Project Risk Assessment Using Fuzzy Inference System

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The article focuses on the risk assessment of project. The risk assessment is a complexity decision making problem. The assessment risk of projects can be solved with Fuzzy Sets Theory. A Fuzzy Inference System is presented in order to risk assessment of the given project.
Keywords: project, risk, risk management, risk assessment, fuzzy sets, fuzzy numbers, Fuzzy Inference System.

1. INTRODUCTION

In todays competitive market of goods proper management of business/project is the key to success of every enterprises. On the present production market we can notice the focus for specialization, high variability, product life cycle shortening, continuous quality improvement, reduction of production costs, etc [22]. Selection of the appropriate projects is a major requirement for an effective enterprise.

The need to manage a one-of-a-kind project has been a commonplace since the construction of the piramids in Egypt [14]. Project-based working, project driven manufacturing are widespread today. In practice it means that production activities are driven by project. The project is driven by customer order. Customer driven manufacturing is a key concept for the factory of the future [25].

The concept of customer driven manufacturing is result from customised products over the past two decades and the trends of production processes of small batch sizes of products. The extreme case of the trends is one-of-a-kind production. The product offered by a customer is manufactured only once. A more common scene for most industrial production shops is the make-to-order MTO production. It means that a variety of products are design and produce from combination of standard materials and components with customers specifications [19].

Projects have become an increasingly important part of the value creation process in many different industrial fields. Enterprises in such industries as aerospace, construction, shipyards, engineering, etc. are companies where the value creation process includes the search, preparation, bidding, negotiation, implementation and transition of a project [12]. The project management play significant role in enterprises, especially in small and medium-sized enterprises SMEs. The European Competitiveness Report shows that small and medium-sized enterprises account 99,8% of all companies in the European Union. SMEs generate 56% of GDP and employ 70% of private sector workers [6]. According to paper [23] projects account on average for one third of the turnover of SMEs. Additionally, the paper shows that the projects in small and size enterprises account for almost one fifth of the economy. This is more than is spent on large infrastructure projects in the Western economy [24].

Project management has become very popular. Recent research tends to emphasize the role of project risk management. Risk management is one of the nine focuses in project management. It can be defined as a system which aims to identify and quantify all risks to which the business or project is exposed so that a conscious decision can be taken on how to manage the risks [16]. Project risk management is crucial process. It should be implemented in a systematic manner from planning phase through the project completion phase.

One of the important phase of the project risk management is risk assessment. In practice, risk assessment is complex process. It can be difficult to assess the risk associated with the project due to the uncertainty. The difficulties comes from imprecise informations, incomplete informations, non-obtainable, informations and unquantifiable informations. In such circumstances, the risk assessment can be only approximate not exact. The crisp numbers are replaced by linguistics terms. The linguitics terms are converted into a fuzzy numbers by using appropriote conversion scale. Fuzzy numbers are very usefull to express the project risk.

The paper presents an approach to project risk assessment. The rest of the paper is organized as follows: in Section 2, overview of the project risk management is reviewed based on the actual researches. In Section 3, the proposed approach to risk assessment is presented. Section 4 presents an example of the project risk assessment using the Fuzzy Inference System implemented in Matlab software. Conclusions are offered in Section 5.

2. OVERVIEW OF THE PROJECT RISK MANAGEMENT

Planning and realization of projects always have a certain level of uncertainty. This is due to the fact, that projects are often innovative and unique and it is difficult to predict the direction of realization in uncertain situations [20]. The uncertainty is the result of not having full access to information and characteristics of a project type. Uncertainty can be defined as probability that the objective function will not reach its planned target value [11]. More about uncertainty can we find in paper [18].

Uncertainty is associated with risk. In practice it means that the higher the uncertainty the greater the risk [1]. One of the major characteristics of projects is their level of risk. This means that too many undesirable events may cause delays of project, excessive spending, unsatisfactory project results or even total failure.

Risks have two-edged nature, such as threat and challenge. The chance of something happening that will impact on objectives may have possitive or negative impact [16].

Risk due to its possible (negative) consequences involves issues of security threats of project [3]. Risk can be defined as the potential for complications and problems with respect to the completion of a project task and the achievement of a project goal [15]. Other definitions of risk are available in the literature such as the exposure to the possibility of economic or financial loss or gain, physical damage or injury [11], or delay, as a consequence of the uncertainty associated with pursuing a particular course of action [2], the probability of losses in a project or a barrier to success [9].

