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Conceptual Framework of Sustainable Management of the Process of Forming a Project Team with Functional Redundancy

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Abstract: The paper examines the impact of the COVID-19 pandemic on human resource management processes in project-oriented companies. It is proposed to use formal transformations on groups of performers. The use of formal transformations will reduce the influence of the subjective factor and improve the quality of sustainability management decisions made when forming a project team. The formalization of the selection process of applicants and the distribution of work among the performers have been considered. The existing methods of forming a project team with functional redundancy are approximate. Methodological support for the process of forming a project team with functional redundancy, based on a logical-combinatorial approach, and allowing to form project teams under given constraints, is proposed. A method of forming a functionally redundant project team based on formal transformations of groups of performers has been developed. The use of the apparatus of symbolic sequences for the formation of a project team with functional redundancy is proposed. An example of using the proposed method when forming a command with functional redundancy is considered. It is shown that the use of this methodological support makes it possible to select the composition of the project team with the minimum number and the minimum value of the characteristic.

Keywords: project management; human resource management; building a project team; functional redundancy; formal transformations; sustainability management

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1. Introduction

Changes in the conditions for the functioning of project teams caused by the pandemic showed the unpreparedness of project-oriented companies to quickly adapt project management mechanisms in a multi-project environment and the need to introduce new approaches to management.

Adapting the design approach to the unique characteristics of the project and its environment increases the likelihood of successful project execution under given constraints.

According to the *Pulse of the Profession* 2021 report [1,2], one of the most significant changes that have occurred over the past year, along with digital transformation and the application of business strategies, is the formation and development of organizational adaptability.

The need to take into account the changes occurring during "Stewardship outside the organization" ensures the sustainability of the project-oriented company and sustainable

entrepreneurship [3]. "Create a collaborative project team environment" and "Embrace Adaptability and Resiliency" are some of the basic principles required to ensure effective project management in accordance with *The Standard for Project Management* (seventh edition) [3].

The need to apply formalized approaches to human resource management to ensure the reliability of the project team's functioning is noted in the PMI standards both at the project portfolio level [4] and at the program level [5].

During the 2020–2021 COVID-19 crisis, sustainability has become a business priority. There has been a transition from talent management to the selection of multifunctional team members (Full Stack) and the formation of intact teams. According to the Hays' recruiting company, 27% of companies that implemented business in 2020–2021 faced the need to reduce staff. If, before the pandemic, the formation of teams without a strict limitation on the number of team members was characteristic, the attraction of high-quality performers (A-Players) was observed, which led to the formation of teams that are "redundant" in terms of the functional principle, then during a pandemic, the need to reduce costs on personnel while tightening the requirements for ensuring sustainable project management, which leads to the need to create a functionally redundant adaptive project team [6]. According to [7], the COVID-19 pandemic is negatively affecting the financial performance of small and medium-sized enterprises in Europe. The investigation of more than 5800 small businesses in the USA provided in [8] shows that, due to the pandemic, mass layoffs and closings have already occurred, and the risk of closings is negatively related to the expected duration of the crisis.

Thus, the problem to be solved is the need to improve the sustainability of project and program management in a multi-project environment while reducing the cost of resource management.

The aim of this paper is to develop a conceptual framework of sustainable management of human resources, forming a project team with functional redundancy based on a logical-combinatorial approach and allowing managing project human resources under given constraints.

The further structure of the paper is as follows: Section 2, namely current research analysis, provides an overview of up-to-date research connected with the paper. Section 3, Materials and Methods, proposes the scientific hypotheses and tasks, which are going to be solved in the given paper. Section 4 describes the results obtained within the research. The conceptual framework of the logical-combinatorial method for constructing formal models of the sustainable management of the team is proposed, the method of forming a functionally redundant project team is developed, the processes of data collection and processing are described. The analysis of options for distributing applicants by functionally redundant teams is provided. Section 5 discusses the obtained results. The conclusions section describes the outcomes, limitations of the study, and future research.

2. Current Research Analysis

The development of effective methods of human resource management is an urgent task that requires the synthesis of resources of individual projects within the framework of existing constraints in a multi-project environment. Theoretical and applied issues of human resource management of projects implemented in companies are reflected in the works of domestic [9,10] and foreign authors [11–13]. The recommendations given by the National Competence Baseline, NCB Version 4.0 [9] reflect the need for certain competencies but do not take into account the level of competencies and the criticality of these competencies for the portfolio project at a certain point in time, which is important when managing projects in a multi-project environment.

As noted in the PMI PMBoK [3] standard, among the factors that allow achieving a synergistic effect when forming a team are:

- team agreements;

- organizational structures;
- processes.

V.M. Molokanova's paper [10] provides an analysis of the synergistic aspects of adaptation of an organization to a change in the external environment through a portfolio of projects, considers the impact of complication of adaptation processes to changes in the external environment of a project on the viability of a company, introduces coefficients of adaptability and synergy that can be used to assess the effectiveness of transformation of processes human resource management and Sustainability management.

According to the definition given by Patanakul P., Milosevic D. [11], multi-project management is the management of a group of projects, programs, project portfolios carried out by one or more organizations in the region in a certain period to achieve the strategic goals of the industry or a certain circle of stakeholders. This approach to multi-project management made it possible to identify the characteristic features of multi-project management, which must be taken into account when ensuring the formation and functioning of adaptive project teams: the presence of a certain circle of stakeholders; availability of a pool of resources; the need to ensure the management of critical competencies; specific requirements for resource management; attracting performers to several projects. Most companies, when assessing management efficiency in a multi-project environment, take into account only cost indicators. In the studies of Patanakul P., Milosevic D. [11], it is proposed to use the structure of project management efficiency in a multi-project environment. The application of measurement criteria to assess the effectiveness in managing a group of multiple projects will allow evaluating the effectiveness of the proposed methods according to the criteria: assignment in the project, allocation of resources (resource endowment, resource persistence), organizational culture for the organizational level, project management processes, competence of managers in a multi-project environment for the operational level, organization, project, personnel.

D.A. Novikov, M.V. Belov, V.N. Burkov, and N.A. Korgin [12–14] suggest considering the formation of a project team as a synthesis of a game with a variable composition. Since when managing projects in a multi-project environment, the requirements for the resources included in the multi-project pool may differ depending on the specifics of the project and the tasks to be solved, it is advisable to consider them as heterogeneous resources. Amol Singh [15], F. Li, Z. Xu, H. Li [16], R. Hoda, L. K. Murugesan [17], W. Song, H. Xi, D. Kang, J. Zhang [18] note the need to take into account the environment of the project when choosing a centralized or decentralized scenario to sustainability management.

The proposed method of forming a functional-redundant adaptive project team will be based on the need to take into account the specifics of the project, the implementation environment, and the management style.

The COVID-19 pandemic has highlighted the relevance of studying the impact of emotional intelligence and empathy on the effectiveness of interaction in a project team during a crisis. S. Bushuyev, I. Babayev, D. Bushuiev, N. Bushuyeva, J. Babayev, N. Ruslan [19–21] showed that during a pandemic, team members have an additional information load, which leads to the need to take into account the requirements for resilience when forming project teams. When organizing the functioning of a team in a period of instability, the issues of resilience and adaptability are of particular importance, since their presence ensures the fulfillment of the assigned project tasks under the given constraints under the influence of infodemic and pandemic.

To increase the viability of the team in the security-oriented system, a model for the formation of information systems is proposed [22]. When defining a project management system, we have to consider the system stiffness options. The introduction of rigid project management systems that ensure the management of critical competencies is advisable in projects with high costs of error (nuclear industry, military industry, industry 4.0, energy management, etc.) [23,24]. M. Jennex, S. Zyngier [25], V. Kharchenko [26,27] highlight the specifics of the implementation of critical infrastructure projects under certain resource and time constraints in a multi-project environment in an unstable project environment with a

high information load puts forward certain requirements for resource management processes: adaptability, availability of teams, limitation of personnel involvement, functional redundancy, management of critical competencies. D. Steinbrecher [28,29] emphasizes that for enterprises of the machine-building and aerospace industries, when implementing projects in the field of national security and defense, there is a high risk of losing critical knowledge due to the influence of the human factor and when using ineffective management method resources. Thus, the applied problem of ensuring the management of critical competencies in the formation and functioning of teams in a multi-project environment by means of functionally redundant project teams is relevant.

One of the ways to improve the efficiency of the team's functioning is to reduce the burden on management personnel through the use of a decision support system. The use of specialized information systems that integrate various aspects of the functioning of the project team provides monitoring and management of critical knowledge in the organization, taking into account the specifics of the projects being implemented. However, methods proposed by O. Zachko, D. Kobylkin, O. Kovalchuk, V. Markov [30], M.C.M. Banaria, E.J.W. Ang, W.P. Majan, G. Ng [31] are not intended to solve the problem of the functionally redundant project team. The formation and development of human resources competencies in a multi-project environment is a complex multi-criteria task that requires special approaches to its solution [32,33]. Existing methods discussed in papers by V. Cavalcante, C. Cardonha, R.A. Herrmann [34], L. Shuai, Z. Zhicong, Y. Xiaohui, H. Kaishun, Z. Shaoyong [35], W. Song, H Xi, D. Kang, J. Zhan [18], J.L. Ponz-Tienda, V. Yepes, E. Pellicer, J. Moreno-Flores [36] address the Resource-Constrained Project Scheduling Problem (RCPSP) and Resource-Constrained Project Scheduling Problem with Bounded Multitasking (RCPSPBM), allow solving the assignment problems with given restrictions, but do not allow taking into account functional redundancy for projects in a multi-project environment.

