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Method of allocation of labor resources for IT project based on expert assessments of Delphi

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Abstract— An essential component of the development and implementation of information systems is a clear definition of the project team, which is formed from possible options of company employees or freelancers in conditions of limited company resources. Based on the method of expert evaluation of Delphi, a study of qualifications and characteristics that are crucial for the implementation of project work on the development and implementation of IT projects, the level of significance of each parameter on the impact of the complex project is assessed, they are ranked according to the degree of importance for the project implementation; the critical parameters that entail the most significant project risks are identified. The importance of the selection of employees in the project team with certain levels of competence following the qualifications for the role performed and the appointment of responsible executors for project work according to their compliance is substantiated; the value of the qualification rank for different employees is taken into account in determining the type of work for which it will be assigned for the optimal distribution of all project work. The scientific novelty is to substantiate and evaluate the comparative importance of factors that limit the appointment of each developer to perform design work using the method of group expert evaluation of Delphi.

Keywords—*project, expert assessments, ranking, project risks, concordance coefficient, rank of assessments*

I. INTRODUCTION

In the conditions of modern society, the importance of effective management of both socio-political and production processes is becoming increasingly important. The growing complexity of projects, on the one hand, and the accumulated management experience, on the other

hand, have made it necessary and possible to create an ideology and methodology for project management. Among the prerequisites for the growth of the national economy, an important role is played by the formation of a new generation of managers of knowledge and skills to use a modern project approach to solving problems of management processes at different levels, focusing on these processes project management as a new progressive toolkit in the field of management.

System errors during project development are multiplied and passed from project to project. Typical errors include:

- insufficient analysis of the problem; lack of description of stakeholders;
- weak development and imperfect structuring of the project goal;
- attempts to solve many different goals in one project;
- lack of correlation between project objectives, potential benefits, and problems;
- need for indicators to assess project progress, ignoring assumptions and risks.

Therefore, the study and improvement of methods and tools of project management, namely the selection of personnel for the development and implementation of projects, is an urgent scientific task.

An essential problem of project management in the information systems implementation field is staff selection and involvement [1,2]. Experts with extensive experience are in high demand, but attracting them requires quite a lot of money, which leads to an increase in the cost of the whole project. Beginners are less paid, but for their

development, gaining experience that is possible when involved in project work is necessary. According to the specification of each project, it is essential to determine the parameters, and competencies specialists who can be involved in the project should have to compare the relevant assessments to be able to include specialists of different levels in relevant work [3,4]. Therefore, to involve staff, it is necessary to conduct research on their professional competence and other factors that require thorough analysis (responsibility, teamwork, ability to make independent decisions, etc.) [5]. Appropriate ranking of software development specialists will be based on the method of Delphi expert assessments [6,7].

The project manager appoints staff to carry out project work [8,9]. The quality, cost, and duration of realization of each work and the project as a whole depend on this decision [10]. Therefore, it is necessary to apply techniques to identify and reduce the risk of management decisions when appointing staff [11]. The Delphi method, as a method of scientific research, will highlight those criteria in the selection of personnel that directly depend on each employee, both within his role and the impact of these factors on the implementation of tasks throughout the project.

At the same time, these works need to fully reflect the issues of methodological analysis of the factors determining the competence of employees of IT companies in software development. Based on the above, the study of factors determining the competence of employees of IT companies in software development is an urgent scientific task.

The purpose of the article is to analyze the factors determining the competence of IT companies in software development and, based on the expert evaluation method of Delphi, to develop a model for appointing employees to project work.

II. PRESENTATION OF THE MAIN MATERIAL OF THE RESEARCH

When modeling business processes, much attention is paid to the performers of individual elements of the model - functions/tasks. After all, the quality of starting a business process and its implementation in the described activities depends on the correct distribution and establishment of relationships between the roles. Therefore, when describing specific tasks, it is necessary to determine the executor and the supporting roles for each process action and the overall result achieved.

The need for high-quality IT products is proliferating. If it took months and even years to implement an information system development and implementation project earlier, business requires fast and high-quality results. That is why there is a question of appointment to the design work of personnel with appropriate qualifications and characteristics. It should also be borne in mind that one employee can not perform all the work of the project, even if he has the highest qualifications and competencies, so you need to create conditions for objective assessment and involvement of all project team members to work depending on their competence and job requirements, to which they will be appointed executors.

