Fuzzy Controller of IT Project Management

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Abstract

The external environment can be favorable for the IT project, i.e. provide opportunities for timely and successful achievement of the goal. 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. 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. Factors of the project environment that may affect its implementation, managers mostly predict at the stage of project origin. But it is impossible to determine such an impact in advance, because the IT project operates in conditions of uncertainty. Therefore, in the study of the impact of the project environment on its implementation and completion, it is advisable to use fuzzy logic. The fuzzy controller of IT project management, proposed by the authors, consists of subsystems that allow analyzing the impact of both external and internal environmental factors on the time of individual works or stages of the project, financial, human resources, and in total - on project completion. Each of the subsystems can be considered as separate self-sufficient parts. The proposed approach allows project managers to assess the impact of project environment factors on its implementation.

Keywords [1]

IT Project, Project Management, Project Environment, Project Execution Time, Human Resources, Financial Resources, Investments, Fuzzy Controller, Simulink

1. Introduction

Projects in the field of information technology are characterized by certain specifics of their implementation. But, like any other, they are exposed to various factors of the project environment. These factors can contribute to the timely and high-quality implementation of project work, which will lead to the successful achievement of the project goal. But they can, conversely, have a negative impact on the project implementation process. As a result of such impacts, the project undergoes changes that concern either deadlines, or contractors, or other resource provision.

Under the influence of the external environment, in particular its factor such as scientific and technological progress, the form and means of realization of the IT project product may change, and this, accordingly, will require significant changes in time, material, human resources and cost or even refusal to further implementation of this project.

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Project management in conditions of risks and uncertainties caused by both external and internal environment of the IT project requires timely identification of such factors, comprehensive assessment of their impact on project implementation and appropriate decision-making to increase their positive, conversely, eliminate, or reduce negative effects per project.

Since during IT project implementation there is always a some uncertainty associated with the project environment, so it is advisable to manage the project using methods based on fuzzy logic [1, 2], which allow not only assess the project status in real-time, but also proactively manage its successful implementation.

2. Related Work

In research that aimed at identifying factors of the projects implementation influencing, the theory of fuzzy sets is increasingly used, in particular in [3, 4].

The developed contingency risk model [5]demonstrate 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.

The paper [6] provides a step-by-step approach for accurate estimation of time and cost of projects using the project evaluation and review technique and expert views as fuzzy numbers.

The fuzzy logic system developed in [7] 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 influence the financial risk.

The fuzzy model of risk assessment of unsuccessful completion of IT-project was proposed in [8]. The aim of this paper is to identify critical failure factors for IT projects, classify these factors based on their original source, and their prioritize using fuzzy analytic hierarchy process.

The fuzzy inference system for evaluation of project success is presented in [9]. The reliable proposed expert decision-making fuzzy model consists three input variables (project status, project risk, project quality), one rule block and one output variable (project success).

Fuzzy model for the risk evaluation of projects based on the Elena guideline, proposed in [10], comprises a three-stage procedure, including vulnerability assessment, consequence assessment, and the overall risk evaluation. All stages use the fuzzy reasoning to cope with the inherent uncertainty imposed by projects.

The reference [11] presents an expert fuzzy model for evaluation of the project success rate, including partial sub-models.

Reference [12] describes the integrated fuzzy model for evaluating the construction projects by considering the risk factors. Proposed fuzzy model is used to determine the interrelationships and interdependencies among risk factors.

The fuzzy estimation method of the information system providing part influence on the functioning quality is developed in [13]. It`s based on a fuzzy system, the inputs of which are the states of reliability for software, technical and information providing, and the output is the quality of system functioning.

The paper [14] analyzes various methods of structural and parametric optimization for fuzzy control and decision-making systems. Special attention is paid to hierarchical structure selection, rule base reduction, and reconfiguration in the presence of incomplete data sets.

The impact of the external environment of the project on its implementation is considering partly in the fuzzy model [15], which has the input values of the environmental factor, financial and human resources.

