

Formalization of Project Team Formation, Taking into Account the Personality Traits of Candidates

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ABSTRACT The goal of the paper is to create a mathematical model for optimizing the composition of an IT project team, which would take into account the need to maximize the technical skills of candidates, their ability to perform the necessary roles, considering a set of assessments of these factors, as well as the agreeableness and conscientiousness of its members. The model should take into account the limitations on team members' competencies, their working hours, and labor costs. An approach to solving the problem is proposed, which involves presenting the requirements for candidates' competencies and assessing their competencies and abilities to perform specific roles in the project using fuzzy sets. At the same time, assessments of competencies and abilities to perform certain roles are represented by trapezoidal fuzzy intervals. A method is proposed for defuzzifying the problem by calculating the value of the membership function of the requirement at a point equal to the lower modal value of the fuzzy interval describing the properties of the candidates. The proposed task may not have a solution if the candidates' competencies do not meet the constraints. The model allows finding the optimal extension of the set of feasible solutions by training candidates. An example of solving the task of forming an IT team is considered.

KEYWORDS mathematical model; team formation; competency; role; personality trait; fuzzy set; trapezoidal fuzzy interval.

I. INTRODUCTION

The success of an IT project largely depends on the composition of the team implementing it [1]. The website [2] defines a team as 'a group of people with a full set of complementary skills required completing a task, job, or project'. The task of forming a team that will be able to meet the project requirements is complex.

Traditionally, project teams are formed on the basis of subjective decisions made by the people responsible for this process. The subjectivity of such decisions leads to insufficient competence of individual team members, the inability of the team to cope with changing requirements for the project and its product, overspending, and insufficient consideration of the time resources available to team members. Formalizing decision-making on team composition allows these shortcomings to be largely eliminated.

II. LITERATURE REVIEW

Quite a lot of work has been devoted to the issues of formalized team formation. For example, a systematic review of the literature [3] examined 103 articles published between 2010 and 2020.

Among the works of this period, attention should be paid to study [1] whose authors identified the criteria used by IT companies to select team members for software development. They also examined the relationship between the use of these criteria and project success. Project success was measured by criteria such as Costs, Time, Scope, Team Satisfaction, Client Satisfaction, and Project Manager Satisfaction. The study showed that the individual factors of team members—Personality, Behavior, Technical Profile, and Productivity—are the group most strongly correlated with project success.

Work [4] is devoted to the formation of flexible teams. Three criteria are proposed to solve this problem. The first

criterion is that candidates must have the necessary skills, the second is how effectively team members can communicate with each other, and the third is the cost of hiring team members.

Article [5] examined a method for synthesizing a project team in an agile environment and proposed a template for selecting the profile of an ideal team member. The authors used machine learning methods to group team members who could work together effectively in terms of collaboration. The paper proposed an indicator for comparing a team member's profile with the template and identifying the highest-rated candidates.

The authors of [6] developed a hybrid recommendation system for forming teams working according to Scrum, based on fuzzy and rough sets. The system's recommendations are based on determining the best team based on the available personnel for the project and the competencies required for each work package.

Among the works published after 2020, the following are noteworthy. A systematic literature review [7] revealed a need for a comprehensive team selection model that would take into account technical and soft skills requirements, as well as salary and communication costs.

In study [8], a mathematical model for solving the problem of forming a project team was proposed, which involves minimizing communication costs between team members. The constraints of the problem require that each necessary skill be provided, i.e., at least one person with that skill will be included in the team. In addition, it is prohibited to include pairs of candidates who conflict with each other in the team.

The authors of [9] proposed a new formulation of the task of forming a team to perform a given set of tasks. They proposed a mathematical model whose objective function aims to maximize the difference between the weighted satisfaction of task requirements by competent candidates and the maximum workload of candidates.

The authors of [10] proposed a procedure for forming a project team. In the first stage, the algorithm finds the smallest group of candidates who can fully cover all the skills required for the project. In the next stage, candidates are selected based on their social compatibility. Budget constraints are also taken into account.

Paper [11] proposed a mathematical model for the task of team formation, which includes people and artificial intelligence tools. The authors used the goal programming (GP) approach.

The authors of [12] proposed a modified intuitionistic fuzzy approach for forming a project team.

In [13] a variation Bayesian neural network was proposed, which allows finding teams that have experience of cooperation in the past and meet the requirements for a set of skills.

For the preliminary selection of candidates for an IT team, which is especially important when there are many of them, a method of multi-criteria ranking of candidates was developed [14]. The method differs from known approaches in its use of fuzzy numbers to set candidate preferences and assess the general competence of each candidate based on comparison with a benchmark competence, which improves the ability to evaluate candidates [14].

The aim of work [15] was to develop an approach to formalizing the formation of a project team that takes into account multiple fuzzy assessments of candidates' qualities. The authors proposed using a trapezoidal fuzzy interval to describe a set of assessments of specific candidate

characteristics. To determine the compliance of candidates' properties with fuzzy requirements, it was proposed to calculate the value of the membership function of the requirement at a point equal to the lower modal value of the fuzzy interval describing the candidates' properties. This technique made it possible to defuzzify the task.

Particular attention should be paid to works that examine not only the technical competencies of candidates, but also their character traits. In this regard, let us consider the state of affairs in this area.

III. TAKING PERSONAL FACTORS INTO ACCOUNT WHEN FORMING A PROJECT TEAM

One of the most common and recognized approaches to studying personality is the five-factor model of personality, known as the 'Big Five' or OCEAN model. This model is based on the conclusions of many researchers that personality can be described and classified based on five main factors: extraversion, agreeableness, conscientiousness, emotional stability, and openness to new experiences. Among the first works in this area, the contribution of [16] should be highlighted. These factors remain stable and unchanged over time and in different situations. Each of these factors predisposes a person to certain behavior. Questionnaires have been developed to assess the severity of these traits.

The Big Five model can be used for personality analysis, team building, recruitment, leadership assessment and development, and career planning. It allows to identify personality traits that may be important for performing specific roles and tasks.

Study [17] examined the influence of the Big Five personality traits on team performance. Each personality trait was assessed in terms of elevation and variability. Elevation was calculated by averaging the corresponding values of all team members or by summing the individual scores for the trait. The proportion of individuals with high scores for the trait was also used. Variability was assessed by the variance or standard deviation for team members.

Study [17] yielded important conclusions. Neither elevation nor variability of extraversion affects team performance. The higher the level of agreeableness in teams and the more similar team members are in terms of this indicator, the higher their productivity. The exceptions in terms of the influence of elevation of this factor were student teams, whose work was characterized by shorter periods of interaction.

The higher the average level of conscientiousness in a team and the closer the team members are to each other in terms of this indicator, the higher the team's performance. Student teams are an exception.

Increased emotional stability does not have a positive correlation with team performance. Increased openness to new experiences does not have a positive correlation with team performance.

Thus, the agreeableness and conscientiousness of team members are important for team effectiveness. Let us consider these factors in more detail.

