Fuzzy Logic System for IT Project Management

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Abstract

Decision-making processes in IT project management occur, as a rule, in conditions of risk and uncertainty. Therefore, it is advisable to use methods based on fuzzy logic. The authors propose to analyze the influence of both external and internal factors on the time of the project, financial, human resources, on the timeliness of project completion. The developed fuzzy IT project management system consists of subsystems that can be considered as separate self-sufficient parts. The proposed method enabling the project managers to assess the impact of project environment factors on human and financial resources, the duration of individual works and the project as a whole, and create the basis for proactive changes in project activities.

Keywords

IT Project, Fuzzy System, Project Management, Matlab

1. Introduction

The IT project environment is important in its completion success. The implementation of different projects is influenced by factors such as the external environment (political, economic, social, legal, scientific, technical, cultural and natural) and its internal environment (organizational structure of the project management, project team, professionalism of project executors, style work of the project manager, the specifics of the organization of project work, etc.). The implementation of an IT project mostly depends on how timely the influencing factors of its environment identified.

In the process of implementation, the IT project affects by many external and internal factors that cause changes in its initial or current resource parameters. Due to unpredictable manifestations of external and internal factors, the actual cost of the IT project may deviate from the preliminary cost estimate, the human resources involved in the project may change, and the actual duration of the IT project process may differ from the planned one.

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Such changes can later play a crucial role in the success of the IT project, so it is necessary to take into account the external and internal factors of the project and assess their impact on individual parameters of the project in the implementation process.

Since each successful IT project will be implemented in a future, we may assume there, the both uncertainty and risk occur. It is advisable therefore to employ the methods based on fuzzy logic [1, 2, 3, 4, 5, 6, 7] for IT project management.

2. Related Work

Currently, many scientific studies are conducted using fuzzy set theory, aimed at identifying risk situations in the implementation of projects and decision-making to eliminate or reduce their impact [8].

The ability to evaluate risk contingency value by aggregating rules combining company risk index and project risk index using fuzzy logic approach and MATLAB software has been described in Reference [9].

The fuzzy logic system developed in Reference [10] identifies the financial project risk due to changes occur in project values, in the duration of the projects and in the implementation durations.

In Reference [11] the fuzzy model of risk assessment of IT-project unsuccessful completion is proposed.

In Reference [12] a fuzzy model for the risk evaluation of projects is designed. This model is based on the Elena guideline and comprises a three-stage procedure, including vulnerability assessment, consequence assessment, and the overall risk evaluation. All stages employ the fuzzy reasoning to cope with the inherent uncertainty imposed by projects.

The Reference [13] describes a step-by-step approach for accurate estimation of time and cost of projects using the Project Evaluation and Review Technique as well as expert views of fuzzy numbers.

The use of fuzzy logic makes possible the incorporation of knowledge-based assessments into the estimate of the statistical parameters, which permits overcoming the limited availability of information that makes probability-based modeling techniques unsuitable for this purpose [14].

The Reference [15] proposes a model based on fuzzy logic, the inputs of which are financial value, strategic value, level of risk, and output - the level of project priorities.

The fuzzy inference system for evaluation of project success is presented in Reference [16]. The reliable proposed expert decision-making fuzzy model consists of three input variables (project status, project risk, project quality), one rule block (with 125 fuzzy rules) and one output variable (project success).

In Reference [17] a fuzzy model of the management system for the alignment of the value-oriented portfolio of projects has developed. There are four input variables (structure, process, technology and team), and the output variable determines the value of the portfolio. A Mamdani fuzzy inference system is employed to solve the fuzzy modeling problem.

The Reference [18] presents an expert fuzzy model for evaluation of the project success rate, including partial sub-models, and Reference [19] describes the integrated fuzzy DEMATEL-fuzzy ANP model for evaluating the construction projects by considering the risk factors.

The impact of the external environment of the project on its implementation is considering partly in the fuzzy model [20], which has the input values of the environmental factor, financial and human resources.

The conducted analysis of existing References above confirmed that fuzzy modeling does not take into account the impact of the internal environment of the project on its implementation. Therefore, authors have run a deeper research below to monitor the impact of factors of both external and internal environment on the time of the project, financial, human resources, and, consequently, on the timeliness of project completion.

3. Architecture of IT Project Management using Fuzzy Logic

The project environment has an impact on its implementation and successful achievement of project objectives. The external environment can be favorable for the IT project, i.e. provide opportunities for timely and successful achievement of the goal. On the other hand, some environmental factors may be the cause of risk situations in the project implementation, i.e. pose a threat of non-implementation or late implementation.

