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I. V. KONONENKO, S. YU. LUTSENKO

METHOD FOR SELECTION OF PROJECT MANAGEMENT APPROACH BASED ON FUZZY CONCEPTS

Пропонуються математична модель та метод вибору підходу до управління проектом з урахуванням нечіткості уявлень щодо застосовності існуючих підходів. Вибір здійснюється з таких підходів як: PMBOK, ISO21500, PRINCE2, SWEBOK, Scrum, XP, Канбан. Виділено ряд параметрів проекту, що впливають на результат вибору, та визначено степінь їх впливу. Розглянуто приклад застосування запропонованого методу для вибору підходу до управління проектом з розробки програмного забезпечення.

Ключові слова: підхід до управління проектом, вибір, нечіткі уявлення, модель, метод, приклад.

Предлагаются математическая модель и метод выбора подхода к управлению проектом с учетом нечеткости представлений о применимости существующих подходов. Выбор осуществляется из таких подходов как: PMBOK, ISO21500, PRINCE2, SWEBOK, Scrum, XP, Канбан. Выделен ряд параметров проекта, влияющих на результат выбора, и определена степень их влияния. Рассмотрен пример применения предложенного метода для выбора подхода к управлению проектом по разработке программного обеспечения.

Ключевые слова: подход к управлению проектом, выбор, нечеткие представления, модель, метод, пример.

Literature analysis of works that devoted to research of the selection a project management approach and development of effective methods for this problem solution is given. Mathematical model and method for selection of project management approach with fuzzy concepts of applicability of existing approaches are proposed. The selection is made of such approaches as the PMBOK Guide, the ISO21500 standard, the PRINCE2 methodology, the SWEBOK Guide, agile methodologies Scrum, XP, and Kanban. The number of project parameters which have a great impact on the result of the selection and measure of their impact is determined. Project parameters relate to information about the project, team, communication, critical project risks. They include the number of people involved in the project, the customer's experience with this project team, the project team's experience in this field, the project team's understanding of requirements, adapting ability, initiative, and others. The suggested method is considered on the example of its application for selection a project management approach to software development project.

Keywords: project management approach, selection, fuzzy concepts, model, method, example.

Introduction. An approach applied to the project management has a great impact on key project performance indicators: budget, scope, schedule, quality of project product and business benefits. Due to the variety of existing project management guidelines, standards, and methodologies, the task of selection a suitable approach to managing a single project or all projects of a company represents an independent problem. Numerous works of domestic and foreign experts in the field of project management are devoted to research of this problem and development of effective methods for its solution.

Literature analysis and statement of the research problem. In the resource [1] the most commonly used software development methodologies are reviewed and compared. Also, the approach for the development of a strategy for applying the methodology to different types of software projects is created. The main difficulty in software project management methodology selection the authors consider an impossibility of accurate determination of the problem volume at the beginning of the project, since an increase of its size may lead to the necessity of revise the methodology. Key factors in the methodology selection are criticality of the project, project objectives, priorities; scope of the project; used development tools and implemented systems; competence of team members; the geography of development and implementation; culture and tradition of the customer, and integrator companies and, values of the development team.

In the work [2] the main features of the heavy plan-driven and flexible Agile project management methods are highlighted. Selection of approach to a particular project is based on the identification and analysis of risks that arise in the case of applying Agile or plan-driven methods to manage the project. Depending on the risk analysis, one of these approaches or their combination is selected. The analysis takes into account such critical factors of Agile and plan-driven methodologies as: size (number of personnel), criticality (loss due to impact of defects), dynamism (percent requirements change/month), personnel (the level of qualification of the personnel), and culture (the team's ability to work effectively in conditions of freedom or regulation).

The authors of [3] compared five project management methodologies: Agile Development Methods, Microsoft Solution Framework (MSF), PRINCE2, Rational Unified Process (RUP), and the Information Technology Infrastructure Library (ITIL) with the PMBOK Guide (PMI, 2004). As a result, they identified the main criteria of methodology selection: work experience, expert opinion, government regulation, preferences of stakeholders and the client, the client's location.

In [4] methodology is selected according to the answers on questions in four key areas: speed of project completion and product delivery, the necessity of complying formal processes and procedures, the resources available for the project and, finally, the complexity of the project. The resulting output radar chart shows which of the two groups of methods plan-driven or Agile is the most appropriate.

The author of [5] proposed an approach for methodology selection in accordance with the size, sensitivity, and priority of the project. There are definitions of the methodology size (the number of control elements, including operations, standards, stages, processes, etc.), project size (number of people involved in the project), and project sensitivities classification.

In the article [6] a model and method for synthesis of management methodology for a specific project by selecting the processes of the "full" methodology are

suggested. "Full" methodology is proposed to create based on the PMBOK guide, supplementing it with the processes of most popular Agile and plan-driven methodologies. The above method for synthesis of project management methodology allows choosing the best combination of project management processes for conditions of a specific project in terms of such criteria as the cost and the laboriousness of management, as well as risks associated with the use of this combination. It is assumed that the initial data for the task is fuzzy.

