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This scientific monograph presents research on theoretical and practical areas of science in the context of contemporary challenges. The publication encompasses a wide range of subjects within the natural and agricultural sciences, legal and economic sciences, as well as philological and pedagogical sciences. The publication is intended for a wide range of readers, including scientists, educators, postgraduate students, and students.

CHOICE OF INFORMATION TOOLS FOR LEARNING UNDER MODERN CHALLENGES

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Abstract. The section is devoted to addressing the pressing problem of selecting information tools for learning in the context of dynamic transformations of the scientific and educational environment. The rapid development of digital technologies, the spread of online and blended learning, and the emergence of new formats of interaction between participants in the educational process necessitate a revision of approaches to evaluating, selecting, and implementing information and communication technologies. Accordingly, this work substantiates the need to develop a systematic approach to the selection of such tools based on a multi-criteria decision-making model. The analysis of transformational processes, driven by a number of challenges – such as globalization and digitalization of science, as well as the migration of researchers – allowed the formulation of the research *purpose:* the development and software implementation of a rational decision-making model for the selection of information and technological tools based on multiple criteria. On this basis, the *object* of the study was defined as the process of selecting information and technological tools in scientific and educational activities, while the *subject* was determined as the model and methods of multi-criteria rational decision-making and their software implementation. To achieve the research aim, an overview of contemporary models and methods of multi-criteria decision-making applied to the selection of digital tools was conducted. As a result of the comparative analysis, their advantages, limitations, and practical applicability in the educational context were identified. Based on

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this review, the analytic hierarchy process method was substantiated as the most flexible *methodology* for constructing adaptive evaluation systems. A system of criteria and indicators of the effectiveness of information and technological tools was developed, taking into account modern transformational challenges in education. Within the study, a conceptual model of the decision-making process was designed, interrelations between the criteria were identified, and an algorithm for multi-criteria selection was proposed. The mathematical model was implemented as an electronic spreadsheet, ensuring the automation of calculations and serving as a decision-support tool for the selection of online educational platforms. The *practical significance* of the study lies in the creation of a universal toolkit that enables comparative evaluation of educational information tools based on a set of criteria. This approach can be adapted to any number of alternatives and hierarchical levels of criteria, making it suitable for use across various levels of educational institutions. The proposed model is characterized by adaptability – it can respond to changes in technological solutions, the emergence of new educational formats and evolving user needs for accessibility, mobility, and content personalization. *The results of the research* possess both theoretical and practical value. They can be applied to optimize the processes of digital transformation in educational institutions, to plan the implementation of new IT solutions, and to develop evaluation criteria for the effectiveness of digital platforms. Further research will focus on improving the system of evaluation criteria for information technologies with consideration of the stochastic nature of the educational environment, as well as on expanding the mathematical tools for analyzing uncertainty and risks in decision-making processes within the educational sphere.

1. Introduction

Relevance. Modern realities impose numerous requirements on participants in the scientific environment. These requirements arise from transformational processes driven by a series of challenges that affect almost all spheres of human activity. Among the challenges most characteristic of our country are the globalization and digitalization of science, as well as the migration of researchers caused by the full-scale military actions unfolding within the territory of the state.

It is important to emphasize the interdependence of these transformational processes. Globalization in the scientific community encourages active communication with the international research arena, which, in turn, presupposes the intensive use of digital technologies and consequently accelerates informatization. Digital technologies ensure rapid information exchange, collaborative work on research projects, and the dissemination of scientific results. The use of online platforms, video conferencing tools, electronic journals, and databases enables researchers from different countries to collaborate effectively, discuss pressing scientific problems, and publish their findings for global peer evaluation without geographical limitations. This fosters innovation, increases the openness and accessibility of science, and stimulates the integration of national research systems into the global scientific landscape.

The use of digital technologies opens new opportunities for scientists residing outside their home countries but willing to contribute to its development. Through online communication tools, cloud services, collaborative data platforms, and digital laboratories, they can participate in research projects, advise colleagues, conduct studies, and share results in real time. These capabilities create conditions for continuous interaction between research centers regardless of their geographical location.

Such opportunities contribute to preserving the intellectual potential of a country even when its scientists work abroad. They can maintain contact with domestic research institutions, participate in joint conferences and publications, and engage in educational initiatives. Therefore, digital technologies not only overcome spatial barriers but also promote the formation of a global network of cooperation, where knowledge and experience become accessible to the entire scientific community.

The conclusion drawn from the above is that the growing informatization of science is a response to the challenges posed by the turbulent external environment. At the same time, the current level of informatization and the development of digital technologies provide access to an entire universe of possibilities, making it increasingly relevant to organize the conscious selection of information tools within modern transformational processes. These factors substantiate the necessity of applying scientifically grounded decision-making methods to the selection of information and technological tools in scientific and educational activities.

The purpose of this study is to develop and implement a rational decision-making model for the selection of information and technological tools based on multiple criteria.

