Fuzzy Ordering of the Factors Affecting the Implementation of Construction Projects in Poland

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Abstract. *In this paper authors present the set of data on the factors affecting the implementation of construction projects in Poland. To develop that data, surveys were conducted among companies and engineers working in construction industry. The result of the paper is classification of the factors affecting the implementation of construction projects, due to the degree of significance. Elements of the fuzzy sets theory were applied, to order those factors, and to develop their formal description. Authors also describe possibility of using ordered factors, to determine the potential risk of variability of the implementation factors. This could be the basis for the design of construction projects in Polish conditions*

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INTRODUCTION

The complexity of construction projects increases the probability of encountering the risks in their implementation. There are many factors affecting the parameters of construction projects realization. These factors may lead to emergence of project failure risk. That is why they should be identified and sorted, both in accordance with the degree of their relevance, and the level (magnitude) of the given factor. This is very important in order to determine their effect on the construction project parameters.

This paper aims to identify and sort, with respect to degree of significance, the factors that may affect the construction projects in Poland. In this regard, the survey was created. It contains a number of factors affecting the various implementation parameters of construction projects. The survey was distributed to various construction companies operating in Poland. In this paper we present only factors affecting the cost and time of a construction project. The degree of significance (importance) of these factors has been ordered and described with the use of linguistic variables and elements of the fuzzy sets theory.

ANALYSIS OF THE SURVEY RESULTS AND ORDERING THE DEGREE OF FACTORS SIGNIFICANCE

The survey was conducted among construction clients, developers, general contractors, subcontractors and suppliers of building materials. Data were collected from 131 questionnaires. Then data were analyzed and the degree of importance was determined for each factor.

In this paper, authors present only the part of survey results concerning influence of chosen factors on the time and cost of construction project implementation. Following factors were selected in terms of the cost of construction project implementation: *client deadline requirements, changes of material and structural solutions in project documentation, changes in functional requirements, introduced by the investor, incorrect estimation of the scope of works, litigation between the participants of the project, increase in the prices of construction materials, necessary for completion of works, incomplete project documentation, absence of the required decisions or permits, incorrect estimation of project timeline, too high expectations for the quality of execution of the works.*

Following factors were selected in terms of the time of construction project implementation: *changes of material and structural solutions in project documentation, excessive complexity of the procedures for obtaining administrative decisions, changes in functional requirements, introduced by the investor/client, incomplete project documentation, absence of the required decisions or permits, incorrect estimation of the scope of works, excessive length of procedures for obtaining administrative decisions, too high expectations for the quality of execution of the works,*

In the survey, respondents were assessing *the degree of significance* of factors, taking into account *their impact on the implementation parameters of construction project*. In this regard, each respondent was asked to assess each factor with one of fallowing verbal marks: *very low (VL) , low (L), medium (M), high (H), very high(VH).*

After collecting and processing 131 questionnaires, the degree of significance for each factor was determined. The results are shown in the table 1.

TABLE 1. The degree of significance of factors affecting the time and cost of construction project implementation

Factors	**Degree of significance**
1. Factors affecting the cost of construction project implementation	
Client deadline requirements,	high
Changes of material and structural solutions in project documentation	medium
Changes in functional requirements, introduced by the investor	medium
Incorrect estimation of the scope of works	medium
Litigation between the participants of the project	medium
Increase in the prices of construction materials, necessary for completion of works	low
Incomplete project documentation, absence of the required decisions or permits	medium
Incorrect estimation of project timeline	medium
Too high expectations for the quality of execution of the works	low
2. Factors affecting the time of construction project implementation	
Changes of material and structural solutions in project documentation	high
Excessive complexity of the procedures for obtaining administrative decisions	medium
Changes in functional requirements, introduced by the investor/client	medium
Incomplete project documentation, absence of the required decisions or permits	high
Incorrect estimation of the scope of works	medium
Excessive length of procedures for obtaining administrative decisions	high
Too high expectations for the quality of execution of the works	low

THE DEGREE OF SIGNIFICANCE OF FACTORS PRESENTATION IN THE FUZZY SETS NOTATION

To describe and formalize the degree of significance (relative importance) of factors, elements of the fuzzy sets theory were used. Below, authors present basic concepts of fuzzy set theory that are useful in solving the undertaken issues.

The fuzzy set theory was described in the work of Lotfi A. Zadeha [6]. Unlike in classical set theory, in fuzzy set theory it is possible for elements belonging set A_i to have degrees of membership. That degree is called grade of membership, and is described by membership function $\mu_{A_i} : X \rightarrow [0,1]$. If $\mu_{A_i}(x) = 1$, element x is fully included in set A_i, and if $\mu_{A_i}(x) = 0$, element x is not included in the set. However, there is a considerable number of elements which satisfy the A_i condition only to some extent. For example, we can say, that if $\mu_{A_i}(x) > \frac{1}{2}$,element satisfies A_i condition, and if. $\mu_{A_i}(x) < \frac{1}{2}$, element most probably does not satisfy the condition. We will be using this concepts while describing and presenting *the degree of significance* of factors affecting considered construction project parameters.