In [7] areas of application and main characteristics of 30 well-known methodologies for projects creation and project management are defined. Areas of application include the branch of use and size of the project. Such characteristics of the methodology are given: the risk of problems appearance, the complexity of implementation, the intensity of use of resources, frequent changes in the project, support for changes in the scope, support for reporting, document management system, the use of information technology, the accumulation of experience, the process approach, the scenario approach, the project-based approach. This data is recommended to use for pre-selection of methodologies before introducing them into the organization.

The authors of the research [8] compared main characteristics of project management approaches such as PMBOK, CMMI and Agile from the viewpoint of suitability for projects in the microelectronics field. They concluded that it is the best to choose an approach depending on the size of the project and its possible changes in the implementation process. For projects with minor changes, the best approach is considered PMI approach that depending on the size of the project can be used in full (with all fields of knowledge), or in abridged form. For small projects that accompanied by many changes, Agile methods are recommended. For medium and large projects with a large number of changes, the combinations of Agile and PMI methods are most suitable.

In [9] three methods for selecting a project management methodology are proposed. In the case when the project team is not enough familiar with existing methodologies, it is recommended to fill out a questionnaire. According to results of processing the responses, recommendations on the application of methodology are offered. Evaluations of the laboriousness, management costs, and the risks associated with the application of the specific methodology for alternative methodologies allow making more grounded choice. The more in-depth study suggests optimization of project scope subjected to the application of the particular methodology by criteria: profit, time, cost, quality, and risks. The most effective methodology is selected from alternatives considering all given criteria.

Based on the above analysis of the literature, we can conclude that at this stage it is important to identify key factors that influence the choice of management approach for a specific project and development of a formalized method for such approach selection. This task is complicated by the fuzziness in existing recommendations regarding the applicability of different approaches in various cases.

Objectives. The aim is developing a model and method for selection of management approach for a specific project taking into account relevant project parameters and fuzziness of information about the applicability of existing approaches.

Mathematical model and method for selecting of project management approach based on fuzzy concepts. To solve the given problem the questionnaire proposed in [9] is used. In this case, it is somewhat modified and supplemented (Table 1–6). Questions of the questionnaire relate to information about the project, team, communication, critical project risks. The questionnaire should be filled out by the project manager or involved experts.

Table 1 – Number of people involved in the project

Questions	Possible answer	Score
Number of people involved in the project, X_1	More than 100 persons	1
	From 30 to 100 persons	2
	From 10 to 30 persons	3
	Less than 10 persons	4

Table 2 – Customer's experience of working with this project team

Questions	Possible answer	Score
Customer's experience of working with this project team, X_2	Has never worked with this team	1
	Worked with some members of the team	2
	Worked with the project team leader	3
	One or more common projects with the whole project team	4

Table 3 – Evaluation of the Project Team's Expertise by the Project Manager

Questions	Possible answer	Score
1	2	3
Work experi-ence in the given field, X_3	No work experience	1
	Experience of working in the field for less than 2 years	2
	Experience of working in the field from 2 to 5 years	3
	Experience of working in the field for more than 5 years	4
Under-standing of require-ments, adapting ability, initiative, X_4	Almost do not understand the requirements; require frequent explanations and constant control	1
	Understand the requirements, can follow them, but require regular control	2
	Understand the requirements, can follow them, do not require regular control	3
	Have good understanding of the requirements; can follow them without regular control; can suggest better alternatives	4
Experience of cooperation, X_5	Have never worked together	1
	Worked together on the creation of a product but in the different field	2
	Worked together on the creation of one product in a field of interest	3
	Worked together on the creation of several projects in the field of interest	4

Tne end of the Table 3

1	2	3
Knowledge of applied tools and methods, X_6	Tools and methods, applied in the given project, have never been used before and are unknown to the team	1
	Tools and methods, applied in the project, are known to the team but have never been used before	2
	Tools and methods, used in the project, are known to the team but are rarely used	3
	Tools and methods are known to the team and have been widely used before	4
Learning ability, X_7	It is hard for the team to learn new knowledge and technologies, and to adjust to changes	1
	For some members of the team, it is hard to learn new information and technologies, but the team can adjust to changes	2
	Easily absorb new knowledge, can adjust to changes	3
	The team can easily absorb information, always tries to learn something new; can well adjust to the changes	4
Team's ability to clearly formulate and openly express ideas, X_8	Can't clearly formulate ideas and rarely express them	1
	Can clearly formulate their ideas but rarely express them	2
	Can clearly formulate their ideas and openly express them	3
	Can clearly formulate, openly express and justify their ideas	4
Ability to admit mistakes, X_9	Don't admit making mistakes and can't learn from them	1
	Rarely admit their mistakes but try to never make them again	2
	Openly admit making mistakes and try to never make them again	3
	Openly admit making mistakes and always learn from them	4
Team's ability to work effectively in freedom or order, X_{10}	Able to work effectively in full order	1
	Able to work effectively in middle order	2
	Able to work effectively in partial order	3
	Able to work effectively in full freedom	4