Heuristic methods based on expert assessments [12,13] and taking into account the qualification parameters of each member of the project team, taking into account [14,15], can be used for such distributions of workers' assignments:

- lack of sufficient, objective, and reliable information about the complexity of the task for which the executor is assigned;
- a certain uncertainty of a particular task and its impact on the overall outcome of the project;
- a conceptually new task that was not previously performed within the project activities;
- time constraints imposed on the performance of a specific task within the sequence of related project work;
- current parameters of competence and personal characteristics of performers [16].

The Delphi method, which belongs to the heuristic methods, will provide an opportunity to assess based on known parameters of staff qualifications with a sufficient level of reliability: the ability to perform a specific task and the project as a whole; time to complete a particular job; selecting the best employee for the project from alternative options.

To make decisions on the distribution, it is necessary to enter the qualifications of staff for all factors that need to be considered in determining the competencies and capabilities of a particular task. This qualification is assigned on a 100-point scale, where the employee's stuff for each criterion follows the available knowledge, skills, expertise, and competence. By determining such indicators, the processing of Delphi results in the assignment will correspond to the values available at the time of distribution. Such a division can be made in several iterations when the traditional values of staff involvement in the work do not meet the limit on the workload of a particular employee concerning the set of tasks of the project team [17], and taking into account the expert opinion of the project manager.

Each project team is selected following the conditions: complexity, timing, budget, industry, subject area, direction, type of work, etc. [18,19]. When selecting a project team, the manager may also involve external resources, freelancers, or contractors.

In the first stage, it is necessary to evaluate each team member [20, 21]. Employee evaluation can be presented in the form of a matrix; the rows indicate the qualification parameters, and the columns are the requirements for the worker's theoretical knowledge and practical experience. For each qualification requirement, such a matrix contains its competencies. When evaluating staff, you need to form and fill in the matrix data per the selected position. In particular, for the competence "System design. Software design" [22, 23] include:

1. Design of system architecture. Identification of system elements that meet the specified requirements for system architecture.
2. Specification of the system architecture representation. Distribution of requirements by elements of the system.

3. Decomposition of the system into constituent elements. Definition of internal and external interfaces of system elements.

4. Identification of components of hardware, software, and manual operations in system architecture.

5. Development and debugging program code at modules and databases level.

6. Perform verification between system requirements and system architecture - development and debugging testing procedures for each software module.

7. Analysis and optimization of software code and testing procedures using appropriate tools.

8. Maintaining consistency between system requirements and the system's architectural design.

9. Interaction with the project development team during project implementation.

The more knowledge and experience an employee has, the higher the marks in the competence matrix. The general level of competence in a particular area is defined as a fraction of full compliance with these points.

It is essential that for each type of work, each competence has its weighting factor, as different jobs require special qualifications. The appropriate level of qualification for each job is formed based on the qualification matrix and rank data, which qualifies a specific type of work for which the relevant executors should be assigned.

Therefore, the next step is to turn the qualification matrix into a rank matrix.

The ranking is the placement of the required skills in ascending (or descending) order following the requirements of the project and the work performed on it. In turn, the number of ranked factors corresponds to the number of criteria by which the assessment of employee qualifications, this value will be equal to k . The evaluation criteria will range from 1 - the most important criterion, to k - the least important. If some ranks have the same level of weight to perform a certain type of work on the project, then standardized ranks are assigned to them [6].

So to assign employees to the project, we have their number w , respectively, each employee receives his serial number from 1 to w . Each employee has their own qualification levels according to each of the k criteria. When assessing competence, we determine the number of employees who have the appropriate criterion w_j . E_{ij} - an estimate of the relative weight of the employee i by qualification j ; R_{ij} - rank formed by the j -th qualification for the i -th employee.

Let's form a system of statistical indicators, based on certain purposes:

- for average indicators of qualification criteria:

$$S_j = \frac{\sum_{i=1}^w E_{ij}}{W_j} \quad (1)$$

- for intermediate qualification ranks:

$$\bar{Q}_j = \frac{\sum_{i=1}^w R_{ij}}{w} \quad (2)$$

- qualification coefficient of project group participants:

$$K_j = \frac{w_j}{w} \quad (3)$$

Since each member of the project team may have different levels of qualifications, for different criteria it is necessary to determine the scope of qualifications in points.

$$L_j = F_{j \max} - F_{j \min} \quad (4)$$

where L_j - the scope of the j -th criterion of qualification of employees;

$F_{j \max}, F_{j \min}$ - respectively, the maximum and minimum value of the assessment of qualifications of employees according to the j -th criterion.

