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MODEL AND METHOD FOR SYNTHESIS OF PROJECT MANAGEMENT METHODOLOGY WITH FUZZY INPUT DATA

Literature analysis concerning the selection or creation a project management methodology is performed. Creating a "complete" methodology is proposed which can be applied for managing projects with any complexity, various degrees of responsibility for results and different predictability of the requirements. For the formation of a "complete" methodology, it is proposed to take the PMBOK standard as the basis, which would be supplemented by processes of the most demanding plan driven and flexible Agile Methodologies. For each knowledge area of the PMBOK standard, the following groups of processes should be provided: initiation, planning, execution, reporting and forecasting, controlling, analysis, decision making and closing. The method for generating a methodology for the specific project is presented. The multiple criteria mathematical model and method are developed for synthesis of methodology when initial data about the project and its environment are fuzzy.

Keywords: project management methodology, Fuzzy multiple criteria decision making, synthesis method.

Introduction. The list of existing methodologies is sufficiently representative and includes both heavy plan-driven and flexible Agile Methodologies. Selection of methodology for managing a particular project has a significant influence on many project parameters, its product and the success of project in general. The problem of selecting the management methodology for single project or projects of a company, as well as the formation of a special methodology, is discussed extensively in the literature.

Literature analysis and statement of research problem. In research carried out by M.E. Ilas et al. [1] are compared main characteristics of project management guidelines such as PMBOK, CMMI and Agile from the viewpoint of suitability for projects in the microelectronics field. In accordance with the results of this comparison, it was concluded that choosing the best methodology depends on the size of project and degree of its changes. For projects with insignificant changes approach PMI appeared the best. Depending on the project size it can be used a full PMI (with all knowledge areas) for medium and large projects, or a reduced PMI set for small projects. For small projects with many changes, Agile methods can be applied. For medium and large projects with many changes, a combination of Agile and PMI methods is best suited.

M. Spundak [2] suggested the idea of creating a special methodology for project based on different approaches. One of the major problems in this regard appears to be finding the optimum composition of elements in appropriate methodology. The decision about choosing the elements which should become part of the methodology must be based on the characteristics of specific project and organization, as well as project manager’s experience and expert knowledge. The author compared the heavy and flexible methodologies with indicators such as clarity of the requirements for project and product, participation of users in project, documentation requirements, project size, organizational support, project team specifications, criticality of the product, project plan specifications. The given comparison is proposed for using methodology selection.

The author concludes that possibly the best methodology could be a combination of elements, based on flexible and traditional approach because neither fully flexible nor fully traditional project management methodology doesn't fit completely.

O.N. Ilyina [3] suggested the definition of project management methodology structure and formation mechanism for a corporate project management methodology. At the first stage of this mechanism estimating the maturity level of corporate project management system (CPMS) is suggested. Then requirements of the company for the given system are determined. In the third stage, composition and structure of elements of CPMS are determined. In the fourth stage, selecting elements from the methodological knowledge base of project management and their comparative analysis are done. The fifth stage involves the formation of a content of elements of methodology. At the sixth stage, the elements are combined in order to make an individual methodology. At the end, approbation of the result and repeated assessment of CPMS maturity are carried out.

Since each methodology has its own strengths and weaknesses, J. Charvat [4] believes that perspective is the application of two or more methodologies for developing the methodology, which is more appropriate for project and environment. One of the ways to the successful implementation of projects is selection, customization and implementation of a unified methodology for various teams in the organization. In selection and customization of a methodology, it's necessary to consider requirements such as budget, team size, used technologies, tools and techniques, project criticality, training, documentation, best practices, lessons learned and examination of existing processes [4].

Based on research conducted by A. Cheema et al. [5], tools have been proposed to facilitate customization of existing project management methodologies. On the basis of the literature review in this work, project parameters that must be considered in selecting methodology or processes are proposed. These include: nature of the project (criticality and complexity of project), project size, team size, number of stakeholders, location of stakeholders, experience of project manager, requirements of flexibility, understanding of the customer, customer's

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availability, budget, time, risk, iterative development process, team skill level and team type.

Based on the values of the parameters selection a specific set of processes which best satisfy the needs of the project is proposed.

