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Development of a Fuzzy Logic System to Identify the Risk of Projects Financed from Structural Funds

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Abstract: The fuzzy logic system developed in this research paper seeks to identify the financial risk of projects financed from structural funds when changes occur in project values, in the duration of the projects and in the implementation durations. Those two factors are known to influence the financial risk. The fuzzy system was simulated using Matlab and the results showed its operation and the conclusion that the financial risk of the project is dependent on the developments values and on the implementation duration. The developed and tested fuzzy logic system provides information on financial risk intensity organized into three categories: small, medium and large and on the inflection point of transition from low risk to high risk. This is considered an early warning system for the management staff with responsibilities in structural funds.
Keywords: Fuzzy Logic System (FLS), artificial intelligence, financial risk, structural funds, centroid method.

1 Introduction

The fuzzy logic systems (FLS) are used as a tool for decisions making, for the projects financed from structural funds, for the early identification of risks that affect the performance of the allocation of funds for EU member countries, through various financial instruments known as operational programs. The risk of the projects financed from structural funds has various forms, but the most important remains the financial aspect, that generates losses for the budget of the member states. Although there are now used statistical methods for risk measurement, the most common being the standard deviation (σ^2), it should be noted that they have a major drawback since they reflect the risk at the project level. Moreover, the classical statistical indicators provide insight into project financial risk without taking into account the influence factors or correlations that exist between the various projects [3]. FLS have the advantage of being able to identify the financial risk for the entire portfolio of projects contained by the operational program and to contribute to the decision of management to avoid or eliminate the financial risk. The FLS input variables of this model are set according to the project particularities, on which ultimately depend the financial risk of the project, or project value (VP) and the duration of their implementation (DI). The output variable is the financial risk of the project (RF). The assessment of the financial risk of the project (as an output variable of FLS) was structured by verbal expressions (specific to fuzzy logic): high financial risk, medium financial risk and low financial risk, depending on the seriousness of the risk but also to highlight the intensity of the losses from the budget allocated to EU member states as a result of the manifestation of the financial risk event [6]. The FLS developed to identify the financial risk of the projects financed from structural funds becomes a novelty in literature but also a management tool for decision makers. With the help of FLS they can measure the financial risk for all the projects entering in the structure of the operational program. Based on these ways of measuring the financial risk, identified using FLS, corrective action can be taken for the efficient and fair presentation of structural funds for member states of the EU budget.

2 The concept of financial risk of projects financed from structural funds

The financial risk of the projects financed from structural funds is a fairly new concept both in literature and in practice. In essence the financial risk of the projects should answer the following question: "What is the financial size of the potential loss that a member state is expected to suffer, due to the implementation of projects financed from structural funds?" The project financial risk depends on a number of factors determined by the main project implementation cycle. In this category are included factors that are measured through the implementation period, resulting the physical progress of projects or the requests repayment duration. In practice, the most important factor that influences the financial risk of the project remains the physical progress [11]. The physical progress, although it seems a technical term, is most often defined as the ratio between the duration of implementation of a project under implementation cycle (D_{ic}) and the duration of implementation actually achieved (D_r) according to a relation of the form:

$$P_f = \frac{D_r}{D_{ic}} \times 100 \tag{1}$$

The achieved physical progress can record higher values than those set, for a project suitable for the implementation cycle, situation in which the financial risk of the project is small or can record lower values, where the financial risk of the project increases. The financial dimension of a project risk therefore depends on the value of the project (V_p), on the physical progress established under implementation cycle (p_{fc}) and on the actual physical progress achieved (p_r) after a relationship of the form:

$$R_f = V_p(p_{fc} - p_{fr}) \tag{2}$$

or

$$R_f = V_p \times (\frac{D_{ct}}{D_{ip}} - \frac{D_r}{D_{ip}}) \tag{3}$$

The higher is the difference between the physical progress of the project under implementation cycle (p_{fc}) and the actual physical progress achieved (P_{fr}), the higher is the risk of losing a larger amount of the budget allocated to a project. In practice, the most common form of financial risk measurement remain in the project's value (V_p) and the deviation of the achieved implementation duration of the project D_r towards the set one based on implementation cycle (D_{ci}), after a relationship of the form:

$$P_f = V_p \times \frac{D_{ci} - D_r}{D_{ci}} \times 100 \quad (4)$$

There are projects with high financial risk, for which the difference between the two periods (according to implementation cycle and the one actually achieved) is far from average, or projects with low financial risk for which the same difference is close to average. The average difference between the two periods is determined for all projects that are part of the operational program. To appreciate the intensity of the financial risk of a project it can be used the standard deviation or variance [13], characterizing the removal from the average financial risk of a project after a relationship of the form:

$$R_f = \sqrt{\frac{1}{N}\sum_{i=1}^{n} R_{fi} - \overline{R_f}} \quad (5)$$

Depending on the value of this statistical indicator, the intensity of the financial risk is estimated. The higher is the percentage value of this indicator, the higher is the financial risk of lossing the budget allocated to projects. The indicator, thus, doesn't provide a complete picture of risk, as it is determined based on historical values recorded in previous periods of time [2]. In FLS , the financial risk of the projects will be divided into three categories (large, medium and small), considered as an output of the system. In essence, the financial risk of a project, regardless its quantification and intensity, depends on a number of factors that will transform the input for FLS, as follows [10]:

1. The value of projects, that influences the size of the financial risk: The rule is simple: The higher is the project value and the deviation from the implementation period, the higher is the financial risk

2. The project implementation duration, which is determined according to the intensity of risk: The implementation period is known in the literature as the duration necessary to implement a project, so that it can be achieved its project objectives and outcome indicators. The further the implementation period of this project removes from the one set according to the implementation period, the higher is the risk that a part of the budget will be lost.The project value and its implementation duration, as influencing factors underlying the financial risk will be considered for FLS as input variables.

3 The development of the FLS to identify financial risk of a project

Each fuzzy logic system supposes four distinct phases [14] as follows: setting the input variables and their associated fuzzy sets, the fuzzy rule base identification, the establishment of fuzzy inference operators and defuzzification. In the first stage of development of the fuzzy logic system were established the input variables mentioned above, namely: the project value (PV) and the duration of implementation (DI), while the output variable (result) is the financial risk of the project. The input variables are structured according to the size of their impact on financial risk. The project value (VP) is divided into three categories, namely: high value projects (HVP), the average project value $VP_{\overline{m}}$, and the small projects value VP_m. At the same time, the duration of project implementation is structured according to the exceeding of the project implementation duration to that established in the implementation cycle as follows: high exceeding (between 180 days and 360 days) (DIM), average exceeding (between 90 days and 180 days) $DI_{\overline{m}}$ and low exceeding DI_m under 90 days. The financial risk of the project, as the output variable of the system, is determined by the fuzzy base rules, the fuzzy inference operators as well as by the expert assessments, that are divided into three categories namely: high financial risk (RFM), average financial risk $RF_{\overline{m}}$ and low financial risk RF_m. In order to completely define the fuzzy set, for the input variables were established the following membership functions [3]:

1. The trapezoidal membership function, for the value of projects (VP) defined according to the value types of projects

2. The triangular membership function, for the exceeding duration of the project implementation (DI) which was also structured in: high, medium and low exceeding;

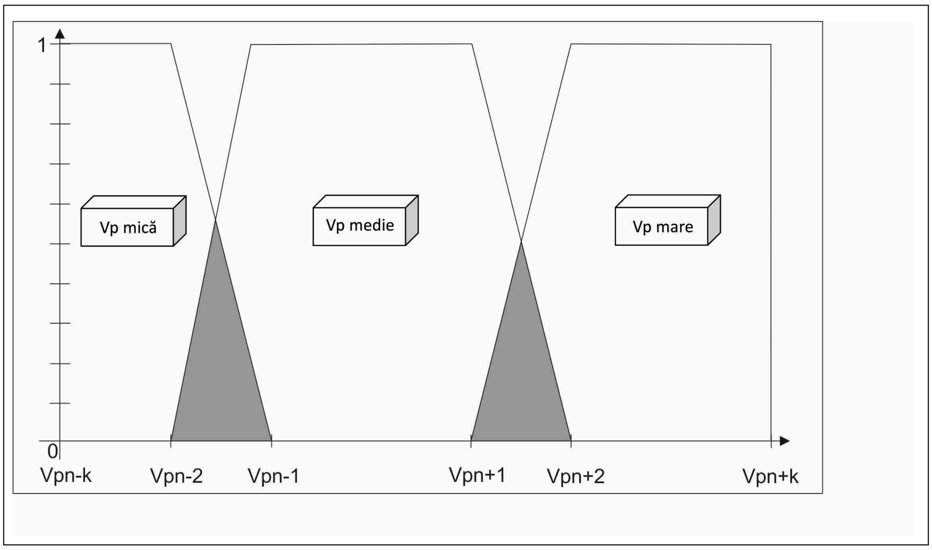

Figure 1: The trapezoidal membership function for the input variables

The fuzzy sets allow the partial membership of elements, the fuzzy membership degree being able to take any value from 0 (not belonging) to 1 (full membership). For example, the trapezoidal membership's function for $VP \in [VP_{n-2}, VP_{n+2}]$, and for project with medium values will be expressed as:

$$\mu_{VPM}(VP) = \begin{cases} 0 & \text{if } VP_{n-2} < VP \text{ and } VP > VP_{n+2} \\ \frac{VP - VP_{n-2}}{VP_{n-1} - VP_{n-2}} & \text{if } VP_{n-2} \leq VP \leq VP_{n-1} \\ 1 & \text{if } VP_{n-1} \leq VP \leq VP_{n+1} \\ \frac{VP_{n+2} - VP}{VP_{n+2} - VP_{n+1}} & \text{if } VP_{n+2} \leq VP \leq VP_{n+1} \end{cases}$$

Similarly, the trapezoidal membership function for the interval $VP \in [VP_{n-k}, VP_{n-1}]$, which corresponds to the values of small projects, which will be expressed as follows:

$$\mu_{VPm}(VP) = \begin{cases} 0 & \text{if } VP < VP_{n-k} \text{ and } VP > VP_{n-1} \\ \frac{VP_{n-1}-VP}{VP_{n-1}-VP_{n-2}} & \text{if } VP_{n-2} \leq VP \leq VP_{n-1} \\ 1 & \text{if } VP_{n-k} \leq VP \leq VP_{n-2} \end{cases}$$

The triangular membership function for the input variable, the exceeding of the duration of implementation (DI) of the project is represented in figure no.2. The triangular membership function can be expressed, for example, for the low exceeding of the duration of implementation by the relationship, ($DI \in [DI_{n-k}, DI_{n-1}]$):

$$\mu_{DIm}(DI) = \begin{cases} 0 & \text{if } DI_{n-k} < DI \text{ and } DI > DI_{n-1} \\ \frac{DI-DI_{n-k}}{DI_{n-2}-DI_{n-k}} & \text{if } DI_{n-k} \leq DI \leq DI_{n-2} \\ \frac{DI_{n-1}-DI}{DI_{n-1}-DI_{n-2}} & \text{if } DI_{n-2} \leq DI \leq DI_{n-1} \end{cases}$$

Similarly, the triangular membership function for the input variable, the duration of the implementation of the project on the interval $[DI_{n-2}, DI_{n+2}]]$, can be expressed as:

$$\mu_{DI\overline{m}}(DI) = \begin{cases} 0 & \text{if } DI_{n-2} < DI \text{ and } DI > DI_{n+2} \\ \frac{DI-DI_{n-2}}{\dot{D}I_{n-2}-DI_{n-2}} & \text{if } DI_{n-2} \leq DI \leq \dot{D}I_{n-2} \\ \frac{DI_{n+2}-DI}{DI_{n+2}-\dot{D}I_{n-2}} & \text{if } \dot{D}I_{n-2} \leq DI \leq DI_{n+2} \end{cases}$$

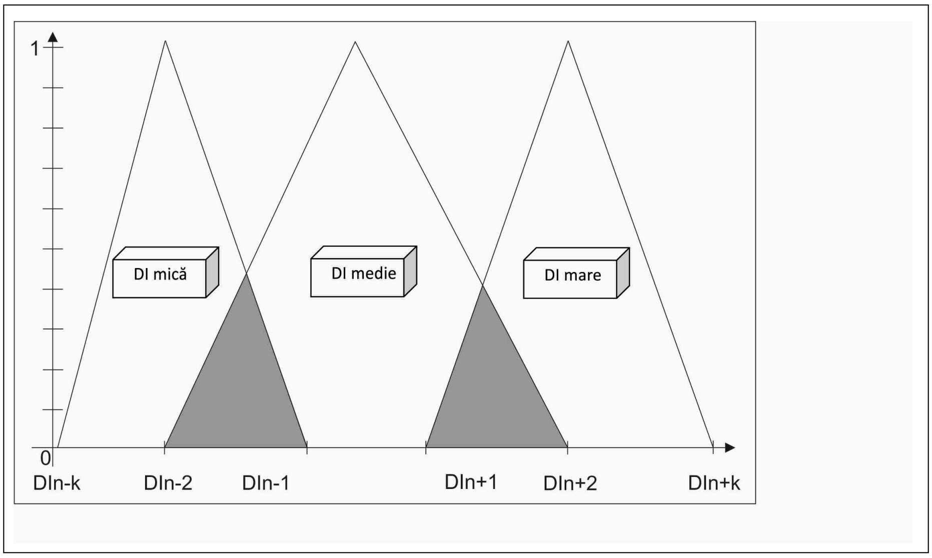

Figure 2: The triangular membership function for input variable of the system - The duration of implementation (DI)