The analysis of mathematical models of resources allocation, formation, and functioning of project teams is presented in Table 1. When analyzing the models, the possibility of solving problems was considered: Multipurpose Resource Allocation Problem (MORAP), Resource-Constrained Project Planning Problem (RCPSP), Multi-agent approach to project management in real-time, Robust Resource-Constrained Multi-Project Scheduling Problem (RRCMPSP), Critical Chain Method (CCM), Resource-Constrained Project Scheduling Problem with Bounded Multitasking (RCPSPBM).

The directions for solving the problems of the formation and functioning of teams are presented in Table 2.

Table 1. Analysis of models of formation and functioning of project teams.

Task	F. Li, Z. Xu, H. Li, 2020 [16]	W. Song, H. Xi, D. Kang, J. Zhang, 2018 [18]	V. Cavalcante, C. Cardonha, R. Herrmann, 2013 [34]	L. Shuai, Z. Zhicong, Y. Xiaohui, H. Kaishun, Z., 2018 [35]	Messelis T., De Causmaecker P., 2014 [37]	X.B. Li, M. Nie, G.H. Yang, 2017 [38]	P.O. Skobelev, 2013 [39]	E. Afruzi, A. Aghaie, A. Naja, 2020 [40]	S. Kreter, J. Rieck, J. Zimmermann, 2016 [41]	F. Deblaere, E. Demeulemeester, W. Herroelen, 2011 [42]	K. Fan, W. You, Y. Li, 2013 [43]
Multipurpose Resource Allocation Problem (MORAP)					+						+
Resource-constrained project scheduling problem (RCPSP)			+	+	+				+	+	
A multi-agent approach to project management in real-time	+	+				+	+				
Robust Resource-Constrained Multi-Project Scheduling Problem (RRCMPSP)								+			
Critical Chain Method (CCM)						+					
Resource-Constrained Project Scheduling Problem with Bounded Multitasking (RCPSPBM)			+	+					+	+	

Table 2. Directions of solving problems of formation and functioning of teams.

Direction	Apparatus Used
Assignment problem	Optimization methods for solving the problems of forming the composition of teams, the distribution of roles, and scope of work
Game-theoretic models	Game theory for describing and studying the processes of formation and functioning of teams (Marshak–Radner model, models of collective incentives, models of reputation and performance standards)
Experimental researches	Simulation experiments, business games
Reflexive models	Reflexive game theory

When determining the effectiveness of a team's functioning, it is advisable to use the following tools:

- modified methodological indicators of project value [44];
- multilayer model of emotional infection with the earn value method [45];
- methods for optimizing a project taking into account resource constraints [34,41,42].

These methods are aimed at increasing the efficiency of the team's functioning, but they do not include the stability and viability of a project-oriented organization, which is especially important during a pandemic, which is especially important for ensuring sustainability management.

According to a study by Deloitte [46], 82% of companies changed their approach to ensure the welfare of their employees in 2020–2021. The most relevant directions for the development of the corporate program for ensuring the welfare of human resources (in addition to ensuring financial stability) are:

- mental health provision;

- stress at work reduction;
- psychological contract provision;
- the negative impact of remote work minimization;
- load between resources to reduce overtime and eliminate leaveism redistribution.

To ensure the principles of adaptability and resilience at the stage of forming a project team in a multi-project environment, it is advisable to use functional redundancy. Functional redundancy is understood as the ability of several performers to perform a specific function. The formation of project teams with functional redundancy was considered in [47].

A. Shipulin [48] proposed an approximate method for solving the problem of personnel selection with functional redundancy, based on an assessment of the characteristics of applicants and the degree of their relevance in the project. The methods of forming a functionally redundant command, presented in [48], are approximate and do not give an exact result because it is a greedy method that chooses the dominant row at each step. It is shown that the functional reservation problem belongs to discrete optimization problems, is NP-hard, and requires polynomial time to solve it, which creates difficulties when trying to solve these problems using modern technical means. The upper bounds for the complexity of exact methods are comparable to the complexity of the exhaustive search. H. Fallah, A.N. Sadigh, M. Aslanzadeh [49], R.Z. Farahani, N. Asgari, N. Heidari, M. Hosseininia, M. Goh [50], H. Peng, Y. Qin, Y. Yang [51], improved greedy algorithms by introducing some randomness. These randomized or probabilistic greedy algorithms perform better than pure greedy algorithms but do not allow for cost information and functional redundancy.

One of the aspects of resilience is the ability of the project team to ensure the implementation of the project in the event of changes, which can be achieved by forming functionally redundant adaptive commands, in which resources are redistributed when the operating conditions change [52–54].

Thus, an urgent task is to ensure flexible reallocation of resources in projects of a multi-project environment through the formation of a functionally redundant project team.

This study considers the creation of a method for constructing a functionally redundant project team, which is based on formal transformations of the models for the formation and functioning of project teams, which, in contrast to the existing ones, allows us to determine the composition of the project team under given constraints, taking into account the requirements of the functional redundancy, which allows you to execute projects without loss of functionality with a smaller number of performers.

3. Materials and Methods

Scientific hypotheses:

- The COVID-19 pandemic has led to a reduction in personnel costs in project-oriented companies while tightening constraints (time and resource constraints), which has led to the need to increase the sustainability of project and program management in a multi-project environment while reducing resource management costs.
- In order to ensure the principles of Creating a collaborative project team environment, Embrace Adaptability and Resiliency, defined in *The Standard for Project Management* (PMBoK seventh edition, 2021), it is proposed to increase the adaptability and resilience of teams through the use of functional redundancy at the stage of forming project teams.
- Since when managing human resources, it is necessary to formalize the process of selecting applicants and distributing work between performers, it is proposed to use formal transformations on groups of performers: selection of performers who implement a specific function; definition of disjoint groups; unification of groups. The use of formal transformations in the formation of the project team will eliminate the influence of the subjective factor (stakeholders of resource management processes), which will lead to an increase in the quality of Sustainability management decisions.

The use of tools that are based on the proposed method will automate the process of building a functionally redundant project team.

The paper solves the following tasks:

- introduction of formal transformations;
- formalization of the selection process for applicants and the distribution of operations among the performers;
- development of a method for forming a functionally redundant project team based on formal transformations of groups of performers.

4. Results

4.1. Conceptual Framework

The developed method is based on a constructive enumeration of groups of performers and the selection of groups with given characteristics (Figure 1). If there are several options for generated groups of performers, then their comparative analysis is carried out. The criteria are the size of the project team, characteristics (cost, level of competence, level of commitment, etc.).

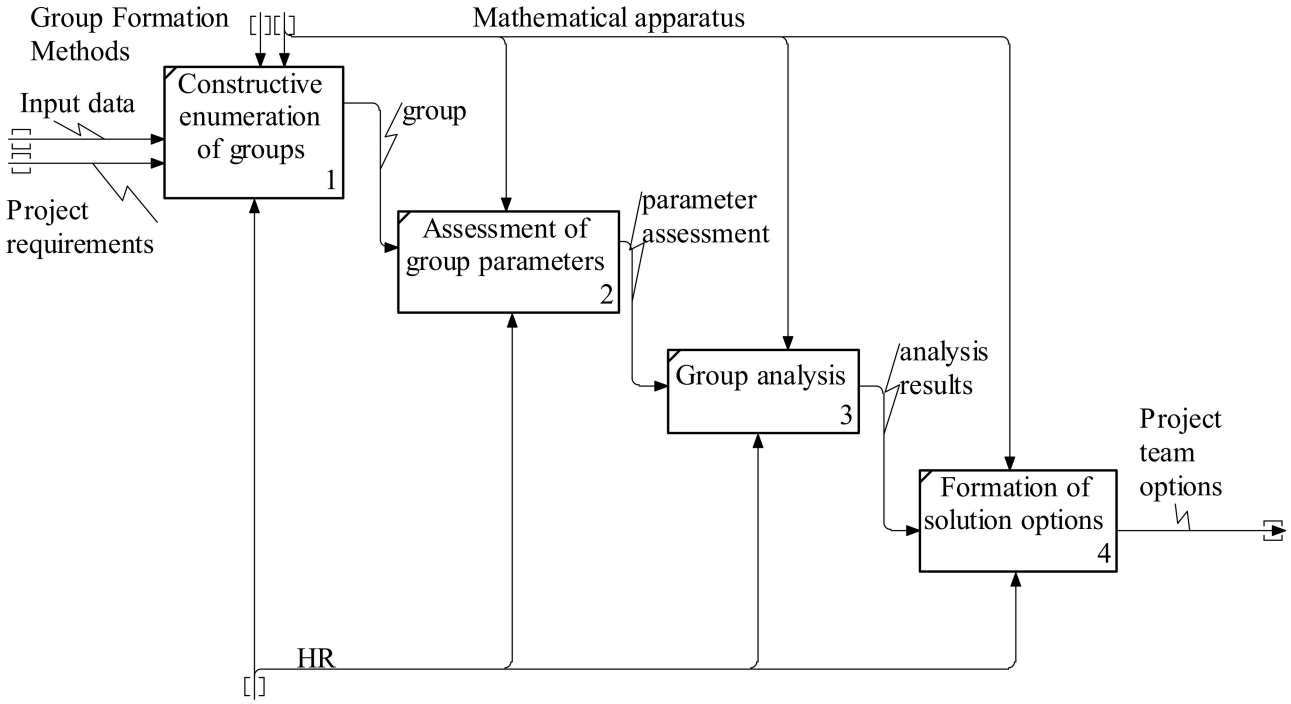

Figure 1. The conceptual framework of the logical-combinatorial method for constructing formal models of the sustainable management of teams.