The article offers a comprehensive methodology which includes the processes selected from PMBOK, PRINCE2, Tenstep, SCRUM, i.e. processes are taken from both the traditional and flexible methodologies to get the benefits of both approaches. Recommendations are given to select the processes considering these parameters. In the article, the requirement of creating an expert system for assisting the project managers in the accurate customization of methodology has been emphasized.

In research by I.V. Kononenko and A.V. Kharazii [6], three methods for selecting a project management methodology are suggested. If the project team is not enough familiar with existing methodologies, it is recommended to fill out a questionnaire. By results of processing the responses recommendations on the application of methodology are given. More valid choice can be made by evaluating for alternative methodologies the laboriousness, management costs, and the risks associated with the application of the specific methodology. The more in-depth study suggests optimization of project scope subjected to the application of the particular methodology. Optimization is carried out by criteria: profit, time, cost, quality and risks. The most effective methodology is selected from alternatives considering all criteria.

I.V. Kononenko & A. Aghaee [7] proposed a method for methodology synthesis based on creating an "ideal" methodology, which includes processes of many well-known approaches. It is further proposed to implement optimization of project scope by criteria: profit, time, cost, quality and risk for the cases of using separate combinations of processes from the "ideal" methodology. According to these criteria, the most rational combination of processes is selected.

Literature analysis showed that there are approaches to selection of methodology for a specific project on the basis of information about the project and its environment. Indicators, which can be used for such choice, are suggested. The methods of selection methodology in various degree of awareness of project team are offered. The authors conclude that perhaps the best would be a combination of different methodologies, heavy and flexible. A variant of "comprehensive" methodology that collected from processes of the four famous methodologies is proposed. Recommendations for choosing processes from "comprehensive" methodologies for the formation of methodology for a specific project are given. The method of methodology synthesis based on optimization of project scope is offered. Developing a mathematical model and method of methodology synthesis for a situation when information about the project and its environment is fuzzy appears actual. As the basis for synthesis, the "complete" methodology may be used, including the most demanding processes from the famous methodologies.

Objectives. The aim is developing a model and method for synthesis of management methodology for a specific project with fuzzy initial data on the project and its environment.

Model and method for synthesis of project management methodology. For the formation of a methodology intended for managing a specific project, it is advisable to create the image of a "complete" methodology. Such methodology is purposed to manage a project with any complexity, various degrees of responsibility for its result and predictability of requirements. For the formation of a "complete" methodology, it is proposed to take the PMBoK standard as the basis, which should be supplemented by processes of the most demanding plan driven and flexible Agile Methodologies.

For each knowledge area of the PMBoK standard, the following groups of processes should be provided: initiation, planning, execution, reporting and forecasting, controlling, analysis, decision making and closing.

The process of methodology synthesis for managing a specific project will be reduced to solving a discrete optimization problem of a set of processes. The following method of formation methodology for a specific project is offered.

1. An expert or group of experts selects at knowledge areas of "complete" methodology the suitable combinations of processes. As a rule, they have the opportunity to propose several variants, the most corresponding ones for the project according to experts opinions.
2. The problem of selecting the best combination of processes from "complete" methodology for a specific project will be solved. As criteria for optimization are applied: laboriousness of performing operations of management, cost of performing operations of management and risks associated to them.
3. The best combination of processes is analyzed by experts, if necessary, their correction is carried out. For selected processes, tools and methods are appointed for their implementation, setting inputs, outputs and connection between processes.
4. The selected processes, tools and methods of their execution apply for project implementation.
5. As the project is implemented, periodic adjustment of processes, the connections between them, tools and techniques are conducted.

Thus, synthesis of project management methodology can be implemented according to the criteria of the laboriousness of management, management cost and risks associated with the use of synthesized methodologies for project management. We assume that from "complete" methodology experts selected H combinations of processes. Management laboriousness components, namely laboriousness of the j th execution process, related to one of the considered methodologies in the h th combinations of processes T_{jh}, $j=\overline{1,J^h}, h=\overline{1,H}$ in general case are fuzzy and only in rare cases can be attributed to the crisp numbers. The same can be said about the cost of the j th execution process, related to one of the considered methodologies in the h th combinations of processes C_{jh}, $j=\overline{1,J^h}, h=\overline{1,H}$. When considering the risks associated with the use of synthesized methodologies for project management, one assesses the negative consequences of risk events and the probability of their occurrence. Both values in the general case, are fuzzy. It is necessary to determine the method of representing fuzzy and crisp values, which is encountered in the synthesis problem of project management methodology, as well as the rules of performing addition, subtraction, multiplication, and division operations.

