required to attain the project objectives through the development of the project management plan.
- **Executing**: processes to complete the work defined in the project management plan.
- **Monitoring and Controlling:** processes to track and review the progress and performance, identify changes to be made and initiating them.

- **Closing**: finalize all activities across all Process Groups to formally close the project or phase

These five Process Management Process groups are linked though the outputs they produce. The output data from one process generally becomes input data to another process. Figure 2 shows how the Process Groups interact, Monitoring and Controlling processes occur at the same time as processes within other Process Groups.

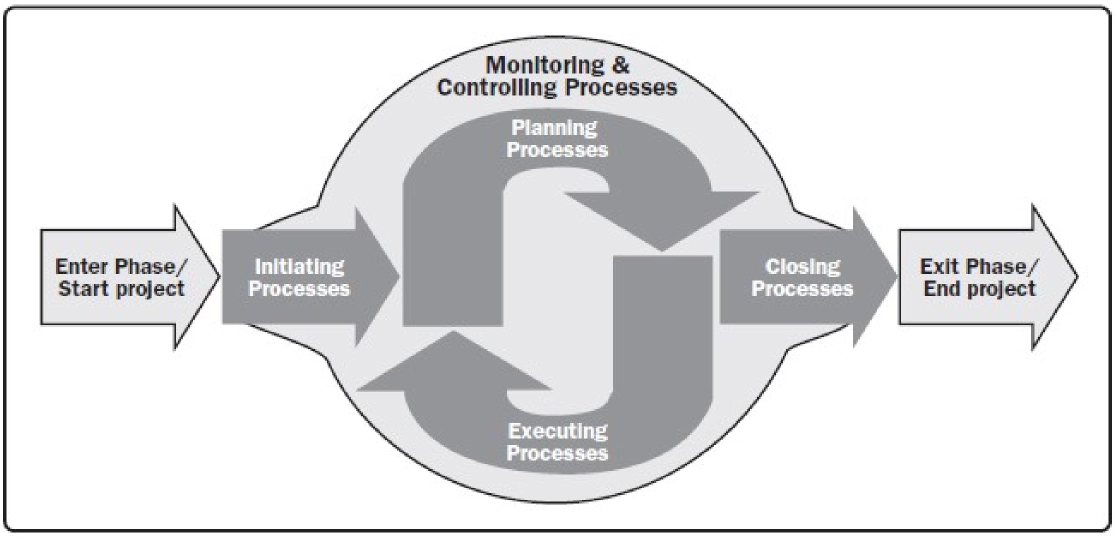

Figure 2: Project Management Process Groups
Source: PMBOK (PMI, 2013)

The 47 project management processes are further mapped to ten separate Knowledge Areas. A Knowledge Area is described by the Project Management Institute (2013) as "a complete set of concepts, terms, and activities that make up a professional field, project management field, or area of specialization". The 10 Project Management Knowledge Areas that PMBOK treats are the following:

- Project Integration Management,
- Project Scope Management,
- Project Time Management,
- Project Quality Management,
- Project Human Resource Management,
- Project Communications Management,
- Project Risk Management,
- Project Procurement Management and

- Project Stakeholder Management.

Appendix A contains a table that represents the mapping of the 47 project management processes into the 5 Project Management Process Groups and the 10 Knowledge Areas.

2.2.1.Project Human Resource Management.

In this section I will provide a more detailed view of the Human Resource Management Knowledge Area, as it is the one that most closely related to the selection of a delivery model, which can be seen as the allocation of the human resources of a project across the world.

Project Human Resource Management consists in organizing, managing and leading the project team. The project team (also referred as project staff) includes the project manager and the individuals (team members) that will carry out the work of the project to meet its objectives. This Knowledge Area involves the following processes:

1. **Plan Human Resource Management**: The process of identifying and documenting project roles, responsibilities, required skills and reporting relationships.
2. **Acquire Project Team**: The process of confirming human resource availability and obtaining the team necessary to complete project activities.
3. **Develop Project Team**: The process of improving competences, team member interaction, and overall team environment to enhance project performance.
4. **Manage Project Team**: The process of tracking team member performance, providing feedback, resolving issues, and managing changes to optimize project performance.

Acquiring Project Team is one of the key processes in project management, the team member assignments together with their resource calendars which are the main outputs of this process will be used as input data for many other processes. Failure to identify and obtain the necessary and most appropriate project team members would affect project schedules, budget, customer satisfaction, project quality, risks… This would decrease the probability of success and, in a worst case scenario, could result in project cancellation (PMI 2013). Figure 4 depicts the process inputs and outputs of this process.

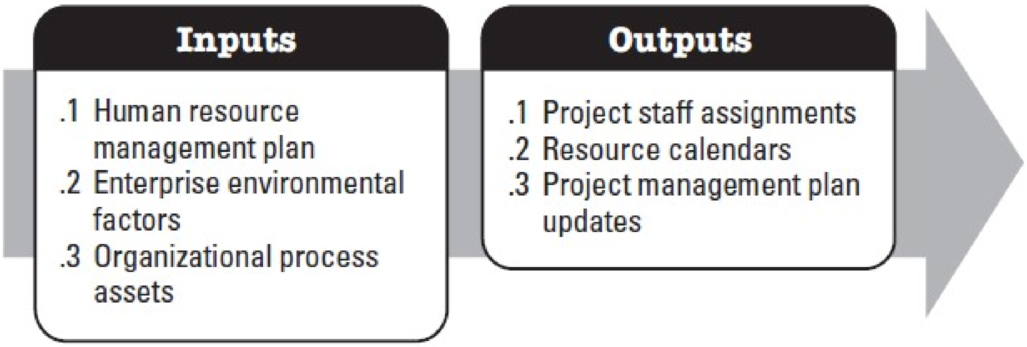

Figure 3: Acquire Project teams: Inputs and Outputs
Source: PMBOK (PMI, 2013)

One of the inputs for this process is the human resource management plan (output of the previous process, Plan Human Resource Management) which provides guidance on how the team members should be identified. It includes the roles and responsibilities that the project demands (positions, skills and competences) and project organization charts indicating the number of people needed for the execution of the project. Other inputs for this process are enterprise environmental factors such as information on human resources (availabilities, competency levels, prior experience); and organizational process assets (standard policies, procedures…).

The outcomes of this process are the identification of the team members that will work on the project (project staff assignation) and the resource calendar with the time periods that each member is available to contribute to the project. This information will be included and updated in the project management plan.

The Tools and Techniques identified as relevant and useful for this process are rather limited. In order to do the project staff assignation two steps have to be followed, selecting the team (choosing who should be part of the team) and actually obtaining it. In order to obtain the staff, PMBOK identifies as common practices pre-assignment, negotiation (with other project managers and externals) and acquisition (subcontracting). Regarding the selection of the team members, the methodology recommends the use of "multi-criteria decision analysis tools", however, no specific tool or method is recommended, just some examples of criteria to be used are given (availability, cost, experience, ability, knowledge, skills, attitude and international factors).

The lack of guidance on tools to be used to select the appropriate team members is a major limitation of this methodology especially because of the growing complexity of making this decision due to the changing landscape that I will describe in the following section.