Let us introduce the notation:

n is the number of performers;
m is the number of functions;
Q is a set of performers;
A is a set of functions;
R is competency matrix;
C is a set of characteristics.

Reservation factors $K = \{k_1, k_2, \ldots, k_m\}$ determine the minimum required number of performers capable of performing this function to ensure the implementation of the project [48].

In the course of solving the problem, a set of options of the distribution of functions between the performers in the project team is formed, which is described by matrix D. If the *i*-th performer performs the function in the team aj, then *dij* = 1, otherwise *dij* = 0.

The task of sustainable management of human resources with functional redundancy is formulated as follows.

For given *Q* (set of performers), *A* (set of functions), *R* (competency matrix), *C* (set of characteristics), *K*, to define *D*, such that:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} d_{ij} c_{ij} \rightarrow min; \quad (1)$$

$$\sum_{j=1}^{m} d_{ij} c_{ij} \leq 1; i = 1, \ldots, n; \quad (2)$$

$$\sum_{i=1}^{n} d_{ij} \geq k_j; \ \ j = 1, \ \ldots, \ m. \quad (3)$$

Since when forming a project team, it is necessary to formalize the process of selecting applicants and distributing operations between performers, it is proposed to use formal transformations on groups of performers.

G is performer group, performer subset *H* = {*h*1, . . .,*ht*}∈*Q*, which implement a subset of functions *F* = {*f*1, . . .,*ft*}∈*A*. G^0 is group which does not contain performers.

The operation of selecting performers implementing the *j*-th function(*A*(*Q*, *j*)):

$$A(Q, j) = {q_1}^j r_{1j} \ v \ \ldots \ v \ {q_i}^j r_{ij} \ v \ \ldots \ v \ {q_n}^j r_{nj}.$$

Identifying groups that do not overlap (⊗):

$G^1 \otimes G^2 = G^1 \chi \ G^2$, *if*$H^1 \cap \mathrm{H}^2 = \emptyset$, *i*$G^1 \otimes G^2 = G^0$ otherwise.

Including a performer in a group (χ):

$$G = {q_{h1}}^{f1} \chi \ {q_{h2}}^{f2} \chi \ldots \chi {q_{ht}}^{ft} = {q_{h1}}^{f1} {q_{h2}}^{f2} \ldots {q_{ht}}^{ft} = \overset{t}{\underset{i=1}{\chi}} q_{h_i}^{f_i}.$$

$G^3 = G^1 \chi G^2$:

if $H = H^1 \cap H^2 = \emptyset$, then $t_3 = t_1 + t_2$, $H^3 = \{H^1, H^2\}$, $F^3 = \{F^1, F^2\}$;

if $H = H^1 \cap H^2 \neq \emptyset$, then $t_3 = t_1 + t_2 - t$, wheret = $|H|$.

$H^3 = \{H^1 \backslash H, H^2 \backslash H, H\}$. $F^3 = \{F^1 \backslash F, F^2 \backslash F, F\}$, where F issubset of functions implemented by executors included in subset H.

Combining groups (v):

$$(G^1 v G^2) \chi G^3 = G^1 \chi G^3 \ v \ G^2 \chi G^3 = G^1 G^3 \ v \ G^2 G^3;$$

$$G^i \ v \ G^0 = G^i, \ G^i \ v \ G^i = G^i.$$

The essence of the method for forming a functionally redundant project team is shown in Figure 2.

The method of forming a functionally redundant project team is based on formal transformations on groups of performers.

Stage 1. Determine the performers implementing the j-th function *A(Q,j)*, *j* = 1, . . .,*m*.

Stage 2. Determine the groups of performers (denoted by *Ej*, *j* = 1, . . ., *m*), which represent the set of groups of performers that implement the function *Aj* with a given reservation coefficient *Kj*

$$E_j = \underset{\eta = k_j}{\overset{\sum_{i=1}^{n} r_{ij}}{V}} \left(\overset{\eta}{\underset{i=1}{\otimes}} A(Q, j) \right).$$

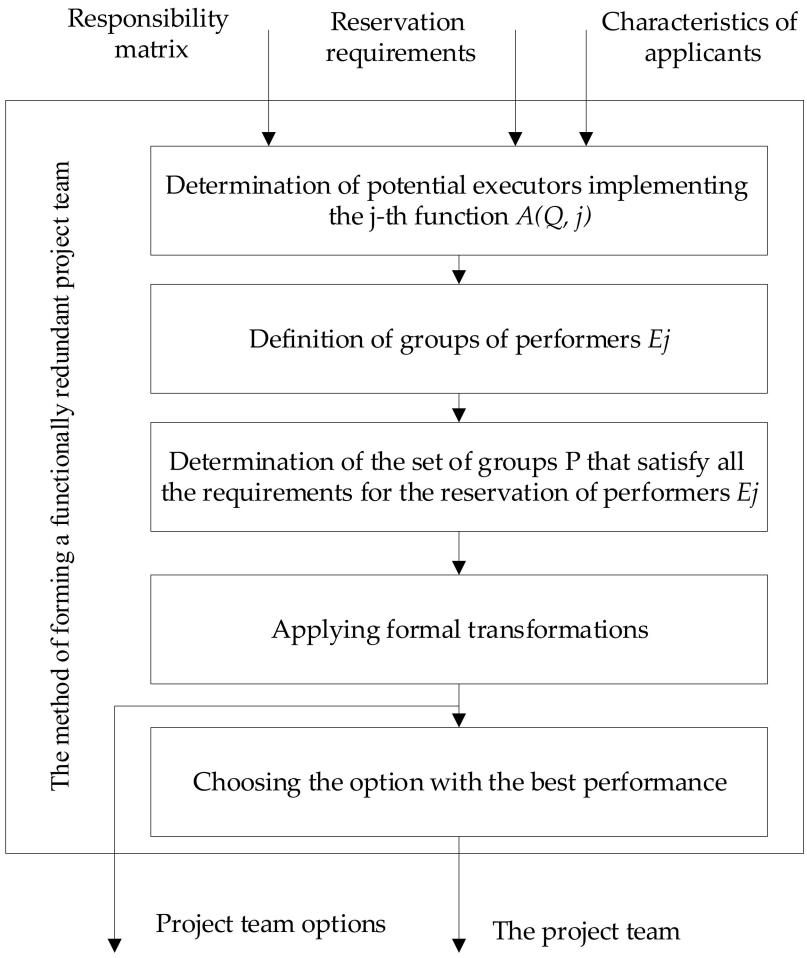

Figure 2. Method of forming a functionally redundant project team.

In the general case, the number of groups of performers forming E_j is determined as follows:

$$\rho_{\mathrm{j}} = \sum_{\tau=k_j}^{\sum_{i=1}^{n} r_{ij}} C_{n}^{\tau}.$$

Stage 3. The set of P groups that meets all the redundancy requirements is determined as follows:

$$\Pi = \underset{j=1}{\overset{m}{\chi}} \left(\underset{\eta=k_j}{\overset{\sum_{i=1}^{n} r_{ij}}{V}} \left(\otimes \underset{i=1}{\overset{\eta}{A}}(Q, j) \right) \right).$$

Stage 4. Let us transform the descriptions of groups obtained in the previous stage to their normal form using the above operations.

The resulting grouping reflects the possible options for building a project team with functional redundancy.

Stage 5. For a given matrix C, we determine the characteristics of each group of performers and choose the best one. If there are several options for building groups of performers, then comparative analysis of their effectiveness is carried out.

When solving this problem, it is necessary to find only the optimal composition of the group of performers who form the project team.

As a canonical form, when describing groups of performers, it is proposed to represent their composition in the form of a serial symbolic sequence, the properties of which

were investigated in [55,56]. The designations of variables and operations in the article correspond to those adopted in the above-mentioned paper.

Let us consider the construction of a canonical form when describing groups in the form of a serial symbolic sequence.

In the general case, for an alphabet $\Omega = \{\omega_1, \ldots, \omega_r\}$, a symbolic (r, m) sequence is a sequence $W = \{w_1, \ldots, w_m\}$, in which $w_i \in \Omega$, $i = 1, \ldots, m$; $m \geq r$ and the sequence W represents all characters from the alphabet Ω. For the problem under consideration $\Omega \in N$.

A subsequence $w_{p+1}w_{p+2}\ldots w_{p+q}$ is called a series in W if

$$w_{p+1} = w_{p+2} = \ldots = w_{p+q};$$

$$w_p \neq w_{p+1}; \text{ with } p \geq 1;$$

$$w_{p+q} \neq w_{p+q+1}; \text{ with } p + q \leq m.$$

The i-th series is described as $S_i(u_i,v_i)$,where u_i is the symbol forming the i-th series, v_i is the length of the i-th series (the number of u_i symbols). A character *(r, m)* sequence W, consisting of h series, is represented as:

$$W = S_1(u_1,v_1)S_2(u_2,v_2) \ldots S_h(u_h, v_h),$$

where $u_i \in \Omega$;

$$\sum_{i=1}^{h} v_i = m$$

The set $U = \{u_1, u_2, \ldots, u_h\}$ is called the structure of the serial sequence, and the set $V = \{v_1, v_2, \ldots, v_h\}$ is called the composition of the serial sequence.

A series $S_j(u_j, v_j)$ is called a series of the i-th type if $u_j = \omega$. The number of series of the i-th type (γ_i) and the number of symbols of the i-th type (λ_i) in the sequence W are determined as follows:

$$\gamma_i = \sum_{j=1}^{h} \beta_j, \ \lambda_i = \sum_{j=1}^{h} v_i\beta_j,$$

$$\beta_j = \left\{ \begin{array}{l} 1, \text{if } u_j = \omega_i, \\ 0, \text{otherwise} \end{array} \right\}$$

The sets $\Gamma = \{\gamma_1,\gamma_2,\ldots,\gamma_r\}$ and $\Lambda = \{\lambda_1, \lambda_2,\ldots, \lambda_r\}$ have the following properties:

$$\sum_{i=1}^{r} \gamma_i = h, \sum_{i=1}^{r} \lambda_i = m.$$

The following operations are introduced on the set of character sequences.