Projects are full of uncertainty. During project execution unexpected events can happen cause of changing scope of the project, economical turbulence, supplier problems with material delivery, resource utilization, personel mobility. The cause of unexpected events can be additional costs and time. The disturbance occuring usually lead either to project makespan or to the project's budget escalation or to both of them simultaneously [10, 21].

The main aims of risk management is to identify and assess risk in the given project. The first step in project risk management is risk identification. In the phase all of potential risks sources are identified. All potential risk factors are determined which may affect the project. The characteristics of risks sources, risks factors are documented. A large number of techniques exist for project risk identification. In order to determine the potential risks of the project the brainstorming and workshops, checklist and prompt lists, questionnaires and interviews, Delphi groups or nominal group technique (NGT), and various diagramming approaches such as cause-effect diagrams, systems dynamics, infuence diagrams are used [16].

Risk assessment is the second phase of the risk management. It is a complex subject shrouded in vagueness and uncertainty. Vague terms are unavoidable since individualas often find it easier to desribe risks in qualitative linguistic terms [4]. The main goal of risk assessment is to measure the impact of the identified risks on the given project.

The risk assessment is a process of prioritizing risks for further analysis by assessing and combining, generally, their probability of occurrence and impact [17]. The following methods are used in project risk assessment: Fault Tree Analysis, Event Tree Analysis, Monte Carlo Analysis, Scenario Planning, Sensitivity Analysis, Failure Mode and Effects Analysis, Expected Monetary Value, Expected Net Present Value, Decision Tree, Program Evaluation and Review Technique (PERT), and fuzzy sets theory [8].

Risk response is the next phase of project risk management. The aim of the phase is to develop options and actions to enhance opportunities and to reduce threats to the given projects objectives. Risk monitoring and control on the project are the last phases of the risk management process. It can be described as the process of implementing a risk response plan, tracking identified risks, monitoring residual risks, identifying new risks, and evaluating the risks process effectiveness throughout the project [17].

3. A NEW APPROACH TO PROJECT RISK ASSESSMENT

Recently, several researches studies on the risk assessment using Fuzzy Sets Theory have been performed. In the paper a new approach to project risk assessment is presented. The approach is based on the Fuzzy Sets Theory. In order to assesst the project risks the Fuzzy Inference System is developed.

The Fuzzy Sets were first proposed by Lukasiewicz in 1920s in an attempt to produce systems which were able to represent a range of truth values covering all real numbers from 0 to 1. Zadeh [26] extended the work on possibility theory in to a formal system of mathematical logic for representing and manipulating "fuzzy" term, called fuzzy logic [4]. Fuzzy Set Theory provides a good mathematical methodology to describe and handle the problem of unprecise project risk assessment. Using fuzzy logic, fuzzy sets may be defined on vague, linguistic terms such as very high probability, low impact, medium level of risk. Fuzzy logic copies the human decision making using levels of possibility in the number of uncertain categories.

According to Zadeh's definition, a fuzzy number Ã is a set of ordered pairs $\{(x, \mu_{\tilde{A}}(x));\ x \in X\}$ where $\mu_{\tilde{A}} : x \rightarrow [0,1]$ and is upper semicontinous. Function $\mu_{\tilde{A}}$ is called the membership function of the fuzzy number.

The fuzzy number $\tilde{A}$ is a fuzzy set whose membership function $\mu_{\tilde{A}}(x)$ satisfies the following conditions [13]:

- $\mu_{\tilde{A}}(x)$ is piecewise continuous,
- $\mu_{\tilde{A}}(x)$ is a convex fuzzy subset,
- $\mu_{\tilde{A}}(x)$ is the normality of a fuzzy subset, implying that for at least one element x_0 the membership grade must be 1, i.e. $\mu_{\tilde{A}}(x_0)=1$.

It is obvious that each decision maker may have another fuzzy number related to each attribute. This fuzzy number may have the shape function defined on various domains. There are many types of membership function, for example: trapezoidal membership function, gaussian membership function, bell membership function [13].

In this paper, for practicality and ease of the project risk assessment, triangular and trapezoidal fuzzy numbers for the estimations are proposed. Considered membership function is defined following:

$$\mu_{\tilde{A}}\ x\ =$$
$$\frac{x-1}{m-1}, 1 \le x \le m \text{ and } 1\ \neq m,$$
$$\frac{u-x}{u-m}, m \le x \le u \text{ and } m \neq u,$$
$$0 \text{ otherwise.}$$

Figure 1 shows the membership function of a triangular and trapezoidal fuzzy number.

