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Algorithms for Solving Problems of Resources Allocation in the Management of Business Processes in Educational Organizations

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Abstract: This article deals with the problem of optimal resources allocation in reference to the area that is currently relevant in the Republic of Kazakhstan, the educational system and management issues in educational organizations in rapidly changing economic and social conditions. A model for the optimal resources' allocation in the management of business processes that exist in educational organizations has been developed using the example of one of the key business processes. Such research methods as search, survey, Fishbone diagrams and heuristic methods were used. A computational algorithm was developed and the testing results on the suggested example were presented. Comparative analysis shows that the developed computational algorithm based on the application of the linear programming method results in the optimal resources allocation in the considered business process. The analysis of existing methods reveals their limitations, particularly in dealing with dependent operations. The research findings and approaches have practical implications for improving the management system and enhancing the quality of business processes in educational organizations. The algorithms and models developed in this study can be applied not only to solve load distribution issues among teachers but also to address resource allocation problems in other areas of educational institutions.

Index Terms: Management of Business Process, Educational Process Planning, Information Flows Management, Algorithm for Optimal Resource Allocation, Distribution of Discipline Credits.

1. Introduction

The optimal resources allocation in various control systems with a given set of constraints is a common problem and is considered in various areas of human activity. For many years, such application areas of these problems as economics, transport, mechanical engineering and radio communications have been the most relevant. Currently, due to the topic relevance of the formation and development of human capital, the educational system and the educational organization in general are attracting much attention [1]. It is suggested to consider the qualitative development of the educational organization as a process that requires innovation management. A wide scope of tasks defined by this problem, the optimal resources allocation for organization management, planning and preparation of the educational process, a qualitative system for information flows organization and management, is of interest.

To this date, intensive computerization of various areas of modern society largely determines the introduction of an information approach to the study and solution of educational problems. At the same time, it is important to build a strategy for management of business processes in the structures of the educational system, as well as the quality of the implementation of the information approach to solving such problems. Business processes modernization in the existing educational system through the introduction of innovative technologies involves the integration of key principles of educational systems management and their subsequent improvement with the use of an institutional approach, which makes it possible to timely identify and determine the ways to change the norms and rules of behavior of subjects of production and consumption of educational services [2]. The resources allocation in the management of business processes that take place in the modern educational system largely depends on the effectiveness of the innovative technologies implementation in the educational sphere.

Two areas of human activity have become crucial for the social and economic development of society: the wide dissemination and use of information technologies in improvement of business processes and the perception of higher education as a key component of the social and economic basis for the development of the whole society. Regular and relatively stable transformations in the public area, which are more often based on the obtained information, require careful study and consolidation of information and competencies already obtained by specialists, and then the study of the following ones [3]. This implies an increase in the scale of demand, accessibility, and openness of the higher education system, including the need to master specific competencies throughout life.

Regular changes in social arrangements, which are based on new knowledge and competencies, involve the correction and adjustments of existing ones, as well as the acquisition of missing ones [4]. This means the need for further improvement of the higher education system, including the need for training in specific competencies throughout the entire working activity. This allows saying that a new paradigm, a new model of the higher education system, which differs significantly from the classical, generally accepted model is being created. New needs of social development set such fundamental tasks for the higher education system, which have no analogues in the past, since the solution of such tasks requires a fundamental revision of the teaching strategy, and hence the principles of the higher education management system [5].

The main objective of this research is to address the problem of resource allocation in educational organizations, specifically focusing on the distribution of discipline credits to form the teaching load of teachers. The study aims to develop a model and algorithm for optimal resource allocation, taking into account the unique characteristics and business processes of educational institutions. The authors hope to enhance the management system in these organizations by integrating innovative technologies and applying linear programming methods. The main limitation is the need for a heuristic approach to correct the initial distribution of credits. By improving resource allocation, the study aims to optimize class scheduling, improve organizational efficiency, and meet the quality criteria established in educational organizations.

This article deals with the problem of resources allocation in the management of business processes that exist in educational organizations, using the example of distribution of discipline credits to form a teaching load of a teacher for a given period. The optimal distribution of discipline credits determines the qualitative formation of the teaching load of a teacher, which should be considered one of the main indicators in the management system for planning and preparing information in an educational organization and affects another important indicator, an effective class schedule that meets the quality criteria established in the educational organization.

2. Literature Review

The educational environment often uses data mining techniques to explore and evaluate teaching performance in Research scientist N.V. Basha [6] in his scientific work addresses a wide range of problematic issues of building an effective algorithm for managing scientific activity based on a multidimensional goals hierarchy, which is of significant practical importance in the context of resource allocation in management of business processes in institutions of the modern higher education system. The author came to the conclusion that statistical data indicate a significant imbalance between the costs for the scientific activity and the achieved performance indicators. According to the scientist, the management of scientific activity is a complex process that can be considered from the point of view of organizing the activities of a specific higher education system's organization, in relation to which there is a solution of specific tasks of building a business process management system of the educational plane. In general, the author's opinion coincides with the results obtained in this study, because it emphasizes the importance of finding the optimal algorithm for scientific activity management in the context of solving priority problems of resource allocation in management of business processes in educational organizations.

I.G. Asadulina [2], in her scientific study of various aspects of the integration of education and business systems in the educational space of a modern higher education institution, notes that an important services feature of the modern education system is that through the provision of educational services, the formation of a wide range of personality resources and the socio and economic system of the given region. At the same time, both can be implemented by ensuring the education quality, which the developers of new state standards in the educational system are inextricably linked to the competencies of future specialists. The topic of competencies came to education from the production sphere as a result of dissatisfaction, primarily of western employers, with the modern educational practice, and more specifically the quality of its educational product, a graduate. Hence, the introduction of the competencies concept can be considered as an attempt to establish a dialogue between manufacturers and consumers of an educational product to ensure the education quality and create a unified educational space. Partially, the researcher's conclusions coincide with the results obtained in this scientific work regarding the distribution of credits among various groups of teachers, in accordance with their competencies. At the same time, the question remains debatable regarding the features of establishing a dialogue between manufacturers and consumers of a particular educational product, since the author has not identified control criteria and the organization sequence of this process.

R.R. Mulimkhanov [7], in his study of the features of building an effective model of strategic management of business process in organizations of the modern educational system, notes that the process of complete management of organizations in the business educational system is an activity aimed at solving specific problems depending on the established priorities, which is based on the use reference strategies with the designation of characteristic features that are peculiar only to them, while applying the principles of evaluation and monitoring of the working strategy, which is based on the balanced parameters system. The scientist's conclusions complete and expand the results obtained in this study, formulating an emphasis on the formation of reference strategies for the implementation of specific tasks for business processes management that take place in modern educational organizations.