1. By merging the sequence $W^1 = S^1{}_1(a^1{}_1,v^1{}_1) \ldots S^1{}_{h1}(a^1{}_{h1},v^1{}_{h1})$ with the alphabet Ω_1 and the sequence $W^2 = S^2{}_1(a^2{}_1,v^2{}_1) \ldots S^2{}_{h2}(a^2{}_{h2},v^2{}_{h2})$ with the alphabet Ω_2 (denoted by $W^3 = \vartheta(W^1, W^2)$ is called the sequence $W^3 = S^3{}_1(a^3{}_1,v^3{}_1) \ldots S^3{}_{h3}(a^3{}_{h3},v^3{}_{h3})$ with the alphabet $\Omega_3 = \Omega_1 \cup \Omega_2$. The number of series in the W^3 sequence depends on the type of symbols $a^1{}_{h1}$ and $a^2{}_1$, as follows. For $a^1{}_{h1} \neq a^2{}_1$, the sequence W^3 has the form:

$$W^3 = S^1{}_1(a^1{}_1,v^1{}_1) \ldots S^1{}_h(a^1{}_h, v^1{}_{h1})\, S^2{}_1(a^2{}_1,v^2{}_1) \ldots S^2{}_{h2}(a^2{}_{h2}, v^2{}_{h2}),$$
$$h_3 = h_1 + h_2.$$

For $a^1{}_h = a^2{}_1$, the sequence W^3 has the form:

$$W^3 = S^1{}_1(a^1{}_1,v^1{}_1) \ldots S^1{}_{h\text{-}1}(a^1{}_{h\text{-}1}, v^1{}_{h\text{-}1})\, S^*(a^*,v^*)\, S^2{}_2(a^2{}_2,v^2{}_2) \ldots S^2{}_{h2}(a^2{}_{h2}, v^2{}_{h2}),$$

where $a^* = a^1{}_h$, $v^* = v^1{}_{h1} + v^2{}_1$, $h_3 = h_1 + h_2 - 1$.

2. The selection of a subsequence in the serial sequence $W^1 = S_1(a_1,v_1)\ S_2(a_2,v_2)\ \ldots\ S_{h1}(a_{h1}, v_{h1})$ (denoted by $W^2 = \Theta(W^1, \alpha, \beta)$) consists in forming a sequence W^2 of the form $S_\alpha(a_\alpha, v_\alpha)\ \ldots\ S_\beta(a_\beta, v_\beta)$, i.e., highlighting series with numbers from α to β.

3. The insertion of the sequence W^2 into the sequence W^1, starting from the μ-th series (denoted by $W^3 = \Psi(W^1, W^2, \mu)$) is defined as follows:

$$W^3 = \Psi(W^1, W^2, \mu) = \vartheta(\Theta(W^1, 1, \mu - 1), W^2, \Theta(W^1, \mu, v^1{}_{h1})).$$

4. A connection of m-ary sequences $W^1, W^2, \ldots, W^k$ (denoted by $W^\nabla = \Phi(W^1, W^2, \ldots, W^k)$) is a sequence W^∇, whose elements (words) are formed as follows:

$$w^\nabla{}_i = w^1{}_i w^2{}_i \ldots w^k{}_i,\ i = 1, \ldots, m.$$

Let us consider the construction of a canonical form when describing groups in the form of a serial symbolic sequence.

If in the task it is necessary to determine only the composition of the group without specifying the functions performed by the members of the group, then to describe the composition of the group, the set $D = \{d_1, \ldots, d_n\}$ is used in which $d_i = 1$, if the i-th performer is included in the group, in otherwise $d_i = 0$, $I = 1, \ldots, n$.

For the considered serial sequence, the alphabet consists of only two symbols $\Omega = \{0, 1\}$, therefore the type of the sequence:

$$W = S_1(u_1,v_1)S_2(u_2,v_2)\ \ldots\ S_{h-1}(u_1,v_{h-1})S_h(u_2,v_h)\ \ldots,$$

in which the symbols u_1 and u_2, which are changed sequentially, can be transformed into a shorter form:

$$W = u_1,v_1,v_2\ ,\ \ldots\ ,\ v_h,$$

uniquely describes the canonical form.

4.2. Collecting Initial Data

The indicators of the resource development process, the assessment of resource management processes strategies is determined by the HR department, RMO within the timeframes specified in the quality management system (monthly, quarterly, etc.). Based on the monitoring data of indicators, a strategy for the development of the company's human resources is formed.

4.3. Processing the Data

Let us consider an example.

Input data:

$$Q = \{q_1, q_2, \ldots, q_{12}\};$$

$$A = \{a_1, a_2, \ldots, a_6\};$$

C is a set of characteristics.

The modified competency matrix R is shown in Table 3.

Let us determine the composition of the team with functional redundancy for the redundancy factors $K = \{3, 1, 2, 1, 2, 1\}$.

Solution.

We determine the performers that implement the functions $A(Q, j)$, $j = 1, \ldots, 6$:

$$A(Q,1) = (q_1{}^1\ v\ q_2{}^1\ v\ q_5{}^1\ v\ q_6{}^1\ v\ q_{10}{}^1);$$
$$A(Q,2) = (q_3{}^2\ v\ q_7{}^2\ v\ q_{11}{}^2);$$
$$A(Q,3) = (q_2{}^3\ v\ q_4{}^3\ v\ q_5{}^3\ v\ q_6{}^3\ v\ q_8{}^3\ v\ q_9{}^3);$$
$$A(Q,4) = (q_1{}^4\ v\ q_3{}^4\ v\ q_7{}^4\ v\ q_9{}^4\ v\ q_{11}{}^4\ v\ q_{12}{}^4);$$
$$A(Q,5) = (q_4{}^5\ v\ q_6{}^5\ v\ q_8{}^5\ v\ q_9{}^5\ v\ q_{10}{}^5\ v\ q_{12}{}^5);$$
$$A(Q,6) = (q_2{}^6\ v\ q_4{}^6\ v\ q_5{}^6\ v\ q_7{}^6).$$

Table 3. Modified Applicant Competency Matrix.

Q/A	a_1	a_2	a_3	a_4	a_5	a_6	C
q_1	1	0	0	1	0	0	5
q_2	1	0	1	0	0	1	3
q_3	0	1	0	1	0	0	8
q_4	0	0	1	0	1	1	4
q_5	1	0	1	0	0	1	9
q_6	1	0	1	0	1	0	6
q_7	0	1	0	1	0	1	5
q_8	0	0	1	0	1	0	6
q_9	0	0	1	1	1	0	8
q_{10}	1	0	0	0	1	0	5
q_{11}	0	1	0	1	0	0	7
q_{12}	0	0	0	1	1	0	9

We define the groups of performers (denoted by E_j, $j = 1, \ldots, m$), which represent the set of groups of performers that implement functions with given reservation factors. The results of calculations of E are shown in Appendix A.

Serial sequences for groups E_1 are shown in Table 4.

Table 4. Serial sequences of groups of performers E_1.

No.	u_1	v_1	v_2	v_3	v_4	v_5	v_6	v_7
1	1	2	2	1	7	0	0	0
2	1	2	3	1	6	0	0	0
3	1	2	7	1	2	0	0	0
4	1	1	3	2	6	0	0	0
5	1	1	3	1	4	1	2	0
6	1	1	4	1	3	1	2	0
7	0	1	1	2	2	6	0	0
8	0	1	1	2	1	4	1	2
9	0	1	1	3	1	3	1	2
10	0	4	2	3	1	2	0	0
11	1	2	2	2	6	0	0	0
12	1	2	2	1	4	1	2	0
13	1	2	3	1	3	1	2	0
14	1	1	3	2	3	1	2	0
15	0	1	1	2	2	3	1	2
16	1	2	2	2	3	1	2	0

Serial sequences for groups E_2 are shown in Table 5.

Table 5. Serial sequences of groups of performers E_2.

No.	u_1	v_1	v_2	v_3	v_4	v_5	v_6	v_7
1	0	2	1	9	0	0	0	0
2	0	6	1	5	0	0	0	0
3	0	10	1	1	0	0	0	0
4	0	2	1	3	1	5	0	0
5	0	2	1	7	1	1	0	0
6	0	6	1	3	1	1	0	0
7	0	2	1	3	1	3	1	1

We define a set of P groups that satisfy all the reservation requirements:

$$P = E_1 \chi E_2 \chi E_3 \chi E_4 \chi E_5 \chi E_6.$$

The results of calculating P are given in Appendix B.

An example of the formation of serial sequences obtained as a result of multiplication of the $E_1 \chi E_2$ groups is shown in Table 6. The same is for other groups.

Table 6. Serial sequences of groups of performers $E_1 \chi E_2$.