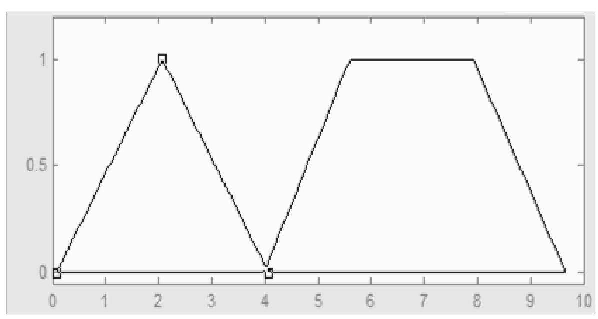

Fig. 1. Membership function of triangular and trapezoidal fuzzy number

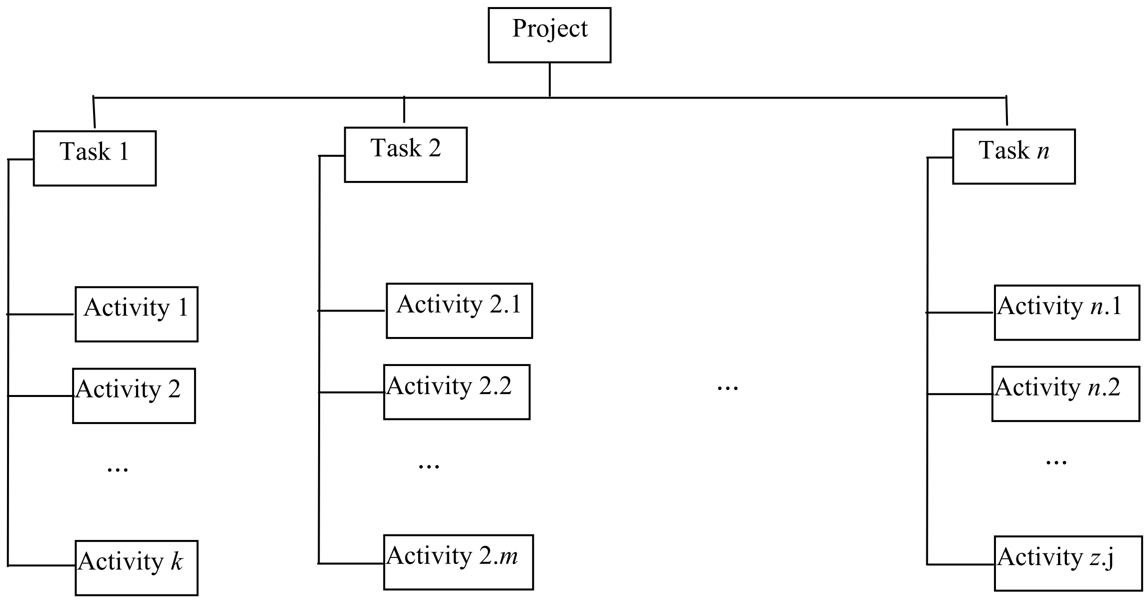

Figure 2. Work Breakdown Structure

The proposed approach to project risk assessment consists of few phases. In the first phase we develope Work Breakdown Structure (WBS). The Work Breakdown Structure is a graphic model of the project, exploding it in a level-by-level fashion down to the degree of detail needed in order to effective planning and project control. The Work Breakdown Structure is also known as Project Breakdown Structure (PBS) (Figure 2). Hierarchical structure defines tasks that can be completed independently of other tasks, facilitating resource allocation, assignment of responsibilities, and measurement and control of the project.

In the second phase all factors that affect the considered project are determined by experts based on their knowledge and experience. Beacause a task/activity can be affected by many different risks all potential risks (R) and their sources (RS) with identified factors (RF) are described and linked with the apprioprate task/activity in WBS. In order to assessment project risk the activities risk is first assessment. The important values are estimated, i.e. the probability (RP) and impact (RI) of the risk factors. The probability and impact of the risk factors are definied using linguistics terms. The risk probability indicates the likelihood that each type of risk will occur. The probability for each risk factors is estimate based on the proposed three-scale: low, medium, high (Tab. 1). The impact of the risks factors depicts potential effect on the project objectives, i.e. cost, time, quality, scope. The scale for determining impact of risk on the respectively objectives is presented in Tab. 2.