Table 4 – Reporting

Questions	Possible answer	Score
1	2	3
Means of communication, X_{11}	Written reports. Formal record-keeping	1
	Voice communication (telephone connection, Internet-conference)	2
Means of communication, X_{11}	On-line communication (ICQ, E-mail)	3
	Direct communication (meetings, video conferences)	4
Frequency of reporting to the Customer, X_{12}	Reports on every operation	1
	Reports on completing the blocks of work	2
	Reports on the readiness of a component of project's product	3
	Reports about project finish	4

Tne end of the Table 4

1	2	3
Understand-ing the scope of works, X_{13}	There is a full list of works; further alternation is impossible	1
	There is a detailed list of works, further alternation is possible	2
	There is an approximate list of project works	3
	The team understands the project goal and several ways for its achievement	4

Table 5 – Project Manager's Responsibility and Main Requirements to the Project

Questions	Possible answer	Score
Consequences in case of unsatisfactory project outcome, X_{14}	Loss of life	1
	Loss of irreplaceable sum of money	2
	Loss of insignificant sum of money	3
	Loss of comfort in work	4
Project cost, X_{15}	More than 1 mln. $	1
	From 300 thousand – 1 mln. $	2
	From 100 –300 thousand $	3
	Less than 100 thousand $	4
Requirements to the project quality, X_{16}	Highest international requirements	1
	International requirements	2
	National requirements	3
	Local requirements	4
Requirements to the realization period of the project, X_{17}	The period is unlimited	1
	Not very urgent	2
	Urgent	3
	Very urgent	4
Requirements to the precise compliance with a deadline, X_{18}	The deadline should be strictly met	1
	Insignificant deviation from the deadline is allowed	2
	Considerable deviation from the deadline is allowed	3
	Compliance with the deadline is not strictly required	4
Requirements change percent /month, X_{19}	Less than 7%	1
	From 7 to 25%	2
	From 25 to 45%	3
	More than 45%	4

Table 6 – Risks Probability

Questions	Possible answer	Score
1	2	3
Probability of occurrence of technical, manufacturing or qualitative risks, X_{20}	Risk is not likely to occur (10%)	1
	Probability of risk occurrence is equal (50%)	2
	Risk is highly likely to occur (75%)	3
	Risk will most probably occur (≥95%)	4
Probability of occurrence of external risks (disruption of work by contractors, unfavorable political, economic situation in the country, market changes, etc.), X_{21}	Risk is not likely to occur (10%)	1
	Probability of risk occurrence is equal (50%)	2
	Risk is highly likely to occur (75%)	3
	Risk will most probably occur (≥95%)	4

Tne end of the Table 6

1	2	3
Probability of occurrence of organizational risks (disruption of funding, delivery of resources, inaccurate prioritizing, etc.) X_{22}	Risk is not likely to occur (10%)	1
	Probability of risk occurrence is equal (50%)	2
	Risk is highly likely to occur (75%)	3
	Risk will most probably occur (≥95%)	4
Probability of occurrence of managerial risks (inefficient planning, controlling, communication problems, etc.), X_{23}	Risk is not likely to occur (10%)	1
	Probability of risk occurrence is equal (50%)	2
	Risk is highly likely to occur (75%)	3
	Risk will most probably occur (≥95%)	4

Each question in the questionnaire we denote as a parameter $X_k, k=\overline{1,K}$ for evaluating the project, where k – the ordinal number of the question, K – the number of questions. For the given questionnaire $K=23$. $X_k=\{x_{1k}, x_{2k},...,x_{Ik}\}$ – set of possible values of the k th parameter. Here $x_{ik}, i=\overline{1,I}$ represents the score corresponding to the i th possible answer to the k th question in the questionnaire, I – the number of possible answers to the k th question. In our case $I=4$ for all K parameters.

We denote all alternative approaches as $A=\{A_1, A_2,...,A_R\}$, where $A_r, r=\overline{1,R}$ – the r th project management approach, R – the number of alternative approaches. The selection is made of such approaches: the PMBOK Guide (A_1), the ISO21500 standard (A_2), the PRINCE2 methodology (A_3), the SWEBOK Guide (A_4), agile methodologies Scrum (A_5), XP (A_6) and Kanban (A_7). Therefore, in our case the number of approaches $R=7$.

Each approach is considered in terms of its applicability to specific situations described in the form of possible answers to the questions. However, this information for given project management approaches is fuzzy, that causes necessity of applying the mathematical apparatus of fuzzy sets.

A fuzzy set A' in $X=\{x\}$ is given by [10]:

$$A'=\{\langle x, \mu_{A'}(x)\rangle \mid x\in X\}, \quad (1)$$

where $\mu_{A'}(x)\in[0,1]$ is the membership function of the fuzzy set A'.

