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RESEARCH ARTICLE

Risk Analysis with Fuzzy Logic in R&D Projects

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ABSTRACT

Since the beginning of the 1950s, it has been seen that Research and Development (R&D) and its projects have touched almost every aspect of life and have changed life. These projects make a great contribution to the development and change of humanity in all fields of work. This developments and changes include pros and cons. There are many gray areas in these projects where many unknowns are discovered or known ones are developed. These gray areas also contain risks due to the nature of obscurity. Therefore, measuring the impact of these risks is very important for the success of the project. To date, many different studies have been carried out in this area where more than one risk analysis method is applied. In this study, it is aimed to calculate the risk analysis on MATLAB using the fuzzy logic method for an R&D laboratory in the food sector in Turkey, in the R&D projects. By gathering the experts in the R&D center, it has been determined which of the risk classes in the literature are suitable for this center, and the project risk has been chosen as the output value. Afterwards, the risk output has been calculated with the established fuzzy system, and the results have been evaluated on the sample scenarios. In this way, the risks and uncertainties included in R&D projects, which are always known, have been made concrete and their visibility has been facilitated.

Keywords: R&D Project, Risk Analysis, Classifications of Risks, Fuzzy Logic

1. Introduction

The pursuit of knowledge has been part of our global world for centuries. For a long time, researchers have followed developments in science and technology, increasing new information and innovations in every field. The emergence of industrialization, the change in industrial policy, and the increased focus on research and development have always occurred in various ways. Every society has followed this path, which is shown as the pioneer of science and economic growth, that is, knowledge, technology and innovations. As science continued to develop, technology was also affected, which resulted in an organizational reset on the technology front, which led to the emergence of the term R&D (Akhilesh, 2014).

Many companies perceive R&D as a difficult practice due to its high uncertainty, uncertain rate of return, and difficulties in managing it. On the other hand, companies that manage to commercialize new technology quickly and precisely gain a significant competitive advantage by using greater market share, very high selling prices and the ability to acquire dominant designs.

The ability to develop new technologies and integrate them into commercialized products using a fast, repeatable and efficient process is the basis of competitiveness for industrial firms (Iansiti and West, 1997). The realization of all these elements can only be possible with R&D, but such projects involve a great deal of risk, as there is a lot of uncertainty in R&D. It is of great importance to determine the impact of these risks on the success of the project or to evaluate them according to the situation during the project. Various methods are used in the literature for risk analysis. Increasing uncertainty, proliferation of information, fulfillment of every new work done with project management and R&D approach create a chaotic situation, which increases risk and necessitates more sensitive risk management techniques.

The concept of R&D has been defined in different ways from different perspectives by many institutions, organizations and scientists in literature. The Organization for Economic Cooperation and Development (OECD) defines R&D as "creative work carried out systematically to increase knowledge and the use of this knowledge to create new applications" (OECD, 2008). R&D is defined by Roussel et al. (1991) as developing new knowledge and applying this knowledge to scientific or engineering fields.

It is obvious that every expenditure made for R&D and the labor consumed will make a return for countries/institutions as advanced technology, and therefore, advanced economy and welfare level. The countries that allocate the largest share to R&D are also at the forefront of development level.

One of the most important factors that distinguishes R&D management from other business functions is that R&D studies contain too much uncertainty. In addition, individuals working in R&D units have very different qualifications compared to other units. R&D processes have a dynamic structure that can change very quickly. For this reason, it is necessary to pay more attention while using principles, methods and management styles which are used in other business functions in R&D units. (Barutçugil, 2009).

R&D projects are even more risky than normal projects and these risks have the power to affect success negatively. Because of that, a good risk analysis study is a must for R&D projects. In addition to many risk analysis methods in the literature, it is possible to calculate the risk ratio of R&D projects with the fuzzy logic method. In this context, there are R&D projects in literature where risk calculations are made with the fuzzy logic method.

Today, R&D is the primary condition for development and survival in such a competitive environment. In addition, successful R&D projects cannot be made with only resource allocation. It should be noted that developed countries also implement modern and scientific R&D management processes and risk management processes. These risks should be managed well, and the resources allocated so much should not be wasted. Risk analysis is also of great importance in this regard.

In the second part of this article, the concepts of R&D and risk are examined in detail, in the third part, fuzzy logic method is mentioned, in the fourth part, risk analysis is applied in Food R&D projects by using fuzzy logic method and finally in the fifth part conclusions and recommendations are given.

2. The Concept of Risk and Risk in R&D Projects

From the point of view of businesses, risk can be expressed as all kinds of obstacles and events that businesses may encounter in line with their previously planned goals and objectives. Risk includes not only dangers but also opportunities. If the risk situation is experienced due to unexpected events, it is considered as danger, if it is experienced as a result of change, it is considered as uncertainty. If the risk situations encountered can be used in favor of the firms, this situation is expressed as an opportunity for the firms. (Keskin, 2006).

The fact that risks can never be eliminated is an issue that deserves special attention. Risks can only be limited by the risk management created by the enterprises themselves and operating effectively (Pehlivanlı, 2010).

2.1 Risk Analysis

Defining the risk means identifying and detecting the risk. The information obtained during the risk identification phase includes the processes of providing solutions to the problems. Research on risk identification shows that this process includes the process of reducing technological, social and political uncertainties and minimizing possible financial losses (Hertz and Howard, 1983).

Every individual involved in the business plays an active role in the success of risk management. However, the main responsibility for defining and managing risks belongs to management (Keskin, 2006). Risk managers prefer several tools and methods to identify risks to prevent risks from being overlooked (Vaughan, 1999). These are interviews and surveys, brainstorming, incident research, risk consultants, insurance checklists, risk analysis questions, flowcharts, financial situation analysis, business process analysis and process mapping, simulation, etc. (Anderson et al., 1994). Risk analysis is the process of estimating, uncovering, measuring, and ranking risks. The purpose of risk analysis is to reveal the cause, effect and severity of each identified risk. Modeling is required to quantify and measure the severity of a particular risk.

The risk matrix is an output of the risk analysis process. The probability and severity of risks evaluated using qualitative or quantitative methods are revealed with the risk matrix in Table 1 (Celayir, 2011).