3. THE CHANGING PROJECT MANAGEMENT REALITY

In the past few years there have been several trends that have changed the way workplace collaboration is conducted and the way organizations deliver their projects, thus, project management is now facing a different reality with new challenges to be tackled.

In this section some of the trends that have affected the way projects are managed will be presented and their impact on the project management field will be depicted.

3.1. Trends affecting project management

The most dramatic change during the past years is undeniably the advancements in Information and Technology (IT) that have influenced economic, culture and every other aspect of society (Leiner et al. 2009) and that have allowed us to enter in the era of information society. The globe is nowadays entangled by millions of networks that connect each and every person in the world; there is a global connection between all continents, countries and people that make the availability and exchange of information almost limitless. These developments have dissolved the barriers of time and physical boundaries and have made possible a global society where the communication, interaction and collaboration between individuals are possible regardless of their geographical location. Shaughnessy (2015) states that there is a digital revolution that results in a "business anywhere, anytime" approach. This approach is undoubtedly changing the field of project management too.

> "Gone are the days when a project manager could manage by walking around… […] in the reality of today's business world, the chances are very good that you will be collaborating with colleagues in other countries. It is best to get ready" (Sangwan et al. 2007).

One of the consequences these technology developments have brought is the accomplishment of business across geographic boundaries (Martinelli et al., 2010). By using technology, project-based organizations are able to perform tasks and deliver their projects across time, distance, and organizational boundaries. The economy has come to the point where resources can be recruited from all around the world to contribute to the same project remotely, without even having to be in the same country. Project management is developing from traditional project work towards a global project management, projects that were traditionally performed by pure face-to-face teams are now being delivered across borders using a virtual team or hybrid teams: organizations are now adopting a global delivery model.

3.2. Increased complexity in decision making: Global Delivery Model selection

The global delivery model can be defined as the process of executing a project using a team that is distributed globally, that is, that the resources located at multiple sites across the globe. Global delivery models can take various forms depending on how the tasks are divided among the members that are separated geographically. This allocation of resources can be made with respect to several criteria other than the location of the client, the project manager or the other team members.

Figure 4 represents one of the many possibilities for the allocation of the project staff: part of the team can be deployed at the client´s site (onsite) or from an office close to the client (offsite) gathering project requirements and doing follow-ups, while other team members execute other parts of the project remotely from other parts of the world (off-shore). The amount of possible combinations of the number of geographic locations from where a project is executed and the amount of team members allocated in each location is limitless, complexity is undoubtedly a relevant characteristic of today's project management context.

Figure 4: Global Delivery Models

3.3. Increased importance of the decision making: Global Delivery Model selection

IT developments have opened the gates for virtual collaboration (Brake 2006). Global delivery models are now possible thanks to the feasibility of using virtual and hybrid teams. A virtual team can be defined as a distributed team with dispersed team members, cultures, knowledge and physical locations that share a common goal of carrying out interdependent tasks relying on Information and Communication Technologies (ICTs) as the primary tool for communication rather than face-to-face contact. In a hybrid project team, team members meet and communicate face-to-face occasionally, whilst working virtual in the majority of the time. Hybrid project teams therefore have a combination of the characteristics found in a traditional face-to-face teams and virtual teams.

Neither geographic, nor informational boundaries are real anymore, with the help of online tools, team members can now communicate and cooperate virtually, while project managers coordinate and control them from distance. Project teams can operate across the world smoothly with the use of virtual collaboration tools, although not without any challenges. Several academic studies have been conducted in the field of virtual project management and its challenges and advantages (Berry, 2011; AIM Strategies, 2010; Chhay et al., 2013; Kirkman et al., 2002; Malhotra et al., 2007; Jarvenpaa, 1998; Brake, 2006; Amir, 2010; Hunsaker et al., 2008; Pauleen, 2003).

The main advantages derived from working with virtual teams are the cost reduction opportunities (due to the access to cheaper labor and the savings from travelling costs or relocations, among others), the access to a bigger labor pool and the follow-the-sun approach that allows exploiting the time differences having an efficient team 24 hours a day.

The main challenges identified by the literature are summarized in Table 1. They are grouped according to the type of distance that causes them; difference in time zones, the geographical distance and socio-cultural differences. The challenges are further grouped to show if they are threatening the communication and cooperation among team-members, or the ability of project managers to coordinate the team activities and progress or control their performance. These challenges are a threat the overall project success.

	Communication	Coordination	Control
Temporal distance	-Reduced opportunities for synchronous communication due to time zone differences	-Higher costs for coordination related activities, project managers have to work out of the regular hours	-Deadlines can be subject to delays due to work being spread over different time zones
Geographical distance	-Difficulties in sharing knowledge and experience between team members -Difficulties to develop trust among the team -Lack of face-to-face contact can lead to feelings of isolation that affect work performance	-Less informal contact which can decrease critical task awareness and further delay response -Lack of training and support from the project manager, other team members and the company	-It is challenging to communicate a coherent vision and strategy across countries -Lack of engagement and commitment as some members have never met personally -Free riding because of lack of personal relationships and difficulties to control
Socio-cultural distance	-Increased probabilities of socio-cultural misunderstandings -The language used for communication might not be the mother tongue of the team members leading to misinterpretations	-Inconsistency in work practices across different cultures can hamper effective coordination -The increased instances of misunderstanding can lead to reduced cooperation	-Different cultures' perception of authority and hierarchy can harm team morale -Managers must adapt to local rules and regulations based on socio-cultural differences

Table 1: Challenges of using Virtual Teams

From this table it can be concluded that the use of virtual teams compared to the traditional face-to-face project teams bring more threats to the project success into the picture which makes the decision of the delivery model even more important than before. Besides, new criteria should be considered when making the decision to try to minimize the threats associated with using global delivery models through virtual teams; these increase in the number of criteria to consider results in a further increased complexity of the decision making process.

4. MULTI- CRITERIA DECISION ANALYSIS TOOL

4.1. Need for tools and techniques to assist decision-making

During this project I have identified the need to develop further the project management methodology PMBOK to provide project managers with tools and techniques that will help them make informed and objective decisions on the project delivery model, which means selecting the location of the project team members.

The most widely used and recognized project management methodology; the Project Management Body of Knowledge (PMBOK) was described in section 2.2. In this section I focused on the human resource management Knowledge Area in order to gain a better understanding of the assistance project managers are currently given if they follow such methodology. It was found that the usage of an objective multi-criteria decision tools to select team members and their location is recommended by the methodology, however, there is a lack of guidance on specific tools or techniques to use.

The analysis of the changing project management context (section 3) led to the conclusion that selecting the location of the project team members has now become a complex and time-consuming process due to the great number of possibilities and combinations for allocating the resources geographically and the new criteria that should be taken into account. Apart from the complexity of the decision making process, this section also made evident the increased importance of selecting the project team, as working with virtual/hybrid teams allocated all over the world bring new threats to the project success into the equation.

This identified increased complexity and importance of selecting the project staff has brought into light the upcoming need to provide guidance on tools and methods to assist project managers.

