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A MODEL FOR PLANNING THE WORKLOAD OF TEACHERS, TAKING INTO ACCOUNT RISKS AND IN ACCORDANCE WITH THE REQUIREMENTS OF THE EUROPEAN SYSTEM OF CREDIT MODULES OF HIGHER EDUCATION

Abstract: A model for planning the workload of teachers is proposed to address the unique demands of a credit-modular system in higher education, aligning with the European Credit Transfer and Accumulation System (ECTS) standards. This model seeks to balance teacher workload by considering various types of associated risks, such as shortages of qualified staff, limited resources, and the risk of department overload. The primary objective is to structure teaching plans for discipline modules in a way that optimizes available university resources while adhering to credit requirements. To maintain stability in higher education institutions and support the creation of new educational programs, it is essential to address key challenges. The ongoing progressive changes in the education sector of the Republic of Kazakhstan necessitate efforts to enhance the effectiveness of higher education institutions, develop innovative educational programs, and improve the overall quality of education. Key aspects of this model involve integrating risk management into the planning process, which allows for a more adaptive and resilient approach to curriculum design. By systematically linking different types of workloads to associated risks, the model facilitates the development of balanced teaching plans that support both educational quality and staff well-being. The study concludes that this model can be a powerful tool for optimizing teacher workload distribution,

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potentially enhancing the stability of the educational process. Additionally, the model lays the groundwork for the creation of software tools that could automate workload planning, enabling higher education institutions to mitigate risks more effectively. The proposed approach, therefore, not only improves planning accuracy but also aligns with European higher education standards, ensuring a sustainable, high-quality educational experience.

Keywords: Teacher workload planning, curriculum optimization, European Credit Module system, discipline

Introduction

The successful solution of the tasks facing the Republic of Kazakhstan on the way to its integration into the world economy is impossible without highly qualified specialists. A special role in this process belongs to higher education institutions (universities). In the context of scientific and technological progress, the requirements for specialists, the quality of their knowledge, skills and abilities are increasing, the amount of information that a student with the same study period must learn is constantly increasing. Ensuring stable operation of higher educational institutions and the development of new educational programs. The progressive changes taking place in the field of education of the Republic of Kazakhstan require solving important tasks to ensure the productive work of higher education institutions, the development of new educational programs, and improving the quality of education.

Since one of the most important strategic tasks at the present stage of modernization of the higher education system of the Republic of Kazakhstan is to ensure the quality of training specialists at the level of international requirements, it is necessary to talk about the urgent introduction of qualitative changes in the educational process in higher education institutions. The educational process in higher educational institutions is a system of bodies educational and didactic activities aimed at implementing the content of education at a certain educational or qualification level in accordance with state education standards [1], [2], [3]. To this end, most researchers direct their efforts to improve the educational process, in particular, to create automated knowledge control systems [4], [5], quality control systems for the educational process [9], [10], the development of universities [11], the creation of an information environment for learning and management [12]. Considerable attention is paid to defining the features of university management, analyzing the conditions of their functioning, defining managerial functions, etc. [13], [19].

Recently, a large number of studies have been conducted to improve the educational process, in particular, the creation of automated teaching and knowledge control systems [4], quality control systems for the educational process [6], [7], and the development of a higher educational institution (university) [8]. Considerable attention is paid to defining the features of university management, analyzing the conditions of their functioning, defining managerial functions, etc. However, some aspects of the introduction of management technologies in accordance with the Bologna process, in particular those related to the planning and optimization of educational work, are not sufficiently covered in publications.

There is a need to create information systems and technologies that would quickly and effectively adapt curricula to the state of the environment, the conditions of the educational process in universities and the level of knowledge of students. This issue is primarily relevant in connection with the introduction of a credit-modular system for organizing the educational process in higher educational institutions and the need to develop educational and methodological support for training specialists in this system, considering the requirements of ECTS [17], [18].