Some researchers suggest, in addition to fuzzy systems, to develop fuzzy controllers that make management processes particularly effective in conditions of risk and uncertainty.

In the paper [16], the analytical structure of a Takagi-Sugeno Fuzzy Logic Controller with two inputs and one output for software development effort estimation is discussed. The analytical study is also presented with two sample inputs.

The paper [17] deals with the problems of fuzzy controllers design. The optimization approach for increasing efficiency of fuzzy controllers design process based on their structural-parametric optimization are discussed.

Given current trends in the fuzzy logic methods using in project management, the authors proposed in [18] to analyze the influence of both external and internal factors on the project time, financial, human resources, to 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.

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 (see Figure 1) [18].

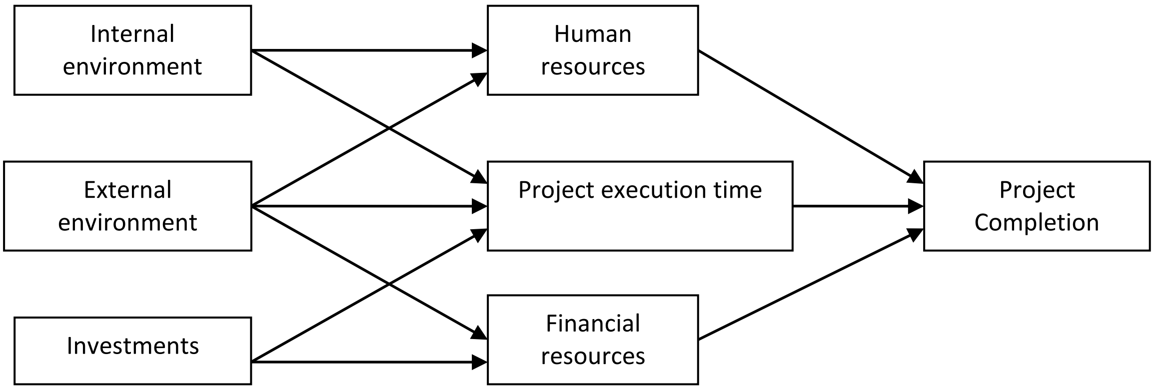

Figure 1: The impact of the project environment on its completion

As can be seen from Fig. 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 [19-21]. The general scheme of this fuzzy system is given in Figure 2 [18].

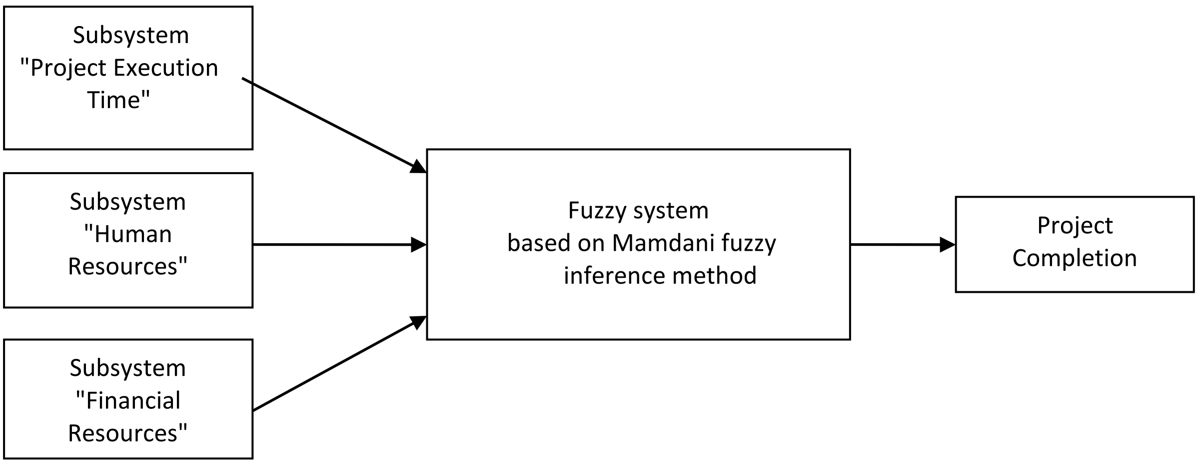

Figure 2: The general structure of the fuzzy system "Project Completion"

3.1. Subsystem "Project execution time"

The subsystem for analyzing the project execution time as input variables has external and internal environment and investments (see Figure 3) [18].