4.2. Multi-criteria decision analysis tool proposition

It has become clear that complexity of selecting the location of the project staff has been continuously increasing. For this reason, the decision-making process costs much more time and it may even be impossible to determine a suitable decision without the assistance of an objective and standard method or tool.

The project human resource allocation problem can be represented as a selection process of potential sites in order to satisfy all applied requirements in the best possible way. Due to the changing project management reality, a wide range of criteria is required to be taken into account simultaneously before a decision about the delivery model can be reached. Thus, project managers are in need of a multi-criteria decision analysis tool.

Apart from the increased number of criteria to be considered, it should also be noted that some of these criteria are set with the objective to mitigate the negative impact of virtual teams' challenges in project success. Some of these criteria are related to international factors resulting from cultural, geographical, and temporal distance. It can then be concluded that a wide variety of subjects are involved in this decision making process and thus, expert knowledge in various fields is required.

To address the above aspects, I propose a fuzzy expert system as the method to assist project managers in the delivery model selection.

5. FUZZY EXPERT SYSTEM

The idea of fuzzy logic was invented by L. A. Zadeh in 1965, Professor of the University of California at Berkeley. Zadeh (1965) described the term fuzzy logic as follows:

> "Fuzzy logic is determined as a set of mathematical principles for knowledge representation based on degrees of membership rather than on crisp membership of classical binary logic"

The proposed expert system is based on Fuzzy Inference Systems (FIS). Fuzzy Inference Systems are a way for mapping an input space to an output space by using fuzzy logic (Chen, 2000).

Due to their intuitively and simplicity, Fuzzy Inference Systems have been applied in several fields (Ross, 2004). Implementations of fuzzy logic include applications in industrial manufacturing, automatic control, banks, automobile production, hospitals, libraries and academic education. I now propose to apply it in the project management field.

I will first introduce the main concepts of Fuzzy Inference Systems to then show through an example the potential they have to assist project managers with making a decision on the delivery model to be used.

The theoretical concepts explained along this section have been retrieved from research from Chen (2000); Ross (2004); Piltan & Sowlati (2016) and Yatsalo, Korobov & Martinez (2017).

5.1. Theoretical basis

Fuzzy inference is the process of mapping input variables to an output space via fuzzy logic based mechanism which consist of If-Then rules, membership functions and fuzzy logical operations.

The most commonly used technique for fuzzy inference is the Mamdani method. The Mamdani-style fuzzy inference process as depicted in Figure 5 involves three steps: fuzzification of the variables, the inference engine (rule evaluation and aggregation of the rule outputs) and defuzzification. These steps will be described along this section, the two last steps won't be explained in much detail due to the technical complexity of the processes involved.

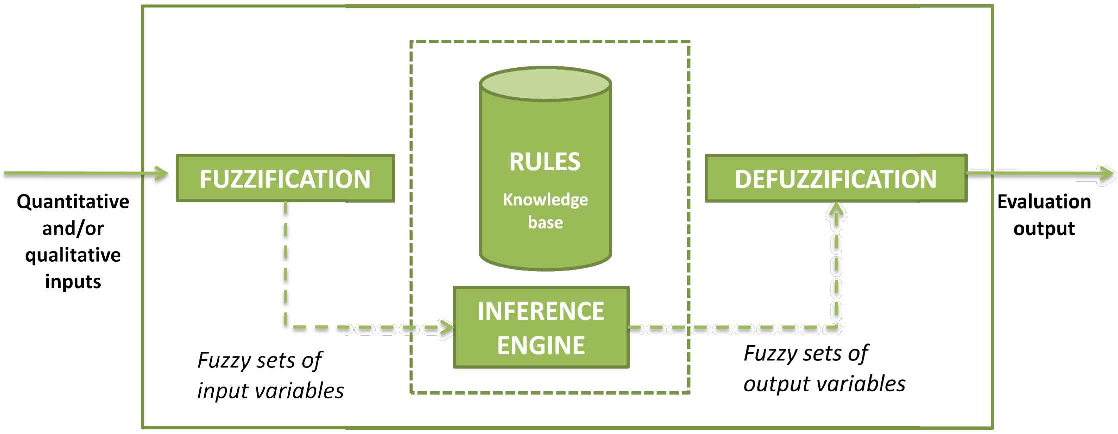

Figure 5: Mamdani Fuzzy Inference Process

5.1.1.Fuzzification of the data

The first step, fuzzification, consists in converting classical or crisp data into fuzzy data via Membership Functions. Crisp numerical values of input variables are transformed into equivalent membership values of fuzzy linguistic sets. The membership values describe the degree of belonging to a fuzzy set.

Fuzzy set: A variable can be described by linguistic terms and a linguistic term is represented by a fuzzy set. With classical sets, an element either belongs to the set or it doesn't belong. With Fuzzy sets, elements have a degree of membership between completely belonging to the set and completely not belonging to the set. Both input and output variables have to be described using linguistic terms.

A membership function is a curve that assigns to each point in an input/output space the corresponding membership value, or degree of membership to a fuzzy set.

Figure 6 depicts a variable (Height) with three linguistic terms (Short, Average, Tall). Each linguistic term has its own membership function.

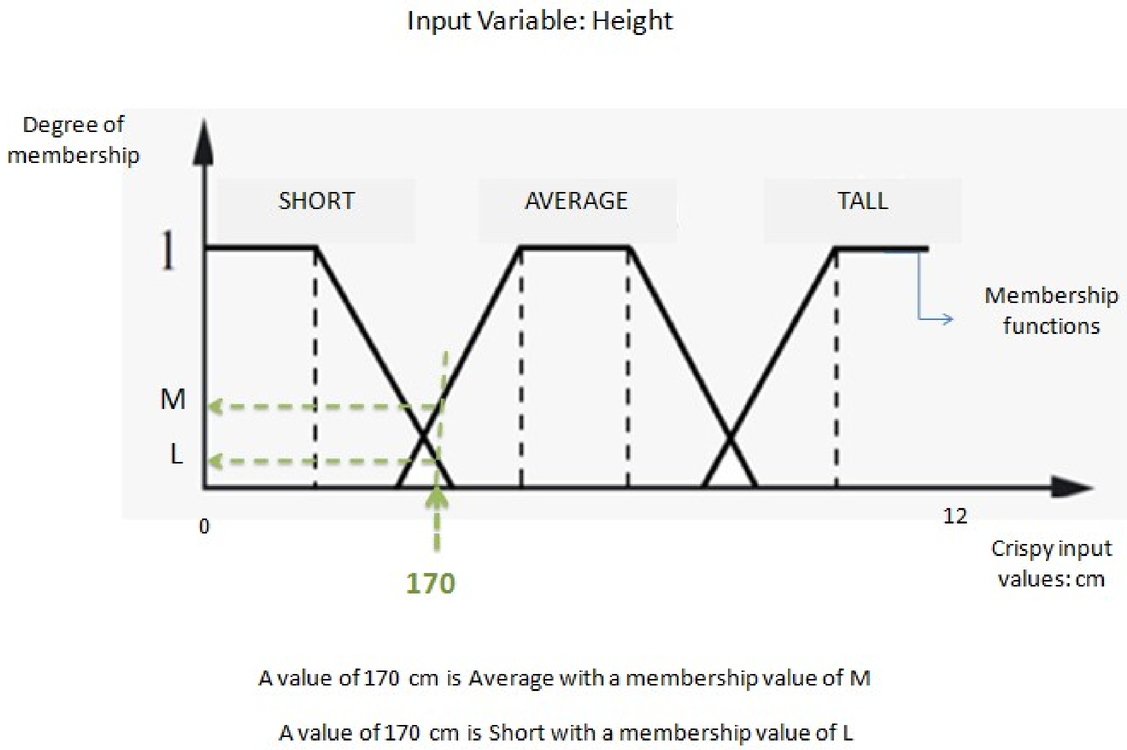

Figure 6: Membership Functions

For every crisp value the variable can take (x axis), a membership value between 0 and 1 (y axis) is assigned to each linguistic term via the Membership Functions. A value of 170 cm belongs to the fuzzy set Average with a membership value of M and to the fuzzy set Short with a membership value of L.