However, some aspects of educational process management, in particular those related to the planning of the educational process, are insufficiently covered [14], [19]. There is a need to create information systems and technologies that would allow you to quickly and effectively plan the educational process. This issue is primarily relevant in connection with the introduction of a credit-modular system for the organization of the educational process in higher education and the need to develop educational and methodological support for training specialists in this system, in particular, curricula for training specialists taking into account the requirements of ECTS [15], [16].

There is a need to create information systems and technologies that would allow you to quickly and effectively plan the educational process. It is planning that underlies the management of the educational process. And without effective planning, it is impossible to achieve the above goals.

Methods and materials

The main document for planning training is the curriculum. The curriculum of a specialty is a normative document defining the list and scope of normative and elective disciplines, as well as the sequence of their study.

In fact, the curriculum of a particular specialty N is a set of disciplines that are studied in this specialty [19]:

$$\Lambda = \{D_1, \dots, D_i, \dots, D_n\},$$

where Λ is the curriculum of the specialty; D is the academic discipline Λ; n is the number of subjects included in the curriculum.

Each discipline, in turn, is represented by a set of training modules:

$$D_i = \{M_{i1}, \dots, M_{ij}, \dots, M_{im_i}\},$$

where *Mij* is the *jth* module of discipline D; *mi* is the number of modules included in discipline *D*.

It is considered any *Mij* module as a formal nine:

$$M_{ij} = \left\langle t_{ij}^{c}, t_{ij}^{\phi}, G_{ij}, V_{ij}, r_{ij}, M_{ij}^{*}, Y_{ij}, S_{ij}, D_{ij} \right\rangle, i = \overline{1, n}, j = \overline{1, m_i},$$

where t_{ij}^{c} – the beginning of the module study is located (set as the week number);

t_{ij}^{ϕ} – the end of the module (indicated as the week number);

G_{ij} – the amount of student workload (academic hours);

V_{ij} – the amount of teaching load of teachers (academic hours);

r_{ij} – rating (priority) of the module.

M_{ij}^{*} – a set of precursor modules (modules of different disciplines that need to be studied before starting to study this one).

Y_{ij} – the department where the module is taught.

S_{ij} – the need for computers and other technical facilities, or specialized classes.

D_{ij} – the need for methodological support.

Let's take a closer look at the module parameters:

1. The beginning of teaching the module t_{ij}^{c}:

A) if the set of predecessor modules is empty $M_{ij}^{*} = 0$, то $t_{ij}^{c} \geq 1$.

Б) if the set of predecessor modules is not empty $M_{ij}^{*} \neq 0$, then $t_{ij}^{c} > \max_{M_{kl} \in M_{ij}^{*}} (t_{kl}^{\phi})$.

2. Passing the module t_{ij}^{c}:

A) if the module is not a precursor to other modules, then $t_{ij}^{\Phi} \leq t^{max}$ (t^{max} – standard duration of training);

Б) if a module is a precursor to other modules, then $t_{ij}^{\phi} < \max_{M_{ij} \in M_{kl}^{*}} (t_{kl}^{c})$.

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3. The volume of students' academic workload. Educational activities are divided into types of educational work:

$$G_{ij} = g_{ij}^{lek} + g_{ij}^{prac} + g_{ij}^{lab} + g_{ij}^{IPC} + g_{ij}^{CW} + g_{ij}^{CP} + g_{ij}^{CGW} + g_{ij}^{SP} + g_{ij}^{Dis} + g_{ij}^{Ind} + g_{ij}^{SK}, \quad (1)$$

where g_{ij}^{lec} – the amount of lectures;
g_{ij}^{prac} – the amount of practical classes/seminars;
g_{ij}^{lab} – the amount of laboratory classes;
g_{ij}^{IPC} – the amount of individual work of students;
g_{ij}^{CW} – the amount of workload for the course work;
g_{ij}^{CP} – the amount of workload for the implementation of the course project;
g_{ij}^{CGW} – the amount of workload for performing calculation and graphic (individual) work;
g_{ij}^{SP} – the amount of workload for students' practice;
g_{ij}^{Dis} – the workload of the dissertation;
g_{ij}^{Ind} – the amount of independent work of students;
g_{ij}^{SK} – the amount of burden on the control of students' knowledge.