No.	u_1	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9
1	1	3	1	1	7	0	0	0	0	0
2	1	2	2	1	1	1	5	0	0	0
3	1	2	2	1	5	1	1	0	0	0
4	1	3	2	1	6	0	0	0	0	0
5	1	2	3	2	5	0	0	0	0	0
6	1	2	3	1	4	1	1	0	0	0
7	1	3	6	1	2	0	0	0	0	0
8	1	2	4	1	2	1	2	0	0	0
9	1	2	7	2	1	0	0	0	0	0
10	1	1	1	1	1	2	6	0	0	0
11	1	1	3	3	5	0	0	0	0	0
12	1	1	3	2	4	1	1	0	0	0
13	1	1	1	1	1	1	4	1	2	0
14	1	1	3	1	1	1	2	1	2	0
15	1	1	3	1	4	2	1	0	0	0
16	1	1	1	1	2	1	3	1	2	0
17	1	1	4	2	2	1	2	0	0	0
18	1	1	4	1	3	2	1	0	0	0
19	0	1	2	1	2	6	0	0	0	0
20	0	1	1	2	3	5	0	0	0	0
21	0	1	1	2	2	4	1	1	0	0
22	0	1	2	1	1	4	1	2	0	0
23	0	1	1	2	1	1	1	2	1	2
24	0	1	1	2	1	4	2	1	0	0
25	0	1	2	2	1	3	1	2	0	0
26	0	1	1	3	2	2	1	2	0	0
27	0	1	1	3	1	3	2	1	0	0
28	0	2	1	1	2	3	1	2	0	0
29	0	4	3	2	1	2	0	0	0	0
30	0	4	2	3	2	1	0	0	0	0

Table 7 shows the results of multiplication for $t = 4$.

Table 7. Serial sequences of groups of performers P for $t = 4$.

No.	u_1	v_1	v_2	v_3	v_4	v_5	v_6
1	0	1	2	2	1	3	1
2	0	1	1	3	2	2	1
3	0	1	1	3	1	3	2
4	0	2	1	1	2	3	1
5	0	4	3	2	1	0	0
6	0	4	2	3	2	0	0

Table 8 shows the results of multiplication for $t = 5$.

Table 8. Serial sequences of groups of performers P for $t = 5$.

No.	u_1	v_1	v_2	v_3	v_4	v_5	v_6	v_7
1	0	1	2	2	2	2	1	0
2	0	1	2	2	1	3	2	0
3	0	1	1	3	2	2	2	0
4	0	2	1	1	3	2	1	0
5	0	2	1	1	2	3	2	0
6	0	4	3	2	2	0	0	0
7	1	3	2	1	3	1	0	0
8	1	2	3	2	2	1	0	0
9	1	2	3	1	3	2	0	0
10	1	1	1	1	1	2	3	1
11	1	1	3	3	2	1	0	0
12	1	1	3	2	3	2	0	0
13	0	1	2	1	2	3	1	0
14	0	1	1	2	3	2	1	0
15	0	1	1	2	2	3	2	0

Table 9 shows the results of multiplication for $t = 6$.

Table 9. Serial sequences of groups of performers P for $t = 6$.

No.	u_1	v_1	v_2	v_3	v_4	v_5	v_6	v_7
1	0	1	2	2	2	2	2	0
2	0	2	1	1	3	2	2	0
3	1	3	2	2	2	1	0	0
4	1	3	2	1	3	2	0	0
5	1	2	3	2	2	2	0	0
6	1	1	1	1	1	3	2	1
7	1	1	1	1	1	2	3	2
8	1	1	3	3	2	2	0	0
9	0	1	2	1	3	2	1	0
10	0	1	2	1	2	3	2	0
11	0	1	1	2	3	2	2	0
12	1	3	1	2	3	1	0	0
13	1	2	2	3	2	1	0	0
14	1	2	2	2	3	2	0	0

Let us transform the descriptions of the groups obtained in the previous step to a non-collapsible form. The result of the transformation P is given in Appendix C. The obtained result reflects the possible options for building a project team with functional redundancy (Tables 10 and 11).

Table 10. Group descriptions for $t = 4$.

No.	The Numbers of the Performers Included in the Group				Number of Performers Implementing Functions					
					a_1	a_2	a_3	a_4	a_5	a_6
1	2	3	6	10	3	1	2	1	2	1
2	2	6	7	10	3	1	2	1	2	2
3	2	6	10	11	3	1	2	1	2	1
4	3	5	6	10	3	1	2	1	2	1
5	5	6	7	10	3	1	2	1	2	2
6	5	6	10	11	3	1	2	1	2	1

Table 10 shows that options 2 and 5 have greater functionality.

Table 11. Group descriptions for $t = 5$.

The Numbers of the Performers Included in the Group					The Numbers of the Performers Included in the Group					The Numbers of the Performers Included in the Group				
1	2	3	4	6	1	2	9	10	11	1	5	6	11	12
1	2	3	4	10	1	3	4	5	6	1	5	7	8	10
1	2	3	6	8	1	3	4	5	10	1	5	7	9	10
1	2	3	6	9	1	3	4	6	10	1	5	8	10	11
1	2	3	6	10	1	3	5	6	8	1	5	9	10	11
1	2	3	6	12	1	3	5	6	9	1	6	7	8	10
1	2	3	8	10	1	3	5	6	10	1	6	7	9	10
1	2	3	9	10	1	3	5	6	12	1	2	6	9	11
1	2	4	6	7	1	3	5	8	10	1	2	6	10	11
1	2	4	6	11	1	3	5	9	10	1	2	6	11	12
1	2	4	7	10	1	4	5	6	7	1	2	7	8	10
1	2	4	10	11	1	4	5	6	11	1	2	7	9	10
1	2	6	7	8	1	4	5	7	10	1	2	8	10	11
1	2	6	7	9	1	4	5	10	11	1	5	6	7	9
1	2	6	7	10	1	4	6	7	10	1	5	6	7	10
1	2	6	7	12	1	4	6	10	11	1	5	6	7	12
1	2	6	8	11	1	5	6	7	8	1	5	6	8	11
1	5	6	9	11	1	5	6	10	11	2	5	7	10	12
2	3	4	5	6	2	3	6	10	12	2	5	8	10	11
2	3	4	5	10	2	4	5	6	7	2	5	9	10	11
2	3	4	6	10	2	4	5	6	11	2	5	10	11	12
2	3	5	6	8	2	4	5	7	10	2	6	7	8	10
2	3	5	6	9	2	4	5	10	11	2	6	7	9	10
2	3	5	6	10	2	4	6	7	10	2	6	7	10	11
2	3	5	6	12	2	4	6	10	11	2	6	7	10	12
2	3	5	8	10	2	5	6	7	8	2	6	8	10	11
2	3	5	9	10	2	5	6	7	9	2	6	9	10	11
2	3	5	10	12	2	5	6	7	10	2	6	10	11	12
2	3	6	7	10	2	5	6	7	12	2	5	6	11	12
2	3	6	8	10	2	5	6	8	11	2	5	7	8	10
2	3	6	9	10	2	5	6	9	11	2	5	7	9	10
2	3	6	10	11	2	5	6	10	11	3	4	5	6	10
3	5	6	7	10	3	5	6	8	10	3	5	6	10	11
3	5	6	10	12	3	5	6	9	10	4	5	6	7	10
4	5	6	10	11	5	6	7	8	10	5	6	7	10	11
5	6	8	10	11	5	6	7	9	10	5	6	7	10	12
5	6	9	10	11	5	6	10	11	12					

The number of performers implementing the functions is shown in Table 12.

Table 12. Descriptions of the "functional-reservation groups for $t = 4$" property.

Number of Performers Implementing Functions	Functions					
	a_1	a_2	a_3	a_4	a_5	a_6
Minimum	3	1	2	1	2	1
Maximum	4	2	4	3	3	4

An analysis of the options for distributing applicants to functionally redundant teams is shown in Figure 3.

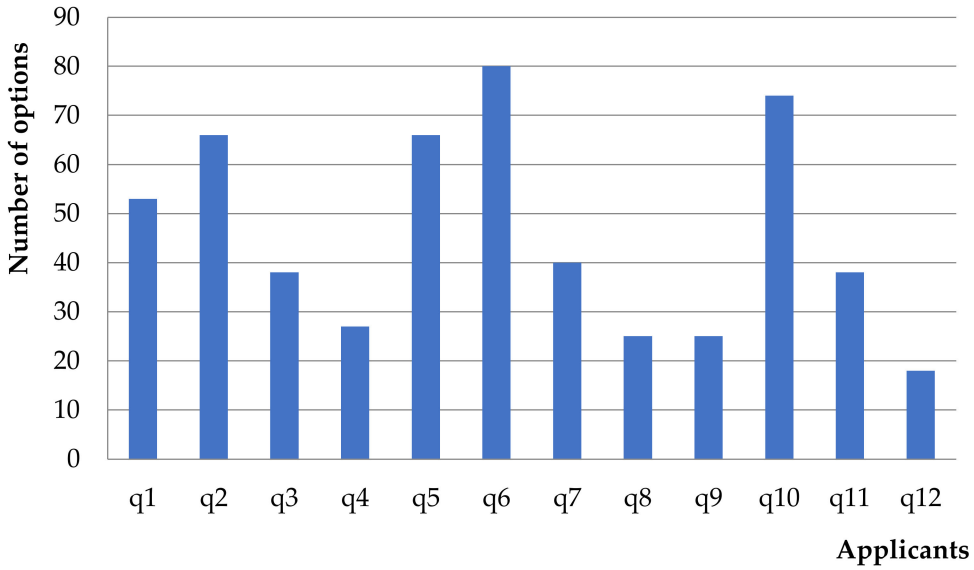

Figure 3. Analysis of options for distributing applicants by functionally redundant teams.

The figure shows that the most in-demand as a performer are applicants q_6 (80 options), q_{10} (74), q_5 (66), q_2 (66).

For a given matrix C, we determine the characteristics of each group of performers and choose the optimal one (according to a given criterion). If there are several options for building groups of performers, then comparative analysis of their effectiveness is carried out. Since C in this example is the cost of performing the work, we select the options with the minimum cost.