When appointing employees for project work, it is necessary to consider not only the absolute and average values of the competence of each project team member but also the relative values and their average weight. To do this, perform a rationing of the importance of qualification indicators of each working group member and calculate the weighted average values.

$$N_j = \frac{\sum_{i=1}^w N_{ij}}{\sum_{j=1}^k \sum_{i=1}^w N_{ij}} \quad (5)$$

$$N_i = \frac{F_{ij}}{\sum_{j=1}^k F_{ij}} \quad (6)$$

When using the Delphi method, it is necessary to assess the degree of consistency in the appointment of each project team member for a particular type of work. Such character can be determined both for the whole project team based on concordance coefficients and for individual pairs of employees who can be assigned to a specific job according to the coefficient of pair rank correlation.

According to the agreed assessment of the employee's professionalism, we calculate the concordance coefficient according to the formula:

$$K_{kon} = \frac{\sum_{j=1}^w (Q_j - \frac{\sum_{j=1}^w Q_j}{w})^2}{\frac{1}{l} \left[w^2 (k^3 - k) - w \sum_{i=1}^w \sum_{j=1}^l (h_j^2 - h_j) \right]} \quad (7)$$

Where h - the number of related qualifications in the relevant competence;

l - number of project teams in the team.

The concordance coefficient varies within $0 \leq K_{kon} \leq 1$. The higher the value of the concordance coefficient, the greater the qualification and compliance with the task has the appropriate employee. The statistical value of the concordance coefficient in accordance with the set of characteristics and functional parameters of the project team member is solved by the Pearson consistency criterion χ^2_p [24].

$$\chi_j^2 = \frac{\sum_{j=1}^w (Q_j - \frac{\sum_{j=1}^w Q_j}{w})^2}{\frac{1}{l} \left[wl(w+1) - \frac{1}{l-1} \sum_{i=1}^w (t_i^3 - t_i) \right]} \quad (8)$$

where t_l – the number of employees participating in different project teams.

The calculated value of χ^2_p is compared with the tabular values of χ^2_τ for $l - 1$ degrees of freedom of project teams and levels of importance, we take the value of 0.9.

For each functional task it is necessary to compare the tabular value of the requirements for the tasks and the calculated value of f .

After analyzing the possibilities of ranking and determining the values of competencies, we determine the list of qualification criteria that must be met by the employee "Software Development Specialist" in accordance with ISO / IEC 15288: 2008, ISO / IEC 12207: 2008, descriptors e-CF areas of ICT competencies [22] (table I).

TABLE I. LIST OF REQUIRED SKILLS OF WORKERS

№	Competences to perform work on the implementation of CRM system	№	Competences to perform work on the implementation of CRM system
1	Design and development	15	Development of forecasts
2	Development of business plans	16	Relationship management
3	Process improvement	17	IC quality management
4	Customer support	18	Architecture design
5	Organization of training	19	Ensuring the procurement process
6	Staff training	20	Deploying solutions
7	Coordination of IC and business strategy	21	Information and knowledge management
8	Development of documentation	22	Development of IC quality assurance strategy
9	Systems integration	23	Change management
10	Testing	24	Service level management
11	Contract management	25	Problem management
12	Development of information security strategy	26	Implementation of technologies
13	Application development	27	Risk management
14	Information security management	28	Support for change

Each qualification requirement for the project team members forms a direct relationship with the relevant qualifications of the project team members.

The table of employee qualifications is formed based on performance indicators of each project team member on already completed projects. This qualification level

may also include the opinion of experts who are project managers [1].

The qualification assessment matrix is formed based on indicators of the quality and efficiency of a specific task by each employee. The initial values of the matrix are created based on the results of employee evaluation after the probationary period and change during the certification of personnel, which is performed as part of periodic inspections and the closure of each project in which the contractor participated. The main requirements for forming the value of qualifications are the parameters of planned and actual performance indicators of the tasks assigned to the executor. With a negative result, when the deadlines go beyond the targets (which also include time for verification, validation, and testing, return to debugging, and selection of subtasks), the level of qualification may decrease with a quality result of the completion of tasks - the stuff of the performer increases.