A.K. Kazantsev and D.K. Meshkis [3] in a joint scientific study considered a number of problematic aspects of the business processes modeling of an educational institution based on the modern technologies. The researchers came to the conclusion that the use of distance learning methods in organizations of the modern educational system has broad prospects for ensuring high quality of solving the problems of resource allocation in the management of business processes in educational organizations. According to the researchers, distance learning has earned a great reputation as a certain alternative to conventional higher education, although it is usually perceived as a variant of distance education. Without going into disputes about the place of distance learning, they emphasize the conclusion that this type of learning in a higher education institution is one of the main options for information technology in the context of fundamental transformations of the higher education system, which contributes to the strengthening and further improvement of the processes of resource allocation in management of business process in the educational system. In the context of the results analysis of this scientific work, such a conclusion seems disputable, because the distribution of the classroom load among teachers of an educational institution with the introduction of distance learning is problematic due to the difficulty of ensuring the quality control of this process.

L. Taylor [8] in his scientific study considered the issues of the information support of the educational process in a modern higher education institution, taking into account its specifics and specific business processes that are typical for the education organization. The researcher came to the conclusion that qualitative information support of the educational process of a modern higher educational institution is impossible without well-adjusted and coordinated efforts of a number of responsible persons aimed at ensuring the timely control over the quality and volume of information entering the educational space of a modern higher education institution. In addition, researchers note that without achieving a well-coordinated management of business processes in an education organization, it is impossible to achieve a high level of organization of the educational process as a whole. The conclusions of the research scientist almost completely coincide with the results obtained in this scientific work, in particular, linking aspects of the organization of the educational process in the information space of a modern higher education institution with the need to develop and implement algorithms for implementing the model of optimal resource allocation in order to form the classroom load of a teacher.

K. Rubenson [9], in his study of modern resource management technologies in the educational space of a higher education institution focuses on the fact that any significant achievements in the field of management of business process that take place in the educational space of a modern higher education institution are inextricably linked with the development and the implementation of the latest software algorithms that allow effectively managing of all processes in an educational institution. The researcher concludes that the improvement of software algorithms allows dramatically increase the efficiency of resource allocation in management of business processes in an educational institution, which has a positive impact on the construction of the educational process in an educational institution as a whole. Thus, the scientist's conclusions complete and significantly expand the results of this scientific work, because they emphasize the importance of developing effective algorithms for distributing the load on teachers during the educational process, and also indicate the need to organize additional scientific researches within the framework of the mentioned topic.

A team of researchers, represented by A.V. Danilov et al. [5], in a joint study of modern business process management systems note that the practical application of service-oriented architectures makes it possible to guarantee coherence in the organization and implementation end of business processes in a modern educational institution. At the same time, the development and application of a mobile intellectual process control complex based on a scientific approach with the use of a large number of agents generally expands the potential, guaranteeing a significant adaptability of business processes in the structure to changing external conditions, high mobility and quality of business processes in accordance with the final stated tasks. According to researchers, it is these advantages that are achieved by increasing the system intelligence, applying the experience gained in the functioning of the full amount of data in the field of organizing business processes in a modern educational institution and providing a high-quality solution to the problem by many private agents. The conclusions of the researchers do not directly contradict the abovementioned results, significantly supplementing them in the context of revealing the searching prospects for new opportunities for creating dynamic intelligent process control systems based on a scientific approach with the use of a large number of agents.

3. Methodology

A model for the optimal resources allocation for the business process of forming the teaching (classroom) load for the academic year in the educational organization, part of the discipline's distribution (credits for disciplines) to teachers, based on information processes and quality requirements in a particular higher education institution, has been developed [10]. The resources of a higher education institution are studied on the example of the International Educational Corporation. By polling survey of employees involved in this business process (dean's offices, registrar's office, the department of academic policy and quality, the accounting and finance department, the digitalization department), as well as studying the documents that are freely available on the higher education institution's website and provided by the polled employees, relevant data on the types that compile the components of the studied business process and a set of end resources supporting them has been identified [11-13].

Due to the fact that the business process has many interrelated resources and causes that affect it, a Fishbone diagram was used to conduct a qualitative analysis, as a tool that allows to identify the main resources of the business process, key relationships between resources and problems [4; 14-16]. A visual picture of the business process' analysis of a higher education institution on the formation of the teaching load for the academic year and factors affecting the quality of the business process was obtained. The received Fishbone diagram (Fig. 1) contains 5 main resource blocks, each containing up to 6 levels in its block.

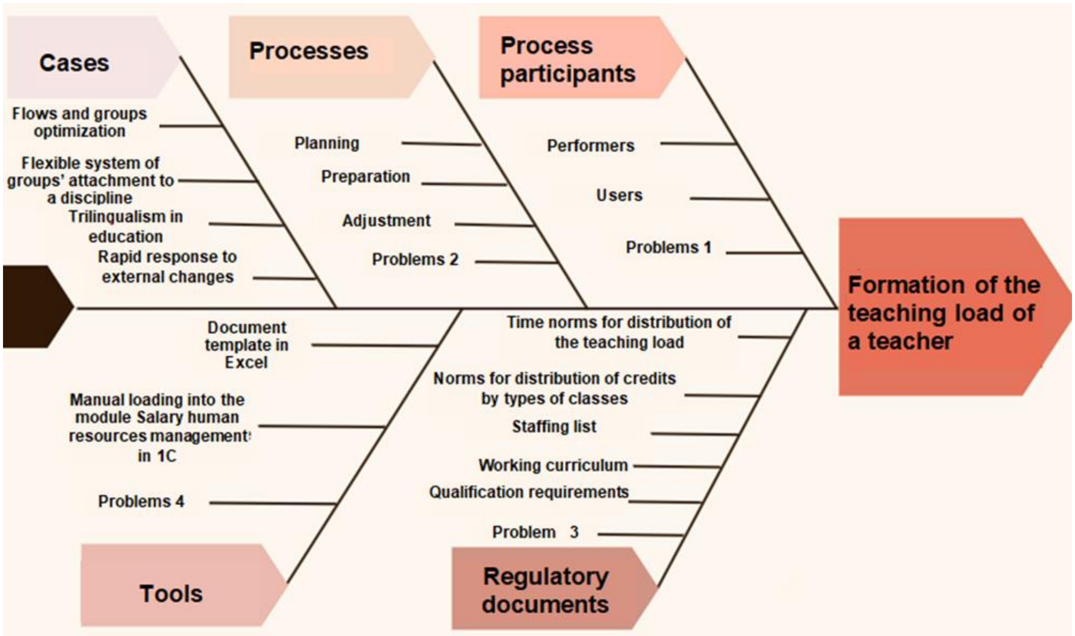

Fig. 1. Fishbone diagram of the business process of forming the teaching load of a teacher

The proposed method in this research is based on mathematical modeling to achieve optimal resource allocation in educational organizations. The model incorporates constraints, assumptions, and objectives specific to educational institutions. Linear programming methods are applied to optimize the allocation of discipline credits, taking into account factors such as load distribution, academic degrees, and vacancies. This mathematical model serves as the foundation for the algorithm designed to implement the resource allocation process.

The algorithm is implemented in software, providing a user-friendly interface for inputting data and running the optimization process. The algorithm utilizes the developed mathematical model to generate optimized resource allocation solutions. The algorithm also includes a heuristic approach to correct the initial distribution of credits, addressing any shortcomings of the initial allocation. The results of the algorithm are evaluated and analyzed to assess its effectiveness in improving class scheduling, organizational efficiency, and the fulfillment of quality criteria in educational organizations.