Thus, the applicability of the r th approach to each of specific situations corresponding values $x_{ik}, i=\overline{1,I}$ of the k th parameter $X_k=\{x_{1k}, x_{2k},...,x_{Ik}\}$, will be regarded as the fuzzy set $A_{rk}, k=\overline{1,K}$:

$$A_{rk}=\{\langle x_{1k}, \mu_{A_{rk}}(x_{1k})\rangle, \langle x_{2k}, \mu_{A_{rk}}(x_{2k})\rangle,...,\langle x_{Ik}, \mu_{A_{rk}}(x_{Ik})\rangle\}, \quad (2)$$

Membership function $\mu_{A_{rk}}(x_{ik}), i=\overline{1,I}$ determines the degree of applicability of the r th approach to the situation that corresponding the i th possible answer to the k th question in the questionnaire. Membership functions of all approaches are defined by experts. They are given in Table 7. A graphical representation of these functions for the parameter X_1 (number of people involved in the project) is shown in Fig. 1–7.

The project management approach $A_r, r=\overline{1,R}$ is characterized by its applicability to each alternative answer of all K questions in the questionnaire. That is $A_r=\{A_{r1}, A_{r2},...,A_{rK}\}$.

Responses of a project manager or an expert on the questionnaire form the project evaluation $B=\{B_1, B_2,...,B_K\}$, where $B_k, k=\overline{1,K}$ – the fuzzy set, that determines the conformity of the project to situations corresponding values $x_{ik}, i=\overline{1,I}$ of the k th project parameter $X_k=\{x_{1k}, x_{2k},...,x_{Ik}\}$:

$$B_k=\{\langle x_{1k}, \mu_{B_k}(x_{1k})\rangle, \langle x_{2k}, \mu_{B_k}(x_{2k})\rangle,...,\langle x_{Ik}, \mu_{B_k}(x_{Ik})\rangle\}, \quad (3)$$

Membership function $\mu_{B_k}(x_{ik}), i=\overline{1,I}$ determines the degree of project compliance to the situation corresponding the i th possible answer to the k th question in the questionnaire.

In order to determine the most appropriate management approach for a specific project is necessary to estimate the distance from the project evaluation $B=\{B_1, B_2,...,B_K\}$ to each of these approaches $A_r=\{A_{r1}, A_{r2},...,A_{rK}\}$, $r=\overline{1,R}$. To solve this problem, let us consider the methods of determining the distance between fuzzy sets.

The most widely used distances for fuzzy sets A, B in $X=\{x_1, x_2,...,x_n\}$ are [11]:

- the Hamming distance $d(A,B)$:

$$d(A,B)=\sum_{i=1}^{n}|\mu_A(x_i)-\mu_B(x_i)|; \quad (4)$$

- the Euclidean distance $e(A,B)$:

$$e(A,B)=\sqrt{\sum_{i=1}^{n}(\mu_A(x_i)-\mu_B(x_i))^2}. \quad (5)$$

However, formulas for calculating Hamming and Euclidean distances proposed in [11], do not fully reflect the specifics of the problem. In this case, if the value of the membership function for the approach is superior to the value of the membership function for the project or equal to it, the distance between these two coordinates should be considered as zero. In other words, the membership function for the project is covered by the membership function for the approach or else, differently, the approach is fully consistent with the project.

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For further use of Hamming and Euclidean distances, the distance for the i th value of the k th parameter between the given approach A_r, $r=\overline{1,R}$ and project evaluation B will be:

$$d_{ik}(A_r,B)=\begin{cases}0, \text{ if } \left(\mu_{A_{rk}}(x_{ik})-\mu_{B_k}(x_{ik})\right)\geq 0\\ \left(\mu_{A_{rk}}(x_{ik})-\mu_{B_k}(x_{ik})\right), \text{else.}\end{cases} \quad (6)$$

Then the total distance between the approach A_r and the project evaluation B in K parameters using the Hamming distance $d(A_r,B)$ is:

$$d(A_r,B)=\sum_{k=1}^{K}\sum_{i=1}^{I}|d_{ik}(A_r,B)|, r=\overline{1,R}. \quad (7)$$

It should take into account that not all parameters for solving the problem of choosing the project management approach are equivalent. To display the degree of influence of the k th parameter on the result of problem-solving let us introduce weighting coefficients $\alpha_k, k=\overline{1,K}$ which satisfy conditions:

$$\sum_{k=1}^{K}\alpha_k=1,\ \ 0\leq\alpha_k\leq 1, k=\overline{1,K} \quad (8)$$

Weighting coefficients values are defined by experts (Table 8).