Table II presents the qualifications of the project team of 15 members involved in the development and implementation of CRM system.

TABLE II. QUALIFICATION ASSESSMENT MATRIX OF PROJECT TEAM MEMBERS

Qualification (sequence according to table. 1)	Project team members														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	45	90	90	60	20	35	0	95	65	95	70	65	85	70	50
2	5	65	35	35	35	90	75	15	35	5	0	75	0	65	5
3	35	55	50	40	90	50	60	45	80	65	15	15	25	95	0
4	10	35	85	80	25	30	65	5	50	40	80	80	45	15	10
5	55	55	45	70	0	20	30	40	5	100	50	5	60	70	25
6	85	50	40	100	35	55	65	30	30	25	85	75	70	85	50
7	15	20	60	95	25	60	0	90	90	70	0	35	95	70	15
8	20	15	60	75	5	15	10	55	95	25	100	30	40	5	75
9	25	95	50	10	30	100	65	40	65	45	60	15	95	75	65
10	55	50	25	0	65	65	50	10	100	55	35	45	35	35	85
11	20	50	10	75	70	30	10	40	5	80	50	85	15	0	50
12	80	35	55	90	85	55	50	100	5	60	20	95	70	55	15
13	5	60	10	5	95	20	50	60	60	45	55	45	85	30	35
14	30	5	15	0	10	75	70	60	25	85	55	20	85	30	30
15	45	45	85	35	35	50	40	65	75	20	5	30	50	30	10
16	10	15	20	30	45	60	90	85	90	5	45	80	15	50	15
17	95	90	60	15	15	45	75	50	30	90	5	30	25	65	0
18	85	10	70	35	10	100	70	65	95	0	50	50	65	90	35
19	70	25	80	85	90	25	100	0	90	55	25	30	85	55	60
20	85	70	55	70	85	85	20	65	95	90	15	100	35	0	25
21	55	35	20	30	95	65	65	70	0	25	85	75	15	5	95
22	80	60	45	55	60	100	75	15	40	55	85	50	85	35	50
23	20	40	0	45	65	55	30	30	90	60	100	50	95	40	55
24	15	35	90	80	75	70	85	75	5	0	10	45	90	35	65
25	75	35	25	100	40	45	45	95	15	0	10	85	50	40	25
26	25	0	85	45	95	60	85	65	60	90	85	0	65	25	0
27	50	10	30	60	30	40	45	25	40	85	40	95	0	40	45
28	85	60	30	100	60	10	35	100	90	45	35	95	95	90	15

According to the qualification assessment matrix of the project team members, we will rank qualification

assessments. Given the parameter that we consider the qualification criterion's importance in ranking, the list of qualification requirements is arranged in descending order where 1 is the essential qualification required for project implementation, and 28 - is the least important. This order of qualification levels is formed within the company or project teams based on project implementation indicators and results, the proportions of the number of tasks on the project that require the appropriate level of qualification, and the research of project team members. To calculate the relative weight of each qualification criterion, we take into account the staff of this project team member, which will ensure the possibility of fulfilling appointments for project work in accordance with the requirements. Rank rankings of qualifications will be entered in table III.