People with a high level of agreeableness usually show empathy for other people's problems and emotions, have good relationships with others, and easily find common ground. They are characterized by a willingness to help and do good deeds. Such people adapt better to a team and are not confrontational. They may also be more successful in careers that require teamwork and cooperation.

People with high conscientiousness scores are disciplined, meticulous, and thorough. They are goal-oriented, persistent, reliable, and organized, which ultimately increases their productivity and success at work and in their personal lives. They can be relied upon to keep promises and adhere to agreements. People with high conscientiousness scores tend to have higher academic and work success and lower levels of absenteeism.

In [18], an algorithm for team formation is proposed, whose objective function is to maximize the weighted sum of the level of satisfaction with interaction between team members, conscientiousness, extraversion and neuroticism. The algorithm is illustrated by the example of forming student teams to carry out projects in the field of software engineering. The results of the study showed that team members' traits such as conscientiousness and extraversion tend to improve team performance, while neuroticism tends to hinder it.

In this regard, it should be recalled that in their conclusion in [19] the authors pointed to conscientiousness and its aspects as the main predictors of team performance. Agreeableness, extraversion, and neuroticism were not found to be important for performance, and openness to new experiences even showed a moderate negative correlation with team performance in the study. The study was conducted on 129 student engineering design teams consisting of three, four, or five members each.

When considering various options for forming a project team, it may turn out that none of them fall within the set of acceptable solutions. In particular, the requirements for certain competencies of candidates may not be met. In such a situation, it is advisable to use the ideas of system optimization by V. M. Glushkov to solve the problem of forming a project team [20]. The essence of system optimization lies in finding the optimal expansion of the set of acceptable solutions. To do this, additional task variables are introduced, which determine the consideration of one or another option for changing the task constraints. Each option for expanding the set of acceptable solutions involves a certain cost (penalty), which must be optimized.

An analysis of the above-mentioned and many other works on formalizing the formation of project teams has shown that most studies approached the task from the perspective of maximizing the sum of the team's technical competencies. The results of studies devoted to the influence of team members' personality traits on project effectiveness are somewhat ambiguous. However, these results suggest that agreeableness and conscientiousness are important characteristics for a professional IT team.

The aim of this work is to create a mathematical model for optimizing the composition of an IT project team, which would take into account the need to maximize the technical competencies of candidates, their ability to perform the necessary roles when there are multiple assessments, as well as the agreeableness and conscientiousness of its members. The model should take into account that the competencies of team members must meet the requirements, their working hours must meet the labor intensity requirements, and labor costs must not exceed the allocated budget. If there is no solution to the problem, system optimization should be envisaged, i.e., the optimal option for training candidates should be found.

To form an effective team, it is advisable to add a function to the target functions of the task that takes into account the total level of agreeableness and conscientiousness of its

members. Assessments of these factors can be obtained by surveying candidates. There are quite a few questionnaires with varying numbers of questions for assessing the 'Big Five' factors. We will use questionnaire [21] as an assessment tool. Questionnaire [21] consists of fifty questions. Test results are presented as a percentile, i.e., the percentage of other people who took the test and scored lower than the test taker. We will take into account the agreeableness and conscientiousness scores of team member candidates when forming the team.

IV. MATHEMATICAL MODEL

We assume that the competency requirements for project team candidates have been defined. These may include both technical requirements and requirements for the ability to perform certain roles within the team. In this case, we are referring to the nine roles identified by R. Meredith Belbin [22].

A set of indicators has been introduced to assess candidates in relation to project requirements $K = \{1, 2, \dots, m\}$ the values of which together characterize all candidates and allow evaluating them in relation to all project requirements. First, for each indicator $k \in K$ it is necessary to define the value, which meets the project requirements. Given the subjective nature of the formation of such an assessment, we use a fuzzy assessment that corresponds to the expression 'the indicator k should be approximately on the same level with \bar{q}_k or higher'. Mathematically the fuzzy set \bar{Q}_k is defined as a set of ordered pairs like: $\langle q, \mu_{Q_k}(q) \rangle$, where $q \in Q$, is an element of the accepted scale on the project, and $\mu_{Q_k}(q)$ is a membership function that matches each of the elements $q \in Q$, some real number from the interval $[0, 1]$. We define the membership function $\mu_{Q_k}(q)$ as follows:

$$\mu_{Q_k}(q) = \left\{ \begin{array}{l} 0, q \leq \bar{q}_k - \Delta\bar{q}_k \\ \left(\frac{q - \bar{q}_k + \Delta\bar{q}_k}{\Delta\bar{q}_k} \right), \bar{q}_k - \Delta\bar{q}_k \leq q \leq \bar{q}_k \\ 1, \bar{q}_k \leq q \end{array} \right\}, \quad (1)$$

where $\bar{q}_k \in Q$ – the desired clear level of the k -th indicator, $k \in K$; $\Delta\bar{q}_k$ – permissible from the point of view of the project deviation from the level \bar{q}_k ; Q – assessment scale.

Newer and more innovative projects tend to have a higher level of uncertainty and, accordingly, a higher value of $\Delta\bar{q}_k$.

If the requirements for the ability to perform roles according to R. M. Belbin are not specified, then for the corresponding k we have the following values: $\bar{q}_k=0$, $\Delta\bar{q}_k = 0$ and $\mu_{Q_k}(q) = 1$.

We assume that n candidates for roles in the team are being considered. In this case we have a set of numbers of candidates for the project team $N = \{1, 2, \dots, n\}$.

Suppose that we have r assessments of the competences of the j -th candidate for indicator k , i.e., $\bar{C}_{jki} \in Q$, $k \in K$, $j \in N$, $i = \overline{1, r}$. Given the uncertainty and subjectivity of competence assessments, we assume that for each indicator, each candidate is characterized by a fuzzy closed interval (segment), which can be interpreted using the following expression: "the assessment of the competences of the j -th candidate for the k -th indicator is approximately in the interval $[\bar{C}_{jkmin}, \bar{C}_{jkmax}]$, where $\bar{C}_{jkmin}, \bar{C}_{jkmax}$ are the minimum and maximum values among the n assessments of the competences of the j -th candidate for the k -th indicator."