In view of weighting coefficients, the total distance between the approach A_r and the project evaluation B in K parameters using the Hamming distance $d_\alpha(A_r,B)$ will be:

$$d_\alpha(A_r,B)=\sum_{k=1}^{K}\alpha_k\sum_{i=1}^{I}|d_{ik}(A_r,B)|, r=\overline{1,R}. \quad (9)$$

The best approach is the one for which the total distance from the project evaluation B using the Hamming distance and taking into account weighting coefficients $\alpha_k, k=\overline{1,K}$ is minimal:

$$A=\arg\min\{d_\alpha(A_r,B)\}, r=\overline{1,R}. \quad (10)$$

The total distance between the approach A_r and the project evaluation B in K parameters taking into account weighting coefficients $\alpha_k, k=\overline{1,K}$ and using the Euclidean distance $e_\alpha(A_r,B)$ will be:

$$e_\alpha(A_r,B)=\sum_{k=1}^{K}\alpha_k\sqrt{\sum_{i=1}^{I}(d_{ik}(A_r,B))^2}\ r=\overline{1,R}. \quad (11)$$

The best approach is the one for which the total distance from the project evaluation B using the Euclidean distance and taking into account weighting coefficients $\alpha_k, k=\overline{1,K}$ is minimal:

$$A=\arg\min\{e_\alpha(A_r,B)\}, r=\overline{1,R}. \quad (12)$$

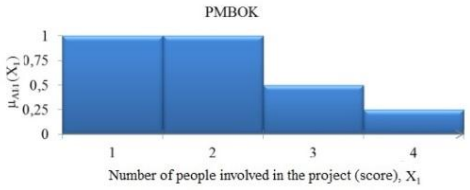

Fig. 1 – PMBOK membership function (parameter X_1)

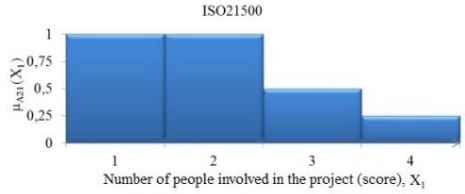

Fig. 2 – IS021500 membership function (parameter X_1)

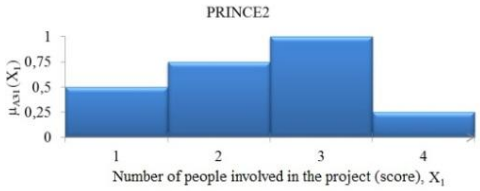

Fig. 3 – PRINCE2 membership function (parameter X_1)

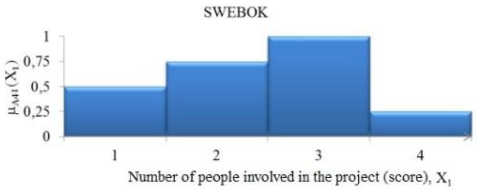

Fig. 4 – SWEBOK membership function (parameter X_1)

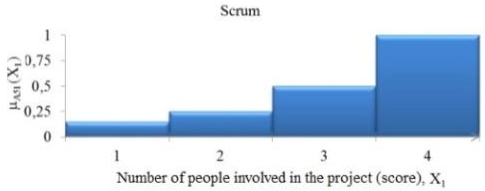

Fig. 5 – Scrum membership function (parameter X_1)

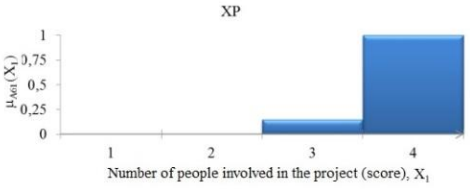

Fig. 6 – XP membership function (parameter X_1)

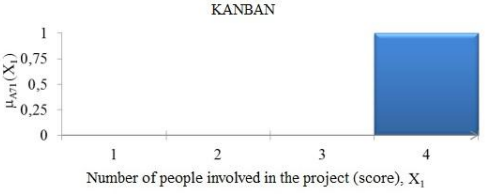

Fig. 7 – Kanban membership function (parameter X_1)

So, the method for selecting of project management approach based on fuzzy concepts about the applicability of existing approaches could be represented as the following steps.

1. For every questionnaire question (project parameter) on the basis of a survey of experts membership functions for all given project management approaches are defined.

2. Experts determine weighting coefficients for all parameters of the project considered in the questionnaire.

3. According to responses to all questions in the project questionnaire, project evaluation membership functions for each of its parameters are formed.

4. For all given approaches are calculated their total weighted distances from the project evaluation using the Hamming distance.

5. The approach for which the distance obtained in the previous step is minimal is selected.

6. For all given approaches are calculated their total

7. weighted distances from the project evaluation using the Euclidean distance.

8. The approach for which the distance obtained in the previous step is minimal is selected.

The calculation results obtained in step 5 and in step 7 are compared and analyzed, the final decision on selecting a particular project management approach is made.