For the FLS were identified the input variables of the system and their membership functions according to fuzzy rules, to which a fuzzy set is completely determined by the set of ordered pairs [7, 8]:

$$A = \{(x, \mu_A(x))/x \in X\} \tag{6}$$

In the second stage of the FLS are set the fuzzy rules base. The specific of these rules is that based on two conditions, namely "if" and ‘"then", are established with the help of experts the influence factors of the financial risk. The number of fuzzy rules base will be equal to $3^2 = 9$ and the financial risk will be divided into three risk classes. The fuzzy rules base for financial risk related to projects financed from structural funds will have the following form:

Rule 1: If the project value is large (VPM) and the exceeding of the duration of the implementation is high (DIM), then the project financial risk is high (RFM);

Rule 2: If the project value is average $VP_{\overline{m}}$ and the exceeding the implementation is high (DIM), the financial risk is high (RFM);

Rule 3: If the project value is small $VP_{\overline{m}}$ and the exceeding of the duration of the implementation is high (DIM), then the financial risk is medium $RF_{\overline{m}}$;

Rule 4: If the project value is large (VPM) and the exceeding of the duration of the implementation is average $DI_{\overline{m}}$, then the financial risk is high (RFM);

Rule 5: If the project value is average $VP_{\overline{m}}$ and the exceeding of the duration of the implementation is average $DI_{\overline{m}}$, then the financial risk is medium $RF_{\overline{m}}$;

Rule 6: If the project value is small VP_m and the exceeding of the duration of the implementation is average $DI_{\overline{m}}$, then the financial risk is small RF_m;

Rule 7: If the project value is large (VPM) and the exceeding of the duration of the implementation is small DI_m, then the financial risk is medium $RF_{\overline{m}}$;

Rule 8: If the project value is average $VP_{\overline{m}}$ and the exceeding of the duration of the implementation is small DI_m, then the financial risk is medium $RF_{\overline{m}}$;

Rule 9: If the project value is small VP_m and and the exceeding of the duration of the implementation is small DI_m, then the financial risk of the project is small RF_m;

The fuzzy rules base for FLS that targets the projects financial risk, aim to capture the best way in which financial risk occurs when there is a change in the value of projects and concomitant a change in terms of exceeding the project implementation duration. Depending on the intensity of these changes, the risk of project budget loss may be, as mentioned above: large, medium or small. On the third stage were applied the fuzzy inference operators on the rules basis generated in the second stage [4]. As shown, the fuzzy rules base is connected by "AND" which means that the operator inference for the rules base is minimum. For each of the previous defined fuzzy rules, is established the degree of membership of the output variable (RF). Therefore will result:

For rule 1: $\mu_{RFM,1} = min[\mu_{VPM}(VP), \mu_{DIM}(DI)]$
For rule 2: $\mu_{RFM,2} = min[\mu_{VP\overline{m}}(VP), \mu_{DIM}(DI)]$
For rule 3: $\mu_{RFm,3} = min[\mu_{VPm}(VP), \mu_{DIM}(DI)]$
For rule 4: $\mu_{RFM,4} = min[\mu_{VPM}(VP), \mu_{DI\overline{m}}(DI)]$
For rule 5: $\mu_{RF\overline{m},5} = min[\mu_{VP\overline{m}}(VP), \mu_{DI\overline{m}}(DI)]$
For rule 6: $\mu_{RFm,6} = min[\mu_{VPm}(VP), \mu_{DI\overline{m}}(DI)]$
For rule 7: $\mu_{RF\overline{m},7} = min[\mu_{VPM}(VP), \mu_{DIM}(DI)]$
For rule 8: $\mu_{RF\overline{m},8} = min[\mu_{VP\overline{m}}(VP), \mu_{DIm}(DI)]$
For rule 9: $\mu_{RFm,9} = min[\mu_{VPm}(VP), \mu_{DIm}(DI)]$