Table 1. Absolute Risk Matrix

Probability	1 (Very Light)	2 (Light)	3 (Medium)	4 (Serious)	5 (Very Serious)
1 (Very Little)	1 Insignificant	2 Low	3 Low	4 Low	5 Low
2 (Little)	2 Low	4 Low	6 Low	8 Medium	10 Medium
3 (Medium)	3 Low	6 Low	9 Medium	12 Medium	15 High
4 (High)	4 Low	8 Medium	12 Medium	16 High	20 High
5 (Very High)	5 Low	10 Medium	15 High	20 High	25 Intolerable

The risk matrix gives an idea about the degree of the analyzed risk, the order of the measures to be developed against this risk and the size of the resource to be allocated for these measures. When Table 2.1 is examined, it is seen that the effect and probability of each risk on the matrix is determined numerically between 1 and 5. In this technique, risks are ranked according to their points in the matrix area from 1 (1x1) to 25 (5x5). The meanings of the dots in the matrix, which are the combination of probability and severity level, can be expressed as follows:

- 15, 16, 20, 25: Unacceptable risk (Red)
- 8, 9, 10, 12: Considerable risk (Yellow)
- 1, 2, 3, 4, 5, 6: Acceptable risk (Green)

Among the risks rated by the risk matrix, the priority ones should be embraced as soon as possible. The possible causes of the risks in the high-risk group should be examined and the actions to be taken and the steps to be taken in order to control these risks should be developed as suggestions.

In Table 2, the analysis of the risks during the risk analysis of the enterprises and the steps to be taken against these risks are summarized.

Table 2. Analysis of risks and order of things to be done in risk analysis (Şafak et al., 2018)

High Risk (16-25)	Studies should be stopped immediately, and studies should not be restarted until the identified risks are reduced to reasonable levels.
Medium Risk (9-15)	Medium risks should only be tolerated in the short term. Then, to reduce the level of risk in a certain period, precautionary plans should be implemented and put into effect.
Low Risk (1-8)	Low risks are largely acceptable following periodic reviews or significant changes.

Risk analysis includes the identification, analysis and rating of risks that may prevent companies from reaching their predetermined goals (Celayir, 2011).

To reduce the severity of the danger that will arise when the risks included in the risk matrix are encountered in the projects and to cope with the risks effectively, a good risk management program should be prepared first. Firms should determine the most appropriate risk analysis method for their organization, considering their own needs and the goals they will achieve. At this point, the firm should compare and evaluate all risk analysis techniques correctly in order not to waste time and resources. However, this selection issue is a very sensitive and critical process. The most reliable method in determining risk analysis methods is to compare these methods with subjective and quantitative criteria (Vorster and Labuschagne, 2005). In the literature, risk analysis methods are defined in two different ways as qualitative and quantitative methods (Karabacak and Soğukpınar, 2004).

There are more than 100 qualitative and quantitative risk analysis methods in the literature. Some of the most commonly used methods are Human Error Identification Method, Fine-Kinney Method, Risk Mapping Method, Event Tree Analysis, What if it happens? Analysis Method, Zurich Hazard Analysis, 3T Risk Assessment Analysis, Bow-Tie Analysis, FMEA, PHA, Fuzzy Logic and Hierarchical Task Analysis.

R&D studies are inherently a risky activity that is done for the first time. It is an absolute necessity to run risk management processes for R&D studies within the logic of Project Risk Management. R&D projects involve a lot of uncertainty, and therefore techniques such as fuzzy logic stand out as a good technique in R&D projects risk analysis. Carlsson et al. (2006) used the fuzzy logic method to identify projects with low risk in portfolio selection in the R&D project.

2.1.1. Identifying Responses to Risks

The biggest step that businesses will take after recognizing and analyzing risks is the process of determining a strategic response to risks. At this point, it is necessary to determine whether the risks are within the risk capacity and risk tolerance of the enterprises and companies. Because the answers of the enterprises to the risks differ according to the risk being within the risk limits that the firm is ready to undertake (Arslan, 2008). The risk attitude of the firm management may develop as avoiding risk, accepting risk, reducing risk or sharing risk. This situation differs according to the risk culture and risk appetite of the enterprises.

With different responses to risk, business management will be able to reduce the severity of the risk and control the negative impact. The answers will differ depending on the importance of the risk to the business and the level of risk. Accordingly, the scale in Table 3 below summarizes the response to the risk and the strategies to be followed according to the degree of impact and probability of the risk:

Table 3. Risk Response Strategies in Terms of Risk Degrees

High		
IMPACT	Medium Level Risk Share	High Level Risk Check & Decrease
	Low Level Risk Accept	Medium Level Risk Check
Low	PROBABILITY	High

There are four different risk response techniques for the risks that may cause danger for the success of the projects carried out by an enterprise. These techniques can also be expressed as the risk management strategies of the enterprise. Risk response techniques are called accepting (risk-taking strategy), controlling (risk mitigation strategy), delegating (risk transfer strategy), and avoiding (risk avoidance strategy) (Acuner, 2005).

2.1.2. Risk Monitoring and Control

Risk monitoring and control includes monitoring risks, monitoring the risk response plan and checking its applicability, and making observations about the effectiveness of this plan. The main purpose of monitoring and controlling the risks is to observe the status of the identified risks, to determine the new risk factors and to ensure that the prepared answers are applied in a healthy way. In this way, the changes in possible risks that may occur during the activities are monitored. This monitoring and control chain, which should continue from the beginning to the end of an activity, should not be completed before the end of the project (Fırat, 2009). Because while the project activities continue, there is a possibility that the possible risks can change, or new risks can emerge.

Monitoring and control activities are the implementation of the policies and procedures determined by the administration and those responsible for the effective implementation of the strategies developed against risk and the management of ongoing risks within the risk tolerance. Controls to be developed in risk management in the institutional sense should include the frequency of risk development and all the activities to reduce the cost of this risk (Ballou and Heitger, 2005). Control activities can be prepared in four different ways as preventive, corrective, directive and supervisory control (Derici et al., 2007).

2.2 Risk Management and Planning in R&D Projects

A project that seeks and questions the development of technical knowledge or skills in scientific or technological fields is called an R&D project. At the same time, projects that contribute to the development, improvement or creation of time, resources, materials, tools, products or services in a way that adds value can also be considered as R&D projects. However, to see innovations and advances in today's science and technology society, it is necessary to produce something new or make improvements with added value. (Tolga and Kahraman, 2009).