4. The amount of teaching load of teachers. The student's educational activity takes place both with the teacher and independently. Within the framework of working with a teacher, a distinction is made between classroom and individual work. In general, the workload of teachers in the module will be equal to:

$$V_{ij} = k_{pro} \cdot g_{ij}^{lec} + k_{gr} \cdot g_{ij}^{prac} + k_{sg} \cdot g_{ij}^{lab} + k_{gr} \cdot g_{ij}^{\mathrm{IPC}} + k_{stud} \cdot v_{CW} \cdot q_{ij}^{CW} + k_{stud} \cdot v_{CP} \cdot q_{ij}^{CP} + +k_{stud} \cdot v_{CGW} \cdot q_{ij}^{CGW} + k_{stud} \cdot v_{SP} \cdot q_{ij}^{SP} + k_{stud} \cdot v_{Dis} \cdot q_{ij}^{Dis} + k_{gr} \cdot v_{SK}, \quad (2)$$

where k_{pro} – the coefficient that determines the proportion of lecture hours of this module in the flow of students. If the stream unites groups of students enrolled in 3 curricula, then $k_{nom} = \frac{1}{3}$;
k_{gr} – the number of groups studying this module;
k_{sg} – the number of subgroups studying this module;
k_{stud} – the number of students studying this module;
v_{CW} – the amount of educational work of the teacher on the guidance of the course work of the 1st student;
q_{ij}^{CW} – a function that takes the value 1 if the course work is provided by the work program of the discipline for this module, and 0 if it is not provided;
v_{CP} – the amount of educational work of the teacher on the management of the course project of the 1st student;
q_{ij}^{CP} – a function that takes the value 1 if the course project is provided by the work program of the discipline for this module, and 0 if it is not provided;
v_{CGW} – the amount of educational work of the teacher to guide the calculation and graphic/individual work of the 1st student;
q_{ij}^{CGW} – a function that takes the value 1 if the calculation and graphic/individual work is provided by the work program of the discipline for this module, and 0 if it is not provided;
v_{PP} – the amount of educational work of the teacher on the management of the practice of the 1st student;
q_{ij}^{PP} – a function that takes the value 1 if practice is provided for this module, and 0 if not;

v_{Dis} – the amount of educational work of the teacher on the management of the thesis of the 1st student;

q_{ij}^{Dis} – a function that takes the value 1 if the dissertation is provided for this module, and 0 if not;

v_{SK} – the amount of educational work of a teacher to control the knowledge of a group of students.

5. Rating (priority) the module r_{ij}. Defines the importance of the module in the training of a specialist. It can take values in the range $0 \div 1$. In the model, it is important that the risk of more important (with higher priority) modules is less

6. Previous modules M_{ij}^*. These are modules of various disciplines that must be studied before starting a given discipline. Implement principles such as advanced learning, continuity, consistency, and continuity of learning. Previous modules of the discipline can use the material that was taught in the modules of the previous discipline. The M_{ij} module, which uses information from the module $M_{kl} \in M_{ij}^*$, is a descendant module, and the M_{kl} module is an ancestor module. If $i = k$, then the modules belong to a general discipline.

The relationship between modules is a predicate, i.e..:

$$z(M_{ij}, M_{kl}) = \begin{cases} 1, there\ is\ a\ connection\ between\ the\ modules \\ 0, there\ is\ no\ connection\ between\ the\ modules \end{cases}.$$

When forming the curriculum, the modules should be organized in such a way that the descendant module is located in time after studying all the ancestral modules. Such placement of modules will be called sequential.

Parallel placement of modules is when the start time of the child module is equal to the start time of the parent module. If there is a connection between the modules, they are always placed sequentially.