In this case, the fuzzy set that determines the fuzzy assessment of the competencies of the j -th candidate by indicator k , $j \in N$, $k \in K$ is equal to

$$\tilde{C}_{jk} = \{ \langle C, \mu_{\tilde{C}_{jk}}(C) \rangle, C \in Q \}$$

The membership function is expressed as follows (Fig. 1).

$$\mu_{\tilde{C}_{jk}}(C) = \begin{cases} 0, & C \leq C_{jk}^{(\alpha)}; \\ \frac{C - C_{jk}^{(\alpha)}}{\bar{C}_{jk \min} - C_{jk}^{(\alpha)}}, & C_{jk}^{(\alpha)} \leq C \leq \bar{C}_{jk \min}; \\ 1, & \bar{C}_{jk \min} \leq C \leq \bar{C}_{jk \max}; \\ \frac{C_{jk}^{(\beta)} - C}{C_{jk}^{(\beta)} - \bar{C}_{jk \max}}, & \bar{C}_{jk \max} \leq C \leq C_{jk}^{(\beta)}; \\ 0, & C \geq C_{jk}^{(\beta)} \end{cases}, \quad (2)$$

where $C \in Q$, $C_{jk}^{(\alpha)}, \bar{C}_{jk \min}, \bar{C}_{jk \max}, C_{jk}^{(\beta)} \in Q$, $k \in K$, $j \in N$, $\mu_{\tilde{C}_{jk}}(C) \in [0, 1]$, $C_{jk}^{(\alpha)}, C_{jk}^{(\beta)}$ are the parameters of the membership function,
 $C_{jk}^{(\alpha)} \leq \bar{C}_{jk \min} \leq \bar{C}_{jk \max} \leq C_{jk}^{(\beta)}$, $k \in K$, $j \in N$.
 The proposed fuzzy set

$$\tilde{C}_{jk} = \{ \langle C, \mu_{\tilde{C}_{jk}}(C) \rangle, C \in Q \}$$

is a fuzzy interval of the $(R - L)$ -type, $\bar{C}_{jk \min}, \bar{C}_{jk \max}$ are the lower and upper modal values of the fuzzy interval.

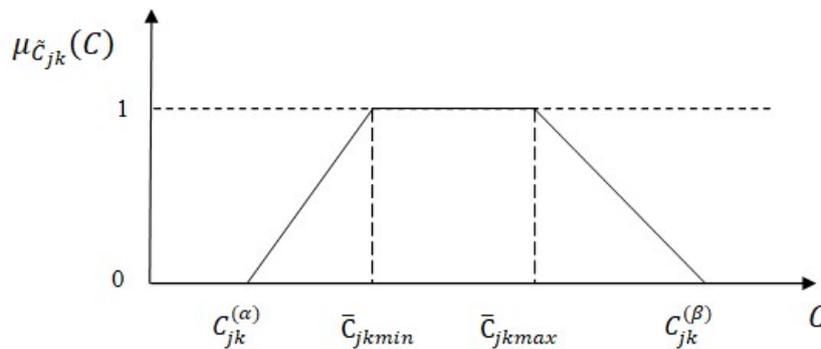


Figure 1. Graphical interpretation of membership function $\mu_{\tilde{C}_{jk}}(C)$.

To form a set of candidates based on the assessment of their competencies in accordance with the project requirements, it is necessary to compare the requirements for the candidate and the assessment of the candidate's competencies. On the set of candidates, it is possible to define an evaluation of compliance of each candidate concerning each requirement of the project as a crossing of two fuzzy sets: project requirements \bar{Q}_k and candidate's competencies \tilde{C}_{jk} . Then fuzzy set \tilde{X}_{jk} , which is the assessment of compliance of the j -th candidate to the requirements by the indicator k , $k \in K$, is formed as a set of ordered pairs

$\langle x, \mu_{\tilde{X}_{jk}}(x) \rangle$, where $x \in Q$, and $\mu_{\tilde{X}_{jk}}(x)$ – the membership function, which can be found as following:

$$\mu_{\tilde{X}_{jk}}(x) = \min_{x \in Q} \{ \mu_{Q_k}(x), \mu_{\tilde{C}_{jk}}(x) \}, k = \overline{1, m}, j = \overline{1, n}. \quad (3)$$

A specialist is considered a candidate, if he or she meets the project requirements by at least one criterion. In other words, for the j -th candidate, among the sets of eligibility assessment \tilde{X}_{jk} , there is at least one set in which $\mu_{Q_k}(\bar{C}_{jk \min})$ has a value of at least v_k (Fig. 2) [15]

$$\mu_{Q_k}(\bar{C}_{jk \min}) = \begin{cases} 0, & \bar{C}_{jk \min} \leq \bar{q}_k - \Delta \bar{q}_k; \\ \frac{\bar{C}_{jk \min} - \bar{q}_k + \Delta \bar{q}_k}{\Delta \bar{q}_k}, & \bar{q}_k - \Delta \bar{q}_k \leq \bar{C}_{jk \min} \leq \bar{q}_k; \\ 1, & \bar{C}_{jk \min} \geq \bar{q}_k. \end{cases} \quad (4)$$

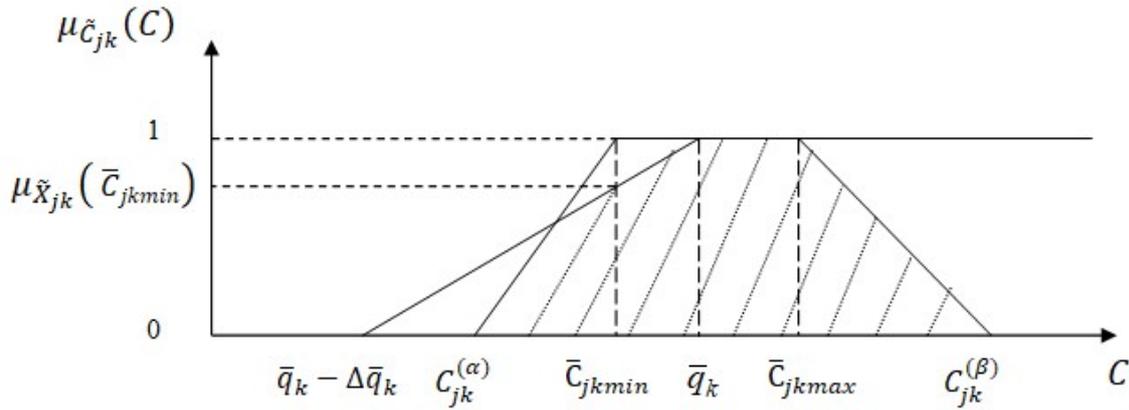


Figure 2. Graphical interpretation of the intersection of membership functions of competence and the requirements for competence [15].

Here v_k is the threshold, for example, it can be $v_k = 0.8$. The threshold determines the minimum value of the membership function of the intersection of the sets of requirements and competencies that allows the candidate to meet the project requirements.

The competence value of the j -th candidate, considering compliance with the k -th requirement, can be determined as follows [15]:

$$d_{jk}(\tilde{X}_{jk}) = \begin{cases} 0, & \bar{C}_{jkmmin} \leq \bar{q}_k - \Delta\bar{q}_k; \\ 0, & \frac{\bar{C}_{jkmmin} - \bar{q}_k + \Delta\bar{q}_k}{\Delta\bar{q}_k} < v_k, \bar{q}_k - \Delta\bar{q}_k < \bar{C}_{jkmmin} < \bar{q}_k; \\ \bar{C}_{jkmmin}, & \frac{\bar{C}_{jkmmin} - \bar{q}_k + \Delta\bar{q}_k}{\Delta\bar{q}_k} \geq v_k, \bar{q}_k - \Delta\bar{q}_k < \bar{C}_{jkmmin} < \bar{q}_k; \\ \bar{C}_{jkmmin}, & \bar{C}_{jkmmin} \geq \bar{q}_k. \end{cases} \quad (5)$$

If the requirement for the k -th indicator is crisp and equal to $\bar{q}_k \in Q, k \in K, k$ - the number of the competency indicator, $K = \{1, 2, \dots, m\}$, then

$$d_{jk}(\tilde{X}_{jk}) = \begin{cases} 0, & \bar{C}_{jkmmin} < \bar{q}_k; \\ \bar{C}_{jkmmin}, & \bar{C}_{jkmmin} \geq \bar{q}_k. \end{cases} \quad (6)$$

Using (5) or (6), one can construct a matrix $A = (d_{jk}(\tilde{X}_{jk}))_{\substack{j=1, \dots, n \\ k=1, \dots, m}}$ whose elements are $d_{jk}(\tilde{X}_{jk})$.

