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Analysis of the degree of risk of R&DI projects using fuzzy logic to identify technical feasibility

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Abstract
Currently, business structures are increasingly focused on pursuit of continuous improvement in their processes so that organizations can remain competitive in the market, since customers require more and more products or services with high quality levels. With the reference this scenario, this work brings a methodology of analysis of the risk of R&DI (Research, Development and Innovation) projects, using the fuzzy mathematical model, developed in an organization whose core business is the research and development of new technologies. This analysis occurs through the development of linguistic variables (input), with the aim of identifying measure the degree of risk in projects. After the determination of the guidelines to be followed, it was possible to obtain results that demonstrate that the developed fuzzy model can assist in the identification and prioritization of the variables that increase the degree of risk of technologies development projects.

Keywords: risks; Processes; Project Management; Fuzzy Logic;

Introduction
Globalization and factors such as the increase in human needs, pandemics and wars have brought to world society the need to accelerate the process of innovation in the various areas of business. The ability to implement research and development projects that generate innovations in products and services that affect not only the competitiveness of organizations in an increasingly demanding market, but also affect the relevance that each nation gains on the world stage. In this context, innovation processes incorporate

practices that influence society as a whole and are not limited to the social characteristics that constitute organizations.

Regardless of size, organizations need to manage all phases of the innovation project to maintain planned deadlines, costs and quality. The greater the degree of complexity, because of the number of activities performed, the greater the need for control over deadlines and costs.

In the process of project management, one can observe a factor of paramount importance for the success of a project, the management of project risks. The first point in project risk management is the identification of risks to be controlled to ensure the success of the project. The identification of the factors that lead to risks to the success of a project plays an important role in this process.

A risk is an uncertain event or condition that, if it occurs, could have a positive or negative effect on one or more objectives. The identified risks may or may not materialize in a project. Project teams strive to identify and assess known and emerging risks, both internal and external to the project, throughout the lifecycle (Pmbok®, 2021).

Wu et al. (2018), proposes a model for selecting responses to risks minimizing expected project losses or delays. The risk categories that make up the project development must be created to use the proposed model. Then, a risk analysis must be carried out, considering the two steps: (1) Risk identification: project members must identify the risks and one of the previously registered categories is assigned. (2) Risk assessment: identified risks are assessed from 3 aspects, impact on project scope, cost or quality. Finally, the model optimizes the search for responses to identified risks and considers the relationship between risk sub-processes. In this way, the model minimizes expected financial losses, schedule delays, or project quality.

Sangaiah et al. (2017), brings a model to prioritize the risks of software development projects through risk classification. The model uses a hybrid approach of multi-criteria analysis and fuzzy logic to achieve a more efficient risk ranking, while allowing for prioritization of resources for the highest priority risk responses. The authors categorize the software development risks identified in previous studies into the five-dimensional risk breakdown framework: (1) requirements; (2) estimates; (3) planning and control; (4) team organization; and (5) project management. After classification, the variables that make up the model are quantified on a scale [0, 1] so that a fuzzy algorithm is applied to deal with uncertainties in the decision-making process.

Based on the context in which organizations seek to improve their processes to achieve quality and minimize negative impacts during project management, this study aims to identify the degree of risk associated with innovation projects through the use of a Fuzzy mathematical model, in such a way that the technical feasibility of implementing innovation projects can be evaluated, and it is even possible to prioritize the implementation of projects when there is a portfolio of projects in the organization.

Bibliographic Review

2.1 Concepts and Theories

2.1.1 Project

A temporary effort undertaken to create a unique product, service, or result. The temporary nature of projects indicates a beginning and an end to project work or a phase of project work. Projects can be standalone or part of a program or portfolio (Pmbok®, 2021).

In general, we can define a project as a series of operations with levels of complexity, non-repetitive and interrelated that are implemented by an organization or set of organizations to achieve established goals within a previously defined planning and budget structure

2.1.2 Project Management

Applying knowledge, skills, tools, and techniques to project activities to meet project requirements. Project management refers to directing project work to deliver the intended results. Project teams can achieve results using a wide variety of approaches (eg predictive, hybrid and adaptive) (Pmbok®, 2021).

Project management is a process that aims to achieve the desired result with the implementation of actions that bring efficiency in the use of available resources.

The actions of the project management process must bring planning, implementation, control and prevention measures and/or correction of eventual deviations that can be identified in its development. Therefore, the project management process consists of three main components: planning, implementation, and oversight Alam Tabriz and Hamzei, 2011).

2.1.3 Project Planning and Control System

The success of projects depends on a systematic approach to planning and controlling activities, considering variables such as execution time and cost. The main function of a project's planning and control system is to prepare, compile, record and maintain information related to the different stages of the project's life cycle and to process, classify and analyze the information and prepare the necessary reports for the project manager. project. The purpose of this system is to direct the project according to the determined schedule and budget, provide the objectives and final products of the project, and store the information resulting from lessons learned and best practices implemented for use in future projects. This system should help the project manager to optimize the three factors of time, cost, and quality in project implementation. Second(Barghi and Shadrokh Sikari, 2020), a good project planning and control system must have the following features: (apud A. HAJ SHIR MOHAMMADI, 2014, p. 436)

2.1.4 Planning and Controlling Stages of a Project

The planning of a project includes actions that are carried out to identify the activities to be developed in the project, identifying their interrelationships, and estimating the time, resources and costs to implement them based on the criteria of the organization generating the project and the customer criteria and expectations.

2.1.5 Risk Management

Second (Barghi and Shadrokh Sikari, 2020) An overall project risk management process consists of nine phases (apud CHAPMAN and WARD, 2003):

- Identification of the main aspects of the project;
- Strategic approach to risk management;
- Identification of the time of occurrence of risks;
- Risk estimation and interrelation between them;
- Assign ownership of risks and provide appropriate responses;
- Uncertainty estimation;
- Estimate the importance of the relationship between the different risks;
- Determination of responses and monitoring of the risk situation;
- Control the stages of implementation of responses to identified risks,(Alam Tabriz and Hamzei, 2011).

It is possible to state, therefore, that due to the uncertain nature of the projects and the need for optimal use of resources, each project faces uncertainties.

The literature on project management makes it evident that each project has uncertainties associated with the development of its activities and, as a result, the identification and management of project risks becomes essential.

Risk management practice includes approach planning, risk identification and analysis, response planning and implementation, and ongoing risk monitoring. Risk management is an essential aspect of all organizational activities. Risk management shapes decision-making processes across the organization and in each of the domains (Pmbok®, 2021).

Risk management focuses on identifying risks and dealing with them appropriately. Projects have individual risks or general risks. The first level is assigned to a specific activity and the second linked to the project.

2.1.6 Project Risk Identification and Assessment

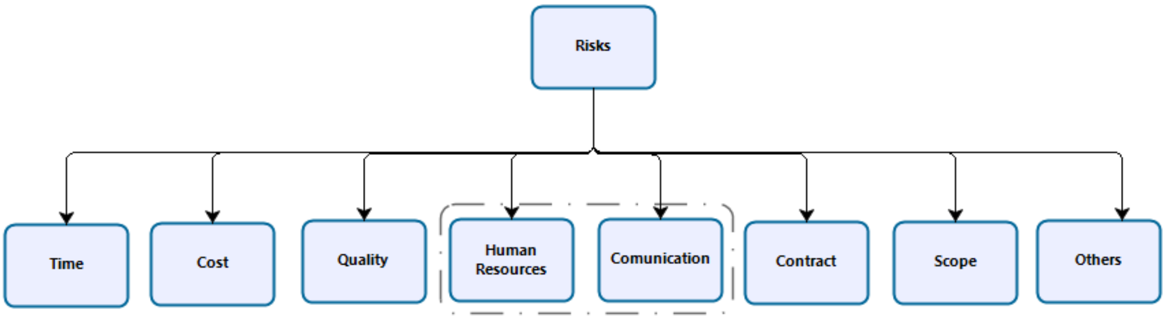
Risk management is the systematic process initially composed of two steps that respond to the project management process, the identification and assessment of risks.

In the literature, it is possible to observe several researchers defining the risk identification stage of a project as the mapping of all risks, of negative or positive impact, to which the project is exposed.

2.1.7 Risk Factors

Risk factors are characteristics inherent to the development of the project that, when worked to minimize its negative impacts, when identifying internal weaknesses in the organization or external threats, or maximize its positive impacts, when identifying internal strengths in the organization's structure or of opportunities inherent to the scope addressed. In projects, risk factors are initially classified with reference to the PMBOK® standard as illustrated in the model in Figure 1 – Classified Risks.

Figure 1 - Classified Risks



Source: PMBOK GUIDE (2011)

Figure 1 illustrates the various factors that impact the degree of risk in a project, one of the most relevant being the scope, which, when poorly defined, has a considerable impact on the other factors.

2.1.8. Fuzzy Logic

According to (Arya and Kumar, 2020) fuzzy set theory and fuzzy logic to address the subjectivity of human judgment in the use of linguistic terms in the decision process was introduced by (Zadeh, 1965). The purpose of fuzzy logic is to solve problems of high degree uncertainty and to represent vague, ambiguous and chaotic information.(Quelch and Cameron, 1994) (Bonvicini et al., 1998). Over the years, fuzzy logic has become a very relevant factor in many areas of knowledge due to its effectiveness and reliability of results, thus becoming an important topic to measure the degree of imprecision.