From the rules analysis is shown that the affiliation of the system financial risk in a fuzzy set can be from one or more fuzzy rules which are likely to result in different degrees of belonging to the same fuzzy set. But it takes a single degree of belonging and in order to establish it, is applied a fuzzy controller MAX corresponding to the reunion of the fuzzy sets. Under these conditions will result [9]:

$\mu_{RFM} = max[\mu_{RFM,1}, \mu_{RFM,2}, \mu_{RFM,4}]$
$\mu_{RF\overline{m}} = max[\mu_{RF\overline{m},5}, \mu_{RF\overline{m},7}, \mu_{RF\overline{m},8}]$
$\mu_{RFm} = max[\mu_{RFm,3}, \mu_{RFm,6}, \mu_{RFm,9}]$

In this stage are obtained the solutions of the fuzzy rules, without a certain amount of input variables in the system (VP_i, DI_i) to be determined the intensity of the financial risk by applying all rules of financial risk in the fuzzy base. It is therefore necessary to identify these solutions at the last stage of FLS, namely defuzzification. In the last stage of defuzzification is extracted a deterministic scalar value, from the fuzzy information which is associated to the output variable, the essence of which is to provide more explicit the best value of the output variable [1]. Each of the result in the third stage of the FLS will be used to determine the surface area (S_i) bounded by the parallel to the horizontal axis, taken through the point that determines the size of the output variable, the horizontal axis (O_x) and the graphic of the function associated to output variables. For a given value of the project (VP_i) and some exceeding of the project implementation duration (DP_i) would result that from the original surface (S_i) only a certain percentage (p) is the result that will be taken into account to determine the final amount of financial risk [5]. The conversion of the fuzzy result in a real number value is done by determining the center of gravity of the surface obtained by aggregating the proportion (p) of the initial areas for each graphical input variables as follows:

$$Z = \frac{\sum_{i=1}^{9} \mu_{VP,DI}(VP_i, DP_i) \times VP_i/DP_i}{\sum_{i=1}^{9} \mu_{VP,DI}(VP_i, DI_i)} \quad (7)$$

The result (S) of equation 7 undergo a conversion from area into a real value through the centroid method, which consists in determining the numerical value (z) through which the perpendicular traced to the horizontal axis divides the S area into two equal parts by a relationship of the form:

$$S = \bigcup_{i=1}^{9} \%pS_i \quad (8)$$

The obtained numerical Z value represents the size of the financial risk of a project that has a certain value and a certain level recorded for the (exceeding) implementation duration of the project. The higher this value is, the higher is the probability of losing a part of the project budget.

4 The FLS simulation for the financial risk of projects financed from structural funds

The developed fuzzy logic system was simulated using MATLAB programming language, taking into account the following assumptions, namely:

1. The input variable - the value of projects was divided into three classes: small projects (between 0 and 350 million UM), average project (between 250 million and 750 million U.M.) and large projects (between 650 million UM and 1,000 mil);

2. The input variable - the exceeding of the project implementation duration was also divided into three classes, namely: low exceeding (between 0 and 90 days), average exceeding (between 60 to 180 days) and high exceeding (between 150 days and 270 days).

In the first FLS stage, were established the input variables and their membership functions. Thus, for the input variable, the project value (PV), was stated the following fuzzy set (trapezoidal membership function) as depicted in Figure 3.

For the input variable, the exceeding of the project implementation duration (DI), resulted the following fuzzy sets (using the trapezoidal membership function) as depicted in Figure 7.

For the output variable, the financial risk of the projects, were established three risk classes, using the triangular membership function as follows: low financial risk for values between 0 and