5.1.2.Fuzzy Inference Engine

This step consists in combining membership values with the fuzzy rules to derive a fuzzy output set. Fuzzy rules can be considered as knowledge base as they are formulated by an expert in any related field of application.

If-Then rules: indicate how to map input variables to the output space. A fuzzy If-Then rule follows the form:

If x is α, Then y is β

The first If-part is called the antecedent, where x is input variable and α is a fuzzy set of the input variable x. The rest Then-part is called the consequent, and y is output variable and β is a fuzzy set of the output variable y.

In the antecedent, logical operators like are AND, OR, NOT can appear as the following:

If x is α AND/OR z is **Ω**, Then y is β

If x is NOT α, Then y is β

The logical operator AND can be easily defined by function min, so the statement 'A AND B' becomes equivalent to min (A, B). Logical OR can be expressed by function max, thus 'A OR B' is equal to max (A, B). The statement 'NOT A' could be defined as 1-A.

Aggregation: Aggregation is the process of unification of the fuzzy outputs of all rules stated. In order to make a decision, the rules have to be combined in some manner. Through an aggregation process, the Inference system combines the fuzzy outputs obtained by each rule into single fuzzy sets.

5.1.3.Defuzzification

From the previous step, aggregated output fuzzy sets are obtained. In order for project managers to make decisions, a defuzzification process is necessary. Through a defuzzification process a crisp output value will be obtained.

5.2. Application of a Fuzzy Expert System

In this section, I will explain through an example how a project manager can make use of a fuzzy inference system to make a decision on the delivery model to be used.

The purpose of the application of fuzzy logic to an example is to show how I envisage that fuzzy logic can assist project managers. The focus of the section will be on the steps or actions that project managers have to perform to design the fuzzy expert system. The selection of variables and the rules set won't be analyzed in great detail. I will provide an example with a limited number of simple and easily understandable input and output variables with few rules that are not very complex and even self-evident. The example will then be a simplified representation of a real decision making process. In a real situation however, as it was presented along the project, the experts will have to define and use a large number of complex variables and rules.

5.2.1.Empirical context

Everis is a multinational consulting company which since 1996 offers business solutions, strategy, development and maintenance technological applications and outsourcing. The company, active in telecom, financial entities, industry, utilities, energy, public management and health, invoiced 816 million Euros in the fiscal year 2014 and has an average annual growth of 20%. Over 17000 people work in offices and high-performance centers in 15 countries across Europe, USA and Latin America. Everis is present in 7 European countries (Belgium, Spain, Italy, Netherlands, Luxembourg, Portugal and the United Kingdom), 7 in America (Argentina, Brazil, Chile, Colombia, Mexico, Peru and the United States) and in Morocco.

Everis opened its office in Belgium in 2010 as key point of Everis growing strategy with the aim to cover, coordinate and deliver high quality services to all European Institutions but since 2014 it also focuses on Insurance, Banking and recently Industry. Within few years, the office has grown to 450 employees compared to the 350 in the previous year and in the fiscal year 2015 it reached more than 45 million Euros, realizing double digit growth (20%).

The office in Brussels is the base for operations within the European Organizations. Since the fiscal year 2011, Everis' revenue in this sector multiplied fourfold achieving 40 million Euros, operating in 10 EU and neighboring countries and in almost 30 bodies. During the last semester of my bachelor degree I was an intern located in this office as part of a team developing a project for the European Commission. Within my project, some team members were working from the office in Brussels with me, but part of the project was being delivered by the office from Barcelona. Looking at the numbers of the office one can easily reach the same conclusion as I did during my experience there, ours was not a unique case, many of the projects that were performed in the office also had their team members distributed across the world in other offices. However, as I explained in the introduction, after discussing with project managers I realized that there was not a standardized procedure or method to follow in order to choose which offices would be involved in the delivery of each project, that is, the select the global delivery model.

The following section provides insights on how I envisage project managers such as the ones from Everis can make use of fuzzy expert systems.

5.2.2. Implementation

In order to develop a fuzzy expert system, project managers will follow the following steps:

1. Specify the problem
2. Select input variables
3. Define linguistic variables and determine fuzzy sets
4. Construct fuzzy rules
5. Build the Fuzzy Expert System

Step 1: Specify the problem

First of all, the project manager would have to identify the output variables that will help them in the decision making. The decision project managers have to make is selecting the delivery model for the project. As I showed in section 3.1, due to the IT developments the amount of possible combinations of the number of geographic locations from where a project is executed and the amount of team members allocated in each location is limitless, therefore, in order to make the decision the project manager has to identify which of the possible combinations of locations is the most suitable for the project. The suitability of each of the possible combinations is then the output variable.

In this example I will assume that the project can be delivered allocating project staff among three locations: A, B and C. Taking Everis as an example, this would for example mean using the offices from Brussels (A), Morocco (B) and/or Madrid (C). Having three potential locations where to allocate the team members imply having the combinations depicted in Figure 7: dividing the team among the three locations (A+B+C) or using only two locations (A+B, A+C or C+B). For the sake of simplicity, the example will focus on the suitability of the Combination 2 (A+B).