Tab. 1. Linguistic terms of risk factors probability

Symbol of risk factor	**Description of risk factor**	**Probability of risk factor**		
		L	**M**	**H**
RF_1				
RF_2				
. . .				
RF_n				

LEGEND: L – Low, M – Medium, H – High.

Tab. 2. Linguistic terms of risk factors impact on project objectives

Symbol of risk factor	Impact of risk factors on project objectives										
	cost					…	scope				
	VL	L	M	H	VH		VL	L	M	H	VH
RF_1											
RF_2											
. .											
RF_n											

LEGEND: VL – Very low, L – Low,

M – Medium, H – High, VH – Very High.

For each activities/task and finally for the given project the total risk level is evaluated. The ouput variable, i.e. risk level is developed as fuzzy subset. The risk level is definied using linguistics terms (Tab. 3). The relations between input parameters (i.e. probability and impact) and output parameters (i.e. risk level) are defined in form of fuzzy rules "IF-THEN".

Tab. 3. Linguistic terms of risk level

Symbol of risk level	Risk level	Description
RL	L	Low risk
RL	M	Medium risk
RL	H	High risk

In the third phase the fuzzy numbers and membership functions for each of the input variables and for the output variables are developed. The linguitics terms are transformed into appropriate fuzzy numbers. The values correspond to fuzzy numbers on the proposed numeric scale 0–1. The membership functions of the fuzzy numbers are shown in Figure 3. The linguistics scale is desribed in Table 4. Figure 4 presents five membership fuctions of impact on project objectives. The linguistics impact scale is presented in table 5. The risk parameters are expressed by triangular and trapezoidal fuzzy numbers.

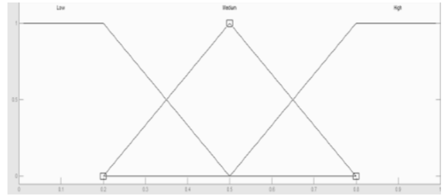

Figure 3. The membership function of the linguistics probability scale

Tab. 4. The lingustics probability scale

Desription of probability	Fuzzy numbers	Interpretation
Low (L)	(0, 0, 0.2, 0.5)	Unlikely
Medium (M)	(0.2, 0.5 0.8)	Likely
High (H)	(0.5, 0.8, 1, 1)	Very likely

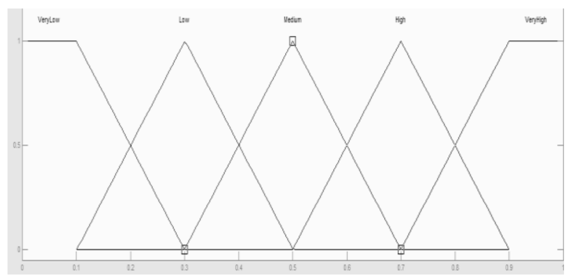

Figure 4. The membership function of the linguistics impact scale

In the next phase the decision rules are determined. The relations between the probability of risk, risks impact and the risk level are perfomed by experts. The experience and expert's knowledge is used for development of IF-THEN rules. The risk level (RL) is determined by risk probability and impact. In order to determine risk level the set of rules is performed. The table 6 presents the relations between risk probability, impact and risk level. The risk level is estimate based on the proposed three-scale: low, medium, high. Some examples of these IF-THEN rules are presented below:

IF risk impact is VH **AND** risk probability is L **THEN** risk level is H

IF risk impact is M **AND** risk probability is L
THEN risk level is M

IF risk impact is VL **AND** risk probability is L
THEN risk level is L

Tab. 5. The lingustics impact scale

Desription of impact	Fuzzy numbers	Interpretation
Very Low (VL)	(0, 0, 0.1, 0.3)	Very small impact
Low (L)	(0.1, 0.3, 0.5)	Small impact
Medium (M)	(0.3, 0.5, 0.7)	Moderate impact
High (H)	(0.5, 0.7, 0.9)	Highly impact
Very High (VH)	(0.7, 0.9, 1, 1)	Very highly impact

Tab. 6. The set of rules to determine risk level

Risk impact	VH	H	H	H
	H	M	H	H
	M	M	M	H
	L	L	M	M
	VL	L	L	M
Risk	level	L	M	H
		Risk probability		

In the final phase the evaluation of a fuzzy rule is based on computing the truth value of its antecedent and applying it to its consequent. This results in assigning one fuzzy subset to each output variable true. In Min Inteferencing where parts of fuzzy rules are labelled with AND logical operation then the fuzzy AND is obtained as the minimum of the membership values of the input variables' membership values. The total risk level is determined by performing a fuzzy union of the resultant magnitude fuzzy sets.