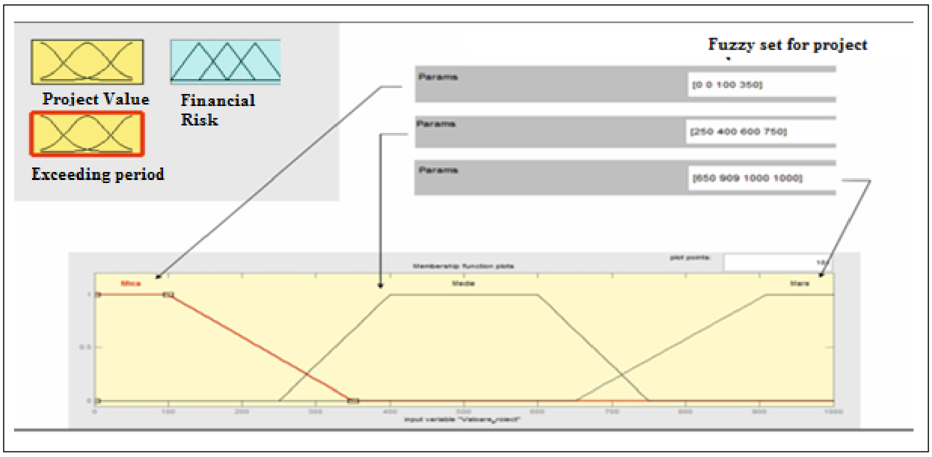

Figure 3: The fuzzy set for the input variable - The project value

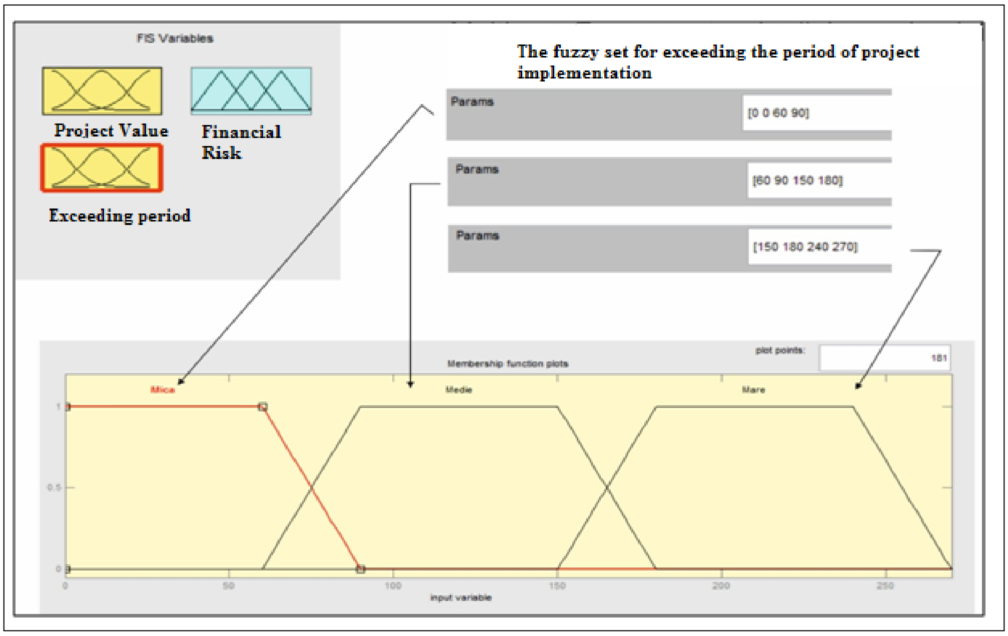

Figure 4: The fuzzy set for the input variable - The implementation duration

3, average financial risk for values between 2 and 6 and greater financial risk for values between 5 and 10. The resulted fuzzy set for the output variable is represented in Figure 5.