Table 7 – Values of project management approaches membership functions

Parameter, X_k	Score, x_{ik}	$\mu_{A_{1k}}(x_{ik})$	$\mu_{A_{2k}}(x_{ik})$	$\mu_{A_{3k}}(x_{ik})$	$\mu_{A_{4k}}(x_{ik})$	$\mu_{A_{5k}}(x_{ik})$	$\mu_{A_{6k}}(x_{ik})$	$\mu_{A_{7k}}(x_{ik})$
X_1	1	1,00	1,00	0,50	0,50	0,15	0,00	0,00
	2	1,00	1,00	0,75	0,75	0,25	0,00	0,00
	3	0,50	0,50	1,00	1,00	0,50	0,15	0,00
	4	0,25	0,25	0,25	0,75	1,00	1,00	1,00
X_2	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	0,75	0,75	0,75	0,75	0,25	0,15	0,00
	3	0,50	0,50	0,50	0,50	1,00	1,00	0,75
	4	0,25	0,25	0,25	0,25	1,00	1,00	1,00
X_3	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	1,00	1,00	1,00	1,00	0,25	0,00	0,00
	3	0,50	0,50	0,75	0,75	0,75	0,75	0,25
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_4	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	3	0,00	0,00	0,00	0,00	1,00	0,50	0,25
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_5	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	3	0,25	0,25	0,00	0,00	0,75	0,50	0,25
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_6	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	1,00	1,00	1,00	1,00	0,25	0,00	0,00
	3	0,50	0,50	0,25	0,25	0,75	0,50	0,50
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_7	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	0,75	0,75	0,75	0,75	0,25	0,00	0,00
	3	0,00	0,00	0,00	0,00	1,00	0,75	0,75
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_8	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	0,75	0,75	1,00	1,00	0,50	0,25	0,25
	3	0,50	0,50	0,50	0,50	1,00	0,75	0,75
	4	0,25	0,25	0,25	0,25	1,00	1,00	1,00
X_9	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	0,75	0,75	1,00	1,00	0,00	0,00	0,00
	3	0,50	0,50	0,50	0,50	1,00	0,00	0,75
	4	0,25	0,25	0,25	0,25	1,00	1,00	1,00

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The end of the Table 7

1	2	3	4	5	6	7	8	9
X_{10}	1	1,00	1,00	1,00	1,00	0,00	1,00	0,00
	2	1,00	1,00	0,75	1,00	0,00	0,00	0,00
	3	0,25	0,25	0,25	0,25	0,75	0,00	0,00
	4	0,00	0,00	0,00	0,00	1,00	0,75	1,00
X_{11}	1	1,00	1,00	0,50	0,50	0,15	0,00	0,00
	2	1,00	1,00	0,75	0,75	0,25	0,00	0,00
	3	0,50	0,50	1,00	1,00	0,50	0,15	0,00
	4	0,25	0,25	0,25	0,75	1,00	1,00	1,00
X_{12}	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	0,75	0,75	0,75	0,75	0,25	0,15	0,00
	3	0,50	0,50	0,50	0,50	1,00	1,00	0,75
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_{13}	1	1,00	1,00	1,00	1,00	0,00	1,00	0,00
	2	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	3	0,00	0,00	0,00	0,00	1,00	0,00	1,00
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_{14}	1	1,00	1,00	1,00	1,00	0,00	1,00	0,00
	2	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	3	0,00	0,00	0,00	0,00	1,00	0,00	1,00
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_{15}	1	1,00	1,00	1,00	1,00	0,00	1,00	0,00
	2	1,00	1,00	1,00	1,00	0,25	0,00	0,00
	3	0,50	0,50	0,50	0,50	0,75	0,25	0,25
	4	0,00	0,00	0,00	0,00	1,00	0,75	1,00
X_{16}	1	1,00	1,00	1,00	1,00	0,25	1,00	0,00
	2	1,00	1,00	1,00	1,00	0,50	0,25	0,25
	3	0,25	0,25	0,25	0,25	0,75	0,50	0,50
	4	0,15	0,15	0,15	0,15	1,00	0,75	1,00
X_{17}	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	0,50	0,50	0,50	0,50	0,50	0,50	0,50
	3	0,00	0,00	0,00	0,00	1,00	1,00	1,00
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_{18}	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	1,00	1,00	1,00	1,00	0,25	0,00	0,00
	3	0,00	0,00	0,00	0,00	1,00	1,00	1,00
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_{19}	1	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	2	0,75	0,75	1,00	0,75	0,00	0,00	0,00
	3	0,00	0,00	0,00	0,00	1,00	1,00	1,00
	4	0,00	0,00	0,00	0,00	1,00	1,00	1,00
X_{20}	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	2	1,00	1,00	0,50	1,00	1,00	0,00	0,00
	3	0,50	0,50	0,25	0,50	1,00	0,00	0,00
	4	0,25	0,25	0,10	0,25	1,00	0,00	0,00
X_{21}	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	2	1,00	1,00	0,50	1,00	1,00	0,00	0,00
	3	0,50	0,50	0,25	0,50	1,00	0,00	0,00
	4	0,25	0,25	0,10	0,25	1,00	0,00	0,00
X_{22}	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	2	1,00	1,00	0,50	1,00	1,00	0,00	0,00
	3	0,50	0,50	0,25	0,50	1,00	0,00	0,00
	4	0,25	0,25	0,10	0,25	1,00	0,00	0,00
X_{23}	1	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	2	1,00	1,00	0,50	1,00	1,00	0,00	0,00
	3	0,50	0,50	0,25	0,50	1,00	0,00	0,00
	4	0,25	0,25	0,10	0,25	1,00	0,00	0,00