Various training options can be used to improve candidates' competencies. If we apply the l -th training option, $l = \overline{1, L}, L$ - the number of training options considered, and then the competence assessments of the j -th candidate, $j \in N$, according to indicator k may change. Let us introduce the variable $y_l \in \{0, 1\}$, where $y_l = 1$ means that the l -th training option is applied, and $y_l = 0$ otherwise. Let us assume that we use a continuous scale from 0 to 4 to assess competencies, where 4 corresponds to the highest level of competency. In this case

$$\begin{aligned} C_{jkmmin}^{\Sigma} &= \bar{C}_{jkmmin} + \sum_{l=1}^L \Delta C_{jkl} y_l, \text{ if } \bar{C}_{jkmmin} + \sum_{l=1}^L \Delta C_{jkl} y_l \leq 4, \text{ else } C_{jkmmin}^{\Sigma} = 4, \\ C_{jkmmax}^{\Sigma} &= \bar{C}_{jkmmax} + \sum_{l=1}^L \Delta C_{jkl} y_l, \text{ if } \bar{C}_{jkmmax} + \sum_{l=1}^L \Delta C_{jkl} y_l \leq 4, \text{ else } C_{jkmmax}^{\Sigma} = 4, \\ C_{jk}^{(\alpha)\Sigma} &= C_{jk}^{(\alpha)} + \sum_{l=1}^L \Delta C_{jkl} y_l, \text{ if } C_{jk}^{(\alpha)} + \sum_{l=1}^L \Delta C_{jkl} y_l \leq 4, \text{ else } C_{jk}^{(\alpha)\Sigma} = 4, \\ C_{jk}^{(\beta)\Sigma} &= C_{jk}^{(\beta)} + \sum_{l=1}^L \Delta C_{jkl} y_l, \text{ if } C_{jk}^{(\beta)} + \sum_{l=1}^L \Delta C_{jkl} y_l \leq 4, \text{ else } C_{jk}^{(\beta)\Sigma} = 4, \end{aligned} \quad (7)$$

where ΔC_{jkl} is the increase in the competence of candidate j according to indicator k for training option l . In this case, to simplify the presentation of the idea behind the approach, we assume that ΔC_{jkl} is a crisp value. If ΔC_{jkl} were fuzzy, this would have to be taken into account in formulas (7).

As a result, the corresponding parameter values in formulas (2)-(6) must be replaced with values that take into account the additions to competencies. The competence of the j -th candidate, taking into account compliance with the k -th requirement, in this case will take the form

$$d_{jk}(\tilde{X}_{jk}) = \begin{cases} 0, & C_{jkmin}^{\Sigma} \leq \bar{q}_k - \Delta\bar{q}_k; \\ 0, & \frac{C_{jkmin}^{\Sigma} - \bar{q}_k + \Delta\bar{q}_k}{\Delta\bar{q}_k} < v_k, \bar{q}_k - \Delta\bar{q}_k < C_{jkmin}^{\Sigma} < \bar{q}_k; \\ C_{jkmin}^{\Sigma}, & \frac{C_{jkmin}^{\Sigma} - \bar{q}_k + \Delta\bar{q}_k}{\Delta\bar{q}_k} \geq v_k, \bar{q}_k - \Delta\bar{q}_k < C_{jkmin}^{\Sigma} < \bar{q}_k; \\ C_{jkmin}^{\Sigma}, & C_{jkmin}^{\Sigma} \geq \bar{q}_k. \end{cases} \quad (8)$$

If the requirement for the k -th indicator is crisp and equal to $\bar{q}_k \in Q, k \in K$, then, taking into account the possible increase in competence, $d_{jk}(\tilde{X}_{jk})$ will take the form

$$d_{jk}(\tilde{X}_{jk}) = \begin{cases} 0, & C_{jkmin}^{\Sigma} < \bar{q}_k; \\ C_{jkmin}^{\Sigma}, & C_{jkmin}^{\Sigma} \geq \bar{q}_k. \end{cases} \quad (9)$$

Next, as additional conditions for the team creation we will consider: the resource of the available time of each candidate per week $time_j$ and cost of working hour for each candidate $rate_j$. In addition, requirements are set for the total cost of labor of team members C_{total} , for the laboriousness of

the project L_{total} , and the time of the project implementation in ρ weeks.

Denote $g = \overline{1, G}$ is a number of a team option. Let us build an assignment matrix $X_g = (x_{ip})_{i=\overline{1, n}, p=\overline{1, n}}$ as diagonal matrix,

where the elements $x_{jj} \in \{0,1\}, j = \overline{1, n}$ on the main diagonal define whether the j -th candidate was selected to the g -th team option ($x_{jj}=1$) or not ($x_{jj}=0$). Then we can build a matrix $A_g = X_g \times A$, that defines compliance of the g -th team with project requirements.

The mathematical model of our multicriteria problem is as follows:

$$X_g^{opt}, Y^{opt} = \arg \max_{x_{jj}, y_l \in S} \begin{cases} \sum_{k=1}^m \max_{j \in N} \{d_{jk}(\tilde{X}_{jk})\}, & (10) \\ \sum_{k=1}^m \lambda_k \sum_{j=1}^n d_{jk}(\tilde{X}_{jk}), & (11) \\ \sum_{j=1}^n (p_{j1} + p_{j2}) x_{jj}, & (12) \\ - \sum_{l=1}^L w_l y_l, & (13) \end{cases}$$

$$S = \{x_{jj}, y_l\} \mid \begin{cases} \mu_{Q_k} (\max_{j \in N} \{d_{jk}(\tilde{X}_{jk})\}) \geq v_k, \forall k \in K, & (14) \\ \sum_{j=1}^n x_{jj} \cdot \rho \cdot time_j \geq L_{total}, & (15) \\ \sum_{j=1}^n x_{jj} \cdot \rho \cdot time_j \cdot rate_j \leq C_{total}, & (16) \\ x_{jj}, y_l \in \{0,1\} & (17) \end{cases}$$

where $d_{jk}(\tilde{X}_{jk}) \in A_g, A_g = X_g \times A; \lambda_k$ is the weight of the k -th indicator;

$$\lambda_k > 0, \quad \sum_{k=1}^m \lambda_k = 1;$$

where p_{j1} is the percentile of the j -th candidate for the agreeableness factor, p_{j2} is the percentile of the j -th candidate for the conscientiousness factor; w_l is the cost of the l -th training option, $l = \overline{1, L}; \rho$ is the number of weeks in which the project is planned; $time_j$ is the working time of the j -th candidate per week.