If for two consecutive modules, one of which, *Mi'p*, is a child module, and the other, *Mir*, is the parent, then the condition is met:

$$\min_{M_{kl} \in M_{ij}^*} (t_{ij}^c) - t_{kl}^{\phi} = R_{kl} > 0, \quad (3)$$

then the M_{kl} module has a time reserve equal to the value of R_{kl}.

By the time reserve *Rk* of module l of the kth discipline, we will understand the zone of possible displacement in time, such that does not lead to displacement of the descendant modules. A set of sequentially arranged modules, the time reserve of each of which is zero, determines the duration of the curriculum. Such a set will be called a critical path, and the modules belonging to this set will be called critical modules. The length of the curriculum should always be equal to the length of the critical path.

7. The department Y_{ij} where the module M_{ij} is taught . Defines the department where the discipline module will be taught. Characterized by:

$$Y_{ij} \in K,\ K = \{k_s\},\quad s = \overline{1, h},\quad k_s = \langle A_s, \Pi_s, W_s, B_s, C_s \rangle,$$

where k_s – department;

A_s – name of the department;

Π_s – Department activity profile;

W_s – the staffing level of the department (expertly set to a value within $0 \div 1$ (0 – there are no teachers, 1 – the department is fully provided with teachers of the necessary qualifications);

B_s – the level of technical and classroom support of the department (masterfully set to a value within $0 \div 1$ (0 – no support, 1 – everything is available);

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C_s – the level of methodological support of the department. It reflects both the existing security and the potential of the department for its creation. It is expertly set to a value within $0 \div 1$ (0 – there is no provision and potential, 1 – everything is there, or can be created).

8. The need for computers and other technical facilities, or specialized classes. S_{ij} is determined by a specially set value within the range of $0 \div 1$ (0 is not necessary, 1 is the maximum need).

The task of planning training is to form a fixed-volume plan based on such a rational set of modules in each quarter, so that the absolute deviation in the workload of the student and teacher is minimal and within the limits determined by the Ministry of Science and Higher Education of the Republic of Kazakhstan. This problem was successfully solved in [19]. But two important aspects were not taken into account in this work: the risks of teaching modules in different semesters/quarters and the amount of teaching load of teachers. Let's consider a more complete learning planning model that takes into account the risks and workload of teachers.

It will be measured the risk by magnitude

$$R_{ij}^k = r_{ij} \cdot p_{ij}^k, \tag{4}$$

where k – the number of the type of risk ($U_k \in U$, – U of risks);

R_{ij}^k – type of risk U_k;

p_{ij}^k – the probability of an event that leads to losses associated with a certain type of risk U_k;

r_{ij} – the rating (priority) of the module, which is proportional to the amount of losses in the quality of training in case of unsatisfactory training.

The main types of risks that depend on the order and time of teaching modules are:

1. Errors in the structural and logical scheme and, accordingly, the omission of the predecessor module (risk U_1). The probability of such absence decreases towards the end of the training (Fig. 1). Then it can be written down

$$p_{ij}^1 = f_1(t_{ij}^c), \tag{5}$$

where p_{ij}^1 – the probability of an error in the structural and logical scheme.

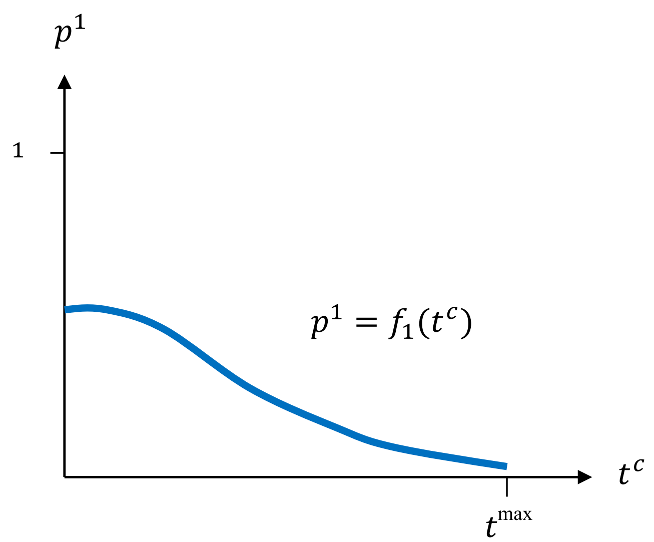

Fig.1. Dependence of the probability of missing the predecessor module in the structural and logical scheme of the specialty