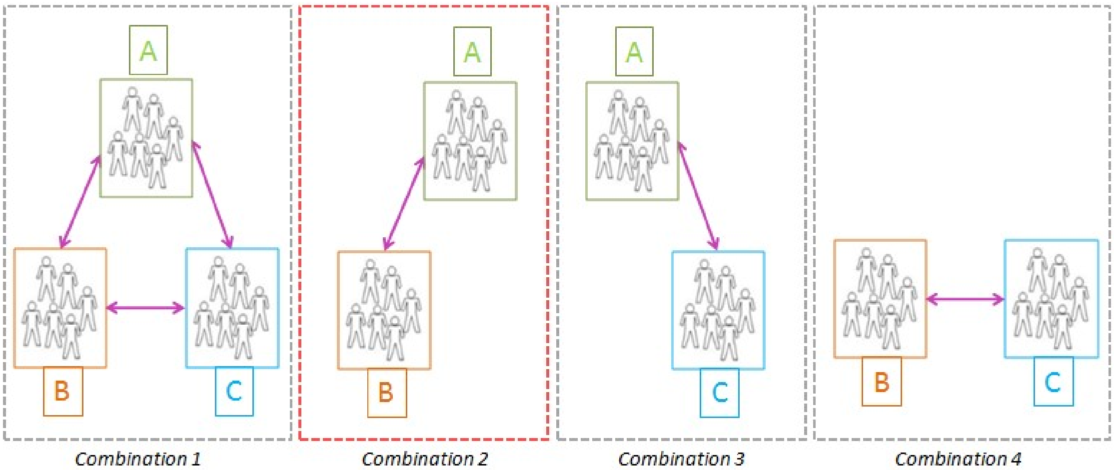

Figure 7: Combination of Global Delivery Models

Step 2: Select input variables

As a second step, the project manager has to decide the input variables that would serve as the basis for the criteria to make the decision. The identification of these factors is a complex endeavor that requires the expertise of project managers. There is a wide range of factors that affect the decision of the delivery mode; some of these were described in broad terms in the PMBOK methodology. Some are related to the project itself like the number of people, skills and knowledge required and the cost of the different locations; others depend on the sector in which the company operates, for instance as Everis is a company that provides consultancy services to European Institutions, so project managers have to take into account regulatory or legal requirements. Besides, as I have already mentioned in other parts of the paper, project managers have to include international factors as a criteria, for instance, differences in labor laws, differences in time zones, political differences…

For this example, as it is shown in Figure 8 I suggest four factors: the cost of labor and the compliance with the project requirements (in terms of skills and knowledge required) of location A and B respectively, the difference in time zones and the cultural differences between both locations. The first two factors (cost and compliance) can be used to measure the suitability of location A and B independently (intermediate output variables). In order to look for factors to measure the suitability of each location independently, project managers can refer to the PMBOK methodology. The other two factors I propose (difference in time zones and cultures) are ways of measuring the impact of having a geographically distributed team (working through virtual collaboration) on project success (see section 3.3). For the rest of the steps I will focus on the input variable Difference in Time Zones.

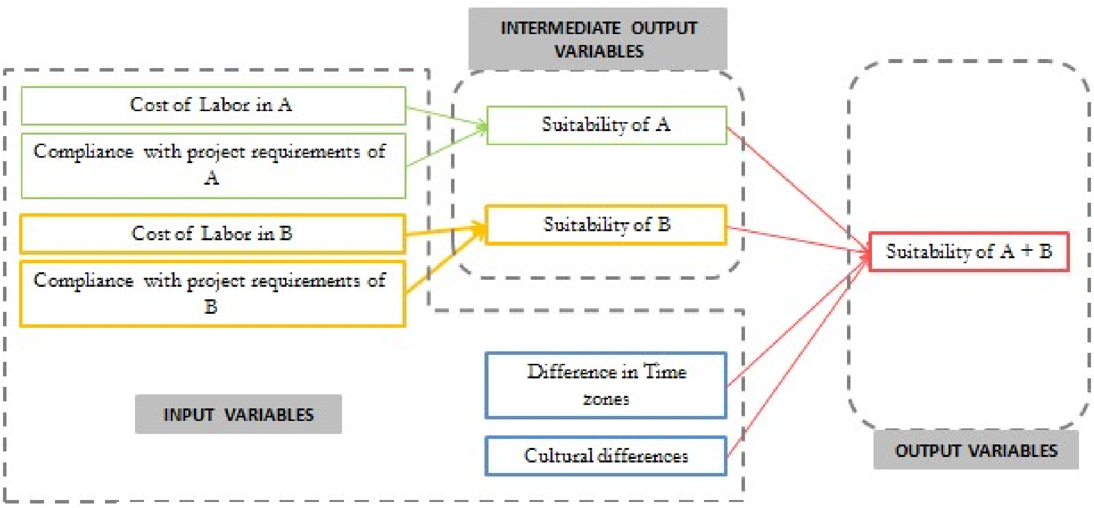

Figure 8 Variables

Step 3: Define linguistic variables and determine fuzzy sets

One characteristic of fuzzy inference systems is that the input and output variables have to be expressed in linguistic terms (fuzzy sets). The crisp numerical values of input and output variables have to be transformed into the equivalent membership values of fuzzy sets. This process is called fuzzification and it is done via membership functions, (see explanation and figure in section 5.1.1)

In practical terms this implies that the project manager has to define the linguistic terms and membership functions for all input and output variables. In this example, I have expressed the input variable "Difference in Time Zones" with the linguistic terms "Small" and "Large". This means that each crispy value (the exact hour-difference between the locations) has to belong to the fuzzy sets of "Small" and "Large" with a degree of membership for each. This quantitative input variable is defined in the range from 0 to 12 hours. The output variable "Suitability of A + B" is described as "Low" and "High" and with a range from 0 to 100.

The membership functions of fuzzy sets can have a variety of shapes, however, the trapezoid is the easiest membership function to define, it can provide an adequate representation of the expert knowledge while at the same time it significantly simplifies the process of computation. In order to define the trapezoid membership function as shown in Figure 9, the project manager with the help of experts would have to define the values a, b, c and d.

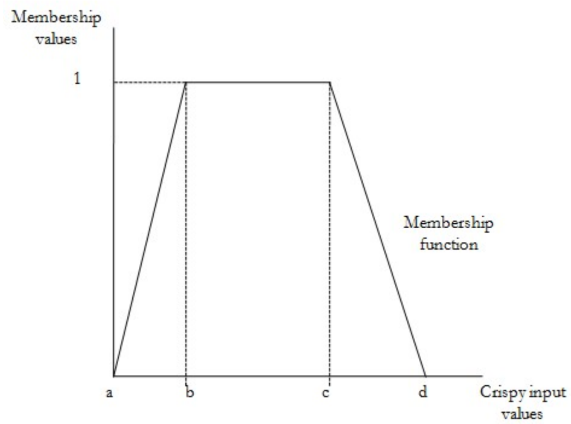

Figure 9: Membership function-Trapezoid

Following our example for the linguistic term Small of the variable Difference in Time Zones, an expert could consider that up to 3-hour difference is a small difference (crispy values of less than 3 hours belong to the fuzzy set Small with a degree of membership of 1) so a=b=0 and c=3 and that from 6-hour difference onwards the time difference can no longer be considered small (crispy values of more than 6 hours belong to the fuzzy set Small with a membership value of 0), implying that d=6, as the hour-difference decreases from 3 to 6 hours, the degree of membership to the fuzzy set Small decreases in a linear form. For the linguistic term Large of the same variable, an expert could say that more than 8 hour difference is a large difference (b=8, c=d=12) and that less than 5 hours cannot be considered a large difference in time zones (a=5), as the time-zone difference increases from 5 to 8 hours, the membership values to the fuzzy set Large increase in a linear way. This is illustrated in Figure 10.