The last phase of the approach is defuzzification. The output variables are defuzzified to get a crisp value. The defuzzification employs the centre of gravity method [7]:

$$y^* = \frac{\sum_{i=1}^{m} y_i \cdot \mu_i}{\sum_{i=1}^{m} \mu_i}$$

where:

y_i – i-th value of output variable,

μ_i – value of obtained membership function for i-th value of output variable,

m – a number of discrete values of output variable.

4. PROPOSED FUZZY INFERENCE SYSTEM

In the section the proposed approach to project risk assessment will be illustrated via a case study. Let us assume an example of a project P1. The Work Breakdown Structure of the project is presented in Figure 5.

The risks, risks factors are identified by experts based on the subjective judgement, knowledge and experience. According to the WBS the hierarchical structure of risk is presented in Figure 6.

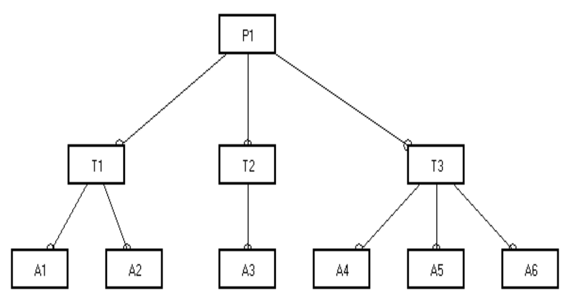

Figure 5. The Work Breakdown Structure of the Project

The proposed approach to project risk assessment is based on Fuzzy Inference System (FIS). The Fuzzy Inference System can be easily implemented using the Matlab software. In order to assessment the risk level of the given project Matlab software will be used. The idea of Fuzzy Inference System is presented in Figure 7.

The input and output variables are identified by experts. The experts described ten risk sources (R1, R2, ..., R10) and nineteen risk factors (RF1, RF2, ..., RF19). The output are risk levels, i.e. risk level of the risk source, risk level of each activity and project risk level.

All input and output variables are of the risk fuzzified. The fuzzification of the input variable, for example project risks factors, i.e. RF1, is presented in Figure 8. In the figure 8 two input variables, i.e. probability and impact of the risk factor RF1 are fuzzified. The output variable, i.e. risk level is fuzzified. The example of variable RL of activity A1 is presented in Figure 9.

The risk level is evaluated using a set of fuzzy rules IF-THEN. The type of fuzzy rules are implemented in Matlab sotfware. An example part of knowledge base based on heuristic knowledge and experience of the project experts is presented in Figure 10. The fuzzy rules taken from Tab. 6 and adopted for risk level evaluated of risk R4. In this example the three risk factors are identified, i.e. RF6, RF7, RF8 (see Figure 6). The risk factors influence on risk R4. The risk level of R4 is determined by performing a fuzzy union of the resultant magnitude fuzzy sets.