Today, R&D projects are considered as one of the most accurate investment decisions that enable businesses and organizations to compete in the globalizing world, to maintain their existence and to grow and develop more. The reason for this is the fact that the life cycles of products and services, caused by the rapid change in technology and customers' demands, are shortened more quickly. Thanks to R&D projects, new products and services are developed, existing ones are improved, and costs are reduced by increasing production efficiency (Heidenberger and Stummer, 1999).

Risk management in R&D projects is to determine the degree of risk of individual or organizational economic resources and the position held and to bring this determined criterion to an acceptable risk situation. Risk management and planning in R&D projects allow the desired goals to be achieved by combining different activity stages (Daft, 1991). In the risk management and planning process in R&D projects, the preparation of the risk management strategy at the very beginning of the project is very valuable in terms of continuous examination as the project continues.

The risk stakeholders in the project, the objectives of the program, the management style of risks and the way of prioritizing the risks are determined in the risk management plans and the reporting studies are completed (Fırat, 2009). In addition, the preparation of the risk management and planning budget for R&D projects and the creation of activity timelines are among the important processes that should be done in the planning process.

Risk management in R&D projects proposes scientific activities for the management and planning of identifiable risk factors. Risk management consists of four stages: Identifying risks (identification), risk evaluation, responding to risks (Kayım, 2006) and monitoring/reviewing risks.

The main purpose of risk management in R&D projects is to identify risks in advance to reduce all losses that may arise due to risks in the planned activity process. When R&D studies are considered as a new product or service development process, it is the reduction and management of uncertainties regarding characteristic information such as product and service delivery time, performance, quality, source, budget, product, development program and total cost are among the objectives of risk management (Özkul and Özdemir, 2014).

3. Fuzzy Logic Method

3.1 Fuzzy Logic Concept

Fuzzy logic as a method aims to create an infrastructure for people to reason with unclear propositions while focusing on linguistic changes in everyday speech. This technique, which is a sub-discipline of mathematics, tries to reflect the accuracy and ambiguity in the natural everyday speech of people. Fuzzy logic is defined as “a method in which propositions containing logical uncertainty are analyzed by filtering through the logical mechanism” (Mazlum, 2014).

Fuzzy logic is like people's thoughts. In other words, fuzzy logic is used quite often in daily life. For example, when people are asked about their satisfaction with any product they buy and use, they don't just say "yes" or "no" in response; They can also say expressions such as “a little, little, good” (Bai & Wang, 2006). Fuzzy logic comes into play here and can show the mental working processes of the brain more accurately, especially in unclear events, compared to classical logic. Groupings with ambiguous features such as recognizing, making sense, informational communication and abstracting have an important role in the human brain and these groupings cannot be made with mathematical expressions (Zadeh, 1965).

Thanks to the fuzzy logic put forward by Zadeh in 1965, a new page has been opened in science and technology. The main intention of fuzzy logic is to establish the basis for fuzzy reasoning by using ambiguous propositions that assume fuzzy set (Aksoy et al., 2003).

The first of the two main events in which fuzzy logic is used most is that people's thoughts and value judgments are applied when the researched situation is very complicated and there is not enough information about this situation. The other is situations where individual reasoning, insights and decision-making are needed (Kandel, 1986). Decisions made in real life are not clear and are not suitable to be matched with exact numerical values. For this reason, it would be more accurate to use verbal variables to express decisions. Here is the most important difference of fuzzy logic from other logic systems. Because fuzzy logic allows the use of verbal variables. Verbal variables are defined as variables that can be matched with expressions in a language (Zadeh, 1975).

3.2. Fuzzy Expert System

The expert knowledge that is used to develop a knowledge base is frequently expressed verbally in linguistic form. To make the system's interaction with the expert and the expert system user as simple as feasible, communication should take place as much as possible in human language, using subjective phrases (Zimmermann, 2001). As a result of this information flow, the information recorded in the knowledge base has become unclear and ambiguous. Because ambiguity leads to erroneous advice and consequences, the system's reliability is questioned. Fuzzy logic integration can be used to overcome this challenge (Tavana and Hajipour, 2020).

A fuzzy expert system is used to address situations where the advice isn't black-and-white or true-or-false, but rather comes in shades of gray called possibilities. (Tripathi, 2011). The process of creating a result value by reasoning within the established rules is defined as "inference". The most used inference methods are the Mamdani method and Takagi-Sugeno-Kang methods. Apart from these, Larsen Method and Tsukamoto Method can be counted among the other inference methods used. Bringing inference sets together and expressing them as a single set is called rule aggregation.

The Mamdani technique is used to put up most of the systems. The Takagi-Sugeno-Kang methodology is the second option; the only difference between it and the Mamdani method is the outcome. The Mamdani approach produces one or more fuzzy sets that must be defuzzified, whereas the Takagi-Sugeno-Kang method produces one or more real linear functions that must be evaluated directly (Tavana and Hajipour, 2020). The general procedure for the system is as follows (Thaker and Nagori, 2018):

Fuzzification: The membership values of each linguistic label are obtained by comparing the input variables with the membership functions on the preceding section of the fuzzy rule.

Inference Engine: On the assumption part, multiply or min the membership values to get the firing strength, which represents the degree of rule fulfillment.

Composition: Generates qualified consequences for each rule, which might be fuzzy, or crisp based on the activation intensity.

Defuzzification: The eligible outcomes are gathered here to provide clear output.

The structure of fuzzy expert system can be seen in Figure 1.