Fuzzy logic assigns different degrees of association (μ) ranging between 0 and 1 to a variable x to indicate variable association for various classes (fuzzy sets).

Second(Tesfamariam and Saatcioglu, 2019)The strength of the fuzzy logic inference system depends on the following features:

- The fuzzy inference system can handle descriptive (linguistic) knowledge and numerical data;
- Use of the fuzzy inference system with an approximate reasoning algorithm to determine the relationships between inputs through which uncertainties can be propagated throughout the process.

Therefore, the fuzzy set contains only the degree of membership to the elements of a set in the interval [0,1] being described in terms of "belongs to" and "does not belong to".

Fuzzy logic brings, therefore, the idea of not restricting between just two values stated in classical logic or Boolean logic, true and false, black and white, but, for example, various shades of gray that indicate the idea of sets with degrees of relevance.

Fuzzy logic is a reasoning that seeks to classify in numbers a certain reality or situation that works with several uncertain and vague variables, with the objective of providing a more consistent basis for the evaluation and decision-making on the analyzed situation.

Second (Pereira, 2010), fuzzy logic has several advantages over classical logic, including flexibility, tolerance for imprecise data, possibility of modeling non-linear functions, possibility of being built based on the experience of specialists, possibility of being integrated with conventional techniques of control, in addition to being based on natural language, the basis of human communication.

Fuzzy logic brings the possibility of pertinence logic using linguistic variables that make it possible to capture a certain degree of uncertainty present in the input variables and translate it into a mathematical modeling that supports a more in-depth assessment of a given topic.

2.1.8.1 Fuzzy Controller

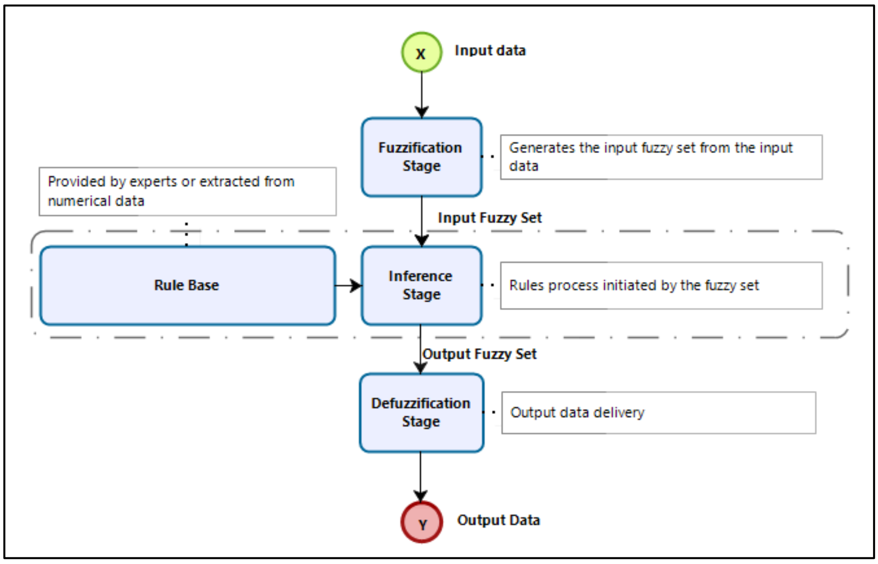
When you want to create a control system for a process, you first need to obtain its mathematical model, using techniques such as the Laplace transform or the Z transform. For that, so that the modeling can be closer to reality, each part of the process to be modeled must be known. This is often not possible, as many real-world variables, which directly or indirectly influence the process, cannot be quantified and others are totally unknown, or even the complete modeling of the system generates extremely large and complex equations.

Systems based on fuzzy logic can produce estimates of a complex nonlinear system without resorting to mathematical models. In this scope, the fuzzy methodology is a method of estimating input and output free from mathematical models. The decision-making logic embedded in the inference structure of the fuzzy implications rule base to simulate human decision making.

Fuzzy processing is, in general, composed of four steps shown in Figure 2.

- Fuzzification stage (generates a fuzzy set of input, from the inputs and their degrees of membership;
- Rule base (provided by experts or extracted from numerical data);
- Inference stage (activates the rules, from a fuzzy input set, generating a fuzzy output set);
- Defuzzification stage (provides the output in R, from the fuzzy output set).

Figure 2 - Example of Basic Structure of a Fuzzy System



Source:(Sizilio, 2012).

Figure 2 illustrates the stages performed by the fuzzy logic after collecting the initial data referring to the topic to be analyzed using the tool.

2.1.8.2 Fuzzification Stage

In this first stage of the fuzzy Logical System, the problem is analyzed and the input data are transformed into linguistic variables. At this point, it is of fundamental importance that all imprecision and uncertainty data are considered and transformed into linguistic variables.

The pertinence functions depend on the concept to be represented and the problem for which they will be used and implemented and may have different forms. A fuzzy set or subset A of a universe X is a set defined by a membership function _A representing a mapping:

$$\mu A: X \rightarrow \{0,1\}$$

being the value of$\mu A(X)$ PFor the fuzzy set is called the membership value or membership degree of. The membership value represents the degree to which it is part of the fuzzy set A. Thus, a value of close to 1 indicates a high degree of membership of an element in a fuzzy set A. If, the element completely belongs to the fuzzy set A. If, the element does not belong to the fuzzy set A.$\times \in X \times \mu A(X) \times \mu A(X) = 1 \times \mu A(X) = 0 \times$

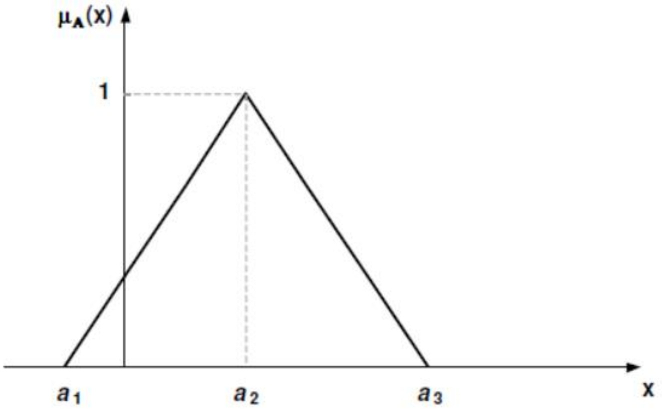
According (Do Carmo Corrêa and Da Silveira, 2012), the pertinence of an attribute in Fuzzy Logic depends on the perception and experience that the specialist has in the proposed subject and these pertinence functions can be demonstrated in several ways.

Of these, the simplest is the triangular function, which is a collection of three points (x,y,z), forming a triangle that represents it. These values must meet the rule. There must be some value where membership is 1. The following Eq. (1) is used to represent the triangular function a<b<c.

$$trimf(x; a, b, c) = max\left(min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right) \quad (1)$$

Figure 3 illustrates a triangular fuzzy number: on the x axis are the values of the variable; the y-axis represents the degree of membership for each value of x. a_1, a_2 e a_3.

Figure 3- Triangular Fuzzy Number



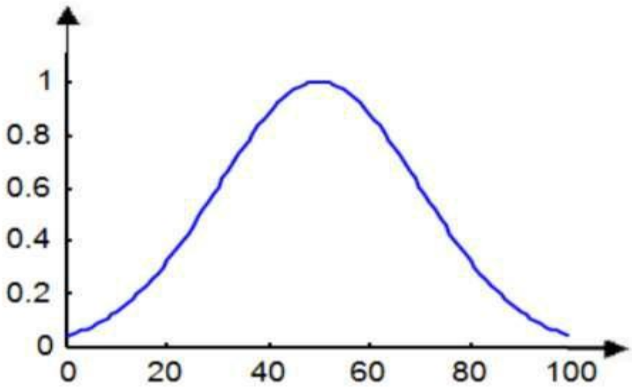
Source: adapted from(Fernandes, 2005).

The triangular fuzzy number illustrated in Figure 3 is used when the parameter under analysis has a variation range and a number within this range has a possibility of occurrence in a single peak greater than the others.

The Gaussian membership construction uses three parameters: x, mean and standard deviation. The equation below represents the Gaussian membership function and in Figure 4, the Gaussian function is illustrated.

$$gaussmf(x, a, b, c) = e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2} \qquad (2)$$

Figure 4 - Bell Function

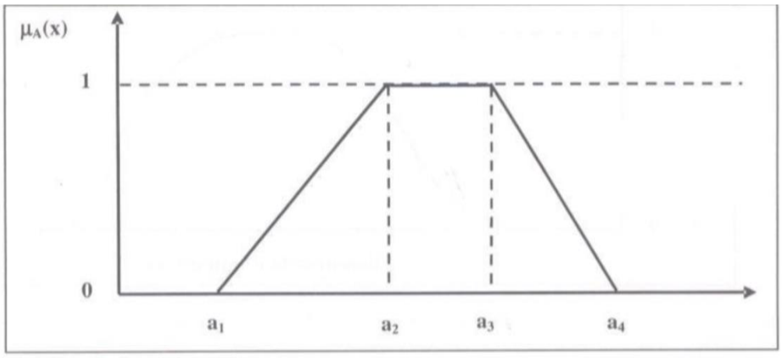


Source: adapted from(Fernandes, 2005).