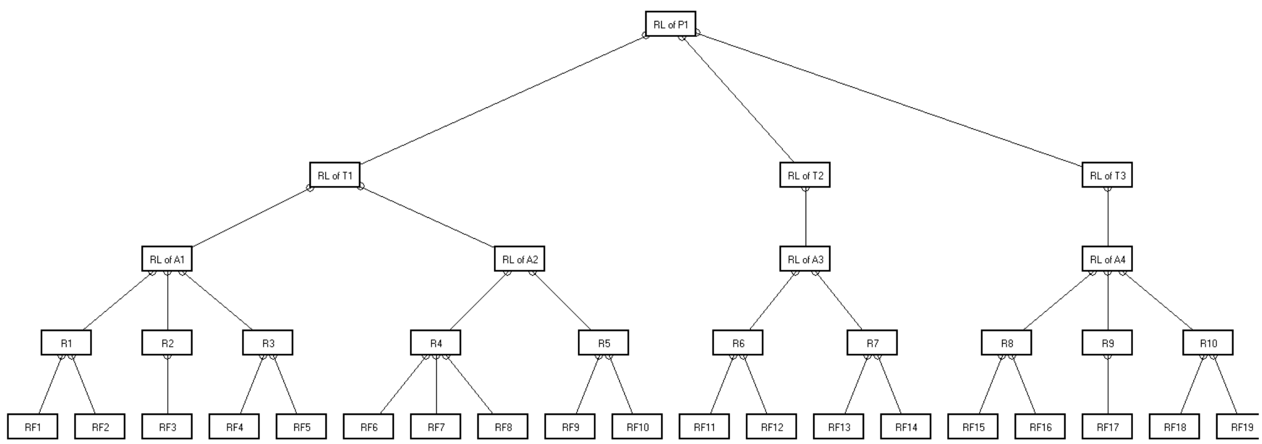

Figure 6. The hierarchical structure of risk assessment

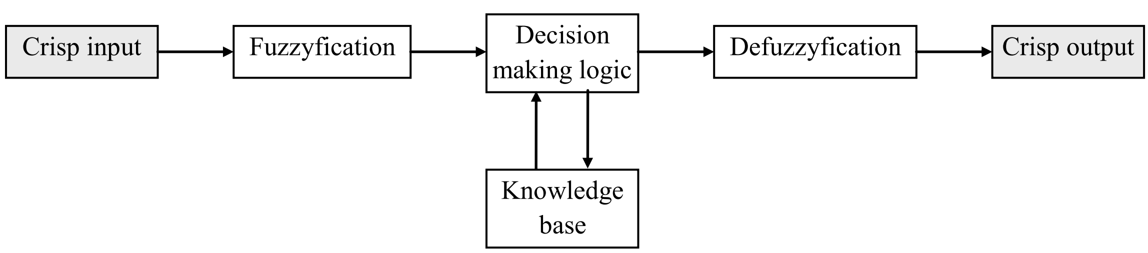

Figure 7. The structure of Fuzzy Inference System

In the same way the risk level is evaluated for other risk sources in the considered project. In the next stage the total risk level of activities (RL of A1, RL of A2, RL of A3, RL of A4) is evaluated. For example the risk level of R4 and R5 determines the total risk level of activity A2. The risk level of R4 of the stage is a input in risk level estimation of risk of activity A2. The output of the stage is the input in the risk level of task assessment. The total risk level of the project is determined by performing a fuzzy union of the resultant magnitude fuzzy sets.

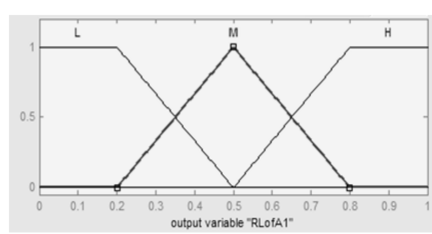

Figure 8. Membership functions of probability and impact of risk factor RF1

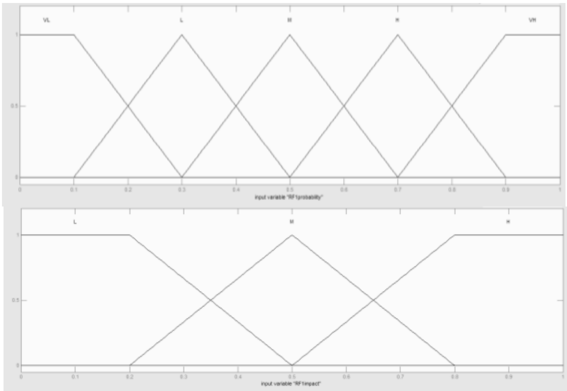

Figure 9. Membership function of risk level of activity A1

The input variables are related to the appropriate fuzzy numbers. The decisions rules are applied. The output variables are defuzzified using centre of gravity method. The process of risk assessment is complete. It means that inferencing and defuzzification are built in appropriate function in Matlab software.

Table 7 presents the input and output variables in risk assessment of the considered risk sources of the project.

Table 8 presents the evaluated risk level of identified risk sources of a given activities. The last column in the table presents the ranking of the ativities. Activity A4 is the most risky. The least risky is activity A2.