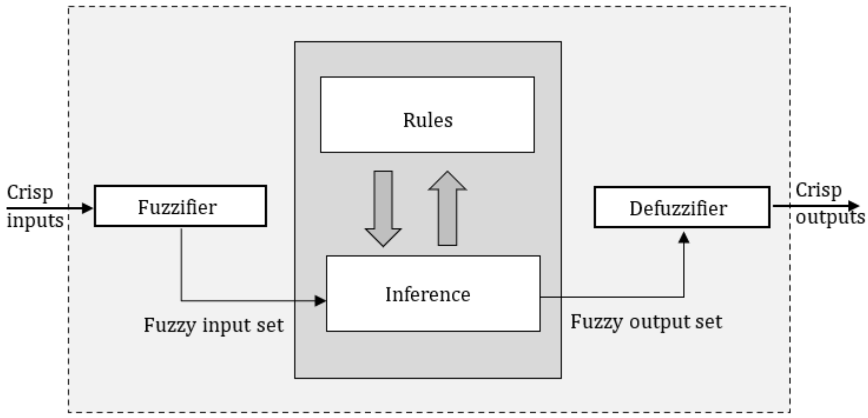

Figure 1. Structure of Fuzzy Expert System (Aly & Vrana, 2006)

It is translated from crisp to fuzzy inputs in the first phase; that is, traditional measurements are changed to fuzzy values using linguistic variables. After fuzzifying the inputs, a collection of if-then fuzzy rule consisting of conditioned fuzzy propositions is generated. In the composition stage, the fuzzy inference engine is employed, which has a specific inference method—here, the Mamdani type. It obtains outputs using fuzzy reasoning techniques and performs computations using fuzzy rules. It concludes by converting fuzzy outputs to crisp values at the end of the process (Kunhimangalam et al., 2013).

Fuzzy expert systems are used in a variety of domains including all management and decisions like portfolio, Project etc. (Tavana and Hajipour, 2020). In table, there is 7 examples of these systems and guidelines about methodologies:

It is known that there are more than 30 defuzzification methods in the literature for fuzzy inference systems. Some of these methods and even the most used ones can be listed as follows; “Maximum membership principle, centroid method, weighted average method, average maximum membership, center of totals, center of largest area, largest first or last membership degree” (Baykal and Beyan, 2004).

In this study, the centroid method is used. This defuzzification method is used especially in Mamdani inference studies. Membership values from running rules work with the logic of collecting the intersecting fields on the output set. Then the geometric center of gravity of these areas is found. This found value is the deciphered output value.

4. Application of Risk Analysis by Using Fuzzy Logic Method in Food R&D Projects

R&D projects have a lot of gray areas, as mentioned earlier in the article. For this reason, risk analysis of R&D projects using fuzzy logic method is the main purpose of the study. Based on the importance of expert opinions in determining the result in fuzzy logic, the study has been carried out by selecting only the R&D laboratory of a food company. In this way, the result of the study has been planned to be very close to the real values, and the study was localized since there may be different risks in different sectors.

To make fuzzy control design, which is necessary for risk analysis with fuzzy logic in food R&D projects, studies have been conducted with face-to-face survey method with 10 experts, who are experts in the subject, who work in the R&D unit of a food company, and whose experience ranges from 2 to 10 years. Before this study, the necessary technical information about fuzzy logic was introduced to the relevant team by organizing a face-to-face meeting, and sample studies were mentioned. The average of the values obtained from these experts was calculated, and a general value range was created for the verbal variables.

In this study, the risk groups are discussed with the experts, and it is agreed on the risk groups in the literature. However, it is agreed to add a risk factor that includes quality risks for the food industry. After the literature research and the evaluation of expert opinions, it is determined that the most important risks in food R&D projects are management and budget, time, quality and technical and personnel risks.

The effects of these four risk groups, which have been determined as a result of the study, on the successful completion of the project in food R&D projects can be calculated with the fuzzy logic method, the successful completion rate of the project can be concluded (determined) in the range of 0-100 values, and this method will be designed to be used as an application in which the team can get support (benefit) in decision-making. “MATLAB Fuzzy Logic Toolbox” application is used in the implementation phase. In this context, while the system is being designed, the input and output values are shown in Figure 2 below.

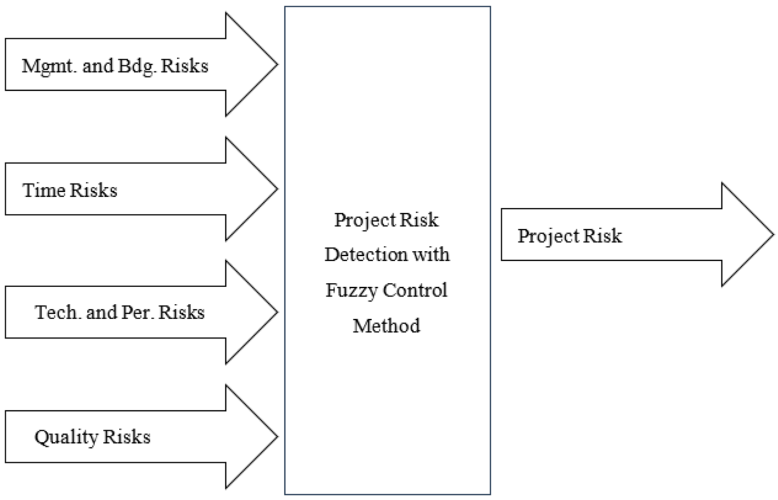

Figure 2. Project Risk Detection with Fuzzy Control Method

As the input parameter:

1- The universal set for management and budget risks is between [0-10].

2- The universal set for time risks is between [0-10].

3- The universal set for technical and personnel risks is between [0-10].

4- The universal set for quality risks is between [0-10].

As the output parameter:

1. Project risk is between 0-100%.

The working logic of the system is based on the evaluation of the existing risks before or during the food R&D project and the evaluation of the project in advance. The Mamdani type fuzzy model was used in all inferences. The fuzzy verbal values of the system input and output values and the properties of the variables are shown in Table 3 and Figure 3 below.

Table 3. Input and output parameters

Variable name	Type	Fuzzy verbal variables
Management & budget risks	input	Low, Medium, High, Very high (L, M, H, VH)
Time Risks	input	Low, Medium, High, Very high (L, M, H, VH)
Technical & personnel risks	input	Low, Medium, High, Very high (L, M, H, VH)
Quality risks	input	Low, Medium, High, Very high (L, M, H, VH)
Project risks	output	Low, Medium, High, Very high (L, M, H, VH)

While using verbal variables in the system, support has been received from experts and literature.