A fuzzy value is an arbitrary fuzzy set $C=\{x,\mu_C(x)\}$, which belongs to the set of real numbers R, where $\mu_C(x)$ is the membership function of fuzzy values, which is a mapping of $\mu_C(x):\rightarrow[0,1]$ [8].

A fuzzy number is a fuzzy value, which has a convex and unimodal membership function [9].

In the given work we confine ourselves to the consideration of unimodal fuzzy numbers $(L-R)$ - type – this is a fuzzy value $C=\{x,\mu_C(x)\}$, which has the membership function of the form [9]:

$$\mu_C(x)=\begin{cases} L\left(\dfrac{a-x}{\alpha}\right), \text{ if } x\le a; \\ R\left(\dfrac{x-a}{\beta}\right), \text{ if } x\ge a, \end{cases}$$

where $\alpha>0,\beta>0$. The parameter a is called modal value of the fuzzy number. The parameters a and β, are called left and right fuzziness coefficients respectively. In general, the function $L\left(\dfrac{a-x}{\alpha}\right)$ and $R\left(\dfrac{x-a}{\beta}\right)$ can be different.

Arbitrary fuzzy numbers $(L-R)$ - type are represented as $D_{\text{LR}}=\langle a,\alpha,\beta\rangle$. In practice, the most widely used fuzzy numbers $(L-R)$ – type have special form, so-called triangular fuzzy numbers and whose membership function is given by [9]:

$$f_\Delta(x,a,b,c)=\begin{cases} 0,\ x\le a, \\ \dfrac{x-a}{b-a},\ a\le x\le b, \\ \dfrac{c-x}{c-b},\ b\le x\le c, \\ 0,\ c\le x, \end{cases}$$

where a,b,c are numeric parameters that can take arbitrary real values when $a\le b\le c$. The parameter b determines the modal value, parameter a specifies the abscissa of the left vertex of the triangular membership function, parameter c - abscissa of the right vertex.

Parameters of triangular fuzzy number $D_\Delta=\langle a,\alpha,\beta\rangle$ can be uniquely identified using triangular membership function parameters $f_\Delta(x,a,b,c)$. Modal value of the triangular fuzzy number a is identically equal to the parameter b triangular membership functions. The left and right fuzziness coefficients are defined as:

$$\alpha=b-a,\ \ \beta=c-b.$$

During the synthesis of project management methodology we have to face both crisp and fuzzy numbers. Thus, the operations of addition, subtraction, multiplication, and division for crisp and fuzzy numbers must be performed. Rules of stated operations for the fuzzy numbers $(L-R)$ - type are well known [8], [9]. To apply these rules for operations with crisp and fuzzy numbers, we present crisp number in the form $A_{LR}=\langle a,\alpha,\beta\rangle$ when $\alpha=0$, $\beta=0$.

We apply crisp and triangular fuzzy numbers for presenting problem parameters of project management methodology synthesis.

We denote cost of the j th execution process related to one of the considered methodologies in the h th combinations of processes:

$$C_{jh}=\left\langle c_{jh},\alpha_{c_{jh}},\beta_{c_{jh}}\right\rangle,$$

where $j=\overline{1,J^h}$, $h=\overline{1,H}$, H is the amount of the combinations of processes, J^h – the number of possible processes in the h th combinations of processes.

Then the objective function of problem - cost of project management will be:

$$C(X)=\sum_{h=1}^{H}\sum_{j=1}^{J^h}\left\langle c_{jh},\alpha_{c_{jh}},\beta_{c_{jh}}\right\rangle\cdot x_h\rightarrow\min_X, \qquad (1)$$

$X=(x_1,x_2,...,x_H)$, $x_h\in\{0,1\}, h=\overline{1,H}, x_h=1,$ if the h th combination of processes is used to manage the project, otherwise $x_h=0$.