A fuzzy number is a convex, normalized fuzzy set $A_i \subseteq R$, R ($X = R$), whose membership function is at least segmentally continuous and has the functional value $\mu_{A_i}(x) = 1$, at precisely one element. Let A $\{(x, \mu_A) : x \in X\}$ and B $\{(x, \mu_B) : x \in X\}$ be fuzzy numbers. Basic arithmetic operations on these numbers as addition (+), subtraction (-), multiplication ($\cdot$) and division (/) are as follows:

$$\mu_{A*B}(z) = \sup_{z=x*y} [\min(\mu_A(x), \mu_B(y))], \forall x, y, z \in R \tag{1}$$

where symbol „*” shall mean respectively „+”, „– „, „ • ” and „/” if y≠0.

One of the important elements of the fuzzy set theory is so called linguistic variable. Linguistic variable adopts natural language expressions as its value. Despite complex mathematical formalism, intuitive sense of linguistic variables is simple. In our case, for example, linguistic variable called "factor degree of significance " can adopt as its value fuzzy sets that represent the features: high, medium, low, etc. In many cases we can encounter the issue of transforming a fuzzy value into precisely defined real number. This procedure is called defuzzification. One of these methods is the center of gravity method, which assigns a real number to membership function. The real number determines coordinate of the center of gravity of the area under the graph of a function:

$$y_c = \frac{\int y\mu(y)dy}{\int \mu(y)dy}. \tag{2}$$

where: y_c – is a real number.

Many articles were devoted to methods and models of linguistic variables membership functions construction, among others [1],[2],[3],[5]. This includes measurement scales. Without going into too much detail, in our case during construction of the membership function, answer should be given to the question: "*To what extent does the X factor belong to fuzzy set A?*", or statement should be made: "*Factor X is more A than factor Y.*". This will allow us to construct the membership function of fuzzy set. Basing on *ranking* of factor degrees of significance obtained during survey, and *fuzzy set definition*, we are able to determine the membership functions of individual factors on a scale [0,10]. Figure 1 shows membership functions of individual fuzzy sets.

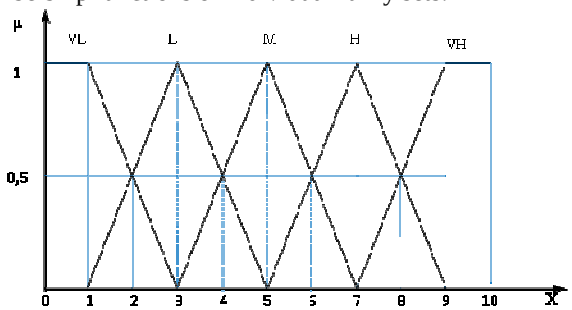

FIGURE 1. Membership function of ordered factors - scale [0,10]

Analytical notation of membership function μ_{VL}, is shown in formula (3):

$$\mu_{VL} = \begin{cases} 1 & for \quad x \le 1 \\ \frac{3-x}{3-1} & for \quad 1 \le x \le 3 \\ 0 & for \quad x \ge 3 \end{cases} \tag{3}$$

Analytical notation of membership function μ_L, is shown in formula (4):

$$\mu_L = \begin{cases} 0 & for \quad x \le 1 \\ \dfrac{x-1}{3-1} & for \quad 1 \le x \le 3 \\ \dfrac{5-x}{5-3} & for \quad 3 \le x \le 5 \\ 0 & for \quad x \ge 5 \end{cases} \tag{4}$$

With regard to the values shown in Figure 1, μ_M and μ_H are described in a similar way. Analytical notation of membership function μ_{VH}, is shown in formula (5):

$$\mu_{VH} = \begin{cases} 0 & for \quad x \le 7 \\ \dfrac{x-7}{9-7} & for \quad 7 \le x \le 9 \\ 1 & for \quad x \ge 9 \end{cases} \tag{5}$$

DESCRIPTION OF THE SURVEY RESULTS APPLICABILITY

One of possible applications of Ordered factors affecting the implementation of construction projects is to determine the size of the construction project execution parameters with respect to those factors. This is especially useful when determining the *variation risk* of these parameters, for example, the risk of exceeding the contracted costs, risks of exceeding deadlines, etc. For general purposes, let us define it as the *variability risk of construction project implementation parameters*.

The starting point for the estimation of the variability risk of construction project implementation parameters is to select (from table 1) potential factors (best matches) affecting the implementation of analyzed project. Then manager (decision maker) adopts (or chooses on his/her own) degree of significance from table 1 and determines linguistic variables describing the relevant state (level) of factor for the analyzed project. The values of those variables may (but not necessarily) have similar membership functions as membership functions of factor degree of significance. The next step is to multiply fuzzy numbers of appropriate membership functions of *degree of significance* by *factor states*. As a result we obtain the overall *variability risk of construction project implementation parameters* connected with particular factor. In order to estimate level of each type of risk, we determine real number for each factor with the use of defuzzification procedure shown in formula (2). At this stage, manager is able to clearly determine which factor is associated with the highest (the lowest) risk level and take (do not take) it into account during project planning. Then it is able to determine the arithmetic means of the centers of gravity for all the factors taken into account in the analyzed implementation parameter of the project, and the corresponding level of risk. This will show individual risk rates in general *variability risk of construction project implementation parameters.*

CONCLUSIONS

Survey results show the importance of the various factors affecting the implementation of construction projects in Poland. It is surprising that the majority of respondents believe that the degree of significance of factor "*increase in the prices of construction materials, necessary for completion of works* " is low taking into account the impact on the cost of the project. This could mean that the building materials market is stable or, that for considered duration of the construction project the probability of changes in price is low.

Application of fuzzy set theory during ordering, describing and modeling various factors can help scheduler/manager in the task of determining the levels of influence of each factor on the planned construction tasks.

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