2. The overload of the department due to the fact that in one semester/ quarter there is a significant load on this department and, accordingly, the decrease in the quality of teaching the module (risk U_2) will be greater than Δ.

The value of Δ can be defined as a relative decrease in the average score for the types of classes in this module:

$$\Delta = 1 - \frac{\sum_{i=1}^{kv} \sum_{j=1}^{ks} b_{ij}^{fact}}{\sum_{i=1}^{kv\Sigma} \sum_{j=1}^{ks\Sigma} b_{ij}^{max}}, \quad (16)$$

where b_{ij}^{fact} – assessment of the *j-th* student according to the *i-th* type of academic work;
b_{ij}^{max} – The assessment score of the *j-th* student for the *i-th* type of academic work.

The probability of risk increases with an increase in the workload of the teachers of the department (Fig. 2).

Then it can be recorded

$$p_{ij}^2 = f_2\left(\frac{V_{ij}}{t_{ij}^{\phi} - t_{ij}^{c} + 1}\right), \quad (7)$$

where p_i^2 – the probability that due to the significant workload at the department, the level of teaching will lead to a decrease in the quality of education by an amount greater than Δ (6).

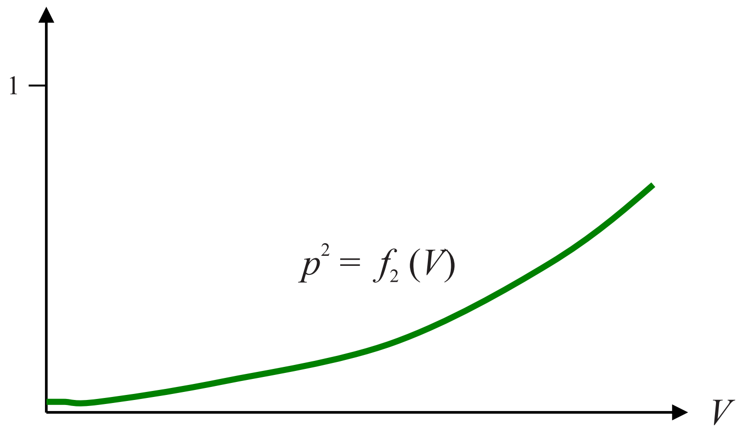

Fig.2. Dependence of the probability of receiving an uneven load at the department on the volume of the academic load

3. The risk of an insufficient number of teachers of the department to ensure the required professional level of teaching the module (risk U_3). The probability of risk increases with an increase in the need for lectures (Fig. 3). It can be fixed

$$p_{ij}^3 = f_3\left(g_{ij}^{lec}, W_s | k_s = Y_{ij}\right), \quad (8)$$

where p_{ij}^3 – the probability that due to the insufficient professional level of teachers, the quality of education will decrease by more than Δ (6).

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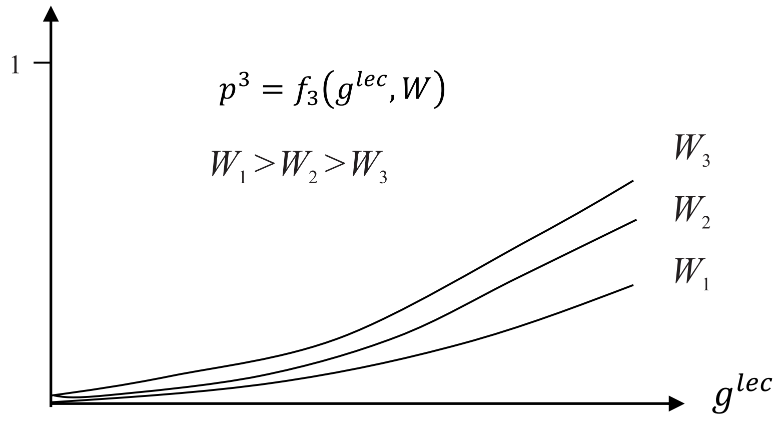