We denote laboriousness of the j th execution process relating to one of the considered methodologies in the h th combination of processes:

$$T_{jh}=\left\langle t_{jh},\alpha_{t_{jh}},\beta_{t_{jh}}\right\rangle, j=\overline{1,J^h}, h=\overline{1,H}.$$

The objective function, which determines the laboriousness of project management, will take the form:

$$T(X)=\sum_{h=1}^{H}\sum_{j=1}^{J^h}\left\langle t_{jh},\alpha_{t_{jh}},\beta_{t_{jh}}\right\rangle x_h\rightarrow\min_X, \qquad (2)$$

We denote negative consequences of the l th risk event, associated with the use of the j th process, related to one of the considered methodologies in the h th combination of processes:

$$V_{ljh}=\left\langle v_{ljh},\alpha_{v_{ljh}},\beta_{v_{ljh}}\right\rangle.$$

We assume that the negative consequences of the l th risk event are evaluated by the ten-point scoring system. Thus, it is proposed to use the rating system presented in Table 1.

Table 1 – Evaluation of risk events consequences

Negative consequences	scores
Catastrophic consequences, leading to death of people	10
Catastrophic consequences, leading to very large material losses and / or personal injury	9
Serious material damage for the company	7-8
Tangible material losses for the company	5-6
Material losses which do not lead to financial difficulties in the company	3-4
Insignificant material losses	2
Practically there are no material losses	1
There are no negative consequences	0

We denote probability of occurring the l th risk event, associated with the use of the j th process, related to one of the considered methodologies in the h th combination of processes as:

$$P_{ljh} = \left\langle p_{ljh}, \alpha_{p_{ljh}}, \beta_{p_{ljh}} \right\rangle.$$

In this case the objective function, which determines risks when applying the selected combinations of project management processes, has the form:

$$R(X) = \sum_{h=1}^{H}\sum_{j=1}^{J^h}\sum_{l=1}^{L} V_{ljh} P_{ljh} x_h =$$
$$\sum_{h=1}^{H}\sum_{j=1}^{J^h}\sum_{l=1}^{L}\left\langle v_{ljh} p_{ljh}, v_{ljh}\alpha_{p_{ljh}} + p_{ljh}\alpha_{v_{ljh}}, v_{ljh}\beta_{p_{ljh}} + p_{ljh}\beta_{v_{ljh}} \right\rangle \cdot x_h = \tag{3}$$
$$\sum_{h=1}^{H}\sum_{j=1}^{J^h}\left\langle \sum_{l=1}^{L} v_{ljh} p_{ljh}, \sum_{l=1}^{L}\left(v_{ljh}\alpha_{p_{ljh}} + p_{ljh}\alpha_{v_{ljh}}\right), \sum_{l=1}^{L} v_{ljh}\beta_{p_{ljh}} + p_{ljh}\beta_{v_{ljh}} \right\rangle \cdot x_h \to \min_x .$$

In the given problem, it is necessary to take into account constraints on the execution costs of project management operations. Constraints will take the form:

$$C(X) = \sum_{h=1}^{H}\sum_{j=1}^{J^h}\left\langle c_{jh}, \alpha_{c_{jh}}, \beta_{c_{jh}} \right\rangle \cdot x_h \le C^{\text{per}}, \tag{4}$$

where C^{per} is the maximum permissible value of all operations cost on project management.

The problem (1) – (4) refers to multi-criteria problems with fuzzy objectives and fuzzy constraint. To solve this problem, the method of MiniMax can be applied in combination with Exhaustive search solutions. Exhaustive search is possible in this problem because it is not necessary to consider all options as alternatives - most of them can be rejected by an expert as is not applicable to the particular project and its environment. Knowledge and experience allow the decision maker, to conclude the inapplicability or inexpediency of using any combination of processes when managing a specific project. And vice versa, based on his intuition, the expert can select comparatively small number of alternative combinations of processes for the further more in-depth study.