The first criterion (10) requires that for each indicator, the team has a member with the highest possible competence value. This will allow us to form a team with the best specialist for each indicator. Such a team will have the maximum possible

knowledge, skills, and abilities and will be able to cope with tasks in time if the requirements for the product or project change.

The second criterion (11) aims at forming a team with the maximum sum of competencies across all indicators, considering the weight of each indicator. This will allow to select the best team in all competencies.

The third criterion (12) will take into account assessments of the candidates' agreeableness and conscientiousness. The higher the value of the objective function (12), the greater the effectiveness of the team.

The fourth criterion (13) is equal to the cost of training candidates.

The task involves four constraints. Constraint (14) means that the team's competencies must fulfil all the project requirements.

Constraint (15) means that the time the team spends on the project must meet the project labor intensity requirements.

Constraint (16) stipulates that the team's labor costs must not exceed the allocated budget.

Constraint (17) assumes that the task contains Boolean variables.

Thus, the solution to the problem is the team option whose maximum competence across all indicators $k \in K$ is the highest possible, the sum of competences across all indicators, taking into account the weight of each indicator, is also the highest, important personal factors are maximally realized, the costs of training candidates are minimized, the maximum competence for each indicator is not lower than the specified level, and the team will be able to complete the project within the available time and budget resources.

This problem belongs to the class of multi-criteria Boolean programming problems. Existing methods can be used to solve it [23, 24].

To ensure the computational practicability of the proposed model, especially when dealing with a large pool of candidates (n), a two-stage selection procedure is implemented. In the first stage, all applicants are ranked based on their compliance with the project requirements using the fuzzy-set-based method described in [14]. This allows for the filtration of the most suitable candidates who meet the baseline criteria. In the second stage, the combinatorial optimization model is applied only to a manageable subset of top-ranked candidates (e.g., n_r individuals, where $n_r \ll n$). This reduction of the search space effectively mitigates the problem of combinatorial explosion (2^n), making the approach efficient and applicable for real-world large-scale IT projects.

V. AN EXAMPLE OF SOLVING THE PROBLEM OF FORMING AN IT PROJECT TEAM

Let us consider an example of solving the problem of team formation for an IT project. It is assumed that the requirements for the competencies of team candidates and the assessment of their competencies are vague. The vague requirements for candidate competencies are presented in Table 1. The indicators of requirements are expressed on a continuous scale from 0 to 4, where 4 corresponds to the highest competency.

Problem conditions: $v_k = 0,9, j = \overline{1, n}, n=3, k = \overline{1, m}, m=5. \lambda_k = 0,2 \forall k = \overline{1, m}.$

The project duration is $\rho = 5$ weeks, the labor intensity of the project is $L_{total}=250$ man-hours, and the acceptable labor costs for the team are $C_{total}=5000$ conventional units.

Table 1. Indicators of competency requirements for candidates

Name of indicator	k	Project requirements	
		\bar{q}_k	$\Delta\bar{q}_k$
Design patterns	1	3	1
Nest.js	2	1	0,3
OOP paradigm	3	2	0,5
S.O.L.I.D Principles	4	2	0,5
Functional testing	5	3	1

Candidate competency assessments, presented as trapezoidal fuzzy intervals, are shown in Table 2.

Table 2. Assessment of candidates' competencies

j	Indicators, k											
	1				2				3			
	$C_{j1}^{(\alpha)}$	\bar{C}_{j1min}	\bar{C}_{j1max}	$C_{j1}^{(\beta)}$	$C_{j2}^{(\alpha)}$	\bar{C}_{j2min}	\bar{C}_{j2max}	$C_{j2}^{(\beta)}$	$C_{j3}^{(\alpha)}$	\bar{C}_{j3min}	\bar{C}_{j3max}	$C_{j3}^{(\beta)}$
1	1	1	1	1	1	1	1	1	2	2	2	2
2	2	3	3	4	0,5	1	1,5	2	1,5	2	2,5	3
3	2,5	3	3,5	3,5	0,5	1	1,5	1,5	1	1,5	2	2,5

End of Table 2

j	Indicators, k							
	4				5			
	$C_{j4}^{(\alpha)}$	\bar{C}_{j4min}	\bar{C}_{j4max}	$C_{j4}^{(\beta)}$	$C_{j5}^{(\alpha)}$	\bar{C}_{j5min}	\bar{C}_{j5max}	$C_{j5}^{(\beta)}$
1	0,5	1	2	3	4	4	4	4
2	1	1,5	2	3	3	3,5	4	4
3	1	1,5	2	2,5	2,6	3	3	3,4

Table 3 presents the results of the Big Five Personality Test [21] for team member candidates. For each candidate, the table shows percentiles, i.e., the percentage of other people who took this test and scored lower than the candidate.

Table 3. Percentiles of candidates on the Big Five Personality Test

j	Personality traits	
	Agreeableness	Conscientiousness
1	51	80
2	60	75
3	65	70

We assume that there are two possible training options for candidates, i.e., $L=2$. When training candidates, depending on the training option chosen, the candidates' competencies will change by an amount of ΔC_{jkl} . When applying the first training option, $\Delta C_{141} = 1$. When applying the second training option, $\Delta C_{242} = 0,5$. The remaining competencies will remain unchanged.

The costs for the first training option are $w_1 = 2000$ conditional units, and for the second training option they are $w_2 = 1000$ conditional units. The available time of each candidate per week $time_j$ and the cost of each candidate's working hour $rate_j$ are shown in Table 4.

Table 4. Available working hours and pay rates

j	$time_j$, hours	$rate_j$, conditional units per hour
1	30	10
2	20	15
3	30	8

From the three candidates, G team options can be formed, where $G = 2^3 - 1 = 7$. These options are shown below

- $g = 1: [0, 0, 1]$,
- $g = 2: [0, 1, 0]$,
- $g = 3: [0, 1, 1]$,
- $g = 4: [1, 0, 0]$,
- $g = 5: [1, 0, 1]$,

Table 6. Assessment of candidates' competencies

lj	Indicators, k											
	1				2				3			
	$C_{j1}^{(\alpha)}$	\bar{C}_{j1min}	\bar{C}_{j1max}	$C_{j1}^{(\beta)}$	$C_{j2}^{(\alpha)}$	\bar{C}_{j2min}	\bar{C}_{j2max}	$C_{j2}^{(\beta)}$	$C_{j3}^{(\alpha)}$	\bar{C}_{j3min}	\bar{C}_{j3max}	$C_{j3}^{(\beta)}$
1	1	1	1	1	1	1	1	1	2	2	2	2
2	2	3	3	4	0,5	1	1,5	2	1,5	2	2,5	3
3	2,5	3	3,5	3,5	0,5	1	1,5	1,5	1	1,5	2	2,5

End of Table 6

jj	Indicators, k							
	4				5			
	$C_{j4}^{(\alpha)}$	\bar{C}_{j4min}	\bar{C}_{j4max}	$C_{j4}^{(\beta)}$	$C_{j5}^{(\alpha)}$	\bar{C}_{j5min}	\bar{C}_{j5max}	$C_{j5}^{(\beta)}$
1	1,5	2	3	4	4	4	4	4
2	1	1,5	2	3	3	3,5	4	4
3	1	1,5	2	2,5	2,6	3	3	3,4

The elements of matrix A for this case are shown in Table 7.