In the trapezoidal fuzzy number shown in Figure 5, membership 0 is assigned to values smaller than a_1 and greater than a_4 (no possibility of a_1 and a_4 occurring). For values between the range a_2 and a_3 the relevance is equal to 1 (total possibility of occurrence of these values). Values between a_1 and a_2 and between a_3 and a_4 are assigned memberships between 0 and 1.In the trapezoidal membership function it is represented by the following equation where thepoints obey the rule. An interesting feature of this function is to allow a membership interval of 100% a <b ≤c <d.

$$trapmf(x, a, b, c, d) = max\left(min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right) \quad (3)$$

Figure 5 - Trapezoidal Fuzzy Number



Source: adapted from(Fernandes, 2005).

Figure 5 illustrates a fuzzy trapezoidal number commonly presented in vector form in which each of its parameters is associated with membership degree 0 or 1. The trapezoidal function has a flat top, being a truncated triangle curve.$(a_1,\ a_2,\ a_3,\ a_4)$.

2.1.8.3 Rule Base

The rule base is used in the second phase of the controller, because it is from there that the calculations referring to the controller inputs can be performed. This rule base is also assembled through the knowledge of the specialist, which, in this case, is anyone who is directly linked to the process and who has great theoretical and empirical knowledge of its operation, seeking to determine what action should be taken for a given input, mapping the input (which would be a linguistic variable) into an output (another linguistic variable).

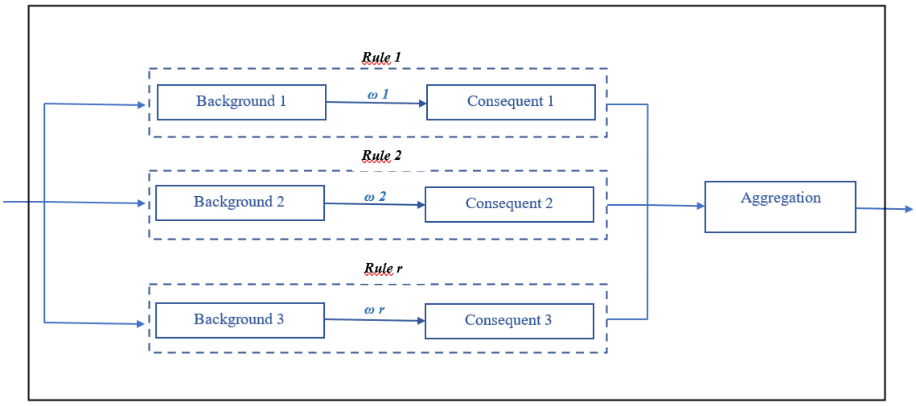
This component, together with the inference engine, can be considered the core of the systems and is where the variables and their linguistic classifications are “stored”. The fuzzy rule is a unit capable of capturing some specific knowledge and a set of rules is capable of describing a system in its various possibilities. Each fuzzy rule, like a classic statement, is composed of an antecedent part and a consequent part, resulting in a structure like:

If <background >**Then**<Consequent>

2.1.8.4 Inference Stage

This is the step responsible for applying a reasoning structure to obtain a fuzzy output. It is at this stage that each fuzzy proposition is mathematically translated using approximate reasoning techniques. In this step, the logical connectives used to establish the fuzzy relationship that models the rule base are defined. Figure 6 illustrates a schematic diagram of the inference stage.

Figure 6 - Schematic diagram of the inference step



Source:(Mozelli, 2008)

The representation of Figure 6 illustrates that at this stage, the inputs are analyzed to generate the fuzzy output set with its respective degree of membership.

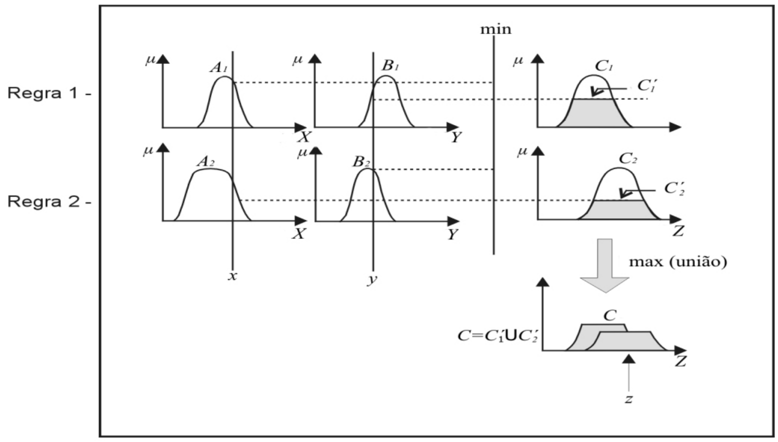
In this study, the inference method of(Mamdani, 1974), in which, an IF – THEN rule is defined by the fuzzy Cartesian product of the fuzzy sets that make up the antecedent (premise) and consequent of the rule. To aggregate the rules, the Mamdani method uses the logical operators AND and OR. In each rule, the logical operator AND is modeled by the minimum operator, while the logical operator OR is modeled by the maximum operator. Next, an example with two rules is presented.

RULE 1: IF (×é A_1 e y é B_1) **THEN** (z é C_1)

RULE 2: IF (×é A_2 e y é B_2) **THEN** (z é C_2)

Figure 7 illustrates an example of a real output of an inference system of the type (Mamdani, 1974), generated from the actual x and y inputs and the composition rules. By defuzzifying the output fuzzy set, the output is obtained máx -min C = C^'$_1$∪C_2 z∈R.

Figure 7 - Schematic Diagram of Inference



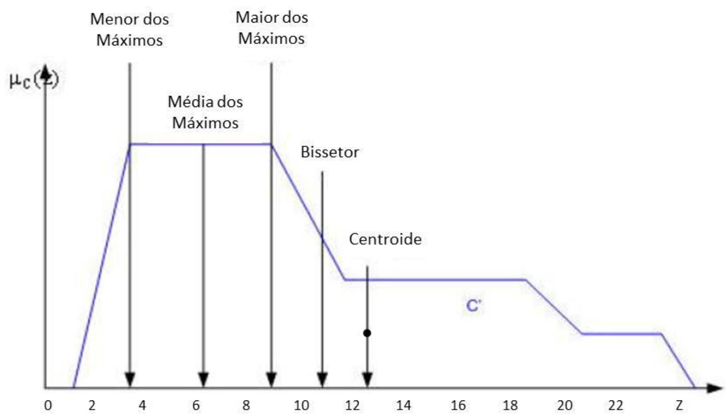
Source:(Lopes et al., 2005)

Figure 7 illustrates that input variables, when submitted to inference rules, generate data (outputs) through defuzzification that allow achieving the intended results with the use of fuzzy logic.

2.1.8.5 Defuzzification Stage

The defuzzification stage is responsible for translating and/or transforming the fuzzy output into a crisp value, that is, values that can be used in non-fuzzy contexts. In other words, it is responsible for the interpretation of the fuzzy output set, it exists in systems such as the one proposed by(Mamdani, 1974). According to(Sizilio, 2012), the most used defuzzification methods that obtain good results are the center of area, the bisector of the area, the largest of the maximums, the average of the maximums and the smallest of the maximums(Jantzen, 1998);(Maraj et al., 2008);(Passino et al., 1998)illustrated in Figure 8.

Figure 8 - Defuzzification Methods



Source:(Maraj et al., 2008)

- **Area Center**: also known as Centroid (centroid, in MATLAB®), this technique calculates the center of the area of the Output Set (CS) generated in the inference stage and determines its projection on the x axis, which is the control output value;
- **Bisector**: called bisector in MATLAB®, in this method the output value of the defuzzification stage is the exact position that divides the CS into two equal areas;
- **Greatest of Maximums**: called lom5 in MATLAB®, this method takes the arithmetic mean of all the maximum values of the CS and is used instead of the criterion
- io of maxima when there is more than one maximum in the function;
- **Maximum Average**: mom6 in MATLAB®, this method calculates the arithmetic mean of all the maximum values of the CS and is used to replace the criterion of maximums when there is more than one maximum in the function;
- **Minimum of Maximum** is an alternative method to the criterion of maximums, because in this method the smallest maximum value found in the scan of the CS set is chosen. In MATLAB® it is called sound[7].

Materials And Methods

3.1 MATERIALS

For development and simulations of the fuzzy model, a computer with i7 processor, 16Gb of ram and windows 10 operating system was used. In addition to reports, maps, forms, data extracted from Bizagi, x etc. projects.

To implement the fuzzy method developed in this work, MATLAB® was used. The membership functions available in MATLAB® are called Membership Functions (MF) and have in their nomenclature the ending “mf”.

3.2 METHODS

The present study is exploratory research regarding its objectives, as it seeks to identify and assess risks in innovation projects. As for the nature, this study deals with applied research to support decisions related to the development of projects using tools for practical applications aimed at solving specific problems. Regarding the objectives, this research has a descriptive character since it seeks to establish relationships between variables inherent to the risks in projects and the general risk degree of the development of a project.

3.2.1 Research Steps

The research stages were developed according to the concepts of fuzzy mathematical model development explained in figure 9.