Table 8 – Weighting coefficients values $\alpha_k, k = \overline{1,K}$

Parameter, X_k	Weighting coefficient, α_k	Parameter, X_k	Weighting coefficient, α_k	Parameter, X_k	Weighting coefficient, α_k
X_1	0,07	X_9	0,03	X_{17}	0,05
X_2	0,02	X_{10}	0,05	X_{18}	0,03
X_3	0,06	X_{11}	0,04	X_{19}	0,07
X_4	0,05	X_{12}	0,04	X_{20}	0,04
X_5	0,02	X_{13}	0,04	X_{21}	0,04
X_6	0,04	X_{14}	0,07	X_{22}	0,04
X_7	0,03	X_{15}	0,07	X_{23}	0,04
X_8	0,02	X_{16}	0,04		

An example of applying the method for selecting of project management approach based on fuzzy concepts. Let us illustrate the application of the above method on the example of the «PTCQR Optimization» software development project [12].

The designed questionnaire is proposed to the Respondent. Respondent defines membership functions of the project evaluation B for all given parameters on the basis of the questionnaire. At that, an evaluation technique is given below.

In the case when the Respondent entirely agrees with the statement of the questionnaire, the membership function for this statement is 1, while functions of remaining statements of the question are zero.

For example, the project budget is 40000 UAH. So, for the parameter X_{15} (project cost) the project evaluation will be $B = \{B_{15}\} = \{\langle 1,0.00\rangle, \langle 2,0.00\rangle, \langle 3,0.00\rangle, \langle 4,1.00\rangle\}$.

In the case where the Respondent finds it difficult to answer the question unequivocally, he determines the degree of belonging the project to each statement of this question.

For example, the project team members have a different experience in the given field – X_3. In the team, that consists of 4 people, one member has no experience (the tester), programmers work experience falls into the category "from 2 to 5 years" and the project manager has more than 5 years of experience in the given field. The project evaluation on the parameter X_3 will be $B = \{B_3\} = \{\langle 1,0.25\rangle, \langle 2,0.00\rangle, \langle 3,0.50\rangle, \langle 4,0.25\rangle\}$.

Project evaluation membership function values or all given parameters are shown in Table 9.

Table 9 – Project evaluation membership function values, B

Parameter, X_k	Score, x_{ik}	$\mu_{B_k}(x_{ik})$	Parameter, X_k	Score, x_{ik}	$\mu_{B_k}(x_{ik})$	Parameter, X_k	Score, x_{ik}	$\mu_{B_k}(x_{ik})$
1	2	3	4	5	6	7	8	9
X_1	1	0,00	X_7	1	0,00	X_{13}	1	0,00
	2	0,00		2	1,00		2	0,00
	3	0,00		3	0,00		3	1,00
	4	1,00		4	0,00		4	0,00
X_2	1	0,00	X_8	1	0,00	X_{14}	1	0,00
	2	0,00		2	0,25		2	0,00
	3	1,00		3	0,75		3	1,00
	4	0,00		4	0,00		4	0,00
X_3	1	0,25	X_9	1	0,00	X_{15}	1	0,00
	2	0,00		2	0,00		2	0,00
	3	0,50		3	1,00		3	0,00
	4	0,25		4	0,00		4	1,00
X_4	1	0,00	X_{10}	1	0,00	X_{16}	1	0,00
	2	0,25		2	0,00		2	0,00
	3	0,75		3	1,00		3	0,00
	4	0,00		4	0,00		4	1,00
X_5	1	0,00	X_{11}	1	0,00	X_{17}	1	0,00
	2	0,00		2	0,00		2	0,00
	3	1,00		3	0,00		3	1,00
	4	0,00		4	1,00		4	0,00
X_6	1	0,00	X_{12}	1	0,00	X_{18}	1	0,00
	2	0,00		2	0,00		2	1,00
	3	0,00		3	1,00		3	0,00
	4	1,00		4	0,00		4	0,00

The end of the Table 9

1	2	3	4	5	6	7	8	9
X_{20}	1	1,00	X_{21}	1	0,00	X_{23}	1	0,00
	2	0,00		2	0,00			
	3	0,00		3	1,00		2	1,00
	4	0,00		4	0,00			
X_{21}	1	0,00	X_{22}	1	0,00		3	0,00
	2	0,00		2	1,00			
	3	1,00		3	0,00		4	0,00
	4	0,00		4	0,00			