Table 7. Elements of the matrix A

Candidates, j	Indicators, k				
	1	2	3	4	5
1	0	1	2	2	4
2	3	1	2	0	3,5
3	3	1	0	0	3

We check the fulfilment of task constraints using different team options. The competencies of team options 1, 2, 3, and 4 do not meet all project requirements, i.e., constraint (14) is not fulfilled for them. Constraint (15) regarding the team's working

$$g = 6: [1, 1, 0],$$

$$g = 7: [1, 1, 1].$$

Matrix $A = (d_{jk}(\bar{X}_{jk}))_{j=\overline{1,n}, k=\overline{1,m}}$, with elements corresponding

to (5) is presented in Table 5.

We check the fulfilment of task constraints using different team options. The competencies of team options 1–7 do not meet all project requirements, i.e., constraint (14) is not fulfilled for them. Constraint (15) regarding the team's working time in the project, which must meet the requirements for the project's labor intensity, is satisfied by teams 3, 5, 6, and 7. Constraint (16) regarding the team's labor costs is satisfied by all teams.

Table 5. Elements of the matrix A

Candidates, j	Indicators, k				
	1	2	3	4	5
1	0	1	2	0	4
2	3	1	2	0	3,5
3	3	1	0	0	3

Thus, the task of forming a team based on the initial values of candidates' competencies has no solution.

When using the first option for training candidates, the competency assessments will change and take the form shown in Table 6.

time in the project, which must meet the requirements for the project's labor intensity, is satisfied by teams 3, 5, 6, and 7.

Constraint (16) regarding the team's labor costs is satisfied by all teams.

Let us calculate the values of the objective functions of problems (10) - (12). The results are shown in Table 8.

As a result, we found that the optimal solution to the problem when applying the first training option for candidates is the seventh option for forming a project team, which includes all candidates. The cost of training candidates in this case will be 2,000 conventional units (the value of the objective function (13)).

When using the second option for training candidates, the competency assessments will take the form shown in Table 9.

The elements of matrix A will take the values shown in Table 10.

Table 8. The values of the objective functions (10) – (12)

Team option	Candidates, <i>j</i>	Indicators, <i>k</i>					Personality traits		The values of the objective functions
		1	2	3	4	5	Agreeableness	Conscientiousness	
5	1	0	1	2	2	4	51	80	-
	2	0	0	0	0	0	-	-	-
	3	3	1	0	0	3	65	70	-
	Maximum	3	1	2	2	4	-	-	12
	Sum	3	2	2	2	7	-	-	-
	Weighted sum of indicators 1-5	0,6	0,4	0,4	0,4	1,4	-	-	3,2
	Sum of percentiles						116	150	266
6	1	0	1	2	2	4	51	80	-
	2	3	1	2	0	3,5	60	75	-
	3	0	0	0	0	0	-	-	-
	Maximum	3	1	2	2	4	-	-	12
	Sum	3	2	4	2	7,5	-	-	-
	Weighted sum of indicators 1-5	0,6	0,4	0,8	0,4	1,5	-	-	3,7
	Sum of percentiles						111	155	266
7	1	0	1	2	2	4	51	80	-
	2	3	1	2	0	3,5	60	75	-
	3	3	1	0	0	3	65	70	-
	Maximum	3	1	2	2	4	-	-	12
	Sum	6	3	4	2	10,5	-	-	-
	Weighted sum of indicators 1-5	1,2	0,6	0,8	0,4	2,1	-	-	5,1
	Sum of percentiles						176	225	401

Table 9. Assessment of candidates' competencies

<i>j</i>	Indicators, <i>k</i>											
	1			2			3					
	$C_{j1}^{(\alpha)}$	\bar{C}_{j1min}	\bar{C}_{j1max}	$C_{j1}^{(\beta)}$	$C_{j2}^{(\alpha)}$	\bar{C}_{j2min}	\bar{C}_{j2max}	$C_{j2}^{(\beta)}$	$C_{j3}^{(\alpha)}$	\bar{C}_{j3min}	\bar{C}_{j3max}	$C_{j3}^{(\beta)}$
1	1	1	1	1	1	1	1	1	2	2	2	2
2	2	3	3	4	0,5	1	1,5	2	1,5	2	2,5	3
3	2,5	3	3,5	3,5	0,5	1	1,5	1,5	1	1,5	2	2,5

End of Table 9

<i>j</i>	Indicators, <i>k</i>							
	4				5			
	$C_{j4}^{(\alpha)}$	\bar{C}_{j4min}	\bar{C}_{j4max}	$C_{j4}^{(\beta)}$	$C_{j5}^{(\alpha)}$	\bar{C}_{j5min}	\bar{C}_{j5max}	$C_{j5}^{(\beta)}$
1	0,5	1	2	3	4	4	4	4
2	1,5	2	2,5	3,5	3	3,5	4	4
3	1	1,5	2	2,5	2,6	3	3	3,4

Table 10. Elements of matrix A

Candidates, <i>j</i>	Indicators, <i>k</i>				
	1	2	3	4	5
1	0	1	2	0	4
2	3	1	2	2	3,5
3	3	1	0	0	3

We check the fulfilment of task constraints using different team options. The competencies of team options 1, 4, and 5 do not meet all project requirements, i.e., constraint (14) is not fulfilled for them. Constraint (15) regarding the team's working time in the project, which must meet the requirements for the project's labor intensity, is satisfied by teams 3, 5, 6, and 7. Constraint (16) regarding the team's labor costs is satisfied by all teams.

Let us calculate the values of the objective functions of problems (10) - (12). The results are shown in Table 11.

Table 11. The values of the objective functions (10) – (12)

Team option	Candidates, j	Indicators, k					Personality traits		The values of the objective functions
		1	2	3	4	5	Agreeableness	Conscientiousness	
3	1	0	0	0	0	0	-	-	-
	2	3	1	2	2	3,5	60	75	-
	3	3	1	0	0	3	65	70	-
	Maximum	3	1	2	2	3,5	-	-	11,5
	Sum	6	2	2	2	6,5	-	-	-
	Weighted sum of indicators 1-5	1,2	0,4	0,4	0,4	1,3	-	-	3,7
Sum of percentiles						125	145	270	
6	1	0	1	2	2	4	51	80	-
	2	3	1	2	2	3,5	60	75	-
	3	0	0	0	0	0	-	-	-
	Maximum	3	1	2	2	4	-	-	12
	Sum	3	2	4	4	7,5	-	-	-
	Weighted sum of indicators 1-5	0,6	0,4	0,8	0,8	1,5	-	-	4,1
Sum of percentiles						111	155	266	
7	1	0	1	2	2	4	51	80	-
	2	3	1	2	2	3,5	60	75	-
	3	3	1	0	0	3	65	70	-
	Maximum	3	1	2	2	4	-	-	12
	Sum	6	3	4	4	10,5	-	-	-
	Weighted sum of indicators 1-5	1,2	0,6	0,8	0,8	2,1	-	-	5,5
Sum of percentiles						176	225	401	

The optimal solution when applying the second option for training candidates is the seventh option for forming a project team, which includes all candidates. The cost of training candidates in this case will be 1000 conventional units (the value of the objective function (13)).