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 35 rules.

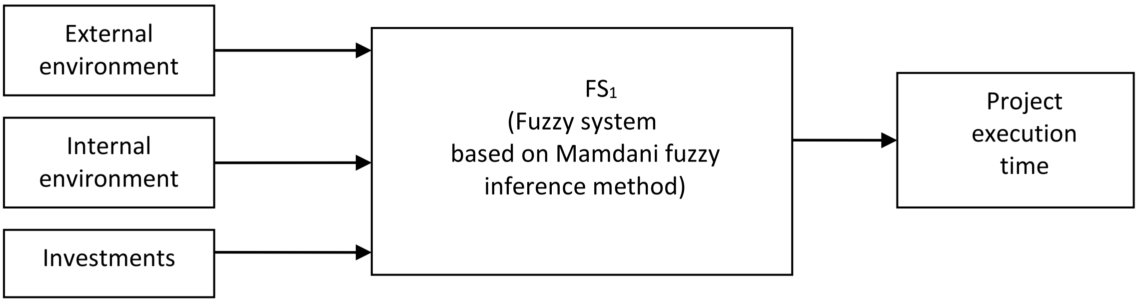

Figure 3: Fuzzy subsystem "Project execution time"

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 (see Figure 4) [18].

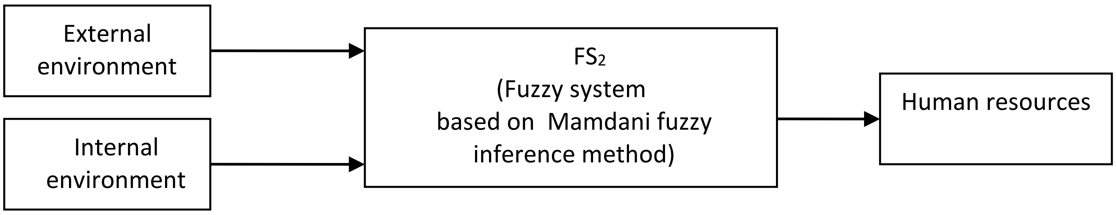

Figure 4: Fuzzy subsystem "Human Resources"

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

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

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

3.3. 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 (see Figure 5) [18].

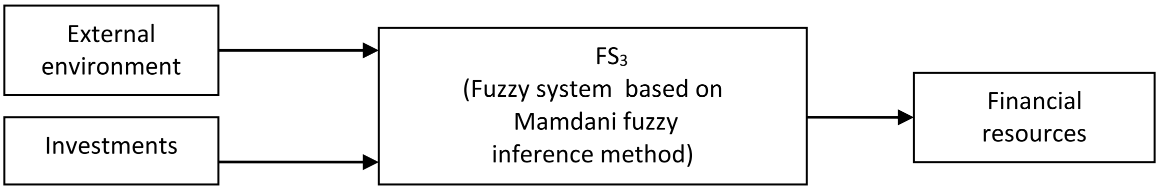

Figure 5: Fuzzy subsystem "Financial Resources"

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 11 rules of the "if then" type. Thus, considering noted structures of fuzzy subsystems, the fuzzy system will have the architecture shown in Figure 6.