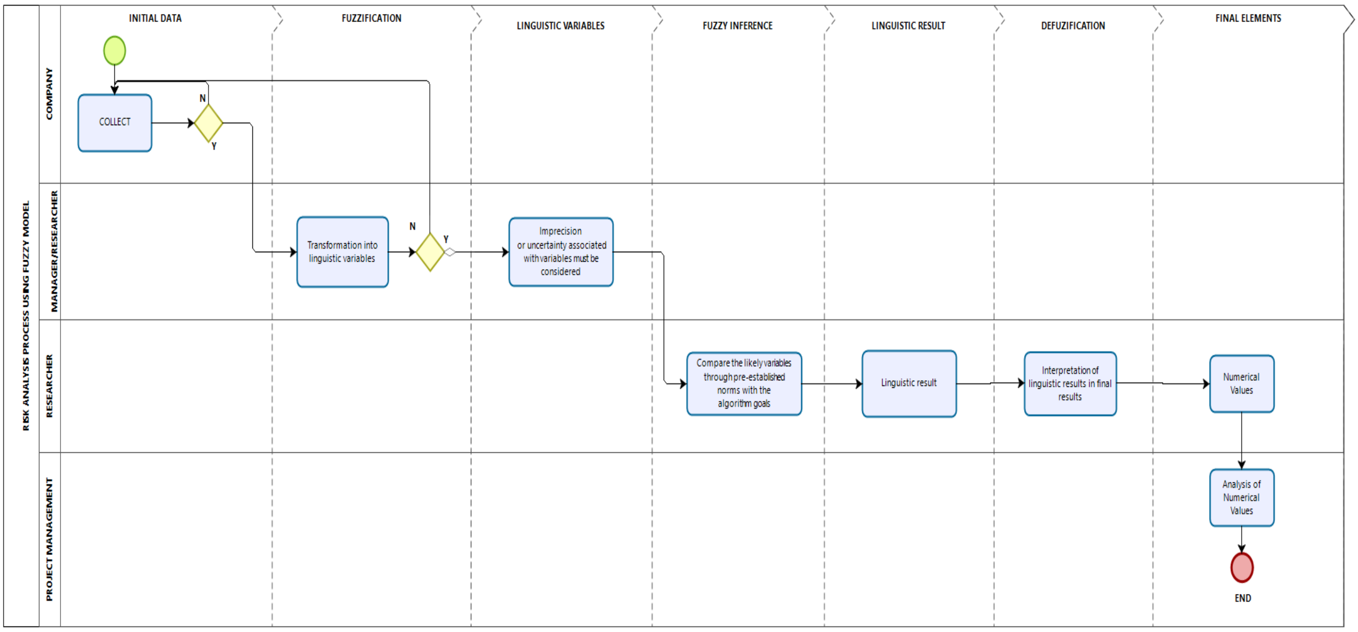


Figure 9 - Fuzzy Mathematical Model

3.2.2 Application of fuzzy logic in the analysis of the degree of risk of a project

The developed case study allows the organization to assess the degree of risk in R&DI projects by identifying the main factors that impact the development of projects as indicated in the PMBOK® and confirmed through the analysis of project history and interviews with professionals from the Project Management of the Research Institute object of this study.

It is also possible to identify that the level of inference of the main factors identified with the highest level of impact on projects also has an influence on other factors relevant to the development of projects in general, such as the quality factor, which is directly affected by the factors highlighted time, cost, scope and human resources, from the evaluation of this study to the conclusion of the degree of risk of a project.

With the data related to the projects developed by the organization that demonstrate the risk factors inherent to each one, simulations were generated based on three stages of fuzzy logic: fuzzyfication, inference and defuzzyfication.

For the description of the fuzzy inference system, a combination of fuzzy methods for operations between input variables (linguistic values) and behavior based on the sequencing of rule creation was used as a basis, making it possible to develop a Fuzzy model for technical analysis of risks associated with R&DI Project Management through the generation of numerical values of logic outputs, thus achieving the objective of the study.

The main steps of the method used were:

- Identification of risk factors (linguistic variables) inherent to projects;
- Establishment of criteria and indicators based on linguistic variables;

- Data Processing and Classification – Development and Implementation of the Rule Base and the Fuzzy System;
- Interpretation of linguistic results in final results (numerical variables).

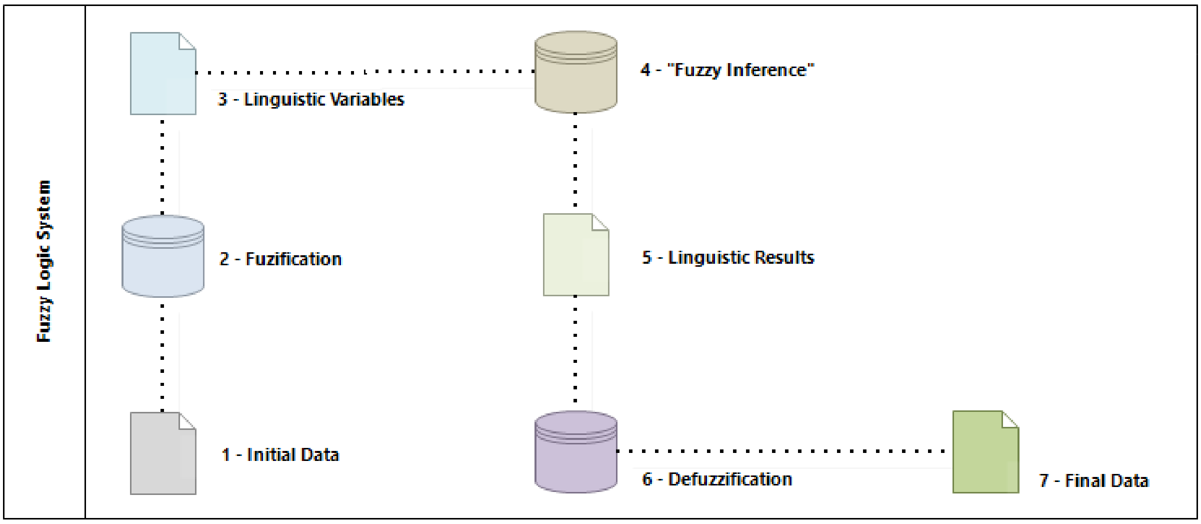
3.2.3 Evaluation Mechanisms by Fuzzy Logic

To assess the degree of risk of a project, risk factors such as cost, time, scope, quality, human resources must be considered, not limited to these.

Based on the literature, interviews with the project management team of the organization object of this study and analysis of the documentation that record the history of projects already developed, it was identified that time, scope, cost and human resources as linguistic variables used to the assessment of the degree of risk in technological innovation projects in the current scenario of global technological advancement in which the organization is inserted.

The Fuzzy Logic System is structured in three main steps which are illustrated in Figure 10.

Figure 10 - Fuzzy Logic System



As shown in Figure 10, in the first step, the fuzzification step" (2) is performed, in which the transformation of the initial data (1) into linguistic variables (3) takes place, a phase in which all information related to imprecision or uncertainty associated with these variables must be considered. In the second step, after adjusting the initial values in linguistic variables (3), the Fuzzy "inference" is the next phase (4), whose purpose is to compare the probable variables among themselves by means of pre-established norms, with the goals of the algorithm achieved. From the Fuzzy logic system, "defuzzification" is the third and last step (6) and comprises the identified linguistic result (5) of the Fuzzy "inference" methodology in final elements (7), in numerical value to be analyzed for identification the degree of risk of the project.

Table 1 presents the Methodological Process of this study, which was developed in three phases:

1. Risk Factors;
2. Fuzzy "Inference" System;
3. Experiment of the Proposed Model.

Each phase is composed of the steps listed in Table 1:

Table 1 - Methodological Process

PHASE	STAGE
Risk factors	Project Management Data Collection
	Definition of the Fuzzy Set
"Fuzzy Inference" System	Development of "Inference" Rules
	Simulation in MatLab R2019a software
Experiment of the Proposed Model	3D Results Simulation
	Conclusion

3.2.3.1 Project Management Data Collection

The Project Management Data Collection consists of identifying risk factors in projects, which were researched in the literature and fed into Fuzzy logic. This step aimed to seek the theoretical framework as well as historical data referring to projects developed by the organization that is the focus of this study on the factors that increase or decrease the degree of risk of a project. The main theoretical framework used was the PMBOK, which explains the main characteristics to be managed to have a successful project.