TABLE III. MATRIX OF QUALIFICATION ASSESSMENT RANKS

Qualification (sequence according to table. 1)	Project team members														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	7,0	2,5	2,5	5,5	9,5	8,0	12,5	2,0	5,0	2,0	4,5	5,0	3,0	4,5	6,5
2	12,0	5,0	8,0	8,0	8,0	2,5	4,0	10,0	8,0	12,0	12,5	4,0	12,5	5,0	12,0
3	8,0	6,0	6,5	7,5	2,5	6,5	5,5	7,0	3,5	5,0	10,0	10,0	9,0	2,0	12,5
4	11,0	8,0	3,0	3,5	9,0	8,5	5,0	12,0	6,5	7,5	3,5	3,5	7,0	10,0	11,0
5	6,0	6,0	7,0	4,5	12,5	9,5	8,5	7,5	12,0	1,0	6,5	12,0	5,5	4,5	9,0
6	3,0	6,5	7,5	1,0	8,0	6,0	5,0	8,5	8,5	9,0	3,0	4,0	4,5	3,0	6,5
7	10,0	9,5	5,5	2,0	9,0	5,5	12,5	2,5	2,5	4,5	12,5	8,0	2,0	4,5	10,0
8	9,5	10,0	5,5	4,0	12,0	10,0	11,0	6,0	2,0	9,0	1,0	8,5	7,5	12,0	4,0
9	9,0	2,0	6,5	11,0	8,5	1,0	5,0	7,5	5,0	7,0	5,5	10,0	2,0	4,0	5,0
10	6,0	6,5	9,0	12,5	5,0	5,0	6,5	11,0	1,0	6,0	8,0	7,0	8,0	8,0	3,0
11	9,5	6,5	11,0	4,0	4,5	8,5	11,0	7,5	12,0	3,5	6,5	3,0	10,0	12,5	6,5
12	3,5	8,0	6,0	2,5	3,0	6,0	6,5	1,0	12,0	5,5	9,5	2,0	4,5	6,0	10,0
13	12,0	5,5	11,0	12,0	2,0	9,5	6,5	5,5	5,5	7,0	6,0	7,0	3,0	8,5	8,0
14	8,5	12,0	10,0	12,5	11,0	4,0	4,5	5,5	9,0	3,0	6,0	9,5	3,0	8,5	8,5
15	7,0	7,0	3,0	8,0	8,0	6,5	7,5	5,0	4,0	9,5	12,0	8,5	6,5	8,5	11,0
16	11,0	10,0	9,5	8,5	7,0	5,5	2,5	3,0	2,5	12,0	7,0	3,5	10,0	6,5	10,0
17	2,0	2,5	5,5	10,0	10,0	7,0	4,0	6,5	8,5	2,5	12,0	8,5	9,0	5,0	12,5
18	3,0	11,0	4,5	8,0	11,0	1,0	4,5	5,0	2,0	12,5	6,5	6,5	5,0	2,5	8,0
19	4,5	9,0	3,5	3,0	2,5	9,0	1,0	12,5	2,5	6,0	9,0	8,5	3,0	6,0	5,5
20	3,0	4,5	6,0	4,5	3,0	3,0	9,5	5,0	2,0	2,5	10,0	1,0	8,0	12,5	9,0
21	6,0	8,0	9,5	8,5	2,0	5,0	5,0	4,5	12,5	9,0	3,0	4,0	10,0	12,0	2,0
22	3,5	5,5	7,0	6,0	5,5	1,0	4,0	10,0	7,5	6,0	3,0	6,5	3,0	8,0	6,5
23	9,5	7,5	12,5	7,0	5,0	6,0	8,5	8,5	2,5	5,5	1,0	6,5	2,0	7,5	6,0
24	10,0	8,0	2,5	3,5	4,0	4,5	3,0	4,0	12,0	12,5	11,0	7,0	2,5	8,0	5,0
25	4,0	8,0	9,0	1,0	7,5	7,0	7,0	2,0	10,0	12,5	11,0	3,0	6,5	7,5	9,0
26	9,0	12,5	3,0	7,0	2,0	5,5	3,0	5,0	5,5	2,5	3,0	12,5	5,0	9,0	12,5
27	6,5	11,0	8,5	5,5	8,5	7,5	7,0	9,0	7,5	3,0	7,5	2,0	12,5	7,5	7,0
28	3,0	5,5	8,5	1,0	5,5	11,0	8,0	1,0	2,5	7,0	8,0	2,0	2,0	2,5	10,0

Based on the data presented in tables 2 and 3, we perform calculations of statistical characteristics of qualification parameters of labor resources.

The calculation for decision-making on the level of qualifications of the company's employees is performed according to the concordance coefficient K_{kon} (7), taking into account the importance of each individual employee in the project team by Pearson's test χ^2_p , determined by formula (8).

Since each member of the project team can participate in several projects, to determine the degree of coherence, it is necessary to take into account the number of contractors involved in the implementation of projects. For the practical work of each participant, this number can not exceed 2 - for complex projects and 4 for simple IT solutions, which are mainly focused on integrating the finished solution in the customer company. Accordingly, if a project team member participates in 3 projects, then $l = 3$. Therefore, we consider the level of competence of employees who have specific competence and can be involved in implementing project work. This number is calculated by standard calculation of the number of qualification values that are greater than or equal to the requirements for the project task. And according to the coefficient of pair rank correlation, we determine the possibility of involving a specific executor in the project work. In such calculations, the main requirement for the appointment of the contractor for project work is the full involvement of each project team member in the project tasks, which provides the ability to monitor the project conditions and deviations.