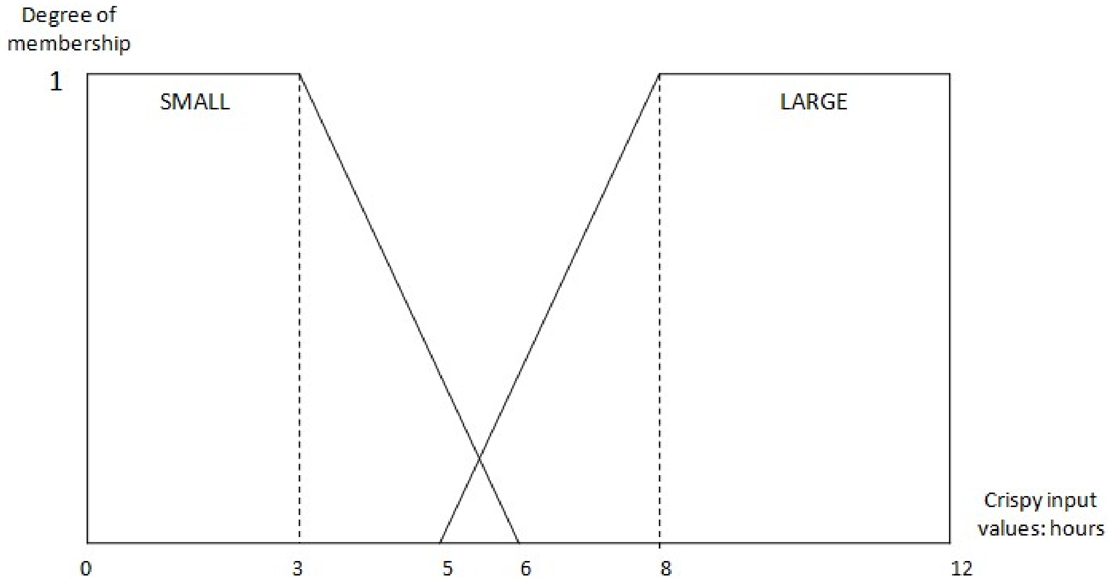

Figure 10: Fuzzy Sets of Difference in Time Zones

Step 4: Construct fuzzy rules

Experts have to create rules to map the relationship between the input and output variables. These rules should be expressed in If-Then form. This task is complex and requires a lot of knowledge and expertise, either the project manager or experts in each of the fields of the criteria used will state the rules. In this example, experts would have to state how variables such as difference in time zones between A & B affect the suitability of delivering the project using that delivery model. Some of the If-Then rules that could be used are the following:

if Difference_in_time_zones_between_A_and_B is Large then Suitability_of_A_and_B is Low
if Suitability_of_A is Low or Suitability_of_B is Low then Suitability_of_A_and_B is Low
if Cultural_distance_between_A_and_B is Low and Suitability_of_A is High and Suitability_of_B is High then Suitability_of_A_and_B is High
if Difference_in_time_zones_between_A_and_B is Small and Suitability_of_A is High and Suitability_of_B is High then Suitability_of_A_and_B is High

Step 5: Build the Fuzzy Expert System

The next task after defining the fuzzy rules and sets is to encode them, which is actually building the fuzzy expert system. To accomplish this task, project managers can choose one of two options: to build their own system using a programming language, or to use a solution software application. In the market different solution softwares already exist that allow the implementation of expert systems for research and industry applications, among them, MATLAB Fuzzy Logic Toolbox1 from the MathWorks. For rapid developing and prototyping of a fuzzy expert system, the best choice is using a solution software. This option is especially preferable for project managers who do not have experience in the field of building fuzzy expert systems.

For this example I have worked with open source fuzzy logic solutions: FuzzyLite, and qtFuzzyLite. qtFuzzyLite is a standalone application with graphical user interface to easily design and build fuzzy inference systems, it uses the library provided by FuzzyLite. FuzzyLite supports many membership functions, many defuzzifiers, rule aggregation, rule implication and rule connection operators.

In practical terms, this step involves project managers incorporating all the above developed information into the software application. First of all, project managers have to edit the input and output variables, for each one of them the linguistic terms have to be identified and the membership functions have to be defined graphically (values of a, b, c and d as explained before), the outcome is captured in Figure 11. Then, the project managers have to incorporate the fuzzy rules that were stated by experts in English like syntax using the Fuzzy Control Language (FCL) standards. An overview of the information developed in the example in the application is captured by Figure 12.

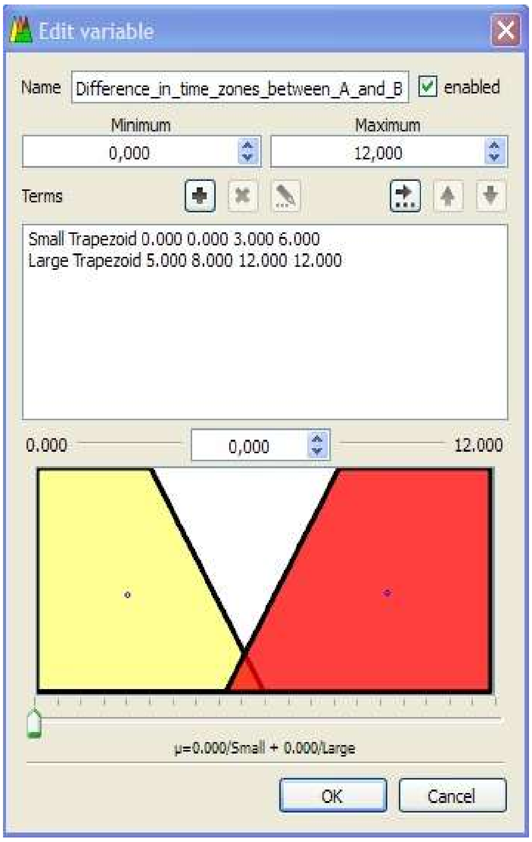

Figure 11

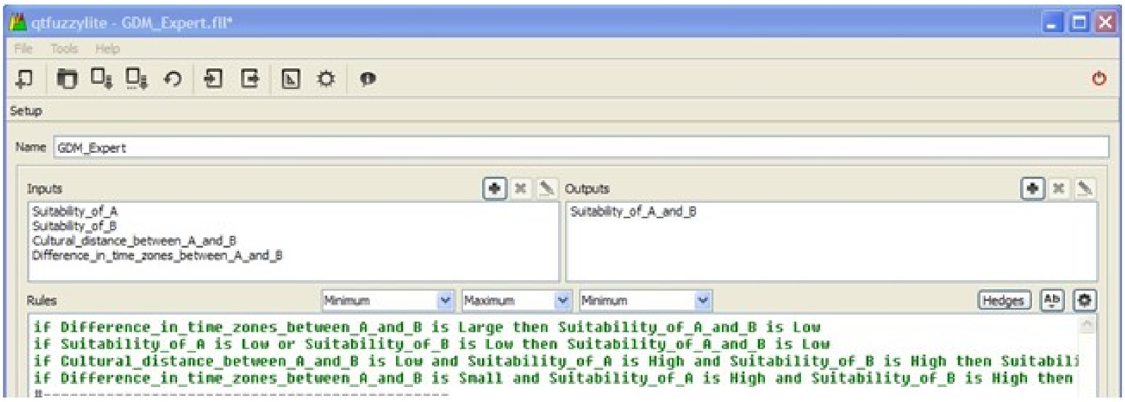

Figure 12

Once the information is incorporated into the application, the project manager will have to set the crispy values for each of the input variables, that is, the actual values of the input variables and the tool will provide the crispy output value. In this example it would mean putting the values of the Difference in Time Zones between Brussels (A) and Morocco (B), a value for their difference in cultures and the suitability of Brussels and Morocco to deliver the project independently (as these are intermediate outputs it would be measured by another expert system using variables like the cost of labor in Brussels/Morocco and whether the office can meet the project requirements in terms of staff number, skills and knowledge). As we defined the output variable as the Suitability of A + B with a range from 0 to 100, the application will provide the project manager with the crispy value, the number between 0 and 100 showing the degree of suitability of that combination of locations, of that delivery model.