The proposed materials and methods in this research facilitate the achievement of the research objectives by providing a structured approach to address the problem of resource allocation in educational organizations. The study utilizes a model and algorithm for optimal resource allocation, which takes into account the unique characteristics and business processes of educational institutions. By integrating innovative technologies and applying linear programming methods, the research aims to enhance the management system in these organizations. The use of a heuristic approach helps to correct the initial distribution of credits, overcoming the limitation of the study. The ultimate goal is to improve resource allocation, optimize class scheduling, enhance organizational efficiency, and meet the quality criteria set by educational institutions.

4. Results and Discussion

4.1. Solution algorithm for the developed model

The following resources are determined: disciplines and teachers that are interconnected, teachers are assigned to each discipline. The list of disciplines is formed in accordance with the contingent of students in the educational program and the individual curriculum of a student for the academic year [17]. Each discipline has an assigned number of credits and is divided into classes types (the form of conducting contact hours), lectures, practical and laboratory classes. The norms for the correspondence of 1 credit to 1 contact hour and the norms for distribution of credits by types of classes, depending on the number of credits assigned to a discipline, have been established [18]. A map of study groups and student flows is formed depending on the course of study, educational program, languages of study and the classroom fund. In accordance with the list of disciplines, their distribution into types of classes, the established norms for distribution of credits by types of classes, maps of study groups and student flows, a general hourly fund for an academic year is formed, which determines the number of disciplines and credits for the academic year, which should be optimally distributed among teachers. The teaching load of a teacher has given limits, determined by the limit for the academic year (in credits), determined by the regulatory documents of a higher education institution [1]. The model of the optimal resource's allocation for the formation of the teaching load of a teacher in terms of the distribution of disciplines (disciplines credits):

1. It is assumed that each teacher has his own rating in the discipline (this does not take into account the distribution by types of classes). The rating is based on certain principles that reflect the quality policy adopted at a higher education institution and the preferences of a teacher himself in the conduction of this discipline [19]. It creates loyalty to the business process. In accordance with the rating of a teacher, a priority matrix for each discipline is formed.

2. In order to meet the formed teaching load in order to ensure the class schedule criteria, a standard is drawn up to assign a certain number of study groups per teacher in a discipline which is determined in credits [20-21]. In the standard formation model a search method is used that takes into account the number of teachers corresponding to a discipline in the state, the given classroom fund and shifts in the study time schedule [22].

Conditions for the model are defined:

– first of all, disciplines are distributed to those teachers who have the highest priority;
– the limit of the need for total hourly fund by discipline, by types of classes is adhered;
– the limit of the teaching load of a teacher is adhered;
– the need of the total hourly fund by disciplines should be equal to the sum of the teaching load of a teacher;
– the remaining need for the total hourly fund by a discipline is distributed in accordance with the principle that as many disciplines as possible (respectively credits) are assigned to a teacher who has a higher priority.

Mathematical description of the model. The objective function is defined as follows:

$$J = \sum_{i=1}^{NP} \sum_{j=1}^{ND} (PRL_{ij} * XL_{ij} + PRp_{ij} * Xp_{ij} + PRl_{ij} * Xl_{ij}) \rightarrow max \tag{1}$$

where: NP is the number of teachers; ND is the number of disciplines; PRL_{ij} is the priority for conducting lecturers by the i-th teacher in the j-th discipline; PRp_{ij} is the priority for conducting practical classes by the i-th teacher in the j-th discipline; PRl_{ij} is the priority for conducting laboratory classes by the i-th teacher in the j-th disciplice; XL_{ij} is the number of credits for lectures conducted by the i-th teacher in the j-th discipline; Xp_{ij} is the number of credits for practical classes conducted by the i-th teacher in the j-th discipline; Xl_{ij} is the number of credits for laboratory classes conducted by the i-th teacher in the j-th discipline.

The function maximum is under limits (2), (3), (4), (5):

$$\sum_{i=1}^{NP} XL_{ij} = KPL_j, \sum_{i=1}^{NP} Xp_{ij} = KPp_j, \sum_{i=1}^{NP} Xl_{ij} = KPl_j,\ j = \overline{1, ND} \tag{2}$$

where: KPL_j is the total number of credits for lectures in the j-th discipline; KPp_j is the total number of credits for practical classes in the j-th discipline; KPl_j is the total number of credits for laboratory classes in the j-th.

$$\sum_{j=1}^{ND} (XL_{ij} + Xp_{ij} + Xl_{ij}) * R_{ij} = NG_i,\ i = \overline{1, NP} \tag{3}$$

$$R_{ij} = \begin{cases} 1, if\ i - \text{th teacher can deliver } j - \text{th discipline} \\ \qquad 0, \text{if otherwise} \end{cases} \tag{4}$$

where: NG_i is the limit of the teaching load of the i-th teacher.

$$XL_{ij} \le XNL_{ij}, Xp_{ij} \le XNp_{ij,} Xl_{ij} \le XNp_{ij} \quad (5)$$

where: XNL_j is the established standard for the class schedule on the number of credits for lectures in the j-th discipline per teacher; XNp_j is the established standard for class schedule on the number of practical classes in the j-th discipline per teacher; XNl_j is the established standard for the class schedule on the number of laboratory classes in the j-th discipline per teacher.

Table 1 provides an example of a visual interpretation of the priority matrix that determines the rating of each teacher in each discipline. The following designations are entered for the priority matrix: disciplines – $S_1, S_2, \ldots, S_{ND}$; teachers – $T_1, T_2, \ldots, T_{NP}$. Priority values take integers in the range from 1 to 10, where "10" means that the i-th teacher has the highest priority in the j-th discipline in the distribution, "0" means that the i-th teacher is excluded from the distribution j-th discipline.

Table 1. An example of the priority matrix that determines the preference for discipline distribution between teachers

	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**…**	**SND**
T1	9	10	0	1	10	0	1		1
T2	10	1	1	2	10	0	2		2
T3	8	4	2	3	1	0	3		3
T4	0	4	9	4	0	0	4		4
T5	4	10	10	6	5	0	10		5
T6	0	9	9	7	0	0	7		6
T7	6	1	4	10	10	8	8		7
…									
TNP	1	8	0	9	4	1	9		10

In the priority matrix, the same priority values are allowed for different teachers, if the number of disciplines is bigger than the number of teachers and the priority of a teacher in the discipline does not have the value "0". The values *KPLj, KPpj, KPlj* are formed from the total hourly fund document and are calculated by the formulas:

$$KPL_j = Kgp_j * KL_{j,} KPp_j = Kg_j * Kp_{j,} KPl_j = Kg_j * Kl_j \quad (6)$$

where: Kg_j is the number of groups in the j-th discipline; KL_j is the number of credits for lectures in the j-th discipline; Kp_j is the number of credits for practical classes in the j-th discipline; Kl_j is the number of credits for laboratory classes in the j-th discipline; Kgp_j is the number of groups that are united in one flow in the j-th discipline. Within the framework of the task, *KPLj, KPpj, KPlj*, XNL_j, XNp_j, XNl_j are not calculated, but are set as allowed values.