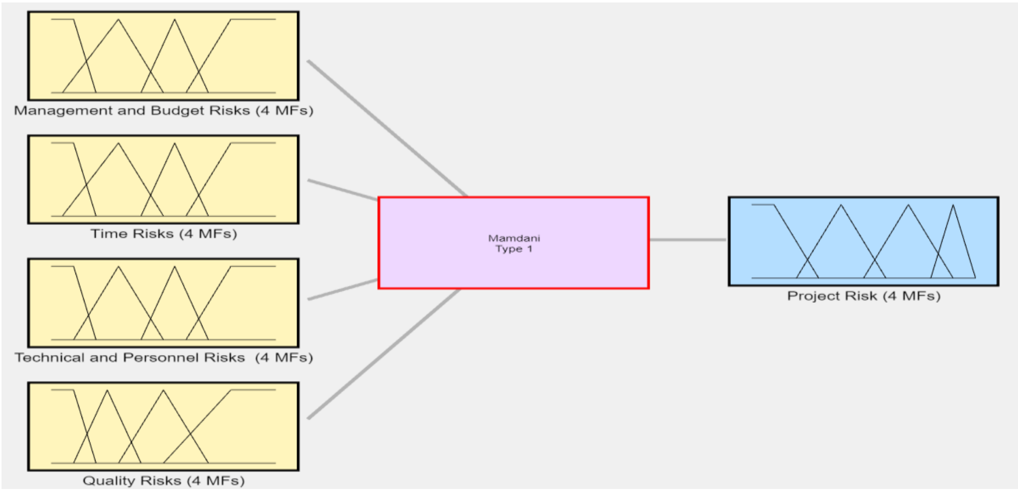

Figure 3. Display of input and output parameters on MATLAB

The mathematical expressions for the linguistic value of management and budgetary risks (X) are shown in Figure 4.

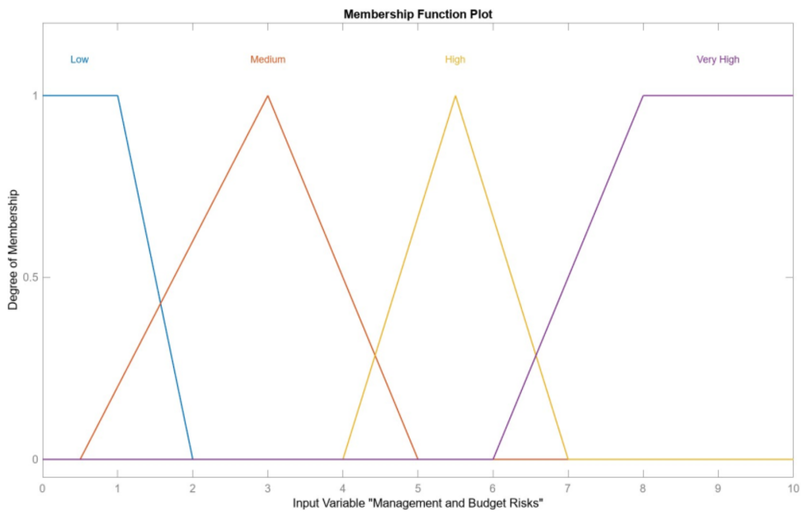

Figure 4. Management & Budget Risks (X)

The values for Management and budget risks for project risk are as follows:

$$\mu_{Low}(X) = \begin{cases} 1\,, If\ x\ \leq 1 \\ \frac{2-x}{1,5}, If\ 1 < x < 2 \\ 0, If\ x > 1 \end{cases} \tag{1}$$

$$\mu_{Medium}(X) = \begin{cases} 0\,, If\ x\ \leq 0,5 \\ \frac{x-0,5}{3-0,5}, If\ 0,5 < x < 3 \\ \frac{5-x}{5-3}, If\ 3 < x < 5 \\ 0\,, If\ x \geq 5 \end{cases} \tag{2}$$

$$\mu_{High}(X) = \begin{cases} 0\,, If\ x \leq 4 \\ \frac{x-4}{5,5-4}, If\ 4 < x < 5,5 \\ \frac{7-x}{7-5,5}, If\ 5,5 < x < 7 \\ 0\,, If\ x \geq 7 \end{cases} \tag{3}$$

$$\mu_{Very\ High}(X) = \begin{cases} 0\,, If\ x \leq 6 \\ \frac{8-x}{8-6}, If\ 6 < x < 8 \\ 1\ If, x\ \geq 8 \end{cases} \tag{4}$$

The fuzzy sets of management and budget risk based on these values are given below.

$$\mu_{Low}(X) = \{1/0, \quad 1/1\,, \quad 0,33/1,5, \ 0/2\}$$
$$\mu_{Medium}(X) = \{0/0,5, \quad 0,6/2\,, \quad 0,5/4, \quad 0/6\}$$
$$\mu_{High}(X) = \{0/4, \quad 0,33/4,5\,, \quad 0,66/6, \quad 0/\ 8\}$$
$$\mu_{Very\ High}(X) = \{0/6, \qquad 0,5/7\,, \ 1/8, \quad 1/9, \ 1/10\}$$

The mathematical expressions for the linguistic value of time risks (Y) are shown in Figure 5.

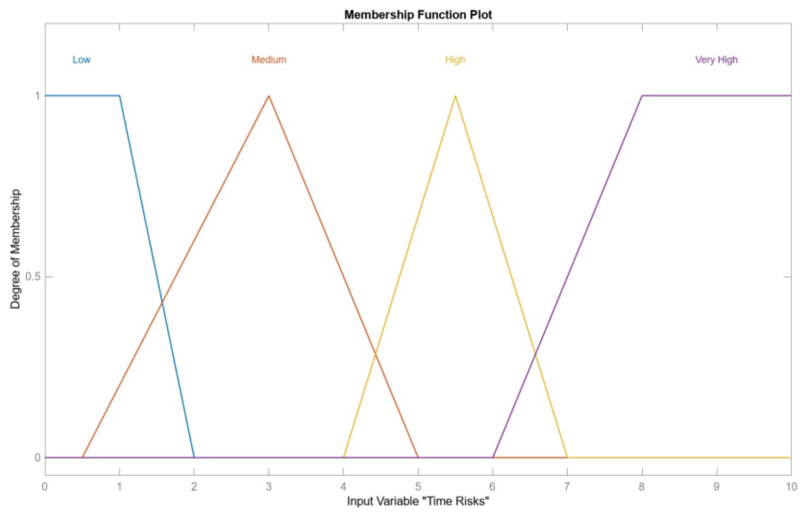

Figure 5. The Linguistic Values of Time Risks

Time Risks values for project risk are as follows.