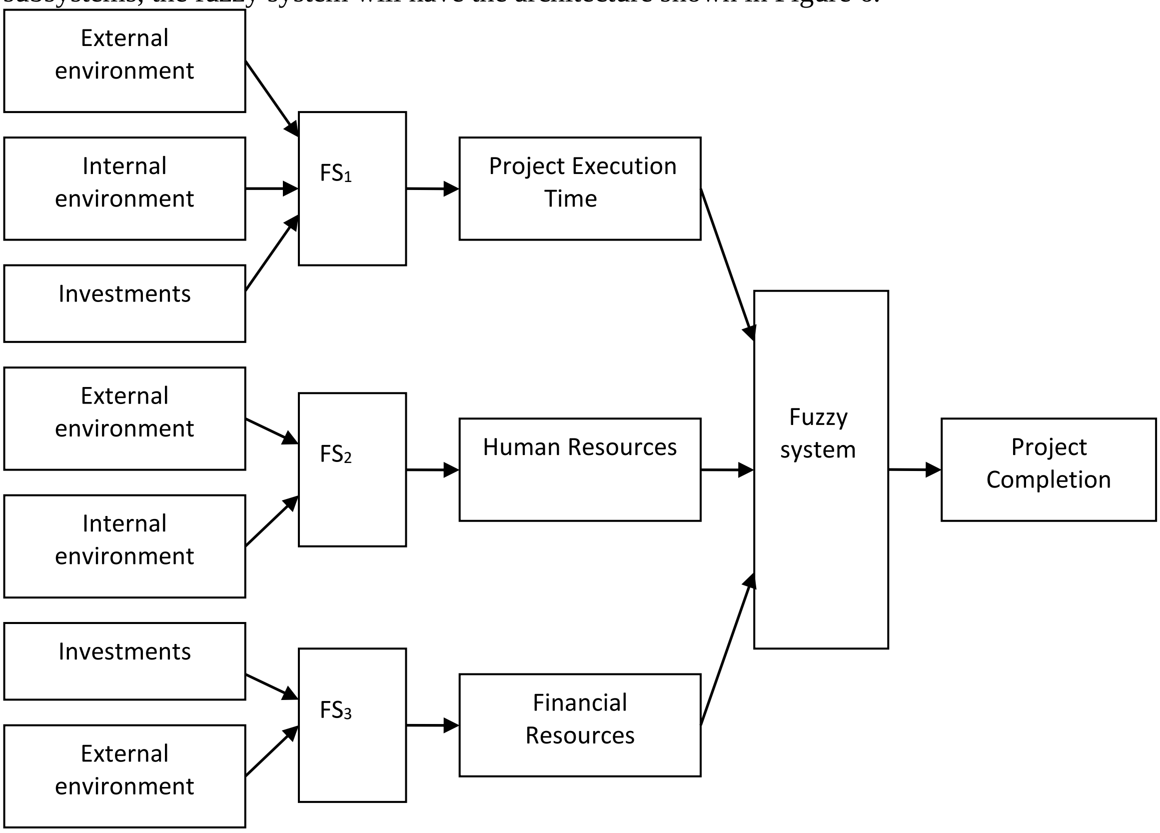

Figure 6: The structure of the fuzzy system "Project Completion"

The proposed fuzzy IT project management system should be implemented using a fuzzy controller.

4. Fuzzy Controller

An important application of fuzzy set theory is fuzzy logic controllers, which are used in various control systems. Instead of a mathematical model to describe the system, such controllers use the integrated knowledge of experts, which in the structure of the representation is close to spoken language and is described using linguistic variables and fuzzy sets

The basic fuzzy controller consists of four main components:

- fuzzification unit (simply changes the inputs so that they can be interpreted and compared with the rules of the knowledge base);
- knowledge base (rule base and knowledge base, in the form of a set of rules on how best to manage the system);
- decision-making unit (a logical inference mechanism that evaluates which rule is currently relevant and then decides what should be submitted for entry);
- defuzzification unit (transmits the conclusions made by the logical inference mechanism to the inputs).

The model of fuzzy controller of access to the evaluation system of a general education institution can be built with the help of Simulink tools. Simulink is an interactive tool for modeling, simulating and analyzing dynamic systems, including discrete, continuous and hybrid, nonlinear and discontinuous systems.

Modeling of the proposed controller is carried out using the Fuzzy Logic Controller unit. This unit connects the fuzzy system developed in the previous section and allows further coding in HDL, which can be used when programming FPGA.