3.2.3.2 Definition of Fuzzy Set

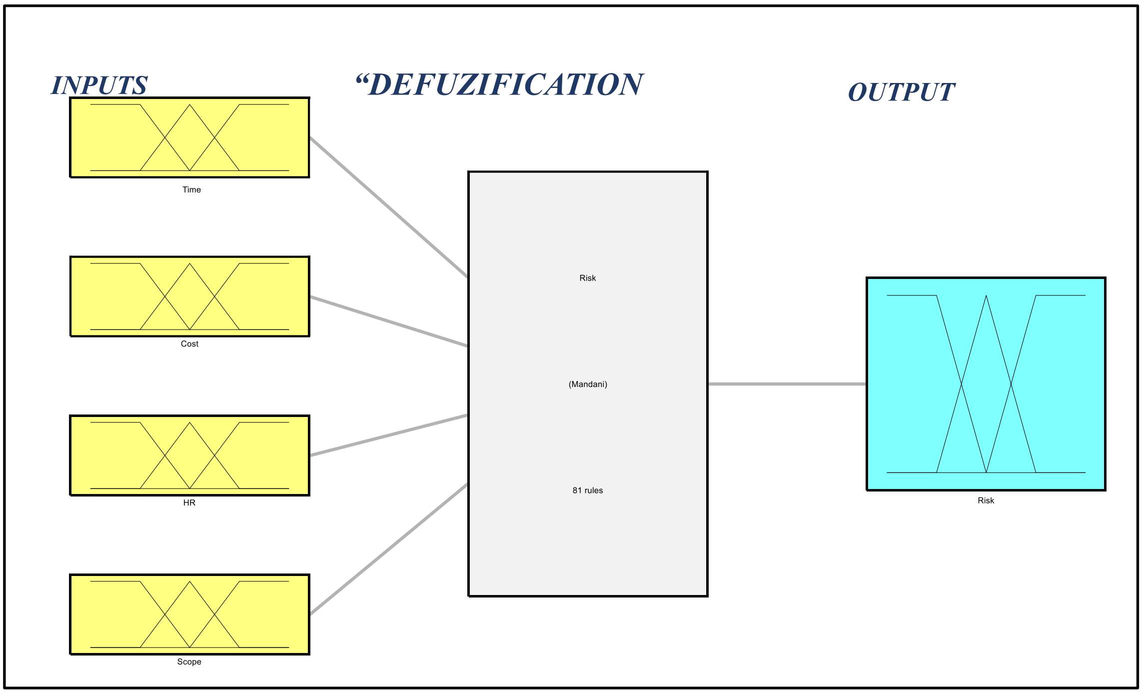
To establish the fuzzy system, the input variables were defined through the identification of the risk factors of a project and according to the inference of each one of them through the analysis of the history of previous projects developed by the organization and through the experience of the professionals belonging the project management sector. Table 2 shows the triangular and trapezoidal membership functions established for the proposed system.

Table 2 - System Relevance Functions

APPETIZER		
Variables	**Numeric Range**	**Linguistic Value**
Scope	[0 - 100]	Poor, Moderate, Good
Time	[0 - 1096]	Short, Moderate, Long
Cost	[0 - 100]	Low, Moderate, High
Human Resources	[0 - 100]	Little, Experienced, Much
EXIT		
Project Risk Degree	[0 - 100]	Low, Moderate, High

Figure 11 illustrates the Fuzzy "Inference" System, which is presented in advance to facilitate the understanding of the text, since it brings a demonstration of the identified risk factors and the definition of the structure of the Fuzzy System to be developed to obtain the Risk Degree of a project.

Figure 11 - Fuzzy "Inference" System (Risk Degree)



It is possible to observe in the representation of Figure 11 that the identified risk factors will be jointly processed by the fuzzy inference system in order to identify the degree of risk of a given project.

3.2.3.3 Definition of Inference Rules

After the fuzzification step of the input parameters, it is necessary to apply the fuzzy ruleset. In this step it is necessary to determine the rules of the decision-making process of the system. The rules defined in this study for the system for analyzing the degree of risk in projects are constructed in the form . The conclusion indicates the set to which the output variable belongs, within the fuzzy sets of this variable. $SE < condição\ 1 < E < condição\ 2 < ENTÃO < conclução >$

In this study, 81 rules were defined for inference of the fuzzy system, described in Table 3, considering the risk factors scope, time, cost and human resources.

Table 3 - Rules of Inference

#	Fuzzy Rules
1	If (Time is Short) and (Cost is Low) and (HR is Little) and (Scope is Bad) then (Risk is High)
2	If (Time is Short) and (Cost is Low) and (HR is Experienced) and (Scope is Bad) then (Risk is High)
3	If (Time is Short) and (Cost is Low) and (HR is Too) and (Scope is Bad) then (Risk is High)
4	If (Time is Short) and (Cost is Moderate) and (HR is Little) and (Scope is Bad) then (Risk is High)
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6	If (Time is Short) and (Cost is Moderate) and (HR is Very) and (Scope is Bad) then (Risk is High)
7	If (Time is Short) and (Cost is High) and (HR is Little) and (Scope is Bad) then (Risk is High)
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12	If (Time is Moderate) and (Cost is Low) and (HR is Very) and (Scope is Bad) then (Risk is High)
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14	If (Time is Moderate) and (Cost is Moderate) and (HR is Experienced) and (Scope is Bad) then
15	If (Time is Moderate) and (Cost is Moderate) and (HR is Very) and (Scope is Bad) then (Risk is
16	If (Time is Moderate) and (Cost is High) and (HR is Little) and (Scope is Bad) then (Risk is High)
17	If (Time is Moderate) and (Cost is High) and (HR is Experienced) and (Scope is Bad) then (Risk is
18	If (Time is Moderate) and (Cost is High) and (HR is Very) and (Scope is Bad) then (Risk is High)
19	If (Time is Long) and (Cost is Low) and (HR is Little) and (Scope is Bad) then (Risk is High)
20	If (Time is Long) and (Cost is Low) and (HR is Experienced) and (Scope is Bad) then (Risk is High)
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25	If (Time is Long) and (Cost is High) and (HR is Little) and (Scope is Bad) then (Risk is High)
26	If (Time is Long) and (Cost is High) and (HR is Experienced) and (Scope is Bad) then (Risco is High)
27	If (Time is Long) and (Cost is High) and (HR is Lots) and (Scope is Bad) then (Risk is High)
28	If (Time is Short) and (Cost is Low) and (HR is Little) and (Scope is Moderate) then (Risk is High)
29	If (Time is Short) and (Cost is Low) and (HR is Experienced) and (Scope is Moderate) then (Risk is
30	If (Time is Short) and (Cost is Low) and (HR is Very) and (Scope is Moderate) then (Risk is
31	If (Time is Short) and (Cost is Moderate) and (HR is Little) and (Scope is Moderate) then (Risk is
32	If (Time is Short) and (Cost is Moderate) and (HR is Experienced) and (Scope is Moderate) then
33	If (Time is Short) and (Cost is Moderate) and (HR is Very) and (Scope is Moderate) then (Risk is
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36	If (Time is Short) and (Cost is High) and (HR is Very) and (Scope is Moderate) then (Risk is High)
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38	If (Time is Moderate) and (Cost is Low) and (HR is Experienced) and (Scope is Moderate) then
39	If (Time is Moderate) and (Cost is Low) and (HR is Very) and (Scope is Moderate) then (Risk is
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41	If (Time is Moderate) and (Cost is Moderate) and (HR is Experienced) and (Scope is Moderate)
42	If (Time is Moderate) and (Cost is Moderate) and (HR is Very) and (Scope is Moderate) then (Risk
43	If (Time is Moderate) and (Cost is High) and (HR is Little) and (Scope is Moderate) then (Risk is
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52	If (Time is Long) and (Cost is High) and (HR is Little) and (Scope is Moderate) then (Risk is High)
53	If (Time is Long) and (Cost is High) and (HR is Experienced) and (Scope is Moderate) then (Risk is
54	If (Time is Long) and (Cost is High) and (HR is Very) and (Scope is Moderate) then (Risk is
55	If (Time is Short) and (Cost is Low) and (HR is Little) and (Scope is Good) then (Risk is Moderate)
56	If (Time is Short) and (Cost is Low) and (HR is Experienced) and (Scope is Good) then (Risk is

57	If (Time is Short) and (Cost is Low) and (HR is Very) and (Scope is Good) then (Risk is Moderate)
58	If (Time is Short) and (Cost is Moderate) and (HR is Little) and (Scope is Good) then (Risk is
59	If (Time is Short) and (Cost is Moderate) and (HR is Experienced) and (Scope is Good) then (Risk
60	If (Time is Short) and (Cost is Moderate) and (HR is Lots) and (Scope is Good) then (Risk is
61	If (Time is Short) and (Cost is High) and (HR is Little) and (Scope is Good) then (Risco is High)
62	If (Time is Short) and (Cost is High) and (HR is Experienced) and (Scope is Good) then (Risk is
63	If (Time is Short) and (Cost is High) and (HR is Lots) and (Scope is Good) then (Risk is Moderate)
64	If (Time is Moderate) and (Cost is Low) and (HR is Little) and (Scope is Good) then (Risk is
65	If (Time is Moderate) and (Cost is Low) and (HR is Experienced) and (Scope is Good) then (Risk is
66	If (Time is Moderate) and (Cost is Low) and (HR is Very) and (Scope is Good) then (Risk is Low)
67	If (Time is Moderate) and (Cost is Moderate) and (HR is Little) and (Scope is Good) then (Risk is
68	If (Time is Moderate) and (Cost is Moderate) and (HR is Experienced) and (Scope is Good) then
69	If (Time is Moderate) and (Cost is Moderate) and (HR is Lots) and (Scope is Good) then (Risk is
70	If (Time is Moderate) and (Cost is High) and (HR is Little) and (Scope is Good) then (Risk is
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78	If (Time is Long) and (Cost is Moderate) and (HR is Very) and (Scope is Good) then (Risk is Low)
79	If (Time is Long) and (Cost is High) and (HR is Little) and (Scope is Good) then (Risk is Moderate)
80	If (Time is Long) and (Cost is High) and (HR is Experienced) and (Scope is Good) then (Risk is Low)
81	If (Time is Long) and (Cost is High) and (HR is Lots) and (Scope is Good) then (Risk is Low)

Results And Discussions

4.1 Simulation in Matlab R2019a Software

With the fuzzy sets defined through the identification of risk factors and the defined inference rules, simulations are carried out in Matlab software, Student R2019A version, using the Fuzzy Toolbox graphic application to visualize the possible conditions for each of these factors and the degree of risk of a project. The Figure 12 is representing the possible conditions identified for defining the scope of a project. According to the literature, the experience of the professionals consulted and the history of projects used in this research, the variation in the condition of definition of this risk factor has a great impact on the elevation of the degree of risk of a project.