$$\mu_{Low}(Y) = \begin{cases} 1\,, If\ y\ \leq 1 \\ \frac{2-y}{1,5}, If\ 1 < y < 2 \\ 0, If\ y > 1 \end{cases} \tag{5}$$

$$\mu_{Medium}(Y) = \begin{cases} 0\,, If\ y \leq 1 \\ \frac{y-1}{2,5-1}, If\ 1 < y < 2,5 \\ \frac{4-y}{4-2,5}, If\ 2,5 < y < 4 \\ 0\,, If\ y \geq 4 \end{cases} \tag{6}$$

$$\mu_{High}(Y) = \begin{cases} 0\,, If\ y \leq 3 \\ \frac{y-3}{5-3}, If\ 3 < y < 5 \\ \frac{7-y}{7-5}, If\ 5 < y < 7 \\ 0\,, If\ y \geq 7 \end{cases} \tag{7}$$

$$\mu_{Very\ High}(Y) = \begin{cases} 0\,, If\ y \leq 6 \\ \frac{8-y}{8-6}, If\ 6 < y < 8 \\ 1, If\ y\ \geq 8 \end{cases} \tag{8}$$

The time risk fuzzy sets found according to these values are given below.

$$\mu Normal\ (Y) = \{1/0,\quad 1/1\,,\quad 0{,}33/1{,}5,\quad 0/2\}$$
$$\mu Medium(Y) = \{0/0{,}5,\quad 0{,}66/2\,,\quad 0{,}6/3,\quad 0/5\}$$
$$\mu High(Y) = \{0/3,\quad 0{,}5/4\,,\quad 0{,}5/6,\quad 0/\ 8\}$$
$$\mu Very\ High(Y) = \{0/6,\quad 0{,}5/7\,, 1/8,\quad 1/9,\quad 1/10\}$$

The mathematical expressions for the linguistic value of Technical and Personnel Risks (Z) are shown in Figure 6.

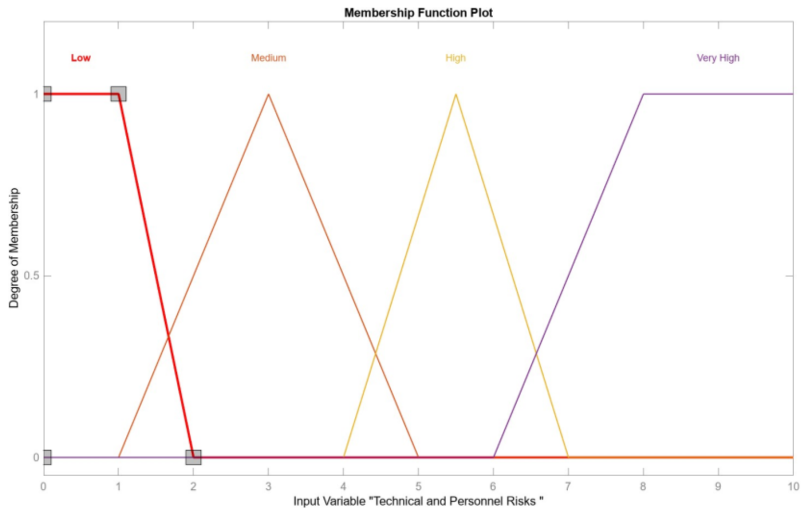

Figure 6. The Linguistic Value of Technical and Personnel Risks (Z)

Technical and personnel risk values for project risk are as follows:

$$\mu Low(Z) = \begin{cases} 1\,, If\ z\ \leq 1 \\ \frac{2-z}{1,5}, If\ 1 < z < 2 \\ 0, If\ z > 1 \end{cases} \tag{9}$$

$$\mu Medium(Z) = \begin{cases} 0\,, If\ z \leq 1 \\ \frac{z-1}{3-1}, If\ 1 < z < 3 \\ \frac{5-z}{5-3}, If\ 3 < z < 5 \\ 0\,, If\ z \geq 5 \end{cases} \tag{10}$$

$$\mu High(Z) = \begin{cases} 0\,, If\ z \leq 4 \\ \frac{z-4}{6-4}, If\ 4 < z < 6 \\ \frac{8-z}{8-6}, If\ 6 < z < 8 \\ 0\,, If\ z \geq 8 \end{cases} \tag{11}$$

$$\mu Very\ High(Z) = \begin{cases} 0\,, If\ z \leq 7 \\ \frac{8-z}{8-7}, If\ 7 < z < 8 \\ 1, If\ z\ \geq 8 \end{cases} \tag{12}$$

The fuzzy sets of technical and personnel risks found according to these values are given below.

$$\mu Normal\ (Z) = \{1/0, \quad 1/1\,, \quad 0{,}33/1{,}5, \qquad 0/2\}$$
$$\mu Medium(Z) = \{0/0{,}5, \quad 0{,}5/2\,, \quad 0{,}5/4, \qquad 0/5\}$$
$$\mu High(Z) = \{0/4, \quad 0{,}5/5\,, \quad 0{,}5/7, \qquad 0/\ 8\}$$
$$\mu Very\ High(Z) = \{0/6, \quad 0{,}5/7{,}5\,, \quad 1/8, \qquad 1/9, \quad 1/10\}$$

The mathematical expressions for the linguistic value of quality risks (Q) are shown in Figure 7.

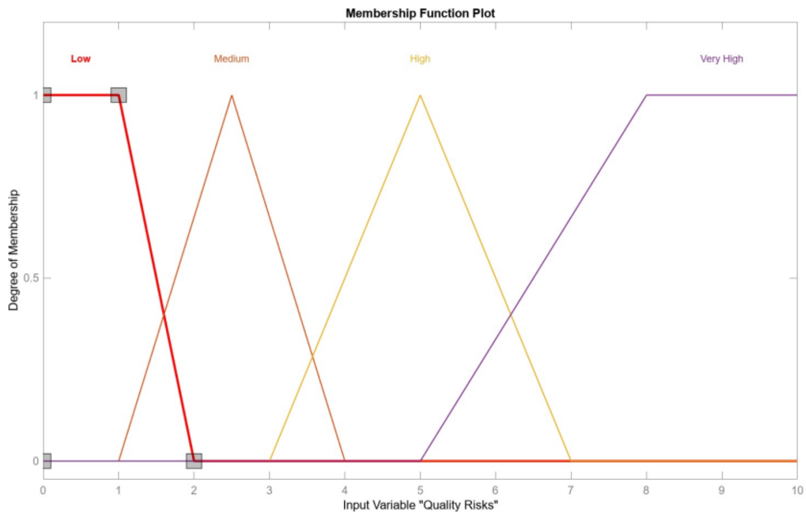

Figure 7. The Mathematical Expressions for The Linguistic Value of Quality Risks (Q)