The proposed fuzzy controller consists of three controllers that implement the subsystems "Financial resources", "Project execution time" and "Human resources", described above, and can be independently implemented in certain systems.

Input variables "External environment", "Internal environment" and "Investments" are set to Random Number.

The general scheme of the fuzzy controller of IT project management is given in Figure 7.

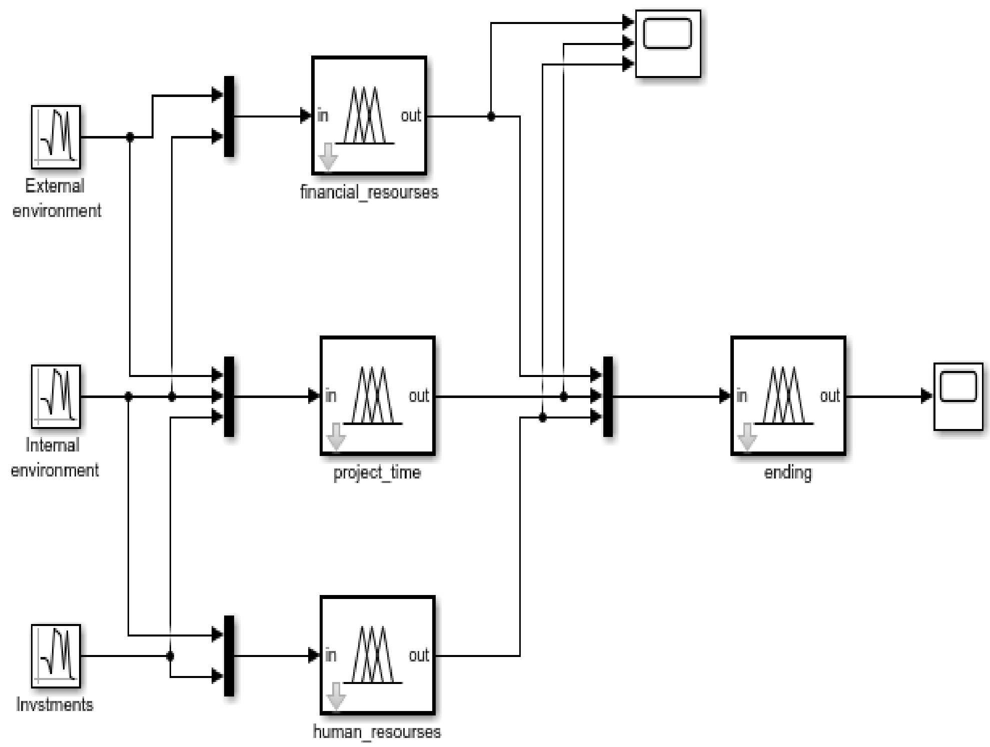

Figure 7: The general scheme of the fuzzy controller

General scheme of every noted subsystem are given in Figure 8.