Figure 12 - Graphical Representation of the Scope Risk Factor

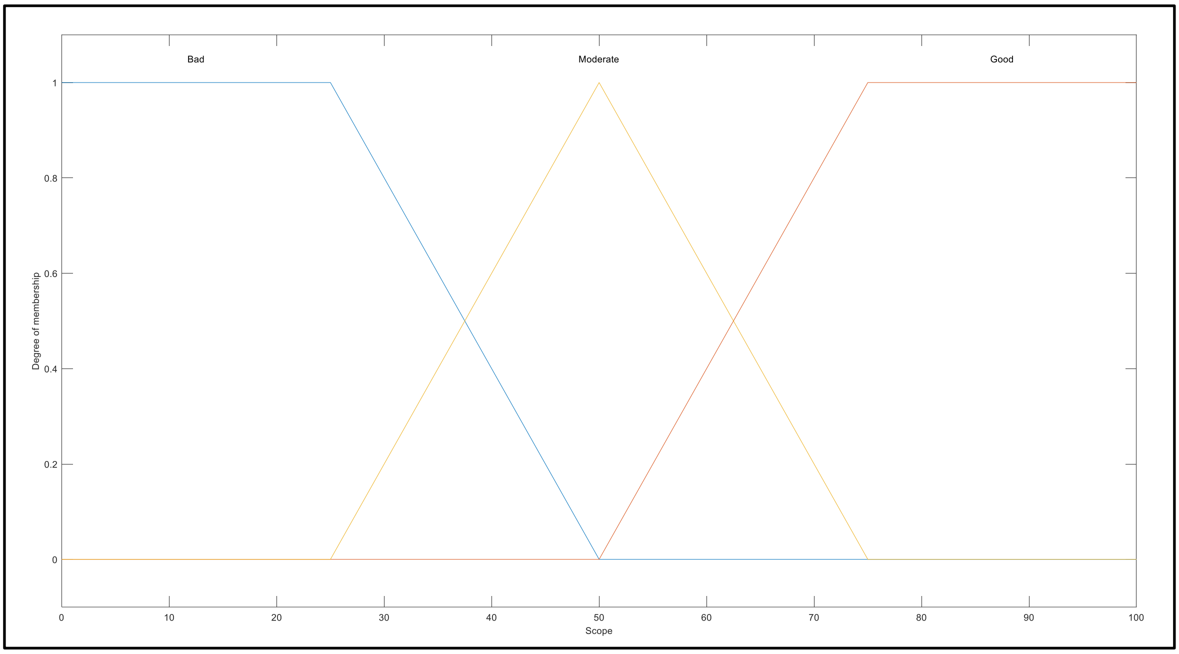


Figure 12 illustrates Bad, Moderate, and good conditions as the scoping levels of a project. For the purposes of this study, the variation from 0 to 100 was considered to visualize the scope definition levels.

The Figure 13 is representing the possible conditions identified for the time established for the development of a project. For the projects developed at the Research Institute object of this study, projects with an execution period of up to one year are considered projects with a short development time, projects with a period of up to two years for development are considered moderate and periods of up to three years or more are considered considered deadlines for project development with long time.

Figure 13 - Graphical Representation of the Time Risk Factor

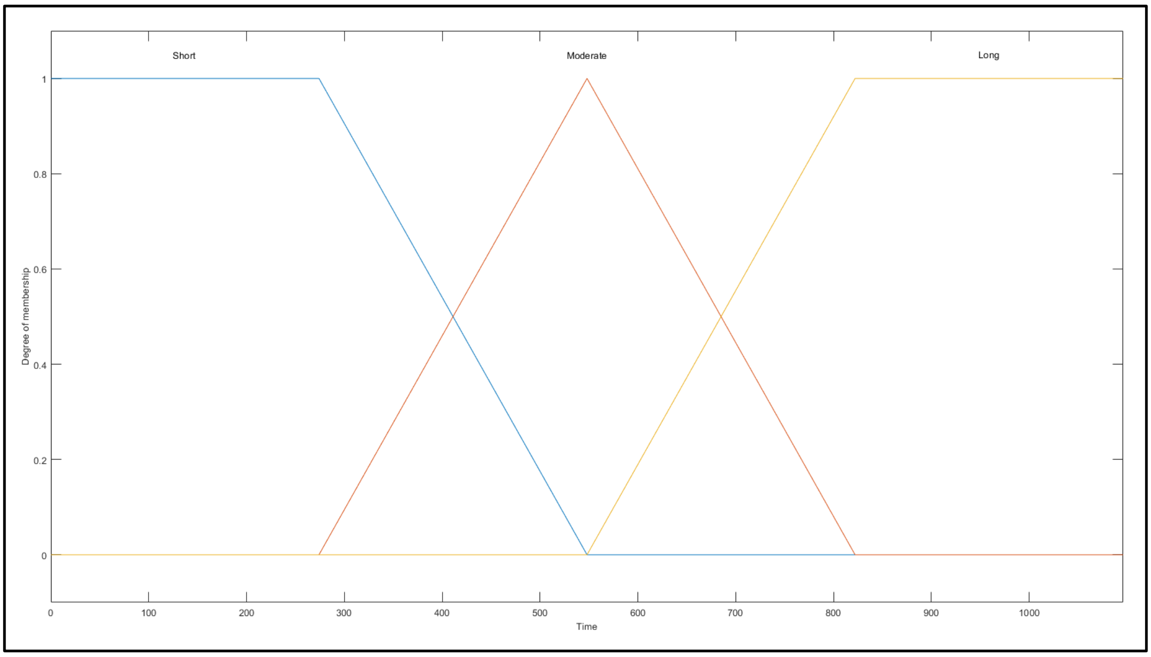


Figure 13 illustrates the graphical representation of the time conditions as Short, Moderate and Long for the development of a project.

Figure 14 represents the possible conditions identified for the cost of developing a project. To analyze the cost of a project, in this study, the variation from 0 to 100 was used for visualization.

Figure 14 - Graphical Representation of the Cost Risk Factor

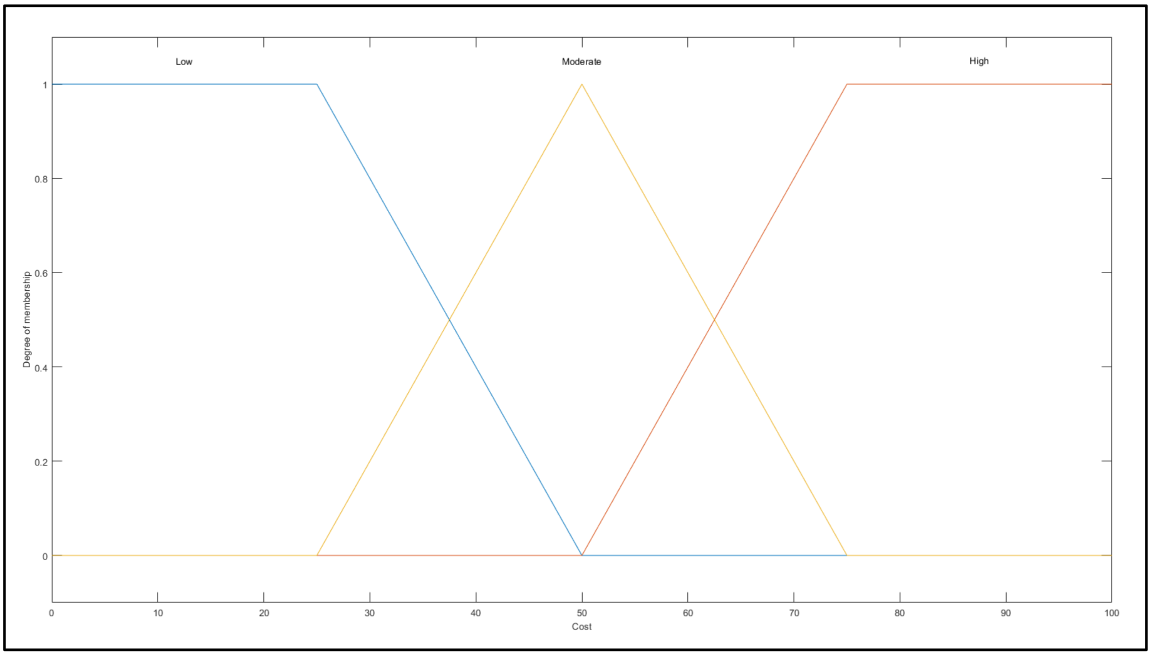


Figure 14 illustrates the graphical representation of the cost conditions as Low, Moderate and High for developing a project.

Figure 15 represents the possible conditions identified for the experience level of a project's development team. To analyze the experience level of a project team, in this study, the variation from 0 to 100 was used for visualization.