Table 13 shows the characteristics of the groups.

Table 13. Group characteristics.

No.	Numbers of Performers, Included in a Group					C	Number of Performers Implementing Functions					
							a_1	a_2	a_3	a_4	a_5	a_6
1	2	3	6	10		22	3	1	2	1	2	1
2	2	6	7	10		19	3	1	2	1	2	2
3	2	6	10	11		21	3	1	2	1	2	1
4	3	5	6	10		28	3	1	2	1	2	1
5	5	6	7	10		25	3	1	2	1	2	2
6	5	6	10	11		27	3	1	2	1	2	1
7	1	2	4	7	10	22	3	1	2	2	2	3
8	1	2	3	4	6	26	3	1	3	2	2	2

5. Discussion

The resulting options for the sustainable management of human resources are options for solving the problem. The analysis of the obtained results shows that the smallest in terms of the number of performers and the value of the cost is option number 2. Performers were selected to the project team: q_2, q_6, q_7, q_{10}. The selected option satisfies the required redundancy ratios; for function 6, this indicator is exceeded, which increases the adaptability and resilience of the selected team. These indicators indicate the possibility of reallocating resources to ensure the management of critical competencies.

The application of the proposed method for the selected example showed an increase in the efficiency of the use of human resources in the formation of teams according to the classification of Patanakul P., Milosevic D. according to the criteria of the effectiveness of assignment in the project and the distribution of resources (reduction of the team size by 1.25 times, the cost by 1.47 times).

The proposed method can be used for various types of projects since the specifics of the project are taken into account when determining the requirements for the human resources and are not reflected in the format of the input data. It is most expedient to use the proposed method in the implementation of projects in the aerospace industry, nuclear energy, industry, providing for the reservation of competencies, management of critical knowledge, adaptation of the project team when the conditions for project implementation change, and the like.

Based on the described method, computer programs "Agile multi-project team management" [57], "Stakeholder-oriented adaptive project resource planning" [58] were developed to select the optimal warehouse for a project team with a given level of functional redundancy.

The operation of the software package is based on the analysis of options for the distribution of functions between members of the project team, assessment of their characteristics, selection of the optimal option, and determination of the functions implemented by each member of the team for providing sustainable management of the project. The developed software is implemented in Borland Delphi environment. The programs are built on a modular basis and allow flexible adaptation to solve a wider class of problems. Communication with the user takes place in a dialogue mode. Input data: matrices of applicants' competencies, requirements for applicants and competencies, matrix of costs.

As a result, a set of team members is formed, corresponding to the functional matrix, and an analysis of the redundancy level is provided. Preparation for the program involves the creation of a source data file, including the number of applicants, the number of functions, competency matrix, characteristics of applicants, and reservation requirements.

6. Conclusions

The article proposes methodological support for the process of forming a project team with functional redundancy, based on a logical-combinatorial approach and allowing to form project teams under given constraints.

Formal transformations are proposed to reduce the influence of the human factor in the formation of the project team, which is especially important when it provides management, critical infrastructure project management, energy management project.

The process of selection of applicants and distribution of operations among performers has been formalized. The formulation of the task of forming a functionally redundant adaptive project team is considered. To describe formal transformations on a set of performers and a set of functions, operations on a set of groups are considered. The developed method is based on a constructive enumeration of groups of performers and the selection of groups with given characteristics. Possible estimates of the properties of groups of performers are considered.

A method of forming a functionally redundant project team based on formal transformations of groups of performers has been developed.

The scientific novelty of the proposed approach is as follows:

- Firstly, a conceptual framework of sustainable management human resources forming a project team with functional redundancy was obtained. It is based on formal transformations of the models for the formation and functioning of project teams. That, unlike the existing ones, allows you to determine the sustainable management human resources of the project team under given constraints, considering the requirements of functional redundancy, which allows you to execute projects without loss of functionality with fewer performers.
- The developed conceptual framework of sustainable management human resources forming a project team with functional redundancy, in contrast to the existing ones, allows managing the human resources of an enterprise subject to changing constraints associated with the global COVID-19 pandemic.

The obtained solutions on test examples showed a decrease in the size of the team by 1.15–1.45 times, the cost (characteristics) by 1.1–1.5 times while meeting the reservation

requirements. When evaluating the effectiveness, we used test problems from the OR-Library, DI-MACS Challenge II, combinatorial configurations of a special type (Stein-7, Stein-12, etc.). The effect of applying the proposed method is greatest for matrices of high dimension, using combinatorial configurations of a special type. The method described above and the software that implements it allows solving the problem up to m = 100, while the best-known methods only up to m = 60. Thus, the functional efficiency of the proposed method is 1.6 times greater.

The application of the proposed method in the formation of a command with functional redundancy is considered using an example. It is shown that the application of this method made it possible to select the sustainable management human resources of the project team with a minimum number (4 performers) and a minimum value of characteristics (cost—19).

A promising area of research is the development of instrumental support to support decision-making when forming a project team with functional redundancy for sustainable management of projects.

In future researches, it is planned to consider additional parameters of team formation, such as the level of resilience, reliability, and adaptability.

A promising direction is the adaptation of the proposed approaches for multi-criteria modeling of human resource management processes in projects in a multi-project environment. The proposed ideas can be used in the agile transformation of human resource management processes.

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Appendix A

$E_1 = q_1q_2q_5 \vee q_1q_2q_6 \vee q_1q_2q_{10} \vee q_1q_5q_6 \vee q_1q_5q_{10} \vee q_1q_6q_{10} \vee q_2q_5q_6 \vee q_2q_5q_{10} \vee q_2q_6q_{10} \vee q_5q_6q_{10} \vee q_1q_2q_5q_6 \vee q_1q_2q_5q_{10} \vee q_1q_2q_6q_{10} \vee q_1q_5q_6q_{10} \vee q_2q_5q_6q_{10} \vee q_1q_2q_5q_6q_{10}$;

$E_2 = q_3 \vee q_7 \vee q_{11} \vee q_3q_7 \vee q_3q_{11} \vee q_7q_{11} \vee q_3q_7q_{11}$;

$E_3 = q_2q_4 \vee q_2q_5 \vee q_2q_6 \vee q_2q_8 \vee q_2q_9 \vee q_4q_5 \vee q_4q_6 \vee q_4q_8 \vee q_4q_9 \vee q_5q_6 \vee q_5q_8 \vee q_5q_9 \vee q_6q_8 \vee q_6q_9 \vee q_8q_9 \vee q_2q_4q_5 \vee q_2q_4q_6 \vee q_2q_4q_8 \vee q_2q_4q_9 \vee q_2q_5q_6 \vee q_2q_5q_8 \vee q_2q_5q_9 \vee q_2q_6q_8 \vee q_2q_6q_9 \vee q_2q_8q_9 \vee q_4q_5q_6 \vee q_4q_5q_8 \vee q_4q_5q_9 \vee q_4q_6q_8 \vee q_4q_6q_9 \vee q_4q_8q_9 \vee q_5q_6q_8 \vee q_5q_6q_9 \vee q_5q_8q_9 \vee q_6q_8q_9 \vee q_2q_4q_5q_6 \vee q_2q_4q_5q_8 \vee q_2q_4q_5q_9 \vee q_2q_4q_6q_8 \vee q_2q_4q_6q_9 \vee q_2q_4q_8 \, q_9 \vee q_2q_5q_6q_8 \vee q_2q_5 \, q_6q_9 \vee q_2q_5q_8q_9 \vee q_2q_6q_8q_9 \vee q_4q_5q_6q_8 \vee q_4q_5q_6q_9 \vee q_4q_5q_8q_9 \vee q_4q_6q_8q_9 \vee q_5q_6q_8q_9 \vee q_2q_4q_5q_6 \, q_8 \vee q_2q_4q_5q_6q_9 \vee q_2q_4q_5q_8q_9 \vee q_2q_4q_6q_8q_9 \vee q_2q_5q_6q_8q_9 \vee q_4q_5q_6q_8q_9 \vee q_2q_4q_5q_6q_8q_9$;

$E_4 = q_1 \vee q_3 \vee q_7 \vee q_9 \vee q_{11} \vee q_{12} \vee q_1q_3 \vee q_1q_7 \vee q_1q_9 \vee q_1q_{11} \vee q_1q_{12} \vee q_3q_7 \vee q_3q_9 \vee q_3q_{11} \vee q_3q_{12} \vee q_7q_9 \vee q_7q_{11} \vee q_7q_{12} \vee q_9q_{11} \vee q_9q_{12} \vee q_{11}q_{12} \vee q_1q_3q_7 \vee q_1q_3q_9 \vee q_1q_3q_{11} \vee q_1q_3q_{12} \vee q_1q_7q_9 \vee q_1q_7q_{11} \vee q_1q_7q_{12} \vee q_1q_9q_{11} \vee q_1q_9q_{12} \vee q_1q_{11}q_{12} \vee q_3q_7q_9 \vee q_3q_7q_{11} \vee q_3q_7q_{12} \vee q_3q_9 \, q_{11} \vee q_3q_9q_{12} \vee q_3q_{11}q_{12} \vee q_7q_9q_{11} \vee q_7q_9q_{12} \vee q_7q_{11}q_{12} \vee q_9q_{11}q_{12} \vee q_1q_3q_7q_9 \vee q_1q_3q_7q_{11} \vee q_1q_3 \, q_7q_{12} \vee q_1q_3q_9q_{11} \vee q_1q_3q_9q_{12} \vee q_1q_3q_{11}q_{12} \vee q_1q_7q_9q_{11} \vee q_1q_7q_9q_{12} \vee q_1q_7q_{11}q_{12} \vee q_1q_9q_{11}q_{12} \vee q_3q_7q_9q_{11} \vee q_3q_7q_9q_{12} \vee q_3q_7q_{11}q_{12} \vee q_3q_9q_{11}q_{12} \vee q_7q_9q_{11}q_{12} \vee q_1q_3q_7q_9q_{11} \vee q_1q_3q_7q_9q_{12} \vee q_1q_3q_7q_{11}q_{12} \vee q_1q_3q_9q_{11}q_{12} \vee q_1q_7q_9q_{11}q_{12} \vee q_3q_7q_9q_{11}q_{12} \vee q_1q_3q_7q_9q_{11}q_{12}$;