Such positive or negative manifestations of environmental factors of the IT project in some way affect the financial and human resources, as well as the implementation time of the project certain stages. For example, the economic conditions of the external environment of the project are related to the project budget. Therefore, they have a direct impact on its financial resources and retention during the project work of professional contractors (human resources), which in turn affects compliance with project timelines. Other unforeseen environmental factors, such as natural ones, which may be accompanied by, for example, energy problems, can increase the execution time of certain works of the IT project and, as a result, cause its untimely execution. Under the influence of the external environment, the need for the product of the IT project or the form of its implementation may change, and this, in turn, will require significant changes in time, material, human and cost resources or even abandonment of further project implementation.

Risk situations associated with adverse effects, such as economic or political factors, can significantly mitigate investments that has been made in sufficient quantities in advance of the project and are therefore a guarantee of its financial stability.

The successful implementation of an IT project is significantly influenced by the internal environment, in particular, the psychological climate and atmosphere in the IT project team, organizational structure, interests, professionalism and degree of involvement in the IT project of its participants, methods and means of communication between them. That is, the internal sources of changes in the project are formed among the project participants in the process of their relationship during the project and are the result of strong or weak manifestations of the internal environment of the project.

These factors have a great influence on the preservation of the contractor number (human resources) and the execution time of individual works of the project. If the strengths of the internal environment of the IT project are manifested. It means that the project team is formed of highly qualified employees, communication tools are established and the leader maintains a normal psychological state in the team, thanks to the right leadership style. Conversely, if the project team is unqualified, the leadership style is chosen incorrectly, the means of communication work poorly or do not exist at all, i.e. the weaknesses of the internal environment prevail, the project will go beyond the time.

Thus, the external environment of the project is manifested in terms of opportunities or threats, the internal environment can have strengths and weaknesses. Together with the investments made in the project, these manifestations of the external and internal environment affect such parameters as financial resources, human resources, time of execution of individual stages or works of the project and, as a consequence, the completion of the project (Figure 1).

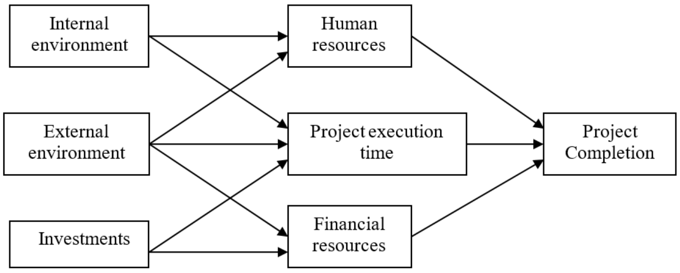

Figure 1: The impact of the project environment on its completion

As can be seen from Figure 1, the impact of project environment factors and the amount of investment can be traced not only on the completion of the project, but also on its individual parameters. Therefore, it is proposed to consider three subsystems "Financial Resources", "Human Resources", "Project Execution Time" as part of the overall environmental impact assessment system, the outputs of which can help the manager to properly assess or predict at any time during the project. The value of a certain parameter, and all the outputs together - to predict the situation regarding the timely completion of the project.

Since the appearance of any factor influencing the implementation of the project is uncertain, it is advisable to create such a system and subsystems in its composition using the methods of fuzzy logic. Dependence of output values on inputs is given by a fuzzy knowledge base on Mamdani algorithm, which is minimum-maximum composition [21], [22]. The general scheme of this fuzzy system is given in Figure 2.

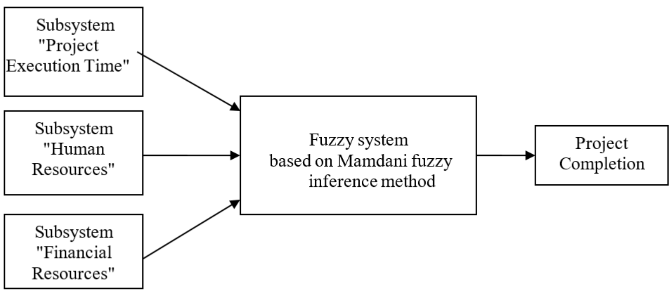

Figure 2: The structure of the fuzzy system "Project Completion"

3.1. Subsystem "Financial Resources"

The subsystem "Financial Resources", taking into account the impact of the external environment and the inward investment of the project, based on fuzzy logic assesses the financial condition of the project (Figure 3).

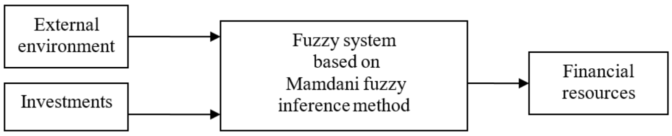

Figure 3: Subsystem "Financial Resources"

The input variable of this subsystem is the external environment, the fuzzy states of which are opportunities or threats.

The states of the input variable "Investments" are large, small, medium.

The output variable of this subsystem has three states: large, small, medium.