Figure 15 - Graphic Representation of the Risk Factor Human Resources

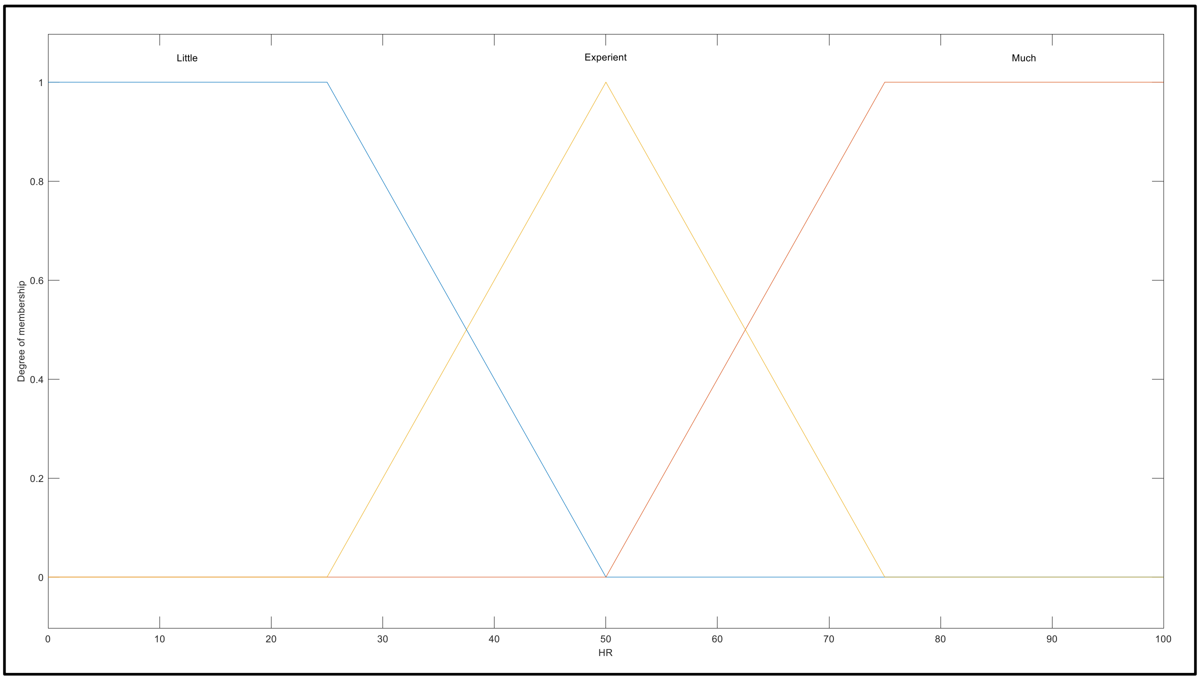


Figure 15 illustrates the graphical representation of the experience level of the development team of a project that can present the conditions of Little Experienced, Experienced and Much Experienced.
The Figure 16 is representing the conditions for the degree of risk of a project after applying the inference rules determined for the fuzzy system. To analyze the degree of risk of a project, in this study the variation from 0 to 100 was used for visualization.

Figure 16 - Graphical Representation of the Degree of Risk

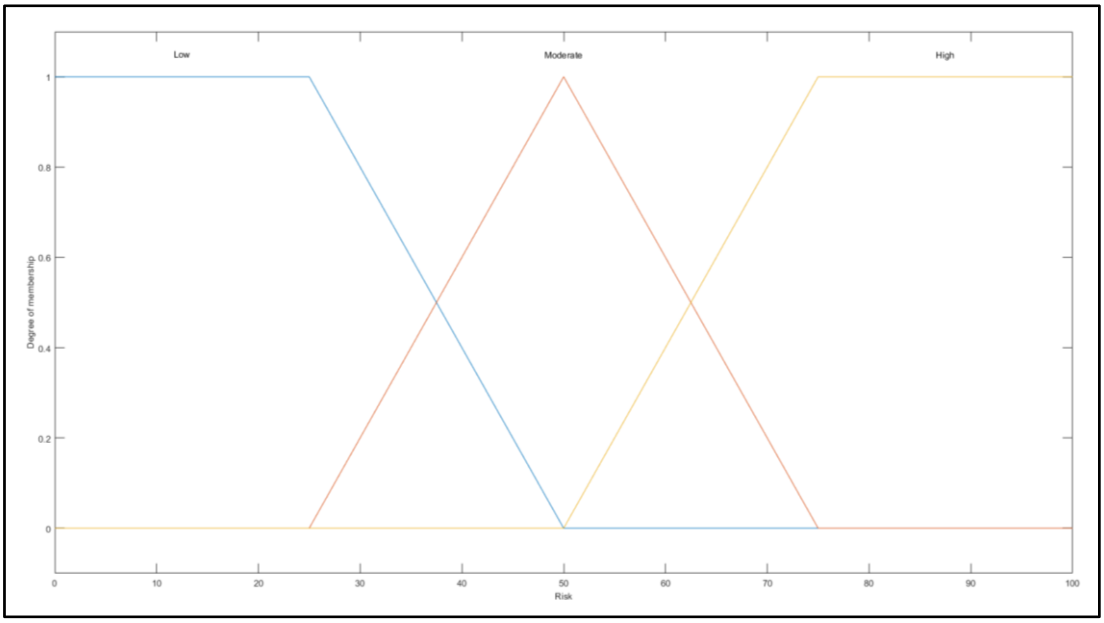


Figure 16 illustrates the graphical representation of the degree of risk of a project that can present conditions of Low, Moderate and High.

For the final phase, Matlab, Student version R2019A - Fuzzy Toolbox will be applied to compile the indicator aggregation algorithm and model simulations.

4.2 Analysis of the Degree of Project Risk Using Fuzzy Logic

The fuzzy model adopted has the analysis data displayed in the rules viewer, enabling the interpretation of the inference process and also demonstrating the functions that reflect on the result of the project risk analysis system.

By varying the values of the risk factors, called inputs, it is possible to analyze the output of the proposed model, reaching a value that allows a correct analysis of the efficiency of the method adopted to support decision making regarding the type of strategy suggested by crossing the input variables.

For greater clarity of the fuzzy model adopted, hypothetical input values will be defined that show, however, the impact that the identified risk factors have on the degree of project risk.

In Figure 17 it is possible to observe that when all risk factors are in a moderate status, the project risk degree is also moderate.

Figure 17- Moderate Inference of Risk Factors

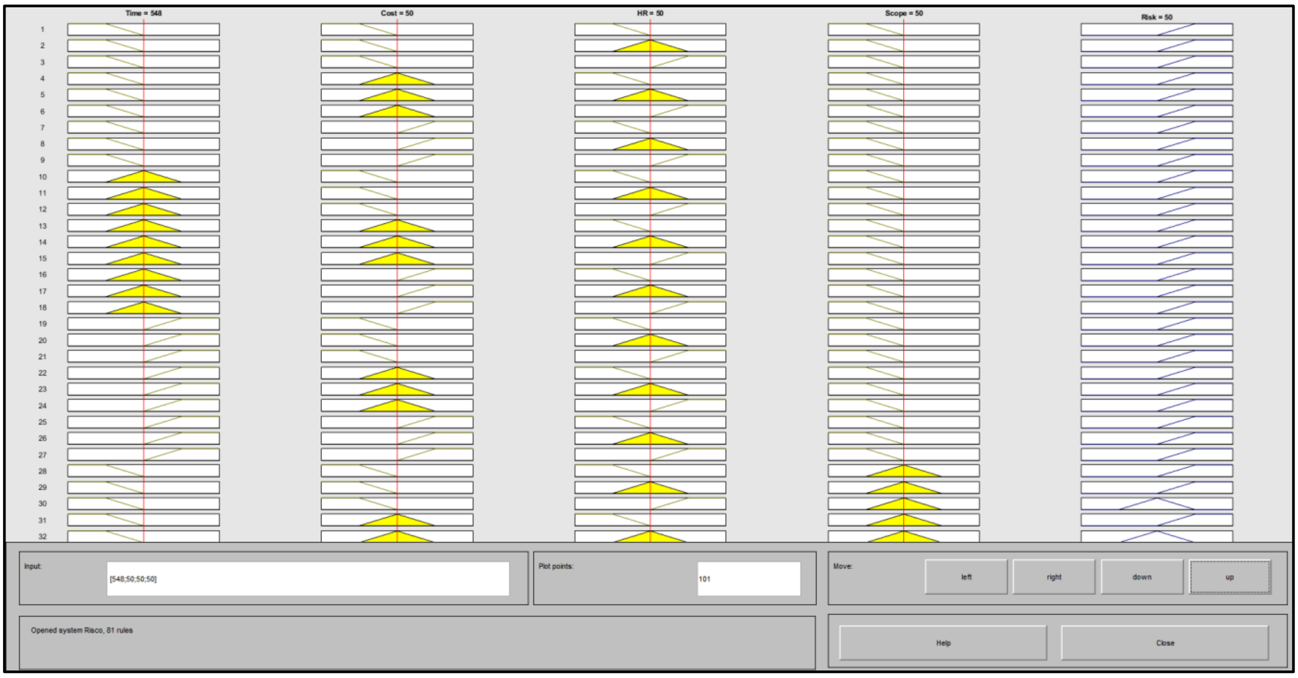


Figure 17 represents the level of project risk unchanged and at a moderate level when all risk factors are kept at a moderate level.