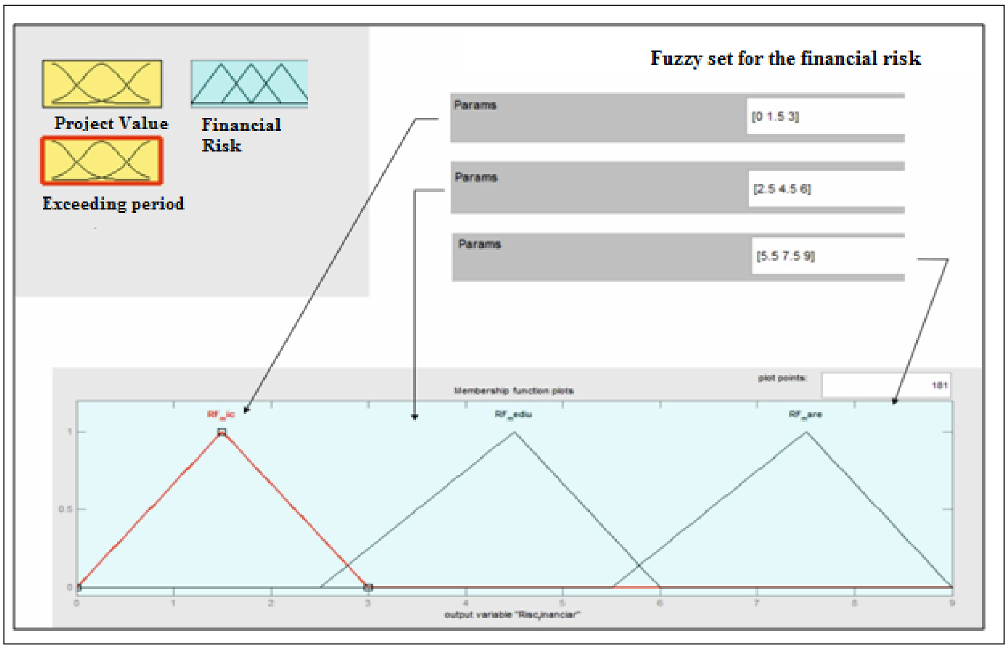

Figure 5: The fuzzy set for the output variable - The financial risk of the projects

After continuing the simulation of FLS, for the financial risk of the projects, were established 9 fuzzy rules base according to the developed and were introduced in the program shown in Figure 6.

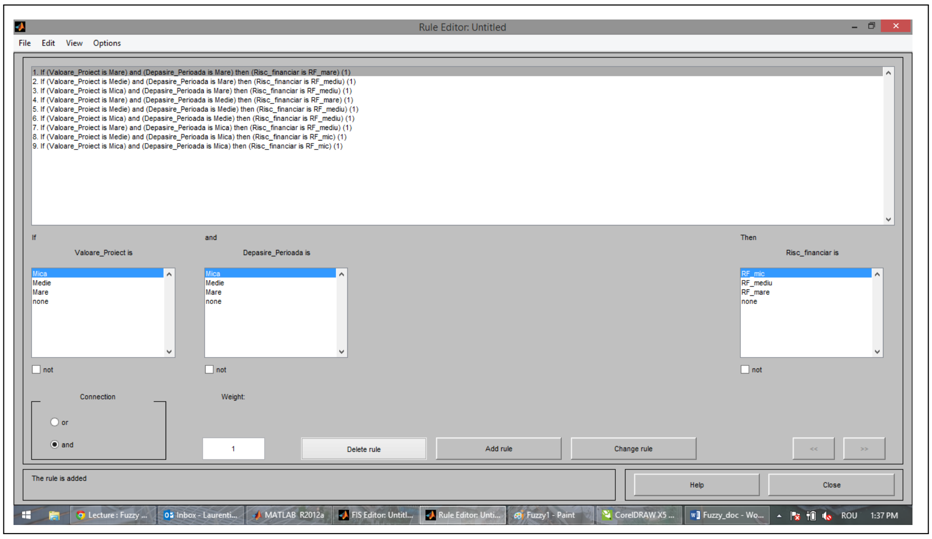

Figure 6: The fuzzy rules base for the financial risk in Matlab

Subsequently were applied the inference operators on fuzzy rules base and the results were presented in Figure 7.

The obtained results are for a project with a value of 500 million U.M., 135-days exceeding duration of the project implementation and a financial risk value of 4.33. The FLS simulation for the financial risk was further carried out for different values of input variables in order

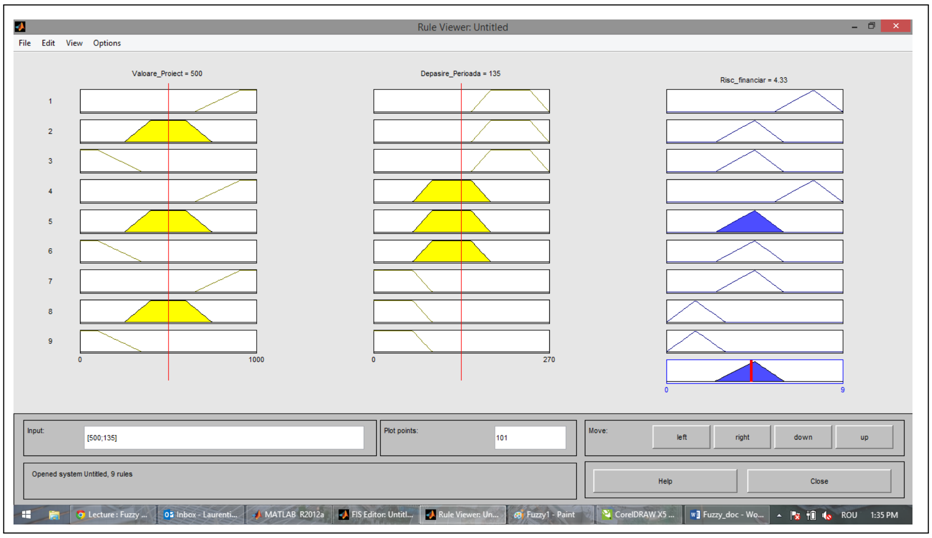

Figure 7: Results obtained by applying the inference operators on fuzzy rules base

to identify the developments that the financial risk has when changes occur in values and in exceeding duration of the project implementation. The results were obtained in Figure 8.