Fig.3. Dependence of the probability of insufficient provision of lectures by the teaching staff

4. The risk of insufficient provision of computer equipment, or other types of equipment, or specialized computer classes and, accordingly, a decrease in the quality of teaching the module (risk U_4). The probability of risk increases with increasing demand and decreasing availability of these funds (Figure 4). Then it can be fixed

$$p_{ij}^4 = f_4\left(\frac{S_{ij}}{B_s|k_s=Y_{ij}}\right), \tag{9}$$

where p_i^4 – the probability that due to insufficient provision of computer or other equipment or specialized computer classes, the quality of education will decrease by an amount exceeding Δ (6).

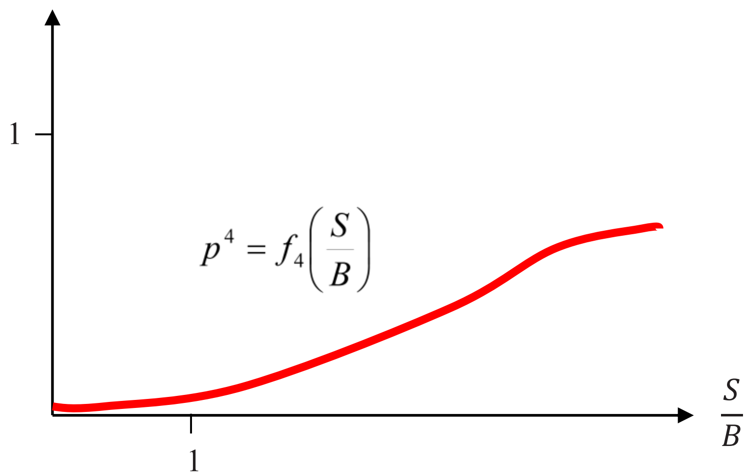

Fig.4. Dependence of the probability of insufficient provision of computer equipment on the need for such provision

5. The risk of insufficient methodological support and, consequently, a decrease in the quality of teaching the module (risk U_5).). The probability of risk increases with increasing demand and decreasing availability of these tools (Fig. 5). It can be fixed

$$p_{ij}^5 = f_5\left(\frac{D_{ij}}{C_s|k_s=Y_{ij}}\right), \tag{10}$$

where p_i^5 – the probability that due to insufficient methodological support, the quality of education will decrease by an amount greater than Δ (6).

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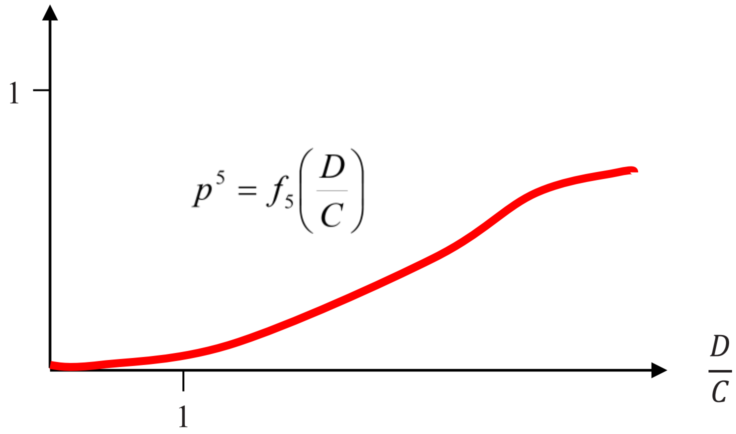