In Figure 18, it is possible to observe that poor definition of the scope has a relevant impact on the degree of risk of the project, even though the other risk factors belonging to the analysis of this study are kept as moderate. This result confirms the information collected from project management professionals at the Institute object of this work, who reported that the scope risk factor is the main contributing factor to the elevation of the risk level of projects.

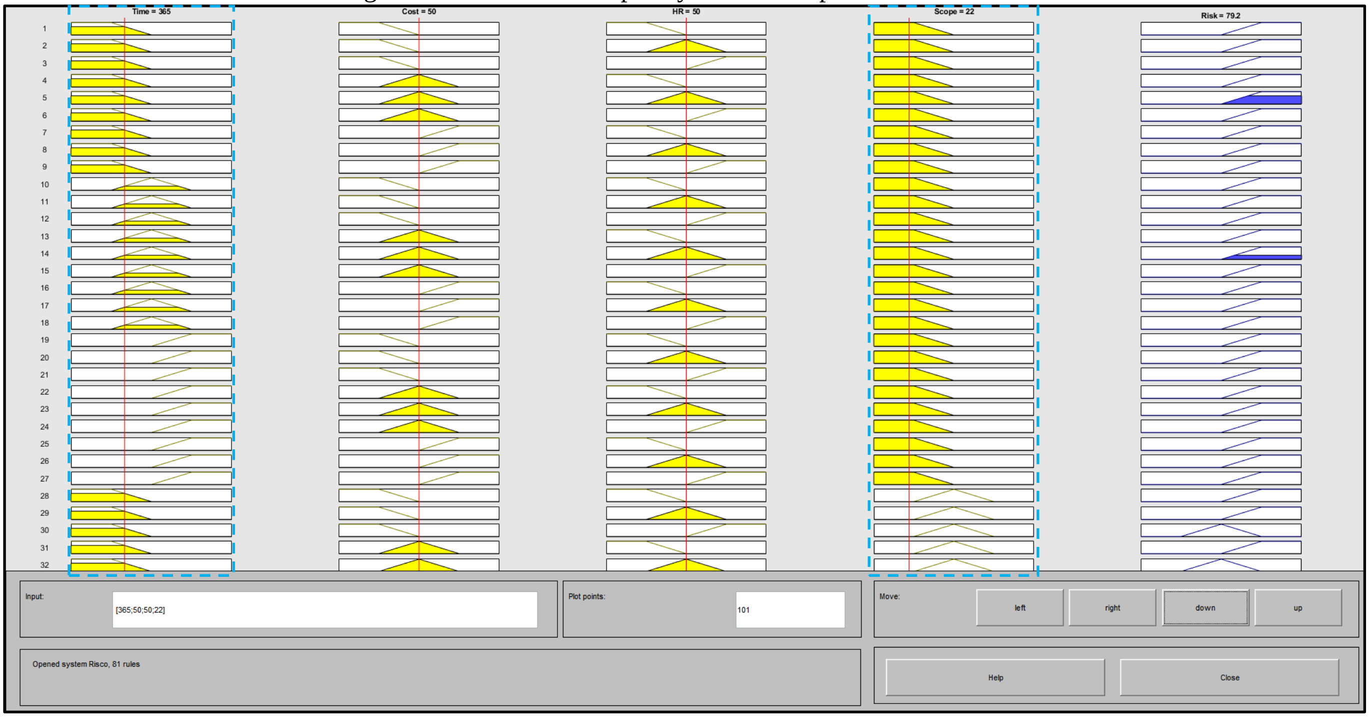
Figure 18 illustrates that poor scope definition has a relevant impact on the degreeproject risk.When

Figure 18 - Scenario with poorly defined scope

changing the scope definition value to 22.4 and keeping the values of the other factors, it is possible to observe that the risk degree has a considerable increase from 50.0 to 80.8. This finding confirms that the use of the fuzzy method allows organizational management to make decisions regarding the prioritization of actions to be taken with a focus on controlling the factors that have the greatest impact on raising the risk level of the project.

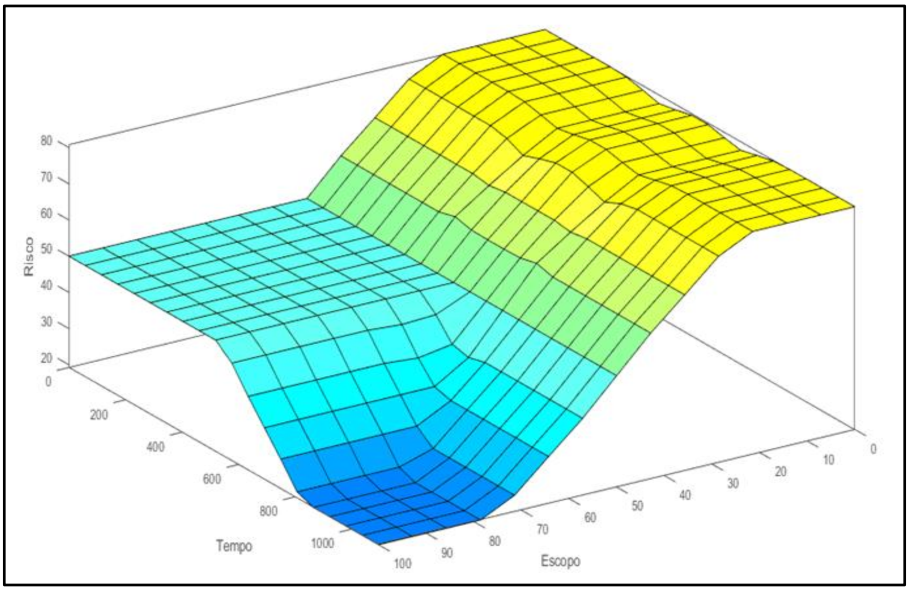
Figure 20 illustrates the surface window generated by the matlab of the proposed study model, where it can be observed that the worse the scope definition and the shorter the time for project development and delivery, with the other factors being kept unchanged. , the greater the degree of risk of the project according to the definitions explained in Figure 19.

Figure 19 - Scenario with poorly defined scope and short time



In Figure 20, it is possible to observe that the most comfortable degree of risk for the development of a project is in a region where there is a long execution time and a better detailing/definition of the project.

Figure 20 - Surface Analysis of the Degree of Risk



Conclusions

Applying the Fuzzy logic model, it becomes possible to identify in a more precise way the degree of risk through the combination of inference levels of risk factors associated with the entire cycle of conception of a project, thus eliminating the subjectivity of the analysis.

Meeting the first specific objective of this study, 04 (four) linguistic variables were identified, called risk factors, whose combined inference levels directly impact the degree of risk of a project.

The linguistic variables identified in this study were scope, time, cost and HR (Human Resources), with the characteristics of each one described and the levels of inference about the degree of risk identified based on the analysis of R&DI projects already developed and the contribution of experts in the area of projects and thus meeting the second and third specific objectives of this work.

From the identification of linguistic variables and the inference levels of each one of them, a Fuzzy inference model was developed to analyze the technical feasibility of the risks associated with R&DI Project Management, which allows a more realistic analysis of the degree of risk of this type of project, enabling decision-making by organizational managers of Research Institutes more effective and focused on the factors that most impact the success of the projects developed. The development and implementation of the fuzzy model to analyze the degree of risk in R&DI projects allowed reaching the fourth specific objective and the general objective of this study.

The experience of professionals in the area of project management brings a relevant contribution to the final result, as it provides the analysis tool with concrete data extracted from real situations that occurred in the management process of already developed projects.

The fuzzy logic model developed in this study allows professionals, even with little experience, to carry out the analysis of the degree of risk of a project from the associated risk factors without subjectivity, since the possibilities for analysis are beyond the simple "yes" or "no" of the usual logic.

Based on the results obtained in this study, some suggestions are shared for project managers of organizations:

1. Identify the risk factors and plan the development of actions that aim to neutralize the risks, recognizing, monitoring and even continuously re-analyzing the risks inherent to the organization's projects using scientific methods such as the model presented here for greater precision and reliability, because without the using scientific methods, the decisions taken by managers can be subjective and detached from reality, putting the success of the project to be developed at risk;
2. Make decisions based on a combination of approaches derived from previous theories and studies, national and international documentation and standards, risk management standards such as the PMBOK® Guide, as well as considering the opinions of the organization's experts and managers who are because of their competence and experience, and thus contribute to the success of the projects and, consequently, the achievement of organizational objectives. achievement of its objectives;
3. Analyze the extent to which risks can affect and be affected, in addition to recognizing that the degree of improvement in each of the risks can be so effective as to improve, in addition to the degree of risk of the project, other risks associated with it. In this way, managers can identify the domino effect of risks and focus their attention on those risks whose improvement can change the entire model.
4. Use multi-criteria decision-making techniques to help prioritize risks;
5. Reduce the ambiguity and complexity inherent to decision making using a model such as fuzzy logic, which has as one of its characteristics a combination of techniques that offer more realistic results through verbal descriptions;

6. Make use of a set of tools that can consider the collective opinions of experts and build an organization and classification model using structuring and multi-criteria approaches to decision making to improve your decisions.

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