$E_5 = q_4q_6 \vee q_4q_8 \vee q_4q_9 \vee q_4q_{10} \vee q_4q_{12} \vee q_6q_8 \vee q_6q_9 \vee q_6q_{10} \vee q_6q_{12} \vee q_8q_9 \vee q_8q_{10} \vee q_8q_{12} \vee q_9q_{10} \vee q_9q_{12} \vee q_{10}q_{12} \vee q_4q_6q_8 \vee q_4q_6q_9 \vee q_4q_6q_{10} \vee q_4q_6q_{12} \vee q_4q_8q_9 \vee q_4q_8q_{10} \vee q_4q_8q_{12} \vee q_4q_9q_{10} \vee q_4q_9q_{12} \vee q_4q_{10}q_{12} \vee q_6q_8q_9 \vee q_6q_8q_{10} \vee q_6q_8q_{12} \vee q_6q_9q_{10} \vee q_6q_9q_{12} \vee q_6q_{10}q_{12}$

$vq_8q_9q_{10}$ $vq_8q_9q_{12}$ $vq_8q_{10}q_{12}$ $vq_9q_{10}q_{12}$ $vq_4q_6q_8q_9$ $vq_4q_6q_8q_{10}$ $vq_4q_6q_8q_{12}$ $vq_4q_6q_9q_{10}$ $vq_4q_6q_9q_{12}$ $vq_4q_6q_{10}q_{12}$ $vq_4q_8q_9q_{10}$ $vq_4q_8q_9q_{12}$ $vq_4q_8q_{10}q_{12}$ $vq_4q_9q_{10}q_{12}$ $vq_6q_8q_9q_{10}$ $vq_6q_8q_9q_{12}$ $vq_6q_8q_{10}q_{12}$ $vq_6q_9q_{10}q_{12}$ $vq_8q_9q_{10}q_{12}$ $vq_4q_6q_8q_9q_{10}$ $vq_4q_6q_8q_9q_{12}$ $vq_4q_6q_8q_{10}q_{12}$ $vq_4q_6q_9q_{10}q_{12}$ $vq_4q_8q_9$ $q_{10}q_{12}$ $vq_6q_8q_9q_{10}q_{12}$ $vq_4q_6q_8q_9q_{10}q_{12}$;

$E_6 = q_2$ vq_4 vq_5 vq_7 vq_2q_4 vq_2q_5 vq_2q_7 vq_4q_5 vq_4q_7 vq_5q_7 $vq_2q_4q_5$ $vq_2q_4q_7$ $vq_2q_5q_7$ $vq_4q_5q_7$ $vq_2q_4q_5q_7$.

Appendix B

$P = E_1\chi E_2\chi E_3\chi E_4\chi E_5\chi E_6 =$ ($q_1q_2q_5$ $vq_1q_2q_6$ $vq_1q_2q_{10}$ $vq_1q_5q_6$ $vq_1q_5q_{10}$ $vq_1q_6q_{10}$ $vq_2q_5q_6$ $vq_2q_5q_{10}$ $vq_2q_6q_{10}$ $vq_5q_6q_{10}$ $vq_1q_2q_5q_6$ $vq_1q_2q_5q_{10}$ $vq_1q_2q_6q_{10}$ $vq_1q_5q_6q_{10}$ $vq_2q_5q_6q_{10}$ $vq_1q_2q_5q_6q_{10}$) χ (q_3 vq_7 vq_{11} vq_3q_7 vq_3q_{11} vq_7q_{11} $vq_3q_7q_{11}$) χ (q_2q_4 vq_2q_5 vq_2q_6 vq_2q_8 vq_2q_9 vq_4q_5 vq_4q_6 vq_4q_8 vq_4q_9 vq_5q_6 vq_5q_8 vq_5q_9 vq_6q_8 vq_6q_9 vq_8q_9 $vq_2q_4q_5$ $vq_2q_4q_6$ $vq_2q_4q_8$ $vq_2q_4q_9$ $vq_2q_5q_6$ $vq_2q_5q_8$ $vq_2q_5q_9$ $vq_2q_6q_8$ $vq_2q_6q_9$ $vq_2q_8q_9$ $vq_4q_5q_6$ $vq_4q_5q_8$ $vq_4q_5q_9$ $vq_4q_6q_8$ $vq_4q_6q_9$ $vq_4q_8q_9$ $vq_5q_6q_8$ $vq_5q_6q_9$ $vq_5q_8q_9$ $vq_6q_8q_9$ $vq_2q_4q_5q_6$ $vq_2q_4q_5q_8$ $vq_2q_4q_5q_9$ $vq_2q_4q_6q_8$ $vq_2q_4q_6q_9$ $vq_2q_4q_8q_9$ $vq_2q_5q_6q_8$ $vq_2q_5q_6q_9$ $vq_2q_5q_8q_9$ $vq_2q_6q_8q_9$ $vq_4q_5q_6q_8$ $vq_4q_5q_6q_9$ $vq_4q_5q_8q_9$ $vq_4q_6q_8q_9$ $vq_5q_6q_8q_9$ $vq_2q_4q_5q_6q_8$ $vq_2q_4q_5q_6q_9$ $vq_2q_4q_5q_8q_9$ $vq_2q_4q_6q_8q_9$ $vq_2q_5q_6q_8q_9$ $vq_4q_5q_6q_8q_9$ $vq_2q_4q_5q_6q_8q_9$) χ (q_1 vq_3 vq_7 vq_9 vq_{11} vq_{12} vq_1q_3 vq_1q_7 vq_1q_9 vq_1q_{11} vq_1q_{12} vq_3q_7 vq_3q_9 vq_3q_{11} vq_3q_{12} vq_7q_9 vq_7q_{11} vq_7q_{12} vq_9q_{11} vq_9q_{12} $vq_{11}q_{12}$ $vq_1q_3q_7$ $vq_1q_3q_9$ $vq_1q_3q_{11}$ $vq_1q_3q_{12}$ $vq_1q_7q_9$ $vq_1q_7q_{11}$ $vq_1q_7q_{12}$ $vq_1q_9q_{11}$ $vq_1q_9q_{12}$ $vq_1q_{11}q_{12}$ $vq_3q_7q_9$ $vq_3q_7q_{11}$ $vq_3q_7q_{12}$ $vq_3q_9q_{11}$ $vq_3q_9q_{12}$ $vq_3q_{11}q_{12}$ $vq_7q_9q_{11}$ $vq_7q_9q_{12}$ $vq_7q_{11}q_{12}$ $vq_9q_{11}q_{12}$ $vq_1q_3q_7q_9$ $vq_1q_3q_7q_{11}$ $vq_1q_3q_7q_{12}$ $vq_1q_3q_9q_{11}$ $vq_1q_3q_9q_{12}$ $vq_1q_3q_{11}q_{12}$ $vq_1q_7q_9q_{11}$ $vq_1q_7q_9q_{12}$ $vq_1q_7q_{11}q_{12}$ $vq_1q_9q_{11}q_{12}$ $vq_3q_7q_9q_{11}$ $vq_3q_7q_9q_{12}$ $vq_3q_7q_{11}q_{12}$ $vq_3q_9q_{11}q_{12}$ $vq_7q_9q_{11}q_{12}$ $vq_1q_3q_7q_9q_{11}$ $vq_1q_3q_7q_9q_{12}$ $vq_1q_3q_7q_{11}q_{12}$ $vq_1q_3q_9q_{11}q_{12}$ $vq_1q_7q_9q_{11}q_{12}$ $vq_3q_7q_9q_{11}q_{12}$ $vq_1q_3q_7q_9q_{11}q_{12}$) χ (q_4q_6 vq_4q_8 vq_4q_9 vq_4q_{10} vq_4q_{12} vq_6q_8 vq_6q_9 vq_6q_{10} vq_6q_{12} vq_8q_9 vq_8q_{10} vq_8q_{12} vq_9q_{10} vq_9q_{12} $vq_{10}q_{12}$ $vq_4q_6q_8$ $vq_4q_6q_9$ $vq_4q_6q_{10}$ $vq_4q_6q_{12}$ $vq_4q_8q_9$ $vq_4q_8q_{10}$ $vq_4q_8q_{12}$ $vq_4q_9q_{10}$ $vq_4q_9q_{12}$ $vq_4q_{10}q_{12}$ $vq_6q_8q_9$ $vq_6q_8q_{10}$ $vq_6q_8q_{12}$ $vq_6q_9q_{10}$ $vq_6q_9q_{12}$ $vq_6q_{10}q_{12}$ $vq_8q_9q_{10}$ $vq_8q_9q_{12}$ $vq_8q_{10}q_{12}$ $vq_9q_{10}q_{12}$ $vq_4q_6q_8q_9$ $vq_4q_6q_8q_{10}$ $vq_4q_6q_8q_{12}$ $vq_4q_6q_9q_{10}$ $vq_4q_6q_9q_{12}$ $vq_4q_6q_{10}q_{12}$ $vq_4q_8q_9q_{10}$ $vq_4q_8q_9q_{12}$ $vq_4q_8q_{10}q_{12}$ $vq_4q_9q_{10}q_{12}$ $vq_6q_8q_9q_{10}$ $vq_6q_8q_9q_{12}$ $vq_6q_8q_{10}q_{12}$ $vq_6q_9q_{10}q_{12}$ $vq_8q_9q_{10}q_{12}$ $vq_4q_6q_8q_9q_{10}$ $vq_4q_6q_8q_9q_{12}$ $vq_4q_6q_8q_{10}q_{12}$ $vq_4q_6q_9q_{10}q_{12}$ $vq_4q_8q_9q_{10}q_{12}$ $vq_6q_8q_9q_{10}q_{12}$ $vq_4q_6q_8q_9q_{10}q_{12}$) χ (q_2 vq_4 vq_5 vq_7 vq_2q_4 vq_2q_5 vq_2q_7 vq_4q_5 vq_4q_7 vq_5q_7 $vq_2q_4q_5$ $vq_2q_4q_7$ $vq_2q_5q_7$ $vq_4q_5q_7$ $vq_2q_4q_5q_7$).