We calculate the values for the 15 members of the company, between which you want to perform the distribution, with a uniform load of functional tasks between the members of the project team. For example, for the first employee, the concordance coefficient $K_{kon} = 0.0954$, χ^2_p (estimated) = 8.764 for the tabular value χ^2_τ for $w = 15$ and the probability $P = 0.9$ is 8.547 [24]. Therefore, $\chi^2_p > \chi^2_\tau$, which means a significant positive impact of the selected employee when choosing a project team, taking into account the peculiarities of functional tasks on the project.

When ranking factors based on the Delphi method, it is necessary to assess how each of the presented employees will be of the highest quality in the performance of tasks following the project plan, which takes into account all 28 functional positions of the tasks. To do this, successive searches of each employee will determine the concordance coefficients and enter the values in table IV.

TABLE IV. CONCORDANCE COEFFICIENT OBTAINED ON THE BASIS OF CONSISTENT SELECTION OF THE EMPLOYEE IN THE PROJECT TEAM

Member of the project team	Consequence	
	Concordance coefficient K_{kon}	Significance of the concordance coefficient χ^2_p
1	0,0954	8,833
2	0,0652	8,233
3	0,0412	8,767
4	0,0838	8,267
5	0,0559	7,467
6	0,0744	8,6
7	0,0646	8,7
8	0,0937	8,967
9	0,0512	7,933
10	0,0737	8,833
11	0,0732	8,767
12	0,0671	8,733
13	0,0675	7,267
14	0,0642	7,987
15	0,0939	8,667

According to the data in table IV, perform a visual representation of the calculations.

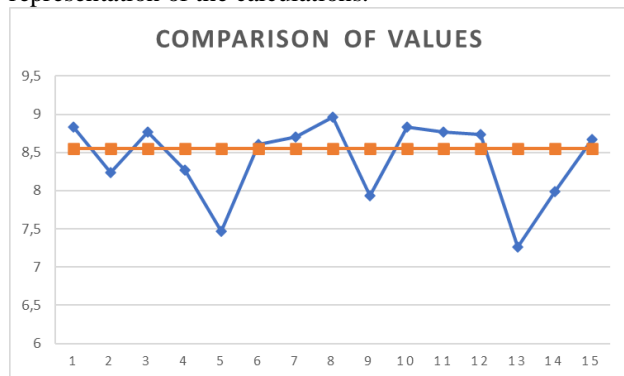


Figure 1. Significance of project team members selection

To assess the relatively important functions of design work, the calculation is based on the average weight of this function, with a higher value of importance - more essential tasks within the project [25]. Accordingly, considering the rank of evaluations, decisions are made regarding the executors and their assignment to project functions within the project team. To do this, you need to make an informed decision about which tasks will be performed by which specialist, as employees in the project team may be qualified in different categories and can perform various tasks, so you need to choose a specific task for the executor the performer who will meet the specified parameters of the requirements for the task, at the same time, this appointment will be optimal in terms of assignments to other tasks of this and other members of the project team [26]. Accordingly, to address this issue, it is necessary to develop a matrix of benefits when a particular executor's involvement in project tasks gives a more favorable result than the involvement of another executor, taking into account all project work.

III. CONCLUSIONS

According to the analysis results, the relevance of the use of expert methods for the distribution of functional tasks of project work among the project team members is proved. The ranking of parameters and qualifications of labor resources - members of project teams. The peculiarity of the presented work is the use of a mathematical model that considers the importance of each staff for the overall project implementation, reducing stakeholders' subjectivity. Carrying out calculations at the planning stage of project teams from the company's employees will allow the selection of those members who will close the issue of solving project problems at the appropriate level, following the qualification requirements, when monitoring the effectiveness of the project team during the project, based on the analysis of the involvement of contractors, the visualization of representations of redundancy or insufficiency of contractors with a certain level of qualification, which affects the progress of the project. Such calculations allow the manager to change the project team and derive or involve executors of specific qualifications to increase the efficiency of project tasks. This issue is especially relevant in implementing projects

according to flexible methodologies when you need to respond quickly to changes in the project. The quality of research depends on the completeness of the factors that determine the conditions of project implementation, the ratio of functional tasks, and the qualifications of performers. The scientific novelty is to substantiate and evaluate the comparative importance of factors that limit the appointment of each developer to perform design work using the method of group expert evaluation of Delphi.

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