The algorithm is based on the application of the integer linear programming method and is presented in fig. 2 in the form of a flowchart.

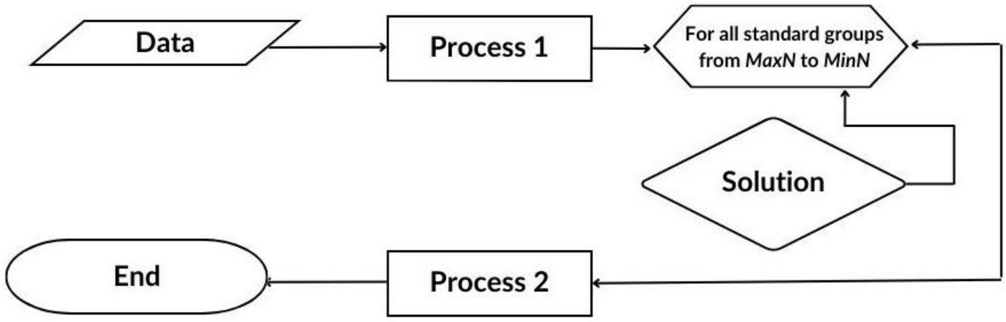

Fig. 2. Flowchart of the algorithm for distribution discipline credits to teachers in accordance with the developed model (1)

In the flowchart each element includes the following description.

1. The "Data" block sets the values:

– the number of teachers and disciplines;

– restrictions of the number of the teaching load limit for each teacher;

– restrictions on the number of credits for each discipline that should be distributed;

– the priority matrix that shows the preference for the discipline's distribution among teachers;

– the standard for credits distribution to teachers, convenient for the optimal classes schedule.

2. The "Process" block includes the following process: disciplines are divided into groups in the standard value and are collected in accordance with the same value, MaxN is determined as the maximum standard value, MinN is determined as the minimum standard value.

3. The "Solution" block includes the following computational steps:

– starting from the group of disciplines that have the maximum standard value (MN), convert the initial data (the standard, the number of credits for the discipline and teacher's workload limit) to integer values, replacing the standard value with "1" and replacing the rest of the initial data with the corresponding values;

– exclude from the distribution the teachers whose discipline priority has the value "0";

– distribute credits for disciplines by the integer linear programming method in accordance with the priority matrix and in accordance with the obtained restrictions on the load limit and the credit limit for discipline, maximize the objective function;

– change the obtained results back by replacing "1" with the standard value in this group, save the result;

– reduce the load limit in accordance with the obtained optimal distribution for the corresponding number of credits.

4. Block "Process 2" includes the following processes:

– calculate the final distribution of credits, summing up the distributed credits for each teacher in the discipline for each standard group;

– in the case of unallocated credits, these credits are allocated to a vacancy.

A program for solving the algorithm has been developed. The program was tested on an example. The analysis of the results shows that the developed model provides the optimal distribution of credits by discipline for the formation of the teaching (classroom) load of teachers.

4.2 Examples of the distribution of discipline credits to teachers

It is necessary to form a classroom load for 15 teachers who need to distribute the maximum number of disciplines credits from the given credits for 12 disciplines (types of classes are not taken into account). The following restrictions on the load limit for 15 teachers are set:

$$i = \overline{1{,}15}, NG_i = \{4, 4, 5, 5, 5, 6, 7, 7, 7, 7, 7, 7, 7, 7, 7\} \tag{7}$$

The total number of credits for each of the 12 disciplines is set:

$$j = \overline{1{,}12}, KPL_j = \{2, 12, 0, 0, 16, 0, 2, 20, 0, 1, 14, 14\} \tag{8}$$

In accordance with the algorithm, set the allowable standard values for the number of credits for each of the 12 disciplines:

$$j = \overline{1{,}12}, XNL_j = \{1, 4, 0, 0, 4, 0, 2, 4, 0, 1, 2, 2\} \tag{9}$$

Table 2 shows the priority matrix for the distribution of disciplines among teachers. The table provides a numerical representation of the preferences for assigning teachers to specific disciplines. Each cell in the table represents the priority value assigned to a particular teacher-discipline combination. The disciplines are represented by columns labeled S_1, S_2, S_3, S_4, S_5, S_6, S_7, and so on, up to SND (where SND represents the last discipline). The teachers are represented by rows labeled T1, T2, T3, and so on, up to TNP (where TNP represents the last teacher). The values in the cells indicate the priority given to each teacher-discipline combination. The higher the priority value, the more preferred that combination is. In this particular table, the values range from 0 to 10. These priority values can be used as guidelines or criteria when assigning teachers to specific disciplines. Higher priority values suggest a stronger preference for a teacher to teach a particular discipline, while lower priority values indicate a lower preference. This matrix helps ensure that teachers are assigned to disciplines in a way that aligns with their expertise or the desired distribution of disciplines among teachers.

Table 2. Priority matrix for the distribution of disciplines among teachers

	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**
T1	0	9	9	0	7	7	0	0	0	1	1	1
T2	10	10	10	9	9	9	8	8	8	0	0	0
T3	3	3	3	10	10	10	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	6	6	9	9	9
T5	6	6	6	0	4	4	0	0	0	0	0	0
T6	7	7	7	0	4	4	10	0	0	0	0	0
T7	0	1	1	0	0	0	0	9	9	8	8	8
T8	0	0	0	0	3	3	0	2	2	10	10	10
T9	0	8	8	0	2	2	0	5	5	0	0	0
T10	0	0	0	0	1	1	0	0	0	4	4	4
T11	0	5	5	0	8	8	0	7	7	3	3	3
T12	0	0	0	0	6	6	0	4	4	2	2	2
T13	0	4	4	0	0	0	0	3	3	7	7	7
T14	0	2	2	0	0	0	0	1	1	6	6	6
T15	0	0	0	0	5	5	0	0	0	5	5	5

Table 3 displays the initial data for the credit's distribution in the context of the standard value group "4." The table consists of two main components: the priority matrix and the load limit. The priority matrix represents the preferences for assigning teachers to specific disciplines within the given group. In this case, the disciplines are represented by columns labeled S_2, S_5, and S_8, while the teachers are represented by rows labeled T1, T2, T3, and so on, up to T15. The values in the cells of the priority matrix indicate the priority given to each teacher-discipline combination. These values range from 0 to 10, representing the preference level. For example, the cell at the intersection of T1 and S_2 has a priority value of 9, indicating a high preference for teacher T1 to teach discipline S_2. The load limit section of the table provides information about the number of credits in each discipline. The number of credits for each discipline is represented by the values in the first row, labeled 12, 16, and 20, respectively. In this case, discipline S_2 has 12 credits, discipline S_5 has 16 credits, and discipline S_8 has 20 credits. The standard number of credits for each discipline is represented in the second row of the load limit section. In this case, all disciplines in the group have a standard number of credits of 4.