The solution of problem (1) – (4) has the following form:

$$X^{\text{opt}} = \arg\min_X \max\left\{C^{\text{norm}}(X), T^{\text{norm}}(X), R^{\text{norm}}(X)\right\}, \tag{5}$$

$$C(X) = \sum_{h=1}^{H}\sum_{j=1}^{J^h}\left\langle c_{jh}, \alpha_{c_{jh}}, \beta_{c_{jh}} \right\rangle \cdot x_h \le C^{\text{per}}, \tag{6}$$

$$\sum_{h=1}^{H} x_h = 1, \tag{7}$$

$$x_h \in \{0,1\}, h = \overline{1,H}, \tag{8}$$

where $X = (x_1, x_2, ..., x_H)$, $x_h = 1$ if the h th combination of processes is used to manage the project, $x_h = 0$ otherwise.

$$X^{\text{opt}} = \left(x_1^{\text{opt}}, x_2^{\text{opt}}, ..., x_H^{\text{opt}}\right), \tag{9}$$

$$C^{\text{norm}}(X) = \frac{C(X) - C^{\text{opt}}}{C^{\text{opt}}}, \tag{10}$$

$$T^{\text{norm}}(X) = \frac{T(X) - T^{\text{opt}}}{T^{\text{opt}}}, \tag{11}$$

$$R^{\text{norm}}(X) = \frac{R(X) - R^{\text{opt}}}{R^{\text{opt}}}, \tag{12}$$

where $C^{\text{opt}}, T^{\text{opt}}, R^{\text{opt}}$ – minimum values of cost, laboriousness of project management and risks associated with the use of synthesized methodology, respectively. Normalization of values of the objective function in accordance with formulas (10) – (12) satisfies the requirement of monotony [10].

The minimum values of $C^{\text{opt}}, T^{\text{opt}}, R^{\text{opt}}$ are obtained as a result of a one-criterion combinatorial optimization problem without taking into account constraints (4).

For searching of the minimum values of fuzzy objective functions (1) - (3) it is necessary to solve the problem of comparison of fuzzy numbers.

The concept of equality of fuzzy numbers follows from the definition of equality of fuzzy sets. Two fuzzy sets $A = \{x, \mu_A(x)\}$ and $B = \{x, \mu_B(x)\}$ are equal, if their membership functions are taking equal values throughout the universe of X, i.e.: $\mu_A(x) = \mu_B(x) \forall x \in X$ [1].

Fuzzy number A is greater than fuzzy number B, if any value of support of fuzzy number A is greater than any value of the support of fuzzy number B [11], i.e.:

$$A > B \Leftrightarrow \{x_1 > x_2 \mid \forall x_1 \in A_S, \forall x_2 \in B_S\},$$

$$A_S = \{x_1 \in X \mid \mu_A(x_1) > 0\} \forall x_1 \in X,$$

$$B_S = \{x_2 \in X \mid \mu_B(x_2) > 0\} \forall x_2 \in X.$$

In general, the relation order on the set of fuzzy numbers is fuzzy [12], except for a situation when the intersection of supports is empty. In the latter case, the relationship between the numbers is crisp.

There are number of methods for solving the problem of comparing fuzzy numbers [13]. They are based on a calculation of the so-called the ranking index - some real function of the compared fuzzy numbers. For comparing fuzzy numbers, it is possible to use the defuzzification procedure [9], which assumes the calculation of some crisp values for fuzzy numbers. Among existing methods of defuzzification, it should be noted the computation of center of mass or centroid of area, which is bounded by graph of membership function for the fuzzy numbers and the x-axis.

For the triangular fuzzy number $D_{\Delta} = \langle a, \alpha, \beta \rangle$, which has the membership function $f_{\Delta}(x, a, b, c)$ the coordinate of center of masses will be equal:

$$d = \frac{a+b+c}{3},$$

i.e., a defuzzification value $D_{\Delta} = \langle a, \alpha, \beta \rangle$ is equal d .

Conclusions. The literature review concerning the selection or formation of project management methodology is performed. It is shown, that the problem of creating a model and method of synthesis methodology for a specific project with fuzzy input data is actual. A mathematical model and method for solving the aforementioned problem are offered.

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