The quality risks values for project risk are as follows:

$$\mu Low(Q) = \begin{cases} 1\,, If\ q\ \leq 1 \\ \frac{2-q}{1,5}, If\ 1 < q < 2 \\ 0, If\ q > 1 \end{cases} \tag{13}$$

$$\mu Medium(Q) = \begin{cases} 0\,, If\ q \leq 1 \\ \frac{q-1}{2,5-1}, If\ 1 < q < 2,5 \\ \frac{4-q}{4-2,5}, If\ 2,5 < q < 4 \\ 0\,, If\ q \geq 4 \end{cases} \tag{14}$$

$$\mu High(Q) = \begin{cases} 0\,, If\ q \leq 3 \\ \frac{q-3}{5-3}, If\ 3 < q < 5 \\ \frac{7-q}{7-5}, If\ 5 < q < 7 \\ 0\,, If\ q \geq 7 \end{cases} \tag{15}$$

$$\mu Very\ High(Q) = \begin{cases} 0\,, If\ q \leq 5 \\ \frac{8-q}{8-5}, If\ 5 < q < 8 \\ 1, If\ q\ \geq 8 \end{cases} \tag{16}$$

The quality risk fuzzy sets found according to these values are given below.

$$\mu Normal\ (Q) = \{1/0, \quad 1/1\,, \quad 0{,}33/1{,}5, \qquad 0/2\}$$
$$\mu Medium(Q) = \{0/0{,}5, \quad 0{,}66/2\,, \quad 0{,}6/3, \qquad 0/5\}$$
$$\mu High(Q) = \{0/3, \quad 0{,}5/4\,, \quad 0{,}5/6, \qquad 0/\ 8\}$$
$$\mu Very\ High(Q) = \{0/4, \quad 0{,}66/6\,, \quad 1/8, \qquad 1/9, \quad 1/10\}$$

The mathematical expressions for the linguistic value of Project Risks (W) are shown in Figure 8.

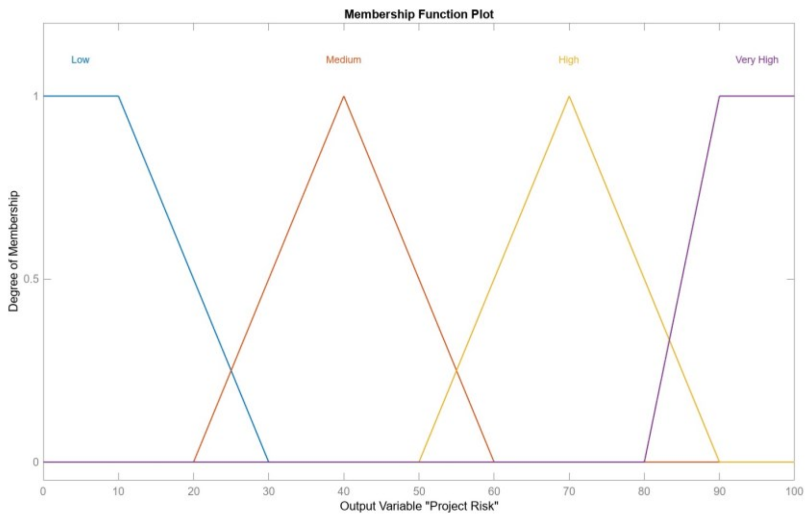

Figure 8. The Mathematical Expressions for The Linguistic Value of Project Risks (W)

The output values of project risk are as follows:

$$\mu Low(W) = \begin{cases} 1\,, If\ w \le 10 \\ \frac{30-w}{20}, If\ 20 < w < 30 \\ 0, If\ w > 30 \end{cases} \quad (17)$$

$$\mu Medium(W) = \begin{cases} 0\,, If\ w \le 20 \\ \frac{w-20}{40-20}, If\ 20 < w \le 30 \\ \frac{60-w}{60-40}, If\ 40\ \le\ w < 60 \\ 0, If\ w \ge 60 \end{cases} \quad (18)$$

$$\mu High(W) = \begin{cases} 0\,, If\ w\ \le 50 \\ \frac{w-70}{80-70}, If\ 70 < w \le 90 \\ \frac{90-w}{90-80}, If\ 80\ \le\ w < 90 \\ 0, If\ w\ \ge 90 \end{cases} \quad (19)$$

$$\mu Very\ High(W) = \begin{cases} 0\,, If\ w \le 80 \\ \frac{100-w}{100-90}, If\ 90 < w < 100 \\ 0, If\ w > 100 \end{cases} \quad (20)$$

Project risk fuzzy sets found according to these values are given below.

$$\mu Low(W) = \{1/0,\quad 1/10\,,\quad 1/15,\qquad 0{,}5/23,\quad 0/30\}$$
$$\mu Medium(W) = \{0/20,\quad 0{,}5/30\,,\quad 1/40,\qquad 1/45,\quad 0{,}5/52,\qquad 0/60\,\}$$
$$\mu High(W) = \{0/50,\quad 0{,}5/60\,,\quad 1/70,\qquad 1/75,\quad 0{,}5/83,\qquad 0/90\}$$
$$\mu Very\ High(W) = \{0/80,\quad 0{,}5/85\,,\quad 1/90,\qquad 1/100\}$$

In the designed system, 4 cases in the input parameters and 4 cases in the output parameter were evaluated and 256 rules were obtained. With the inference mechanism, the decision-making process can be calculated with the defuzzification unit, and the desired final output value can be calculated. Mamdani Max-Min Method is used as inference mechanism and Centroid Method is used as defuzzification mechanism. Table 4 shows some of the fuzzy rules created.