Table 3. Initial data for the credit's distribution for the standard value group "4"

Priority matrix					**Load limit, NG_i**
Priority matrix		S_2	S_5	S_8	
	T_1	9	7	0	4
	T_2	10	9	8	4
	T_3	3	10	0	5
	T_4	0	0	6	5
	T_5	6	4	0	5
	T_6	7	4	0	6
	T_7	1	0	9	7
	T_8	0	3	2	7
	T_9	8	2	5	7
	T_{10}	0	1	0	7
	T_{11}	5	8	7	7
	T_{12}	0	6	4	7
	T_{13}	4	0	3	7
	T_{14}	2	0	1	7
	T_{15}	0	5	0	7
The number of credits in j – th discipline, KPL_j		12	16	20	
The standard number of credits in j – th discipline, XNL_j		4	4	4	

Table 3 contains and visually displays all the initial data obtained by setting the task in the considered example. After replacing the value "4" by "1" from (7), (8), (9), it will be had:

$$
\begin{gathered}
i = \overline{1,3}, XNL_j = \{1, 1, 1\}, \\
j = \overline{1,3}, KPL_j = \{3, 4, 5\}, i = \overline{1.15}, \\
NG_i = \{1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1\}
\end{gathered} \tag{10}
$$

Further, after solving in the developed program in accordance with the given algorithm, obtained the result of the distribution of disciplines credits to teachers, which is presented in the form of the diagram in fig. 3.

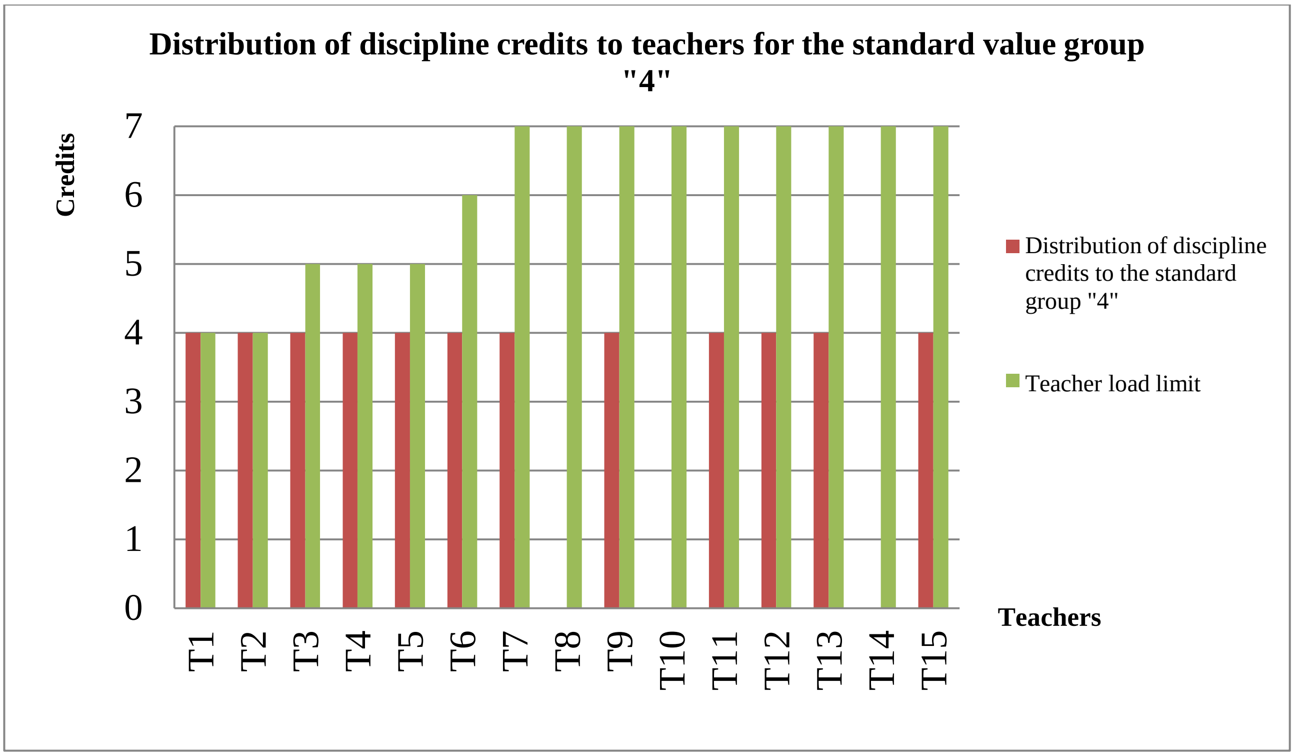

Fig. 3. The result of the distribution of disciplines credits to teachers for the standard group "4"

Thus, authors have distributed credits of the second, fifth and eighth disciplines, where the distribution standard is "4". As it is shown in the diagram in fig. 3, teachers T_8, T_{10}, T_{14} are not allocated with the credits, the rest of the teachers are allocated with "4" credits. *J1* is the value of the objective function after the distribution of credits for the standard value group "4":

$$J1 = 7*4+8*4+10*4+6*4+6*4+7*4+9*4+8*4+7*4+6*4+3*4+5*4=328 \tag{11}$$

Further, perform calculations and distribute the disciplines credits for the standard value group "2", these are the disciplines S_7, S_{11}, S_{12}, in the initial data the (12) load limit is taken and we maximize the objective function value *J2* for this group:

$$i = \overline{1{,}15}, NG_i = \{0, 0, 1, 1, 1, 2, 3, 7, 3, 7, 3, 3, 3, 7, 3\} \tag{12}$$

Table 4. Initial data for the credit's distribution for the standard value group "2"

Priority matrix					***Load limit,*** NG_i
Priority matrix		S_7	S_{11}	S_{12}	
	T_1	0	1	1	0
	T_2	8	0	0	0
	T_3	0	0	0	1
	T_4	0	9	9	1
	T_5	0	0	0	1
	T_6	10	0	0	2
	T_7	0	8	8	3
	T_8	0	10	10	7
	T_9	0	0	0	3
	T_{10}	0	4	4	7
	T_{11}	0	3	3	3
	T_{12}	0	2	2	3
	T_{13}	0	7	7	3
	T_{14}	0	6	6	7
	T_{15}	0	5	5	3
The number of credits in j – th discipline, KPL_j		2	14	14	
The standard number of credits in j – th discipline, XNL_j		2	2	2	

Table 4 presents the initial data for the credit's distribution problem in the context of the standard value group "2." The priority matrix in Table 4 represents the preferences for assigning teachers to specific disciplines within the given group. The disciplines are represented by columns labeled S_7, S_{11}, and S_{12}, while the teachers are represented by rows labeled T1, T2, T3, and so on, up to T15. The values in the cells of the priority matrix indicate the priority given to each teacher-discipline combination. These values range from 0 to 10, where higher values indicate a higher preference. For example, the cell at the intersection of T1 and S_7 has a priority value of 0, indicating no preference for teacher T1 to teach discipline S_7. The standard number of credits for each discipline is represented in the second row of the load limit section. In this case, all disciplines in the group have a standard number of credits of 2.