All input fuzzy variables have another additional state “none”, which describes the case when the fuzzy system did not receive the current value of a certain variable, for example, in case of system failure. Thus, the input variable "Investments" has 4 states for rule base designing, and the variable "external environment" - 3.

The case when there are no values of all input variables is excluded, because in this case the fuzzy system doesn’t work.

Since the input variables have three and four states, respectively, the rule base of this subsystem consists of $3 \cdot 4 - 1 = 11$ rules of the "if then" type.

3.2. Subsystem "Human Resources"

The subsystem "Human Resources", taking into account the current impact of the external environment and the state of the internal environment of the project, evaluates the amount of available human resources for the project.

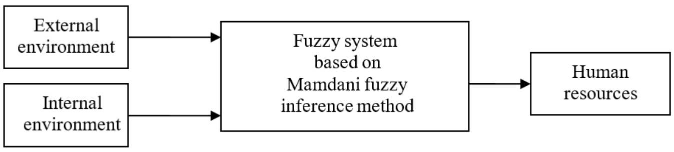

Figure 4: Subsystem "Human Resources"

The distributions of fuzzy sets of input and output variables of this subsystem are as follows:

- external environment: opportunities, threats;
- internal environment: strengths, weaknesses;

Table 1
Correlation of the input and output variables of the fuzzy subsystem "Human Resources"

External environment	Internal environment	Human Resources
Threats	Weaknesses	Small
Threats	Strengths	Middle
Threats	None	Middle
None	Weaknesses	Small
None	Strengths	Large
Opportunities	Weaknesses	Middle
Opportunities	Strengths	Large
Opportunities	None	Middle

- human resources: large, small, medium.

As was note above, all input fuzzy variables have another additional state “none”, which describes the case when the fuzzy system did not receive the current value of a certain variable. The case when there are no values of all input variables is excluded, because in this case the fuzzy system doesn’t work.

The total number of rules of this fuzzy subsystem is $3 \cdot 3 - 1 = 8$. The base of rules is given in table 1. Table 1 provides an example of some of the input and output variables that are based on the fuzzy model rule base.

3.3. Subsystem "Project execution time"

The subsystem for analyzing the project execution time as input variables has external and internal environment and investments (Figure 5).

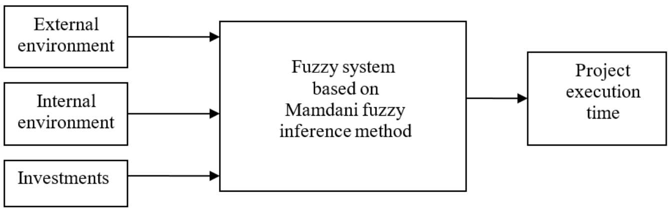

Figure 5: Subsystem "Project execution time"

The distributions of fuzzy sets of input and output variables of this subsystem are as follows:

- external environment: opportunities, threats;
- internal environment: strengths, weaknesses;
- investments: large, small, medium;
- project execution time: overdue, short, scheduled.

The rule base of this subsystem consists of $3 \cdot 3 \cdot 4 - 1 = 35$ rules.

4. Fuzzy System "Project Completion"

The fuzzy system for assessing the timeliness of project completion is based on the Mamdani fuzzy inference mechanism. The outputs of the subsystems, described above ("Project execution time", "Human resources", "Financial resources"), are input variables of the main system. The initial variable "Project Completion" can be in one of the following states: timely (in time), early (in advance), untimely (late).

The total number of rules of the developed fuzzy system, taking into account the “none” states of each of the input variables, is equal to $4 \cdot 4 \cdot 4 - 1 = 63$ rules.

The implementation of the proposed system was carried out in the Matlab environment using Fuzzy Logic Toolbox.

The bell-shaped form, which best reflects fuzzy sets, is used to specify the membership functions of the input variables because it smooths out sharp transitions between values. The bell-shaped form can be described by the equation

$$MF(x) = \frac{1}{1 + \left[\frac{x-c}{a}\right]^{2b}}, \tag{1}$$

which is given by three numbers (a, b, c) corresponding to the abscissas of the extreme points and the center of the curve.

An example of the membership functions of the fuzzy variable "Investment" is given in Figure 6.

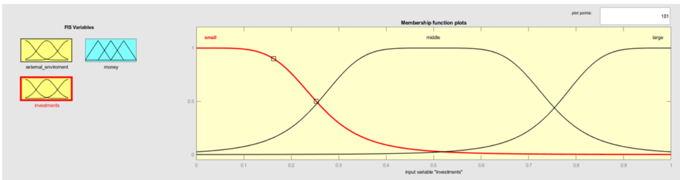

Figure 6: The membership functions of the variable "Investments"

The output variables of each subsystems are set in a trapezoidal shape (allows use them as input variables of the fuzzy system "Project Completion"):

$$MF(x) = \begin{cases} \frac{b-x}{b-a}, a \leq x \leq b, \\ 1, b \leq xc, \\ \frac{x-c}{d-c}, c \leq x \leq d \end{cases} \tag{2}$$

where (a, b, c, d) denote the abscissas of the vertices of the trapezoid. As an example, the form of membership functions of the variable "Human Resources" is given in Figure 7.