This process can be seen in Figure 13. On the left of the picture, the project manager is able to set the crispy values for the input variables. The rules and their degree of truthfulness appear at the bottom of the picture. On the right (see the blue rectangle) the crispy output value is given. For this specific example, the values of the input variables were given randomly and the tool stated that the suitability of delivering the project from Morocco and Brussels had a suitability of 40,250/100. The project manager could compare this value with the value of suitability of the other delivery models in order to make the decision.

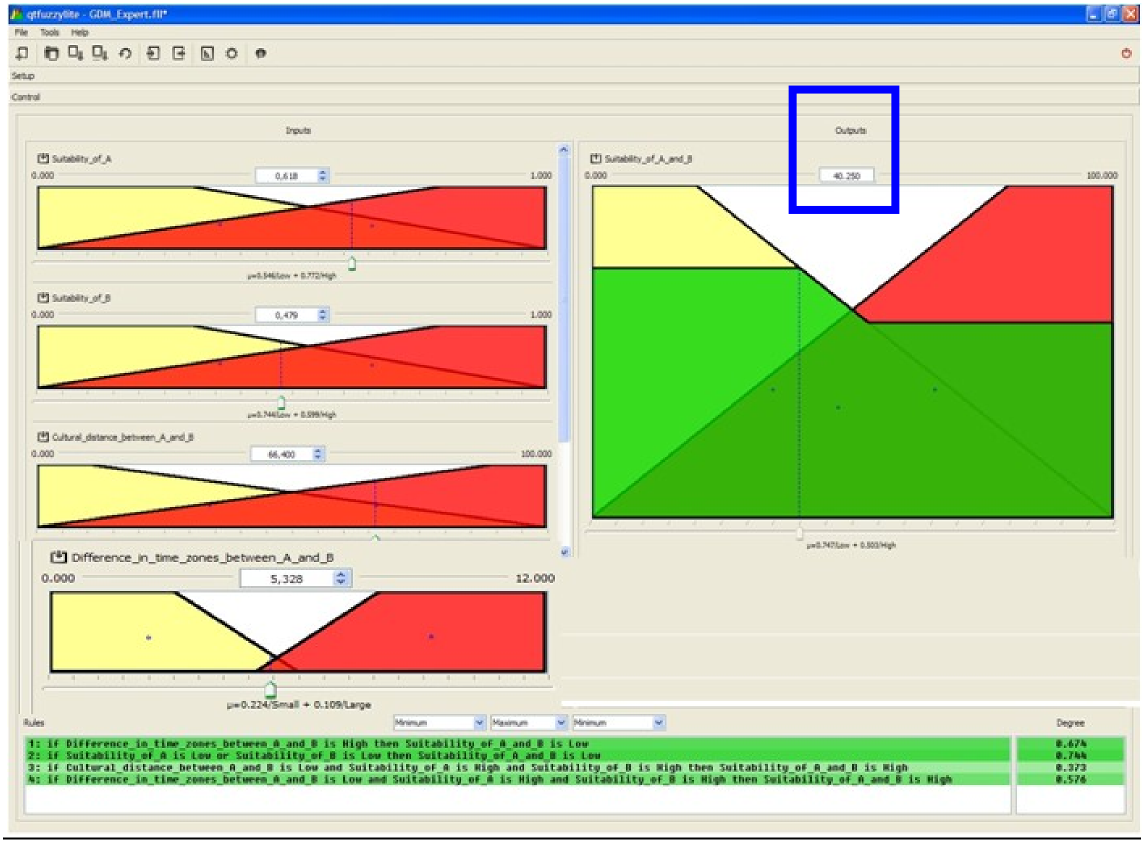

Figure 13

6. DISCUSSION AND CONCLUSION

6.1. Discussion of findings

From the above the application of a fuzzy expert system to the project delivery model decision process, I can now conclude how project managers can benefit from the use of such tool as well as identifying the challenges that they can encounter.

One of the most outstanding advantages of using fuzzy logic is that it reflects how people think; it attempts to model our sense of words and our common sense. Fuzzy inference systems are able to handle linguistic concepts, both input and output variables are described using linguistic terms, this implies that the rules can be stated using a natural language and so, the process of setting rules is close to human thinking. Even though setting the rules is a laborious process due to the amount of variables to take into account, thanks to the possibility of using linguistic terms, this step of the decision making is rather intuitive for the experts, it is definitely simpler to state that having a large time-zone difference between two locations will mean that dividing the project team between those two locations will not be ideal (low suitability) than trying to find how using a location 1hour further impacts in a x% the suitability of that delivery combination

Furthermore, the usage of linguistic terms in fuzzy logic allows working with uncertainty and vagueness. A variable doesn´t have to be black or white, it can have shades of gray. Fuzzy logic enables making distinctions among these shades of gray admitting degrees, similar to the process of human reasoning. Fuzzy logic can look at the world's imprecise terms, in the same way that our brain sees it, and then respond with precise actions.

Other relevant benefits come from the fact that the rules to map the relationship between the input and output variables are set by project managers or experts. The most straightforward advantage one can conclude is that because the rules are defined by experts, the solution the fuzzy expert system provides is highly reliable and knowledge based, however, it is not only limited to that. In the example, I only focused on a specific delivery mode (A+B) and on two input variables, and yet, I was still able to set rules and come up with an output, a concrete measure of suitability of such delivery mode. Then, it is clear that not all rules have to be set by the same expert, therefore we can conclude that one of the advantage resulting from using this method is that experts from different domains can contribute to the decision making process by setting rules in their areas of knowledge independently and simultaneously. This way, more areas of expertise can be covered without complexifying the decision making process. In practice, this means that several members of the organization can simultaneously help build the inference system: different experienced project managers, people in charge of human resource management form each location involved, even external consultants can be hired to contribute to a specific area of expertise such as cultural differences. The involvement of several experts in setting the rules also implies that when project managers rely on the solution provided by the fuzzy expert system, they are engaging in a more objective decision making process. These advantages are of crucial importance because as I showed in section 3, the decision process has become very complex and thus, it requires significant human expertise.

Because of the way fuzzy inference systems are designed, they enable to retain the expert and managerial knowledge about any decision process. Expert knowledge is required for the definition of fuzzy sets (establishing the membership functions) and for setting the rules. As the variables are defined using linguistic terms that are intuitive and easily interpretable, the membership functions and rules can be re-used by other organizational members in similar decision contexts. This is of crucial interest since I am proposing to apply fuzzy logic to the field of project management and projects are by definition temporary (they have a definite end) which means that a project-based organization has to face the decision of a delivery mode as an inherent part of its operations.