After replacing the value "2" by "1" from (12), (8), (9) it will be had:

$$i = \overline{1,3}, XNL_j = \{1, 1, 1\},$$
$$j = \overline{1,3}, KPL_j = \{1, 7, 7\}, (13)$$
$$i = \overline{1,15}, NG_i = \{0, 0, 0, 0, 0, 1, 1, 3, 1, 3, 1, 1, 1, 3, 1\} \quad (13)$$

From the initial data in accordance with Table 4, for the "2" standard value group authors exclude teachers T_3, T_5, T_9, as having a zero-priority value and not participating in the distribution of credits. The result of calculations in the developed program in accordance with a given algorithm is shown in fig. 4.

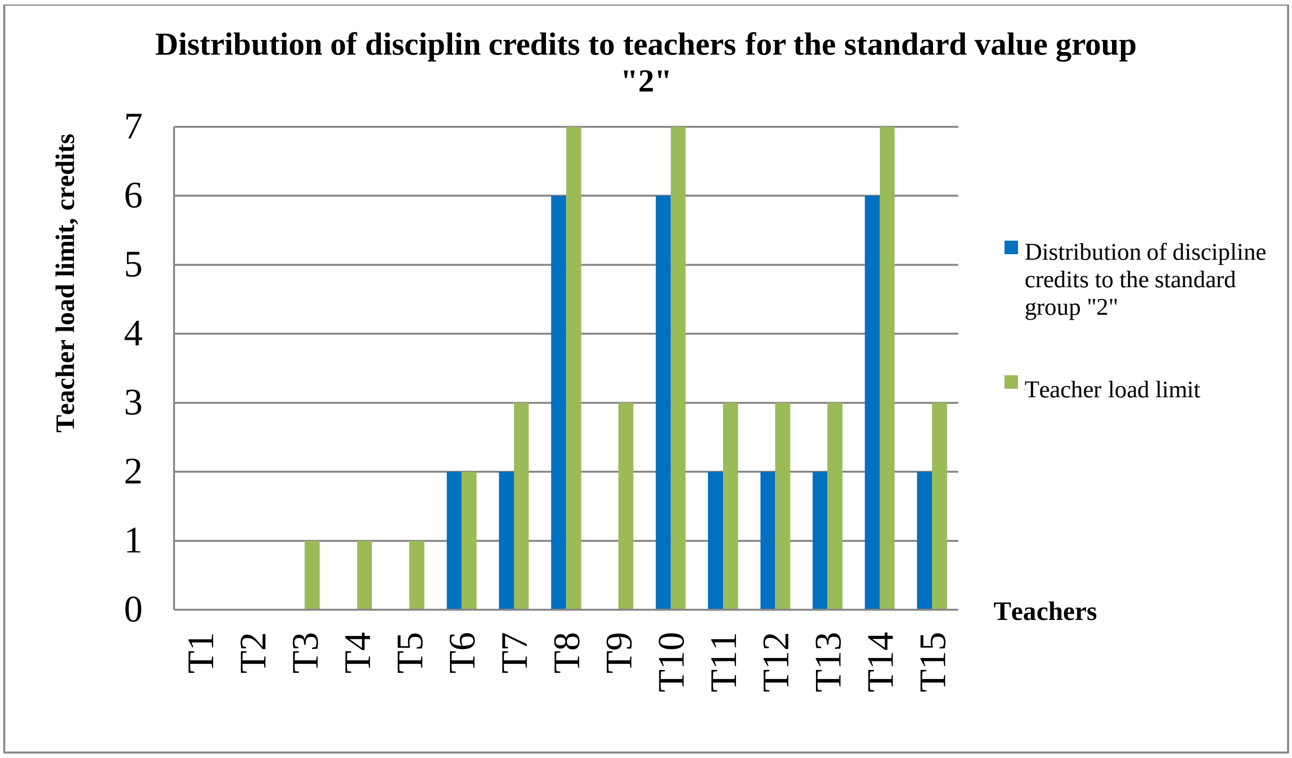

Fig. 4. The result of the distribution of disciplines credits to teachers for the standard group "2"

During this iteration, the credits of the seventh, eleventh and twelfth disciplines were distributed. As the diagram in fig. 4 shows, teachers T_6, T_7, T_{11}, T_{12}, T_{13}, T_{15} are allocated "2" credits, and teachers T_8, T_{10}, T_{14} are allocated "6" credits, the rest of the teachers have "0" credits after distribution. The value of the objective function after the distribution of credits for the standard value group "2" is:

$$J2 = 10*2+8*2+10*2*3+4*2*3+3*2+2*2+7*2+6*2*2+6*2+5*2=190 \quad (14)$$

It remains to perform the calculations and distribution of discipline credits for the "1" standard value group, these are disciplines S_1, S_{10}, in the initial data the load limit is taken (15) and we maximize the value of the objective function *J3* for this group (Table 5).

$$i = \overline{1,15}, NG_i = \{0, 0, 1, 1, 1, 0, 1, 1, 3, 1,1,1, 1, 1,1\} \quad (15)$$

Table 5. Initial data for the distribution of credits for the standard value group "1"

Priority matrix				***Load limit,*** NG_i
Priority matrix		S_1	S_{10}	
	T_1	0	1	0
	T_2	10	0	0
	T_3	3	0	1
	T_4	0	9	1
	T_5	6	0	1
	T_6	7	0	0
	T_7	0	8	1
	T_8	0	10	1
	T_9	0	0	3
	T_{10}	0	4	1
	T_{11}	0	3	1
	T_{12}	0	2	1
	T_{13}	0	7	1
	T_{14}	0	6	1
	T_{15}	0	5	1
The number of credits in j – th discipline, KPL_j		2	1	
The standard number of credits in j – th discipline, XNL_j		1	1	

In calculations (15), (8), (9) will become:

$$\begin{gathered} i = \overline{1{,}2}, XNL_j = \{1, 1\}, \\ j = \overline{1{,}2}, KPL_j = \{2, 1\}, \\ i = \overline{1{,}15}, NG_i = \{0, 0, 1, 1, 1, 0, 1, 1, 3, 1, 1, 1, 1, 1, 1\} \end{gathered} \tag{16}$$

From the initial data for the standard value group "1", authors exclude the teacher T_9, as having a zero-priority value and not participating in the distribution of credits. Fig. 5 shows the result after solving in the developed program in accordance with the given algorithm.