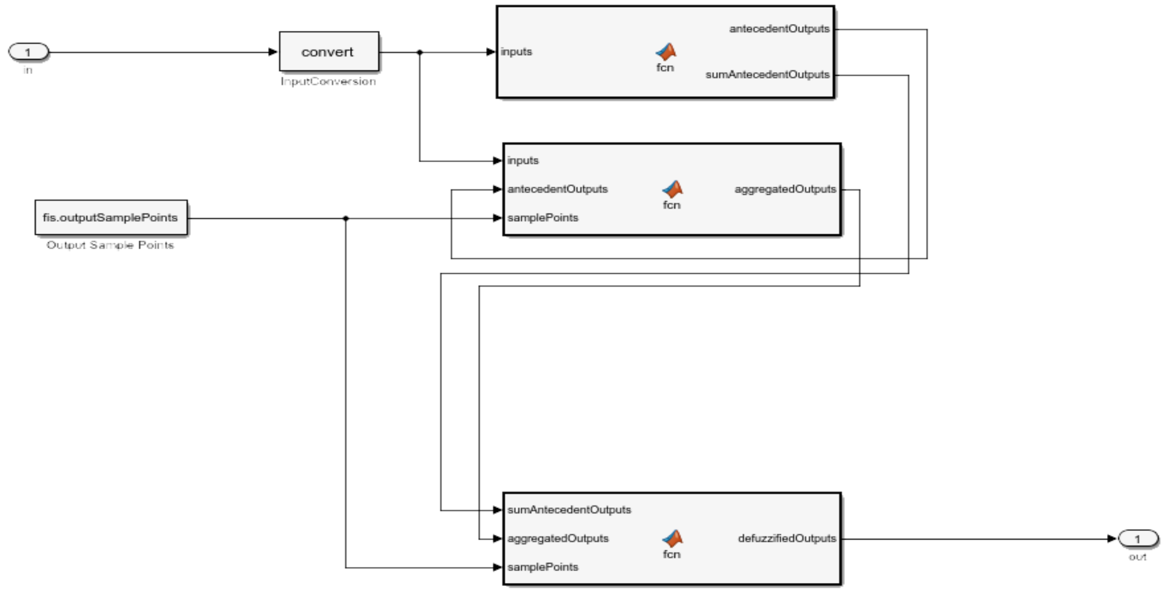

Figure 8: General scheme of subsystem

Figure 9 shows the scheme of processing the input fuzzy values according to the rule of type "if - then". Simulink processes the rules from the knowledge base, taking into account the rating displayed by the constant Weight.

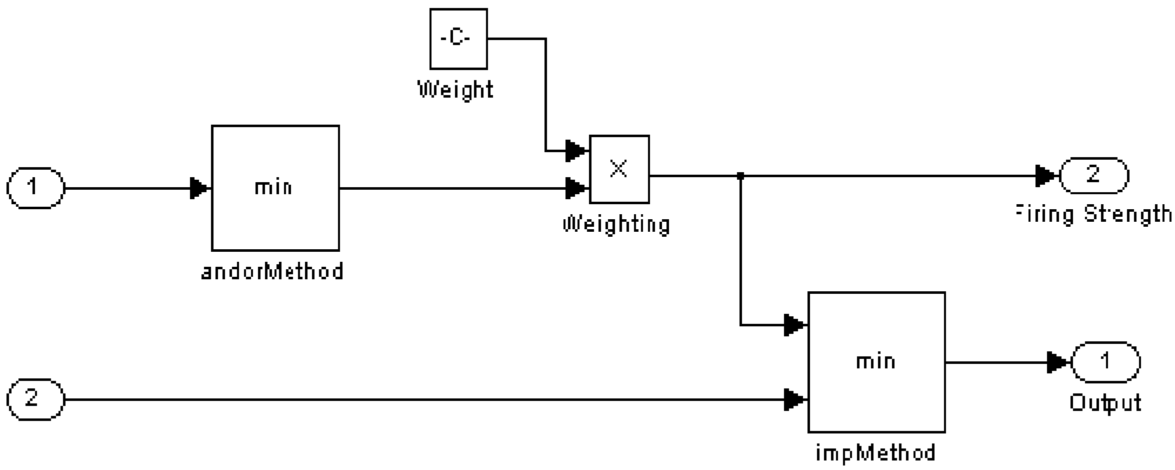

Figure 9: Scheme of processing of incomplete fuzzy values by a rule of type "if - than"

To make a conclusion according to the Mamdani mechanism, the fuzzy controller performs defuzzification. This process performs a "min-max" composition of the rules of the fuzzy knowledge base and gives the value of the center of gravity of the final figure, which corresponds to a certain value of the output variable.

The scheme of defuzzification of the fuzzy controller for IT project management of the breast is presented in Fig. 10.