We calculate total weighted distances between the project evaluation and every approach using the Hamming distance (9):

$$d_\alpha(A_1,B)=\sum_{k=1}^{K}\alpha_k\sum_{i=1}^{I}d_{ik}(A_1,B)=0{,}669;$$

$$d_\alpha(A_2,B)=\sum_{k=1}^{K}\alpha_k\sum_{i=1}^{I}d_{ik}(A_2,B)=0{,}669;$$

$$d_\alpha(A_3,B)=\sum_{k=1}^{K}\alpha_k\sum_{i=1}^{I}d_{ik}(A_3,B)=0{,}724;$$

$$d_\alpha(A_4,B)=\sum_{k=1}^{K}\alpha_k\sum_{i=1}^{I}d_{ik}(A_4,B)=0{,}639;$$

$$d_\alpha(A_5,B)=\sum_{k=1}^{K}\alpha_k\sum_{i=1}^{I}d_{ik}(A_5,B)=0{,}110;$$

$$d_\alpha(A_6,B)=\sum_{k=1}^{K}\alpha_k\sum_{i=1}^{I}d_{ik}(A_6,B)=0{,}255;$$

$$d_\alpha(A_7,B)=\sum_{k=1}^{K}\alpha_k\sum_{i=1}^{I}d_{ik}(A_7,B)=0{,}325.$$

An approach will be selected according to the expression (10):

$$A=\arg\min\{d_\alpha(A_r,B)\}=\arg\min\begin{Bmatrix}0{,}669;0{,}669;0{,}724;\\0{,}639;0{,}110;0{,}255;\\0{,}325\end{Bmatrix}=$$

$$=\arg(0{,}110)=A_5.$$

Thus, as a result of the calculation distances between the project evaluation and given approaches using the Hamming distance, it is recommended to apply the Scrum methodology for managing the project.

Let us perform the calculation of total weighted distances for the same indicators using the Euclidean distance (11):

$$e_\alpha(A_1,B)=\sum_{k=1}^{K}\alpha_k\sqrt{\sum_{i=1}^{I}e_{ik}(A_1,B)},=0{,}659;$$

$$e_\alpha(A_2,B)=\sum_{k=1}^{K}\alpha_k\sqrt{\sum_{i=1}^{I}e_{ik}(A_2,B)},=0{,}659;$$

$$e_\alpha(A_3,B)=\sum_{k=1}^{K}\alpha_k\sqrt{\sum_{i=1}^{I}e_{ik}(A_3,B)},=0{,}724;$$

$$e_\alpha(A_4,B)=\sum_{k=1}^{K}\alpha_k\sqrt{\sum_{i=1}^{I}e_{ik}(A_4,B)},=0{,}639;$$

$$e_\alpha(A_5,B)=\sum_{k=1}^{K}\alpha_k\sqrt{\sum_{i=1}^{I}e_{ik}(A_5,B)},=0{,}100;$$

$$e_\alpha(A_6,B)=\sum_{k=1}^{K}\alpha_k\sqrt{\sum_{i=1}^{I}e_{ik}(A_6,B)},=0{,}268;$$

$$e_\alpha(A_7,B)=\sum_{k=1}^{K}\alpha_k\sqrt{\sum_{i=1}^{I}e_{ik}(A_7,B)},=0{,}337.$$

An approach will be selected according to the expression (12):

$$A=\arg\min\{e_\alpha(A_r,B)\}=\arg\min\begin{Bmatrix}0{,}659;0{,}659,0{,}724;\\0{,}639;0{,}100;0{,}268;\\0{,}337\end{Bmatrix}=$$

$$=\arg(0{,}100)=A_5.$$

The result of the project management approach selection obtained by calculating Euclidean distances corresponds to the previous result. Scrum methodology is considered to be the best in conditions of the given project.

Conclusions. A mathematical model and method for selecting of project management approach based on fuzzy concepts of applicability of existing approaches are offered. They allowing to choose the best project management approach for a particular project of such popular approaches as the PMBOK Guide, the ISO21500 standard, the PRINCE2 methodology, the SWEBOK Guide, methodologies Scrum, XP, and Kanban. A number of parameters of the project and its environment that are important for this choice are identified. It includes the number of people involved in the project, the customer's experience with this project team, the project team's experience in this field and others. For every given parameter its weight in the project management approach selection is defined.

The above method is illustrated on the example of its application to selection of a management approach for software development project.

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Відомості про авторів / Сведения об авторах / About the Authors

Кононенко Ігор Володимирович – доктор технічних наук, професор, Національний технічний університет «Харківський політехнічний інститут», завідувач кафедри стратегічного управління; тел.: (057) 707–67–35; e–mail: igorvkononenko@gmail.com.

Кононенко Игорь Владимирович – доктор технических наук, профессор, Национальный технический университет «Харьковский политехнический институт», заведующий кафедрой стратегического управления; тел.: (057) 707–67–35; e–mail: igorvkononenko@gmail.com.

Kononenko Igor Vladimirovich – Doctor of Technical Sciences, Full Professor, National Technical University "Kharkiv Polytechnic Institute", Head of Strategic Management Department; Tel.: (057) 707–67–35; e–mail: igorvkononenko@gmail.com.

Луценко Світлана Юріївна – Національний технічний університет «Харківський політехнічний інститут», студент; тел.: (093) 735-58-33; e–mail: lutsenkosyu@gmail.com.

Луценко Светлана Юрьевна – Национальный технический университет «Харьковский политехнический институт», студент; тел.: (093) 735-58-33; e–mail: lutsenkosyu@gmail.com.

Lutsenko Svetlana Yuryevna – National Technical University "Kharkiv Polytechnic Institute", student; tel.: (093) 735-58-33; e–mail: lutsenkosyu@gmail.com.