Fig.5. Dependence of the probability of insufficient methodological support on the need for such support

Then the total risk of the M_{ij} module will be equal to:

$$R_{ij} = \sum_{k=1}^{5} R_{ij}^{k} = r_{ij} \cdot \left(1 - \prod_{k=1}^{5}(1 - p_{ij}^{k})\right).$$

Or taking into account the expressions received (5), (7)-(10).

$$R_{ij} = r_{ij} \cdot \left[1 - \left(1 - f_1(t_{ij}^{c})\right) \cdot \left(1 - f_2\left(\frac{V_{ij}}{t_{ij}^{\phi} - t_{ij}^{c} + 1}\right)\right) \cdot \left(1 - f_3\left(g_{ij}^{лек}, W_s \,|k_s = Y_{ij}\right)\right) \cdot \right.$$
$$\left. \cdot \left(1 - \frac{S_{ij}}{B_s|k_s = Y_{ij}}\right) \cdot \left(1 - f_5\left(\frac{D_{ij}}{C_s|k_s = Y_{ij}}\right)\right)\right].$$

The overall risk of the curriculum

$$R = \sum_{i=1}^{n}\sum_{j=1}^{m_i}\left(r_{ij} \cdot \left[1 - \left(1 - f_1(t_{ij}^{c})\right) \cdot \left(1 - f_2\left(\frac{V_{ij}}{t_{ij}^{\phi} - t_{ij}^{c} + 1}\right)\right) \cdot \left(1 - f_3\left(g_{ij}^{лек}, W_s \,|k_s = Y_{ij}\right)\right) \cdot \right.\right.$$
$$\left.\left. \cdot \left(1 - \frac{S_{ij}}{B_s|k_s = Y_{ij}}\right) \cdot \left(1 - f_5\left(\frac{D_{ij}}{C_s|k_s = Y_{ij}}\right)\right)\right]\right), \quad (11)$$

where R – The risk of the curriculum.

Now it can be got the target function of minimizing risks:

$$R = \sum_{i=1}^{n}\sum_{j=1}^{m_i}\left(r_{ij} \cdot \left[1 - \left(1 - f_1(t_{ij}^{c})\right) \cdot \left(1 - f_2\left(\frac{V_{ij}}{t_{ij}^{\phi} - t_{ij}^{c} + 1}\right)\right)\right.\right.$$
$$\cdot \left(1 - f_3\left(g_{ij}^{lec}, W_s|k_s = Y_{ij}\right)\right) \cdot$$
$$\left.\left. \cdot \left(1 - \frac{S_{ij}}{B_s|k_s = Y_{ij}}\right) \cdot \left(1 - f_5\left(\frac{D_{ij}}{C_s|k_s = Y_{ij}}\right)\right)\right]\right) \to min, \quad (12)$$

With restrictions:

1. In accordance with the methodology for the formation of curricula and the calculation of the academic load of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

2. In accordance with the conditions of the university.

As follows from expression (11), the achievement of the required target value is achieved by varying the parameters:

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$t_{ij,}^{c}\, t_{ij}^{\phi}$ – by placing the module within the temporary reserve (4);
V_{ij} – due to changes in the amount of teaching load of teachers (audience – within 33-66÷% of the total number);
W_s – by increasing the staffing level of departments;
Y_{ij} – choosing richer departments;
B_s – by strengthening the technical support of the departments;
C_s – by improving the methodological support of departments.

Conclusion

The developed mathematical model is the basis for the development of methods and software and information tools for optimizing the programmatic implementation of activities (training planning, and in particular expert assessment of specified functional dependencies and calculation of the learning load) in accordance with the target expression (11), as well as the formation and modeling of curricula, the formation of the teaching load of teachers in accordance with the introduced the target function.

The approach described above, as well as a mathematical model for minimizing risks in training planning and workload calculation, will effectively automate the planning of education in higher education institutions. The following works of the authors will be devoted to the further development of methods and tools that implement actions to achieve the target value (11).

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