Another insight I can gather from the above application of fuzzy logic is that even though fuzzy logic is a complex subject, the availability of solution software applications allows project managers to benefit from it and use it to support the decision making process without having to understand the mathematical/theoretical basis behind it. As I showed in the example, when a solution software application is chosen, the project manager only needs to state fuzzy rules in English like syntax, and to define membership functions graphically. It is easy to understand and master and convenient to use, even for new fuzzy system builders.

What is more, the fact that solution softwares provide libraries means that they can be integrated in corporate applications or ERP systems (Enterprise Resource Planning). This would make it possible for the program to automatically collect the information available in different areas of the organization allowing, for instance, obtaining the crispy values of the input variables such as cost of labor in different locations. This fact also facilitates the accumulation of managerial and expert knowledge and the re-usability of the fuzzy sets and rules defined.

The example not only provided insights on the benefits using an expert inference system can bring; it also allowed to identify some challenges the project managers would have to face such as selecting the input variables and measuring them. As I previously described, the selection of input variables is a complex endeavor because there is a wide range of factors that affect the decision of the delivery mode. Project managers can refer to the PMBOK to identify some of the factors regarding the core of the project, but other factors related to the sector in which the project is performed or factors that are a consequence of using virtual teams (international factors) are more complex to be identified.

The second challenge identified is measuring the input variables. Even though the rules are stated using of linguistic terms of (large/small difference in time zones or difference in cultures), the actual crisp values of every input variable affecting the decision have to be measured and incorporated into the inference system for them to be fuzzified. For some quantitative variables such as the difference in time zones or other variables for which indicators exist, identifying the actual crispy value is straightforward. However, for some variables it is complex due to the qualitative nature of the variable or because no objective indicators can be found, this would be the case of trying to get a crisp value of the difference in culture between two countries. Project managers can deal with this difficulty in various ways. One option would be to look at previous research and studies conducted on the topic and make use of publically available propositions of formulas or indicators (for instance, in the case of cultural differences the Inghlegart world values survey or Hofstede's cultural dimensions could be used). As another alternative, the project manager/expert could make use of fuzzy expert systems whose output variable would be the missing indicator (i.e. cultural distance between two countries) and whose input variables are factors that impact the missing indicator that are more easily measured (i.e. differences in language, religion…).

If the project managers follow the Project Management Body of Knowledge (PMBOK) methodology, some of the input variables to select and their measures will be given as outputs of one of the processes to be followed such as the activity resource requirements, project calendars, budget and cost estimates, communication management plan, risk register and stakeholder requirements among others (see appendix A for the table containing the 47 processes in the 10 knowledge areas). The findings of several studies on the existing relationship between the experience of using a project management methodology and project success together with the support the PMBOK gives project managers to identify and measure the input variables is what makes it recommendable to use the proposed fuzzy expert system together with the renowned project management methodology (PMBOK) even though the fuzzy inference system could also be used as a stand-alone tool.

6.2. Conclusion

Throughout the development of this project, I became aware of the need to provide project managers with a multi-criteria decision tool to assist them in the decision of selecting the most suitable global delivery model for their projects. First, through a thorough review of the project management theoretical context I identified a gap on the existing project management methodologies, namely the lack of guidance on specific tools or techniques to use in order to make the aforementioned decision. Then, the analysis of the impact the IT developments have had on the project management reality led to the conclusion that filling the existing gap was of crucial importance due to the increased complexity of the decision making and its impact on project success.

In order to fill the identified gap in project management, I proposed a fuzzy expert system as the tool to help project managers with selecting the most suitable global delivery model for their projects. I provided the theoretical basis behind fuzzy expert systems and I illustrated how I envisage a project manager would design and make use of the expert system. In order to do the latest, I identified and explained the steps and actions a project manager would have to perform by applying the proposed method to a simplified representation of a real decision making process inspired by my internship experience that included the usage of an open solution software.

Through the example I demonstrated the benefits using a fuzzy expert system can bring to project managers in terms of objectivity, reliability and closeness to reality. The suggested method also proved to be fruitful even for project managers with no prior experience in using fuzzy inference systems. I also identified some challenges that project managers are likely to encounter and I proposed in broad terms actions to mitigate their impact.

Future research could, for example, investigate the effect of using the fuzzy expert system on the project management experience studying, for instance, the perceived usefulness by project managers or its impact on indicators of project success. In addition, new research could test the validity of the proposed tool in comparison with other multi-criteria decision tools. Another avenue for research could focus on trying to tackle the identified challenges, studying the factors project manager should take into account in this decision and how to measure them, for example, identifying international factors or factors relevant for specific sectors.

I want to conclude this project by thanking my advisor, Professor Oscar Martín, and the team of Everis Brussels. Without their support, guidance and dedicated involvement, this project would have never been accomplished.

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8. APPENDIX A: PROJECT MANAGEMENT PROCESSES

Knowledge Areas	Project Management Process Groups: Initiating Process Group	Planning Process Group	Executing Process Group	Monitoring and Controlling Process Group	Closing Process Group
4. Project Integration Management	4.1 Develop Project Charter	4.2 Develop Project Management Plan	4.3 Direct and Manage Project Work	4.4 Monitor and Control Project Work 4.5 Perform Integrated Change Control	4.6 Close Project or Phase
5. Project Scope Management		5.1 Plan Scope Management 5.2 Collect Requirements 5.3 Define Scope 5.4 Create WBS		5.5 Validate Scope 5.6 Control Scope	
6. Project Time Management		6.1 Plan Schedule Management 6.2 Define Activities 6.3 Sequence Activities 6.4 Estimate Activity Resources 6.5 Estimate Activity Durations 6.6 Develop Schedule		6.7 Control Schedule	
7. Project Cost Management		7.1 Plan Cost Management 7.2 Estimate Costs 7.3 Determine Budget		7.4 Control Costs	
8. Project Quality Management		8.1 Plan Quality Management	8.2 Perform Quality Assurance	8.3 Control Quality	
9. Project Human Resource Management		9.1 Plan Human Resource Management	9.2 Acquire Project Team 9.3 Develop Project Team 9.4 Manage Project Team		
10. Project Communications Management		10.1 Plan Communications Management	10.2 Manage Communications	10.3 Control Communications	
11. Project Risk Management		11.1 Plan Risk Management 11.2 Identify Risks 11.3 Perform Qualitative Risk Analysis 11.4 Perform Quantitative Risk Analysis 11.5 Plan Risk Responses		11.6 Control Risks	
12. Project Procurement Management		12.1 Plan Procurement Management	12.2 Conduct Procurements	12.3 Control Procurements	12.4 Close Procurements
13. Project Stakeholder Management	13.1 Identify Stakeholders	13.2 Plan Stakeholder Management	13.3 Manage Stakeholder Engagement	13.4 Control Stakeholder Engagement	

Source: PMBOK (PMI, 2013)