Table 4. List of some rules extracted on MATLAB

1. If (Time-Risk is L) and (Technical-and-Personnel-Risk is L) and (Management-and-Budget-Risk is L) and (Quality-Risk is L) then (Project-Risk is L)
30. If (Time-Risk is L) and (Technical-and-Personnel-Risk is M) and (Management-and-Budget-Risk is VH) and (Quality-Risk is M) then (Project-Risk is M)
70. If (Time-Risk is M) and (Technical-and-Personnel-Risk is L) and (Management-and-Budget-Risk is M) and (Quality-Risk is M) then (Project-Risk is M)
93. If (Time-Risk is M) and (Technical-and-Personnel-Risk is M) and (Management-and-Budget-Risk is VH) and (Quality-Risk is L) then (Project-Risk is H)
151. If (Time-Risk is H) and (Technical-and-Personnel-Risk is M) and (Management-and-Budget-Risk is M) and (Quality-Risk is H) then (Project-Risk is H)

204. If (Time-Risk is VH) and (Technical-and-Personnel-Risk is L) and (Management-and-Budget-Risk is H) and (Quality-Risk is VH) then (Project-Risk is VH)
256. If (Time-Risk is VH) and (Technical-and-Personnel-Risk is VH) and (Management-and-Budget-Risk is VH) and (Quality-Risk is VH) then (Project-Risk is VH)

$$Management\ And\ Budget\ Risks(X) = 2\ (Low)$$
$$Time\ Risks(Y) = 5\ (High)$$
$$Technical\ and\ Personnel\ Risks(Z) = 4\ (High)$$
$$Quality\ Risks(Q) = 4\ (High)$$

$$Project\ Risk = 70\ (High)$$
$$Ignited\ Rule: 151$$

Figure 9 shows the results of the values time risks = 5, technical and personnel risks = 4, management and budgetary risks = 2 and quality risks = 4 simulated by MATLAB Fuzzy Logic Tool. The project risk obtained as a result of these values is 70%.

Figure 9. Project Risk 70%

$$Management\ And\ Budget\ Risks(X) = 2\ (Low)$$
$$Time\ Risks\ (Y) = 2\ (Low)$$
$$Technical\ and\ Personnel\ Risks\ (Z) = 3\ (Medium)$$
$$Quality\ Risks\ (Q) = 1\ (Low)$$

$$Project\ Risk = 40\ (Medium)$$
$$Ignited\ Rule: 101$$

Figure 10 shows the results of the values Time Risks = 2, Technical and Personnel Risks = 3, Management and Budgetary Risks = 2 and Quality Risks = 1 simulated by MATLAB Fuzzy Logic Tool. The Project risk obtained as a result of these values has a value of 40%.

Figure 10. Project Risk 40%

$$Management\ And\ Budget\ Risks(X) = 9\ (Very\ High)$$
$$Time\ Risks(Y) = 8\ (Very\ High)$$
$$Technical\ and\ Personnel\ Risks(Z) = 7\ (High)$$
$$Quality\ Risks(Q) = 10\ (Very\ High)$$

$$Project\ Risk = 91.7\ (Very\ High)$$
$$Ignited\ Rule: 240$$

Figure 11 shows the results of the values Time Risks = 8, Technical and Personnel Risks = 7, Management and Budgetary Risks = 9 and Quality Risks = 10 simulated by MATLAB Fuzzy Logic Tool. The Project risk obtained as a result of these values has a value of 91.7%.

Figure 11. Project risk 91.7%

$$Management\ And\ Budget\ Risks(X) = 1\ (Low)$$
$$Time\ Risks(Y) = 3\ (Medium)$$
$$Technical\ and\ Personnel\ Risks(Z) = 1\ (Low)$$
$$Quality\ Risks(Q) = 1\ (Low)$$

$$Project\ Risk = 20.4\ (Low)$$
$$Ignited\ Rule: 64\ and\ 69$$

Figure 12 shows the results of Time Risks = 3, Technical and Personnel Risks = 1, Management and Budgetary Risks = 1 and Quality Risks = 1 values simulated by "MATLAB Fuzzy Logic Tool".

Figure 12. Project Risk 20.4%

5. Conclusion and Further Research

R&D and R&D projects, which maintain their importance in the constantly developing and changing world, will continue to increase their importance in the future. R&D investments of countries are increasing day by day. Developed countries implement qualified and high value-added works and projects with these investments. Realizing R&D projects that shape change involves intense uncertainty and risk. These risks will always exist, but thanks to the developing analysis techniques and databases, the processes of pre-detection, impact assessment and putting the necessary measures into effect will be carried out more effectively. But a risk-free R&D project is not possible.

For these reasons, it is very important to successfully analyze the risk involved in R&D projects. Taking precautionary measures regarding the risks involved in the projects and making interventions on-site and when necessary, provide great benefits to the projects and project teams. Depending on the developing and changing conditions, risk analysis methods also need to keep up with this change.

There are many methods in the literature to make such risk analysis. As a result of the examination of these methods, although different techniques have been used extensively in the previous periods, it is seen that risk analyzes have been made with fuzzy logic recently.

In this context, examples are presented in the article to take early measures for the risks that may occur in the projects or to decide about the project. Face-to-face meetings were held with a food R&D team operating in Turkey, and the working system of the fuzzy logic system was first explained, and the expert group was informed about the technique. Thus, it was possible to get healthier answers to the prepared data collection scale.

In the data collection process, one-on-one surveys were conducted with the experts in the team and input and output variables were determined in accordance with the fuzzy logic principles, then the membership functions of these variables were prepared, and their fuzzy sets were revealed, and a fuzzy system was developed on MATLAB.

After this step, the resulting rules are written and examples that run these rules are produced. Afterwards, inferences were made by using Mamdani's inference mechanism, and as a result, it was determined at what rate the risk of an R&D project was determined by combining which rules. The model was tested by creating hypothetical situations and it was seen that the results obtained could be adapted to the decision-making processes in a healthy way.

As a result, in the light of these data, a mechanism that can help the business units has been implemented, and as can be seen at the end of the study, the impact of the risks involved in the R&D projects on the project success has been made more predictable and visible.

In future studies, it has been evaluated that this method can help project teams in different sectors by working with experts to determine appropriate input and output values. It has been concluded that the results obtained will be a healthy risk assessment and thus a decision support element, with the addition of other criteria based on sector characteristics in every sector that will carry out R&D projects.

The study carried out is an original study in this field and the inferences obtained have valuable results for both scientific and institutions. Subsequent studies can be carried out by re-evaluating the criteria with a similar method.

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Conflict of Interest

No conflict of interest is declared by the authors.

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