When using the first and second options for training candidates, the competency assessments will change and take the form shown in Table 12.

Table 12. Assessment of candidates' competencies

j	Indicators, k											
	1				2				3			
	$C_{j1}^{(\alpha)}$	\bar{C}_{j1min}	\bar{C}_{j1max}	$C_{j1}^{(\beta)}$	$C_{j2}^{(\alpha)}$	\bar{C}_{j2min}	\bar{C}_{j2max}	$C_{j2}^{(\beta)}$	$C_{j3}^{(\alpha)}$	\bar{C}_{j3min}	\bar{C}_{j3max}	$C_{j3}^{(\beta)}$
1	1	1	1	1	1	1	1	1	2	2	2	2
2	2	3	3	4	0,5	1	1,5	2	1,5	2	2,5	3
3	2,5	3	3,5	3,5	0,5	1	1,5	1,5	1	1,5	2	2,5

End of Table 12

j	Indicators, k							
	4				5			
	$C_{j4}^{(\alpha)}$	\bar{C}_{j4min}	\bar{C}_{j4max}	$C_{j4}^{(\beta)}$	$C_{j5}^{(\alpha)}$	\bar{C}_{j5min}	\bar{C}_{j5max}	$C_{j5}^{(\beta)}$
1	1,5	2	3	4	4	4	4	4
2	1,5	2	2,5	3,5	3	3,5	4	4
3	1	1,5	2	2,5	2,6	3	3	3,4

The elements of matrix A will take the values shown in Table 13.

Table 13. Elements of matrix A

Candidates, j	Indicators, k				
	1	2	3	4	5
1	0	1	2	2	4
2	3	1	2	2	3,5
3	3	1	0	0	3

We check the fulfilment of task constraints using different team options. The competencies of team options 1 and 4 do not meet all project requirements; i.e., constraint (14) is not satisfied for them. Constraint (15) regarding the team's working time in the project, which must meet the project's labor intensity requirements, is satisfied by teams 3, 5, 6, and 7. Constraint (16) regarding the team's labor costs is satisfied by all teams. Let us calculate the values of the objective functions of problems (10) - (12). The results are shown in Table 14.

Table 14. The values of the objective functions (10) – (12)

Team option	Candidates, <i>j</i>	Indicators, <i>k</i>					Personality traits		The values of the objective functions
		1	2	3	4	5	Agreeableness	Conscientiousness	
3	1	0	0	0	0	0	-	-	-
	2	3	1	2	2	3,5	60	75	-
	3	3	1	0	0	3	65	70	-
	Maximum	3	1	2	2	3,5			11,5
	Sum	6	2	2	2	6,5			
	Weighted sum of indicators 1-5	1,2	0,4	0,4	0,4	1,3			3,7
	Sum of percentiles						125	145	270
5	1	0	1	2	2	4	51	80	-
	2	0	0	0	0	0	-	-	-
	3	3	1	0	0	3	65	70	-
	Maximum	3	1	2	2	4	-	-	12
	Sum	3	2	2	2	7	-	-	-
	Weighted sum of indicators 1-5	0,6	0,4	0,4	0,4	1,4			3,2
	Sum of percentiles						116	150	266
6	1	0	1	2	2	4	51	80	-
	2	3	1	2	2	3,5	60	75	-
	3	0	0	0	0	0	-	-	-
	Maximum	3	1	2	2	4			12
	Sum	3	2	4	4	7,5			
	Weighted sum of indicators 1-5	0,6	0,4	0,8	0,8	1,5			4,1
	Sum of percentiles						111	155	266
7	1	0	1	2	2	4	51	80	-
	2	3	1	2	2	3,5	60	75	-
	3	3	1	0	0	3	65	70	-
	Maximum	3	1	2	2	4	-	-	12
	Sum	6	3	4	4	10,5	-	-	-
	Weighted sum of indicators 1-5	1,2	0,6	0,8	0,8	2,1	-	-	5,5
	Sum of percentiles						176	225	401

As a result, we conclude that the optimal solution to the problem when applying the first and second options for training candidates is the seventh option for forming a project team, which includes all candidates. The cost of training candidates in this case will be 3,000 conventional units (the value of the objective function (13)).

Of the three training options for candidates, the second option is the most optimal, with costs amounting to 1,000 conventional units.

If there is a restriction that the number of team members must not exceed two, the set of effective solutions will include the third and sixth team options, provided that the second training option is accepted. The third team option is slightly more preferable in terms of the personal qualities of the candidates, while the sixth option has higher competence indicators.

VI. CONCLUSIONS

The subjective formation of project teams has many drawbacks. It leads to insufficient competence of its members, inability to perform important roles, discomfort in working in a team, and low efficiency. One way to solve this problem is to use formalized approaches to forming project teams. Many well-known works in this area have focused on ensuring technical requirements for the product, organizing effective communication between team members, optimizing their workload, and minimizing hiring costs. A number of studies have shown that the ability to perform certain roles in a team is

important for the success of a project. The personal qualities of team members are of great importance. An analysis of existing works did not reveal any mathematical models that would take into account all of the above factors. In [15], a mathematical model for project team formation was proposed that took into account both the candidates' competence to meet the project requirements and their ability to perform nine roles according to R. M. Belbin. This model allows for the use of multiple assessments of a candidate's specific qualities. The model [15] is taken as the basis for our research. A target function is added to it, which aims to maximize the sum of the agreeableness and conscientiousness indicators of team members. These character traits are important for the effective work of an IT team, according to the conclusions of [17]. Clarifications are made to the approach [15] in terms of taking into account the ability to perform certain roles according to R. M. Belbin.

Candidates for an IT project team may not fully meet the requirements for their competencies. In this case, the formalized task of forming a project team has no solution. To solve this problem, the paper proposes using V. M. Glushkov's idea of systemic optimization [20], which consists in searching for the optimal extension of the permissible set of solutions. The paper proposes searching for the optimal solution to the task of team formation, taking into account the training of candidates. This possibility is included in the mathematical model of the task. The proposed task belongs to the class of multi-criteria Boolean programming tasks. To solve it, one of the known methods [23, 24] can be used, including the

application of Machine learning [25]. An example illustrating the application of the proposed approach is given.

The proposed mathematical model is characterized by high scalability, allowing for the inclusion of a significantly larger number of competencies and candidates than shown in the illustrative example. Future research will focus on the empirical validation of this model within large IT companies. For this purpose, the development of specialized software is underway, which will automate the calculation of the compliance coefficient $d_{jk}(\tilde{X}_{jk})$ and the selection of optimal training options for teams of any size.