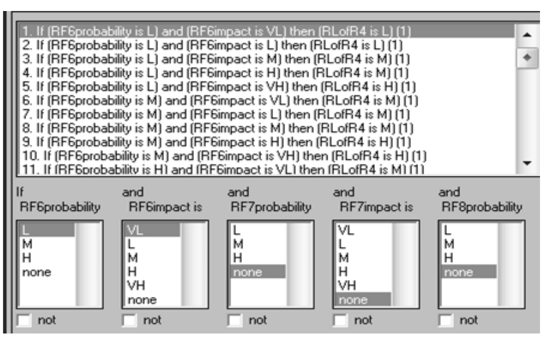

Figure 10. The part of knowledge base

Tab. 7. Input and output variables of project risk assessment of risk factors

Symbol of risk	Input variable		Ouput variable	Risk Level
	Probability	Impact		
RF1	0,3	0,5	RL of R1	0,5
RF2	0,2	0,6		
RF3	0,4	0,2	RL of R2	0,397
RF4	0,5	0,8	RL of R3	0,619
RF5	0,5	0,5		
RF6	0,6	0,5	RL of R4	0,591
RF7	0,1	0,4		
RF8	0,3	0,5		
RF9	0,2	0,3	RL of R5	0,421
RF10	0,4	0,6		
RF11	0,7	0,2	RL of R6	0,665
RF12	0,6	0,7		
RF13	0,1	0,8	RL of R7	0,625
RF14	0,3	0,5		
RF15	0,3	0,4	RL of R8	0,533
RF16	0,4	0,7		
RF17	0,8	0,5	RL of R9	0,817
RF18	0,5	0,6	RL of R10	0,788
RF19	0,6	0,8		

Tab. 8. Input and output variables of project risk assessment of risk sources

Symbol	Input	Risk level	Output	Rank
RL of R1	0,5	RL of A1	0,446	3
RL of R2	0,397			
RL of R3	0,619			
RL of R4	0,591	RL of A2	0,350	4
RL of R5	0,421			
RL of R6	0,665	RL of A3	0,492	2
RL of R7	0,625			
RL of R8	0,533	RL of A4	0,514	1
RL of R9	0,817			
RL of R10	0,788			

In Tab. 9 the risk assessment of tasks is presented. The most risky is task T3, the task T1 is the least risky.

The total risk level of the considered project is evaluated. The crisp value of the risk level is equal to 0,546 (Table 10) . Figure 11 presents the output variable. It means that the given project is not very risky, it can be realized in the enterprise.

Tab. 9. Input and output variables of project risk assessment of activities

Symbol	Input	Risk level	Output	Rank
RL of A1	0,446	RL of T1	0,316	3
RL of A2	0,350			
RL of A3	0,492	RL of T2	0,429	2
RL of A4	0,514	RL of T3	0,514	1

Tab. 10. Input and output variables of project risk assessment of tasks

Symbol	Input	Risk level	Output
RL of T1	0,316	RL of P1	0,546
RL of T2	0,429		
RL of T3	0,514		

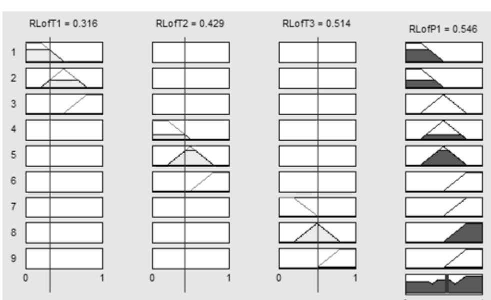

Figure 11. The level risk of project evaluated

5. SUMMARY

Present-day enterprises are transformed from traditional, mass production to execution of a sigle, customised order. These orders can be treated as projects. A project is defined as a set of activities realized in an itegrated and unique way to achieve the project goals using limited resources, and requiring innovativeness and interdisciplanarity of the persons executing given project.

Projects are full of uncertainty. During project execution unexpected events can happen cause of changing scope of the project, economical turbulence, supplier problems with material delivery, resource utilization, personel mobility.

The main aims of risk management is to identify and assess risk in the given project. Fuzzy set theory provides a good mathematical methodology to describe and handle the problem of unprecise project risk assessment. Using fuzzy logic, fuzzy sets may be defined on vague, linguistic terms such as very high probability, low impact, medium level of risk. Fuzzy logic copies the human decision making using levels of possibility in the number of uncertain categories.

In this paper an approach to risk assessment was presented using fuzzy numbers. The proposed approach was ilustrated on an example of project. The risk assesstment process can be useful for project managers as an idificator for the level of project risk. The development of Fuzzy Inference System was implemented in the Matlab software. The proposed tool can help in work of project managers to assess project risk and make the best decision in the project planning process.

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