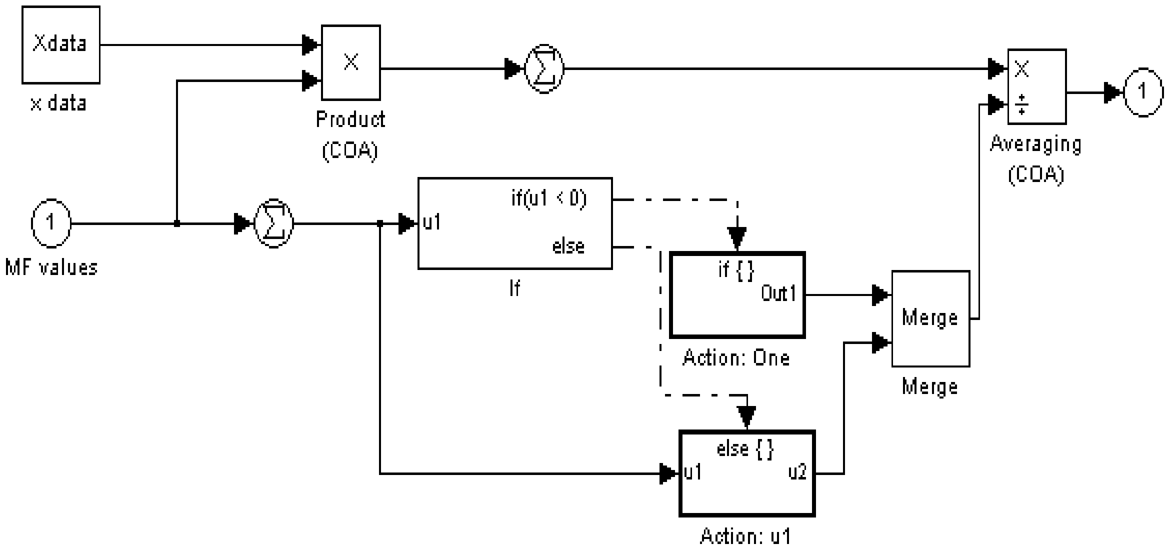

Figure 10: Scheme of defuzzification unit of proposed fuzzy controller

5. Case Study

Analysis of the fuzzy controller is performed by analyzing the data from the Scope Block, which are connected to the corresponding blocks of subsystems "Financial resources", "Project execution time" and "Human resources".

The results of the developed fuzzy controller of IT project management in accordance with the data of Figure 11 are presented in Figure 12.