References

- [1] F. Q. B. Da Silva, A. C. C. França, M. Suassuna, L. M. R. De Sousa Mariz, I. Rossiley, R. C. De Miranda, T. B. Gouveia, C. V. F. Monteiro, E. Lucena, E. S. F. Cardozo, E. Espindola, "Team building criteria in software projects: A mix-method replicated study," *Information & Software Technology*, vol. 55, issue 7, pp. 1316–1340, 2013. <https://doi.org/10.1016/j.infsof.2012.11.006>.
- [2] *Businesspedia. Team: Definition, Characteristics, Types, and Team Building*, 2025, [Online]. Available at: <https://businesspedia.in/team-definition-characteristics-types-and-team-building>.
- [3] G. Stavrou, P. Adamidis, J. Papatthanasiou, K. Tarabanis, "Team formation: A systematic literature review," *International Journal of Business Science and Applied Management*, vol. 18, issue 2, pp. 17–34, 2023. <https://doi.org/10.69864/ijbsam.18-2.174>.
- [4] P. Rostami, M. Neshati, "T-shaped grouping: Expert finding models to agile software teams retrieval," *Expert Systems with Applications*, vol. 118, pp. 231–245, 2018. <https://doi.org/10.1016/j.eswa.2018.10.015>.
- [5] I. Ivan, E. Budacu, M. Despa, "Using profiling to assemble an agile collaborative software development team made up of freelancers," *Procedia Computer Science*, vol. 162, pp. 562–570, 2019. <https://doi.org/10.1016/j.procs.2019.12.024>.
- [6] R. Colomo-Palacios, I. González-Carrasco, J. L. López-Cuadrado, A. García-Crespo, "ReSySTER: A hybrid recommender system for Scrum team roles based on fuzzy and rough sets," *International Journal of Applied Mathematics and Computer Science*, vol. 22, issue 4, pp. 801–816, 2012. <https://doi.org/10.2478/v10006-012-0059-9>.
- [7] M. K. Gürbüz, T. Çetinyokuş, "Competency and collaboration based project team selection: A systematic and methodological literature review," *Journal of Construction Engineering, Management & Innovation*, vol. 8, issue 3, pp. 209–235, 2025. <https://doi.org/10.31462/jcemi.2025.03209235>.
- [8] N. Berktaş, H. Yaman, "A branch-and-bound algorithm for team formation on social networks," *INFORMS Journal on Computing*, vol. 33, issue 3, pp. 1162–1176, 2021. <https://doi.org/10.1287/ijoc.2020.1000>.
- [9] K. Vombatkere, A. Gionis, E. Terzi, "Forming coordinated teams that balance task coverage and expert workload," *Data Mining and Knowledge Discovery*, vol. 39, issue 3, pp. 1–35, 2025. <https://doi.org/10.1007/s10618-025-01090-x>.
- [10] S. G. Ribeiro, A. A. S. Ivo, M. G. V. Ferreira, R. R. Silva, "SOHCO: A strategy for constructing efficient teams," *IEEE Access*, vol. 11, pp. 14575–14586, 2023. <https://doi.org/10.1109/ACCESS.2023.3243805>.
- [11] D. La Torre, C. Colapinto, I. Drosini, S. Triberti, "Team formation for human-artificial intelligence collaboration in the workplace: A goal programming model to foster organizational change," *IEEE Transactions on Engineering Management*, vol. 70, no. 5, pp. 1966–1976, 2023. <https://doi.org/10.1109/TEM.2021.3077195>.
- [12] S. J. Kalayathankal, J. V. Kureethara, S. Narayanamoorthy, "A modified fuzzy approach to project team selection," *Soft Computing Letters*, vol. 3, 2021. <https://doi.org/10.1016/j.socel.2021.100012>.
- [13] R. H. Rad, H. Fani, E. Bagheri, M. Kargar, D. Srivastava, J. Szlichta, "A variational neural architecture for skill-based team formation," *ACM Transactions on Information Systems*, vol. 42, issue 1, pp. 1–28, 2023. <https://doi.org/10.1145/3589762>.
- [14] I. Kononenko, H. Sushko, I. Babayev, R. Abdullayev, "Solving the problem of ranking applicants for a project team with fuzzy assessment of competencies and requirements," *Radioelectronic and Computer Systems*, vol. 2024, issue 2, pp. 230–243, 2024. <https://doi.org/10.32620/reks.2024.2.18>.
- [15] I. Kononenko, O. Kononenko, I. Babayev, R. Abdullayev, "Formalising the formation of project teams considering alternative competence assessments under uncertainty," *Radioelectronic and Computer Systems*, vol. 2025, issue 2, pp. 253–263, 2025. <https://doi.org/10.32620/reks.2025.2.16>.
- [16] D. W. Fiske, "Consistency of the factorial structures of personality ratings from different sources," *The Journal of Abnormal and Social Psychology*, vol. 44, issue 3, pp. 329–344, 1949. <https://doi.org/10.1037/h0057198>.
- [17] M. A. G. Peeters, H. F. J. M. van Tuijl, C. G. Rutte, I. M. M. J. Reymen, "Personality and team performance: a meta-analysis," *European Journal of Personality*, vol. 20, issue 5, pp. 377–396, 2006. <https://doi.org/10.1002/per.588>.
- [18] J. Vasiljević, D. Lavbič, "A data-driven approach to team formation in software engineering based on personality traits," *Electronics*, vol. 13, issue 1, pp. 178, pp. 1–17, 2024. <https://doi.org/10.3390/electronics13010178>.
- [19] T. A. O'Neill, N. J. Allen, "Personality and the prediction of team performance," *European Journal of Personality*, vol. 25, issue 1, pp. 31–42, 2011. <https://doi.org/10.1002/per.769>.
- [20] V. M. Glushkov, "On system optimisation," *Cybernetics*, issue 5, pp. 89–90, 1980. <https://doi.org/10.1007/BF01078504>. (in Russian)
- [21] *Open-Source Psychometrics Project*, 2025, [Online]. Available at: <https://openpsychometrics.org>.
- [22] R. M. Belbin, *Management Teams*, third ed., Routledge, London, 2010, 204 p. <https://doi.org/10.4324/978080963594>
- [23] J. Papatthanasiou, N. Ploskas, *Multiple Criteria Decision Aid. Methods, Examples and Python Implementations*, Springer Cham, 2018. 173 p. <https://doi.org/10.1007/978-3-319-91648-4>.
- [24] M. Ehr Gott, M. Köksalan, M. Kadziński, K. Deb, "Fifty years of multi-objective optimization and decision-making: From mathematical programming to evolutionary computation," *European Journal of Operational Research*, vol. 330, issue 1, pp. 1–25, 2025. <https://doi.org/10.1016/j.ejor.2025.06.012>.
- [25] M. Karimi-Mamaghan, M. Mohammadi, P. Meyer, A. M. Karimi-Mamaghan, E. Talbi, "Machine learning at the service of meta-heuristics for solving combinatorial optimization problems: A state-of-the-art," *European Journal of Operational Research*, vol. 296, issue 2, pp. 393–422, 2022. <https://doi.org/10.1016/j.ejor.2021.04.032>.



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