Appendix C

$P = q_2q_3q_6q_{10}$ $vq_2q_6q_7q_{10}$ $vq_2q_6q_{10}q_{11}$ $vq_3q_5q_6q_{10}$ $vq_5q_6q_7q_{10}$ $vq_5q_6q_{10}q_{11}$ $vq_1q_2q_3q_4q_6$ $vq_1q_2q_3q_4q_{10}$ $vq_1q_2q_3q_6q_8$ $vq_1q_2q_3q_6q_9$ $vq_1q_2q_3q_6q_{10}$ $vq_1q_2q_3q_6q_{12}$ $vq_1q_2q_3q_8q_{10}$ $vq_1q_2q_3q_9q_{10}$ $vq_1q_2q_4q_6q_7$ $vq_1q_2q_4q_6q_{11}$ $vq_1q_2q_4q_7q_{10}$ $vq_1q_2q_4q_{10}q_{11}$ $vq_1q_2q_6q_7q_8$ $vq_1q_2q_6q_7q_9$ $vq_1q_2q_6q_7q_{10}$ $vq_1q_2q_6q_7q_{12}$ $vq_1q_2q_6q_8q_{11}$ $vq_1q_2q_6q_9q_{11}$ $vq_1q_2q_6q_{10}q_{11}$ $vq_1q_2q_6q_{11}q_{12}$ $vq_1q_2q_7q_8q_{10}$ $vq_1q_2q_7q_9q_{10}$ $vq_1q_2q_8q_{10}q_{11}$ $vq_1q_2q_9q_{10}q_{11}$ $vq_1q_3q_4q_5q_6$ $vq_1q_3q_4q_5q_{10}$ $vq_1q_3q_4q_6q_{10}$ $vq_1q_3q_5q_6q_8$ $vq_1q_3q_5q_6q_9$ $vq_1q_3q_5q_6q_{10}$ $vq_1q_3q_5q_6q_{12}$ $vq_1q_3q_5q_8q_{10}$ $vq_1q_3q_5q_9q_{10}$ $vq_1q_4q_5q_6q_7$ $vq_1q_4q_5q_6q_{11}$ $vq_1q_4q_5q_7q_{10}$ $vq_1q_4q_5q_{10}q_{11}$ $vq_1q_4q_6q_7q_{10}$ $vq_1q_4q_6q_{10}q_{11}$ $vq_1q_5q_6q_7q_8$ $vq_1q_5q_6q_7q_9$ $vq_1q_5q_6q_7q_{10}$ $vq_1q_5q_6q_7q_{12}$ $vq_1q_5q_6q_8q_{11}$ $vq_1q_5q_6q_9q_{11}$ $vq_1q_5q_6q_{10}q_{11}$ $vq_1q_5q_6q_{11}q_{12}$ $vq_1q_5q_7q_8q_{10}$ $vq_1q_5q_7q_9q_{10}$ $vq_1q_5q_7q_{10}q_{12}$ $vq_1q_5q_8q_{10}q_{11}$ $vq_1q_5q_9q_{10}q_{11}$ $vq_1q_6q_7q_8q_{10}$ $vq_1q_6q_7q_9q_{10}$ $vq_1q_6q_7q_{10}q_{11}$ $vq_1q_6q_7q_{10}q_{12}$ $vq_1q_6q_8q_{10}q_{11}$ $vq_1q_6q_9q_{10}q_{11}$ $vq_1q_6q_{10}q_{11}q_{12}$ $vq_2q_3q_4q_5q_6$ $vq_2q_3q_4q_5q_{10}$ $vq_2q_3q_4q_6q_{10}$ $vq_2q_3q_5q_6q_8$ $vq_2q_3q_5q_6q_9$ $vq_2q_3q_5q_6q_{10}$ $vq_2q_3q_5q_6q_{12}$ $vq_2q_3q_5q_8q_{10}$ $vq_2q_3q_5q_9q_{10}$ $vq_2q_3q_5q_{10}q_{12}$ $vq_2q_3q_6q_7q_{10}$ $vq_2q_3q_6q_8q_{10}$ $vq_2q_3q_6q_9q_{10}$ $vq_2q_3q_6q_{10}q_{11}$ $vq_2q_3q_6q_{10}q_{12}$ $vq_2q_4q_5q_6q_7$ $vq_2q_4q_5q_6q_{11}$ $vq_2q_4q_5q_7q_{10}$ $vq_2q_4q_5q_{10}q_{11}$ $vq_2q_4q_6q_7q_{10}$ $vq_2q_4q_6q_{10}q_{11}$ $vq_2q_5q_6q_7q_8$ $vq_2q_5q_6q_7q_9$ $vq_2q_5q_6q_7q_{10}$ $vq_2q_5q_6q_7q_{12}$ $vq_2q_5q_6q_8q_{11}$ $vq_2q_5q_6q_9q_{11}$ $vq_2q_5q_6q_{10}q_{11}$ $vq_2q_5q_6q_{11}q_{12}$ $vq_2q_5q_7q_8q_{10}$ $vq_2q_5q_7q_9q_{10}$ $vq_2q_5q_7q_{10}q_{12}$ $vq_2q_5q_8q_{10}q_{11}$ $vq_2q_5q_9q_{10}q_{11}$ $vq_2q_5q_{10}q_{11}q_{12}$ $vq_2q_6q_7q_8q_{10}$ $vq_2q_6q_7q_9q_{10}$ $vq_2q_6q_7q_{10}q_{11}$ $vq_2q_6q_7q_{10}q_{12}$ $vq_2q_6q_8q_{10}q_{11}$ $vq_2q_6q_9q_{10}q_{11}$ $vq_2q_6q_{10}q_{11}q_{12}$ $vq_3q_4q_5q_6q_{10}$ $vq_3q_5q_6q_7q_{10}$ $vq_3q_5q_6q_8q_{10}$ $vq_3q_5q_6q_9q_{10}$ $vq_3q_5q_6q_{10}q_{11}$ $vq_3q_5q_6q_{10}q_{12}$ $vq_4q_5q_6q_7q_{10}$ $vq_4q_5q_6q_{10}q_{11}$ $vq_5q_6q_7q_8q_{10}$ $vq_5q_6q_7q_9q_{10}$ $vq_5q_6q_7q_{10}q_{11}$ $vq_5q_6q_7q_{10}q_{12}$ $vq_5q_6q_8q_{10}q_{11}$ $vq_5q_6q_9q_{10}q_{11}$ $vq_5q_6q_{10}q_{11}q_{12}$

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$q_1q_3q_4q_5q_6q_7q_9q_{10}q_{11}q_{12}$ $\vee q_1q_3q_4q_5q_6q_8q_9q_{10}q_{11}q_{12}$ $\vee q_1q_3q_4q_5q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_1q_3q_4q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_1q_3q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_1q_4q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_2q_3q_4q_5q_6q_7q_8q_9q_{10}q_{11}$ $\vee q_2q_3q_4q_5q_6q_7q_8q_9q_{10}q_{12}$ $\vee q_2q_3q_4q_5q_6q_7q_8q_9q_{11}q_{12}$ $\vee q_2q_3q_4q_5q_6q_7q_8q_{10}q_{11}q_{12}$ $\vee q_2q_3q_4q_5q_6q_7q_9q_{10}q_{11}q_{12}$ $\vee q_2q_3q_4q_5q_6\ q_8q_9q_{10}q_{11}q_{12}$ $\vee q_2q_3q_4q_5q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_2q_3q_4q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_2q_3q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_2q_4q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_3q_4q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee$

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$q_1q_2q_3q_4q_5q_6q_7q_8q_9q_{10}q_{11}$ $\vee q_1q_2q_3q_4q_5q_6q_7q_8q_9q_{10}q_{12}$ $\vee q_1q_2q_3q_4q_5q_6q_7q_8q_9q_{11}q_{12}$ $\vee q_1q_2q_3q_4q_5q_6q_7q_8q_{10}q_{11}q_{12}$ $\vee q_1q_2q_3q_4q_5q_6q_7q_9q_{10}q_{11}q_{12}$ $\vee q_1q_2q_3q_4q_5q_6q_8q_9q_{10}q_{11}q_{12}$ $\vee$

$q_1q_2q_3q_4q_5q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_1q_2q_3q_4q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_1q_2q_3q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_1q_2q_4q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_1q_3q_4q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_2q_3q_4q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$ $\vee q_1q_2q_3q_4q_5q_6q_7q_8q_9q_{10}q_{11}q_{12}$.

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