Table 2
The simulation results of a fuzzy estimation system

Qualification level	Workload	Reliability of technical support	Quality of IS functioning
0.888	0.908	0.45	0.365
0.0764	0.254	0.879	0.498
0.328	0.0665	0.14	0.361
0.909	0.894	0.929	0.5
0.919	0.0567	0.939	0.631
0.928	0.946	0.865	0.497

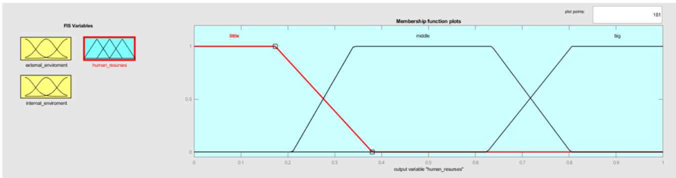

Figure 7: The membership functions of the variable "Human Resources"

5. Case study

Ruleviewer has been used for analysis of the correct operation of the proposed fuzzy system in the Matlab environment. The advantage is that it is possible to evaluate the performance of each subsystem of the proposed system, as well as the overall system. An example of a fuzzy system with given input variables "Project execution time" 0,143, which corresponds to a fuzzy set "short", "Human Resources" 0,113 (fuzzy set "average"), and " Financial Resources " = 0,87 (belongs to the set of "big"). According to the rule base proposed by the authors at such values of input variables, the output of the fuzzy system should be set by the value belonging to the fuzzy set "almost in time".

Data in Table 2 confirms the correct operation of the proposed system due to input and output variables values.

In addition, the correctness of the work is confirmed by the surface values (Figure 8).

The surface presented in Figure 8 confirm the nonlinear effect of the input variables value on the output, i.e. the correctness of the rules base, and hence the work of the developed fuzzy system.

Thus, the fuzzy IT project management system proposed by the authors is workable and can be used in real systems.

Among the systems described in the literature, the closest to the proposed are [18].

The expert decision-making fuzzy model system for the evaluation of project success [18] consists of three sub-models: a fuzzy model of project state evaluation, a fuzzy model of total project risk evaluation, and a fuzzy model of project quality evaluation. There are six input variables, four rule blocks and one output variable in the fuzzy model.

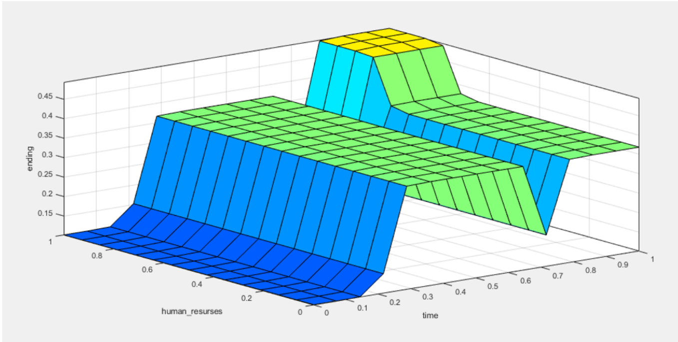

Figure 8: The values surface of fuzzy system

The inputs of the submodel evaluates the project status are represented by two variables: schedule performance index and cost performance index.

The inputs of the sub-model evaluate the total value of project risk are represented by two variables: number of sub-risk and total value of sub-risks.

The inputs of the third sub-model evaluate project quality are represented by two variables: degree of compliance with the requirements and eligibility for use.

Partial outputs from the sub-models are simultaneously inputs for fuzzy model of project success evaluation, from which there is a single output variable – project success.

Although the structure of such a fuzzy system for the evaluation of project success, consisting of three fuzzy sub-models, is similar to that proposed in this paper, but the input variables do not reflect the influence of external and internal environmental factors on external parameters. Thus, the proposed by authors fuzzy system takes into account more project parameters and is therefore better to use.

6. Conclusions and Further Research

The proposed fuzzy IT project management system consists of subsystems, each of them can be used as a separate system for assessing a certain factor. The outputs of each subsystem are input values for a fuzzy system for timeliness estimating of project completion.

The proposed method, based on fuzzy logic, enabling the project managers to assess: (i) the impact of project environment factors on human and financial resources, (ii) the duration of individual works and the project as a whole. Moreover, the proposed method can be considered as the basis for proactive changes in project activities.

The experimental research have been conducted using Ruleviewer in the Matlab environment, and the confirmed a correct operation of the proposed fuzzy system as well as a possibility of its usage in real systems.

A direction of the further research is developing a tool for assessing project completion.

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