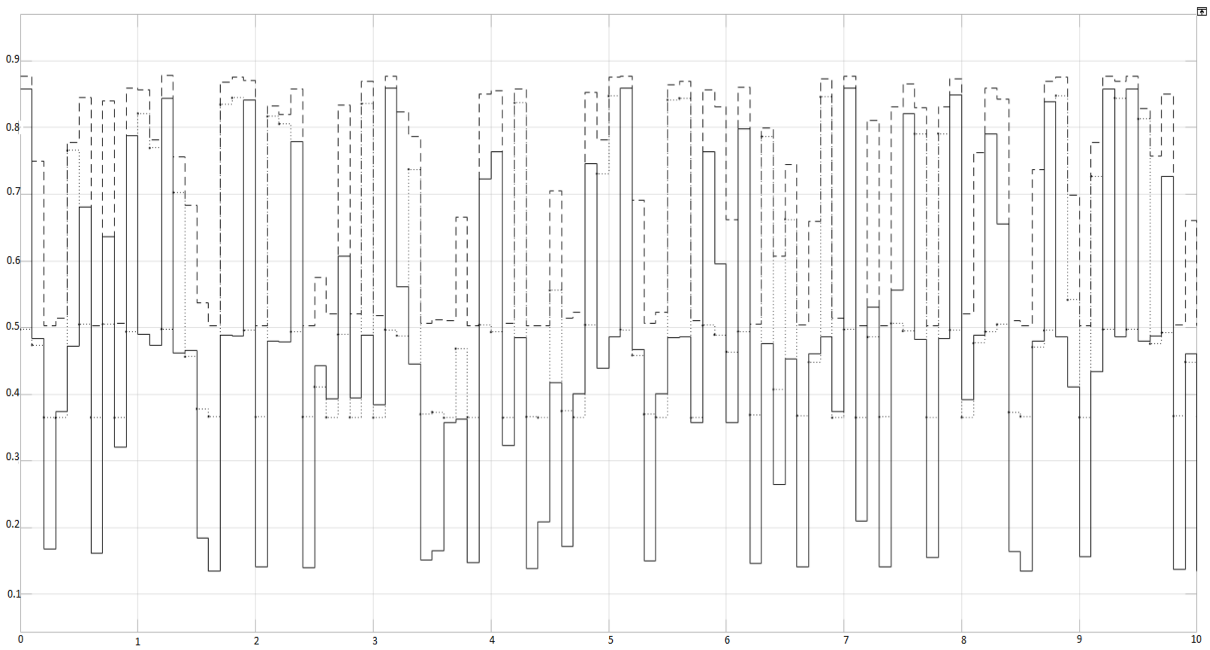

Figure 11: The outputs of fuzzy subsystems

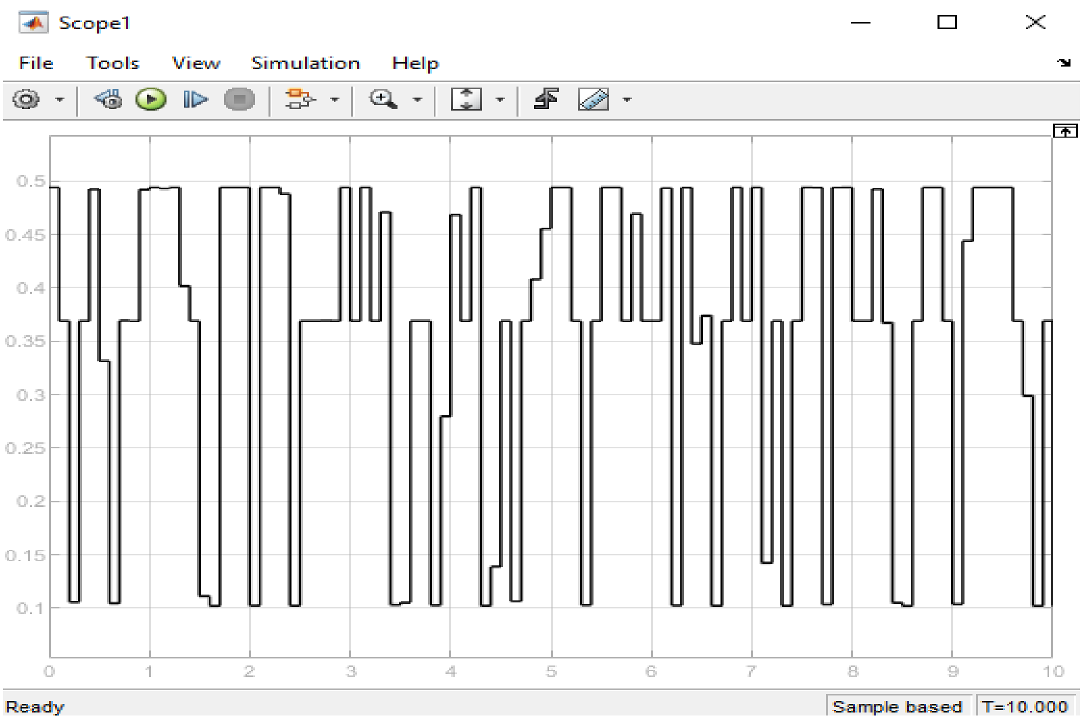

Figure 12: The output of IT project management fuzzy controller

Analysis of simulation results confirms the correctness of the results and the efficiency of the developed fuzzy controller of IT project management. Therefore, the proposed tool can be used in appropriate control systems.

6. Conclusion and Further Research

The proposed fuzzy IT project management controller consists of subsystems, each of them can be used as a separate controller for assessing a certain factor. The outputs of each subsystem are input values for a fuzzy controller 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 Scope Block in the Simulink environment, and the confirmed a correct operation of the proposed fuzzy controller as well as a possibility of its usage in real systems. A direction of the further research is FPGA programming for assessing project completion.

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