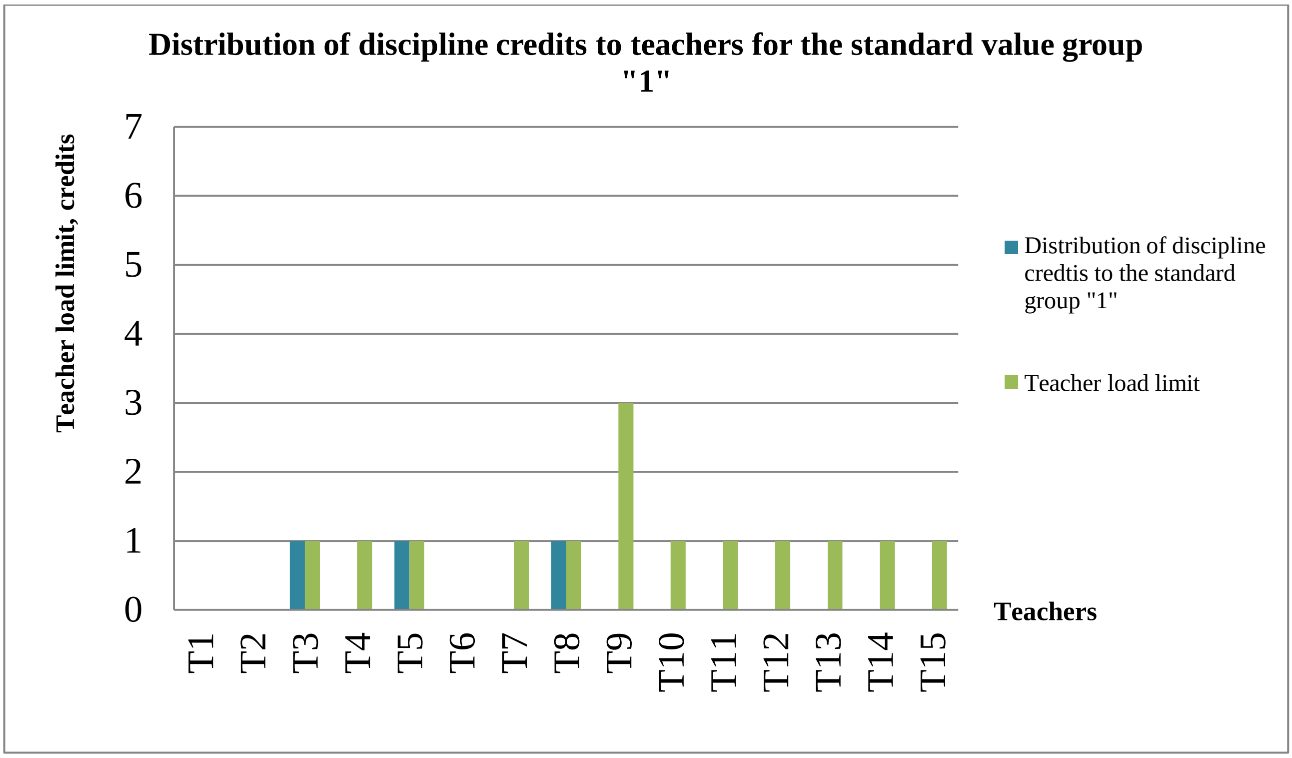

Fig. 5. The result of the distribution of disciplines credits to teachers for the standard group "1"

The credits of the first and tenth disciplines were distributed to teachers. As the diagram in fig. 5 shows, T_3, T_5, and T_8 teachers are allocated "1" credits, the rest of the teachers have "0" credits after distribution, with T_1, T_2, and T_6 teachers having a load limit before distribution of "0". The value of the objective function *J3* after the distribution of credits for the standard value group "1" is:

$$J3 = 3*1 + 6*1 + 10*1 = 19 \tag{17}$$

As a result, summing up all the credits after the distribution into the standard groups "4", "2" and "1", obtain the optimal distribution of credits of 12 disciplines between 15 teachers, which is shown in Table 6. Based on (11), (14) and (17), obtain the maximum value of the objective function *J* for the optimal distribution of the classroom load in accordance with the specified criteria:

$$J = J1 + J2 + J3 = 328 + 190 + 17 = 535 \tag{18}$$

Table 6. The result of the credits distribution to teachers during the execution of the solution algorithm for the developed model of optimal resource allocation by the method of integer linear programming

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	*Initial load limit, NGi*	*Remaining load limit, NGi*
T_1	0	0	0	0	4	0	0	0	0	0	0	0	4	0
T_2	0	0	0	0	0	0	0	4	0	0	0	0	4	0
T_3	1	0	0	0	4	0	0	0	0	0	0	0	5	0
T_4	0	0	0	0	0	0	0	4	0	0	0	0	5	1
T_5	1	4	0	0	0	0	0	0	0	0	0	0	5	0
T_6	0	4	0	0	0	0	2	0	0	0	0	0	6	0
T_7	0	0	0	0	0	0	0	4	0	0	0	2	7	1
T_8	0	0	0	0	0	0	0	0	0	1	0	6	7	0
T_9	0	4	0	0	0	0	0	0	0	0	0	0	7	3
T_{10}	0	0	0	0	0	0	0	0	0	0	6	0	7	1
T_{11}	0	0	0	0	0	0	0	4	0	0	2	0	7	1
T_{12}	0	0	0	0	4	0	0	0	0	0	2	0	7	1
T_{13}	0	0	0	0	0	0	0	4	0	0	0	2	7	1
T_{14}	0	0	0	0	0	0	0	0	0	0	4	2	7	1
T_{15}	0	0	0	0	4	0	0	0	0	0	0	2	7	1

In accordance with the results obtained, in the course of the calculations, Table 6 data show that the credits of all disciplines are fully distributed, the limit of teachers T_4, T_7, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}, T_{15} has not been collected, and the rest of the teachers have used the limit in full. On the considered example, the work of the developed program was tested and a plan for the distribution of discipline credits to teachers was issued, and the model was implemented: all discipline credits were mastered. In order to confirm the optimality of the obtained plan for the credit's distribution with the use of the solution algorithm by the method of integer linear programming, the comparative analysis method was chosen. A second computational algorithm has been developed that solves the distribution of discipline credits to teachers based on the least costs method, when first the discipline credits are distributed to teachers with a priority value of "10", then "9", and so on up to "1". With this solution algorithm, the results for the considered example are shown in Table 7, and the value of the objective function: *J = 450*.

Table 7. The result of the credits distribution to teachers during the execution of the solution algorithm for the developed model of optimal allocation of resources by the least cost method

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	*Initial load limit, NGi*	*Remaining load limit, NGi*
T_1	0	4	0	0	0	0	0	0	0	0	0	0	4	0
T_2	1	0	0	0	0	0	0	0	0	0	0	0	4	3
T_3	0	0	0	0	4	0	0	0	0	0	0	0	5	1
T_4	0	0	0	0	0	0	0	0	0	0	2	2	5	1
T_5	0	0	0	0	0	0	0	0	0	0	0	0	5	5
T_6	0	4	0	0	0	0	2	0	0	0	0	0	6	0
T_7	0	0	0	0	0	0	0	4	0	0	2	0	7	1
T_8	0	0	0	0	0	0	0	0	0	1	2	2	7	2
T_9	0	4	0	0	0	0	0	0	0	0	0	0	7	3
T_{10}	0	0	0	0	0	0	0	0	0	0	0	2	7	5
T_{11}	0	0	0	0	4	0	0	0	0	0	0	0	7	3
T_{12}	0	0	0	0	4	0	0	0	0	0	0	0	7	3
T_{13}	0	0	0	0	0	0	0	0	0	0	2	2	7	3
T_{14}	0	0	0	0	0	0	0	0	0	0	2	2	7	3
T_{15}	0	0	0	0	4	0	0	0	0	0	0	2	7	1

In a comparative analysis, it can be saw that with the developed algorithm with the use of integer linear programming, the value of the objective function (18) is higher by: 535 - 450 = 85 than with the algorithm with the use of the least cost method. Thus, the algorithm with the use of integer linear programming is chosen to implement the model of optimal resource allocation for the formation of the classroom load of a teacher in terms of the distribution of disciplines (discipline credits) between teachers under the given restrictions.