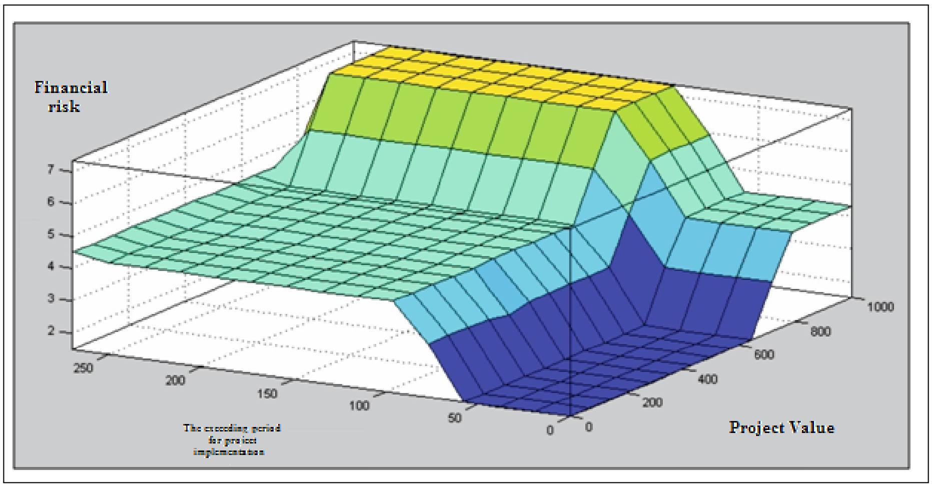

Figure 8: The evolution of financial risk for projects based on input variables

The simulation results are:

1. For project values between 0 and 600 million and an exceeding duration of the project implementation of 55 days, the financial risk tends to zero;

2. For project values between 600 million and 800 million and an exceeding duration of the project implementation between 55 and 100 days, the financial risk is increased from 0 to about 4.5 (and is considered a medium risk);

3. For project values between 800 million and 1,000 million and an exceeding duration of the project implementation between 100 and 270 days, the financial risk is increased from 4.5 to the maximum 9 (being considered a high risk);

5 Conclusion

The computational intelligence is an area of great interest for both specialists in computer science and finance. This is because often are abandoned the statistical concepts and methods that didn't characterize the phenomena and economic processes and are used specific computational intelligence methods that adapt quite well the dynamics of the phenomena studied. The fuzzy logic system developed in this paper, as part of computational intelligence, studies the behavior of financial risk of the projects financed from structural funds when there is a change in the value of projects or in the durations of implementation. This financial risk was defined as the risk of losing a part of the project budget, when there are exceedings in the duration of implementation, based on their implementation cycles. The rules of the fuzzy base were defined according to the impact that the system input variables have on financial risk. The fuzzy inference operators were applied on the basis rules to determine the membership in fuzzy output variable. With the help of defuzzification was ensured the convertion of the fuzzy values in numeric values to determine the size of financial risk for different values of the input variables. Following the simulation for the output variable (the financial risk of projects), were reached the following conclusions:

1. There are situations where the financial risk is zero, or almost zero, for different values of input variables in the system;

2. The financial risk of projects increases as changes occur in the value of projects and in the duration of implementation. This increase in financial risk value becomes in time proportional to changes in the input variables in the system;

3. The financial risk is maximum, when the input variables in the system approach the maximum values that they may register;

The developed fuzzy logic system is a management tool for decision making in the structural funds, under which can be taken measures to avoid or reduce the financial risk, especially for the early identification of the emerging financial risk in the portfolio of projects falling within the structure of the operational program. This early identification of financial risk can be very useful in structural funds management, for taking the necessary actions to avoid this category of risk [12].

The financial dimension of risk can be determined by calculating the financial risk using the formula 4 for each project, where FLS indicates values above the minimum for the financial risk. The value obtained is the value of projects that may be at risk of losing resources that are allocated from the Structural Funds through operational programs. The fuzzy logic can be also developed on classes of projects, through clustering technique to identify financial risk for each class of projects which will be useful in the future because each operational program includes an amount of projects.

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