5. Conclusion

This research significantly advances the field of resource allocation in educational organizations by developing a model for optimal resource allocation based on resource analysis and the business process of forming the teaching load for the academic year. The study formulates restrictions, assumptions, and presents an algorithm and software product for implementation. The conducted studies validate the effectiveness of the developed algorithm in correcting the distribution of credits in the teaching load of teachers, especially in cases of unallocated discipline credits. The research highlights the importance of using a heuristic approach to address such situations, considering factors such as distributing credits to teachers with the fewest load and assigning credits to teachers without academic degrees or vacancies. Additionally, the study identifies challenges related to maintaining the integrity of assigned credits for a discipline when considering different types of classes. These findings and approaches have broad applicability in educational organizations, offering opportunities to enhance the management system and improve the quality of business processes.

The scientific justification for this work lies in the need to optimize resource allocation in the face of changing economic and social conditions in the educational system. By developing and implementing a computational algorithm based on linear programming methods, this research offers a systematic and efficient approach to address resource allocation challenges. The research fills a gap in the current knowledge by providing a model tailored to the specific needs and business processes of educational institutions. Moreover, the study emphasizes the practical relevance of its findings, as the developed algorithms can be applied not only to resolve load distribution issues among teachers but also to tackle resource allocation problems in various areas of educational institutions.

Further uses and extensions of this research can be explored. The model and algorithm developed in this study can serve as a foundation for future research on resource allocation in educational organizations. Extensions could include refining the heuristic approach for correcting the initial distribution of credits or expanding the scope to consider other resource allocation challenges in the educational sector. Additionally, the applicability of the model and algorithm can be examined in different contexts or educational systems, considering the unique characteristics of specific institutions. Ultimately, this research opens avenues for continued exploration and improvement in the field of resource allocation in educational organizations, contributing to the advancement of management systems and the overall quality of business processes.

References

[1] H. Zhou, Z. Deng, Y. Xia, and M. Fu, “A new sampling method in particle filter based on pearson correlation coefficient”, *Neurocomputing*, vol. 216, pp. 208-215, 2016.

[2] I.G. Asadulina, “Integration of education and business in the context of innovative technologies for organizing the educational process at the university”, *Econ. Educ*., vol. 4, pp. 164-172, 2014.

[3] A.K. Kazantsev, and D.K. Meshkis, “Modeling business processes of a modern university based on information technology”, *Innovations*, vol. 2, no. 89, pp. 68-79, 2018.

[4] M.T. Agieva, Yu.V. Babicheva, N.M. Oculist, and G.A. Ugolnitsky, “Problems of analysis and forecasting in target audience management in marketing”, *Large Syst. Manage*., vol. 79, pp. 27-64, 2019.

[5] A.V. Danilov, V.A. Kazakov, and Yu.F. Telnov, “Service-oriented architecture of a dynamic intelligent business process management system”, *Open Educ*., vol. 6, pp. 78-84, 2020.

[6] N.V. Basha, “Algorithm for managing scientific activity based on a multidimensional hierarchy of goals”, *Bull. Siber. Inst. Bus. Inf. Techno*., vol. 3, no. 15, pp. 27-31, 2015.

[7] R.R. Mulimkhanov, “Strategic management in organizations and institutions of business education”, *Creat. Econ*., vol.7, pp. 121-127, 2019.

[8] L. Taylor, *Knowledge, Information and the Business Process*. Oxford: Chandos Publishing, 2017.

[9] K. Rubenson, *Adult learning and education*. London: Academic Press, 2021.

[10] Zh.S. Takenova, “On the role of information systems in educational organizations”, In: Collection of Materials of the International Scientific-Practical Conference "Modern Trends in Architecture and Construction: Energy Efficiency, Energy Conservation, BIM Technologies, Problems of Urban Education in the Direction of Modern Education", pp. 294-299, 2021.

[11] A.A. Tashev, M. Balabekova, D. Baimuratov, T. Farkhadov, A. Ablaeva, and J. Kojamkulova, “Optimization of production planning with limited resources”, *Am. J. Environ. Sci*., vol. 15, no. 5, pp. 782-786, 2015.

[12] A.V. Tebekin, “Evolution of project management methods: world experience and development prospects”, *J. Rus. Entrepr*., vol. 19, no. 24, pp. 3969-3994, 2017.

[13] D. Novikov, *Theory of control in organizations*. New York: Nova Science Publishers, 2013.

[14] D.B. Yudin, and E.G. Holstein, *Tasks and methods of linear programming. Mathematical bases and practical tasks*. Moscow: Librocom, 2016.

[15] L. Briz-Ponce, A. Pereira, L. Carvalho, J.A. Juanes-Méndez, and F.J. García-Peñalvo, “Learning with mobile technologies-students’ behavior”, *Comput. Hum. Behav*., vol. 72, pp. 612-620, 2017.

[16] B. Hobbs, and Y. Petit, “Agile methods on large projects in large organizations”, *J. Proj. Manag*., vol. 48, no. 3, pp. 3-19, 2017.

[17] G. Nabi, N.F. Lina, A. Fayolle, N. Krueger, and A. Walmsley, “The impact of entrepreneurship education in higher education: A systematic review and research agenda”, *Acad. Manag. Learn. Educ*., vol. 16, no. 2, pp. 277-299, 2017.

[18] G. Secundo, P. Del Vecchio, G. Schiuma, and G. Passiante, “Activating entrepreneurial learning processes for transforming university students’ idea into entrepreneurial practices”, *Int. J. Entrepreneurial Behav. Res*., vol. 23, no. 3, pp. 465-485, 2017.

[19] K. Nelson, “Business process modeling in higher education institutions”, Available at: https://www.bpminstitute.org/resources/articles/business-process-modeling-higher-education-institutions#, 2022.

[20] Process management in education: understand its importance. Available at: https://cutt.ly/HXLAzqT, 2022.

[21] K. Wing, “Beginning a journey of knowledge management in a secondary school”, *J. Knowl. Manag*., vol. 20, no. 2, pp. 364-385, 2016.

[22] G. Rosinosky, S. Youcef, and F. Charoy, A genetic algorithm for cost-aware business processes execution in the cloud. Available at: https://hal.archives-ouvertes.fr/hal-01870828/document, 2018.

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