The object of the research is the process of selecting information and technological tools in scientific and educational activities. **The subject** of the research is the model and methods of multi-criteria rational decision-making for the selection of information and technological tools and their software implementation.

To achieve the stated goal, the following **research tasks** are defined:

1. To analyze modern approaches to decision-making in the selection of information and technological tools based on multiple criteria by reviewing existing models, methods, and algorithms; to identify their advantages, disadvantages, and areas of application; and to justify the choice of a suitable modeling method.

2. To develop a system of criteria and indicators of effectiveness for information and technological tools, taking into account current transformational challenges.

3. To design a conceptual model of the decision-making process, including the structure of the model, relationships among the criteria defined in the previous stage, and an algorithm for multi-criteria decision-making based on the selected methods.

4. To construct a mathematical model of multi-criteria selection based on the conceptual framework.

5. To develop a software implementation of the mathematical model for supporting decision-making in the selection of information and technological tools.

6. To formulate recommendations for establishing a system of criteria and indicators of effectiveness for information and technological tools under the conditions of transformation in the scientific and educational environment.

2. Analysis of Modern Approaches to Decision-Making

The Theory of Multi-Criteria Decision-Making is currently widely explored by both domestic and international scholars. This is primarily due to its practical significance, as in real-world activities decision-makers frequently face the problem of choosing the best alternative according to multiple, often conflicting, criteria. Consequently, numerous solution methods have been developed for such problems. These methods can conventionally be divided into two categories: objective methods, which are typically based on statistical data and employ mathematical models and formal algorithms, and subjective methods, in which the "measuring instrument" is the human expert. In the latter case, the accuracy of results strongly depends on the competence and experience of the experts involved.

The limitations of objective methods include the difficulty of quantifying qualitative factors, challenges in implementing models programmatically, and, in some cases, high computational complexity or lack of available statistical data. Objective approaches are most effective in fields where clear problem formulation and reliable data collection are possible, such as information technology, economics, engineering, and logistics. Conversely, subjective methods often lack scientific rigor and, therefore, yield results with lower credibility. They are most commonly applied when qualitative evaluation is required under conditions of vague or incomplete criteria and absence of statistical data – for instance, in innovation management, strategic planning, or social sciences.

A distinct category is formed by intelligent (computer-based) decision-making approaches, which rely on artificial intelligence, fuzzy logic, neural networks, and genetic algorithms. These methods are gaining momentum because they allow the modeling of complex, weakly structured situations where classical approaches are inefficient. However, such methods have several drawbacks and limitations, particularly in scientific and research domains: implementation complexity and high cost, dependence on the quality of training data, high computational resource requirements, and difficulties in verification and validation of results. Typically, intelligent approaches are used when large volumes of data are available, complex data processing is required, or when decisions must be automated or predictive – examples include business analytics, medicine, digital technologies, and expert systems.

The objective of this study is to develop a software tool to support rational decision-making for selecting information and technological tools in scientific and educational contexts. This tool should account for the evaluation of each alternative according to multiple criteria and incorporate user preferences. Intelligent approaches, in this case, would be excessively complex and resource-intensive, while subjective methods would not ensure sufficient objectivity and reproducibility of results. Therefore, it is reasonable to apply objective multi-criteria decision-making methods, which combine quantitative assessment of alternatives with the inclusion of individual priorities, ensuring the rationality, transparency, and flexibility of the selection process.

One of the simplest and most transparent objective multi-criteria decision-making methods is the Weighted Sum Method (WSM) [1]. It is often used as a baseline technique for rational selection of alternatives when quantitative criteria are clearly defined. The WSM involves assigning a weight to each criterion and evaluating alternatives accordingly. The product of criterion weights and their corresponding evaluations reflects the relative importance of each criterion, and the best alternative is determined by the maximum value of the normalized weighted sum.

In [2], the Weighted Sum Method is used as a mathematical tool in developing a hardware–software complex supporting coworking space management – specifically, automating the search, selection, and booking of workplaces. The system accounts for individual workplace characteristics and provides recommendations based on user physical parameters and safety standards. However, the method requires normalization and does not consider interdependencies among criteria. Moreover, the final outcome is highly sensitive to the accuracy of weight assignment and rating scales.

Another objective method is the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) [3], which identifies the best alternative as the one having the shortest distance to the positive ideal solution and the farthest distance from the negative ideal solution. In [4], TOPSIS is applied to optimize energy consumption strategies in buildings. The research aims to develop a comprehensive review reflecting the current state of passive energy optimization strategies based on multi-criteria decision analysis methods and to identify promising directions for further improvement in the selection of strategies, criteria, and optimization techniques.

However, when addressing complex, weakly structured decision-making problems, the aforementioned methods exhibit several limitations: they fail to account for interdependencies among criteria, the decision-maker's preferences across the set of alternatives, and do not include mechanisms for consistency verification or representation of conflict among criteria. Under such conditions, models that incorporate these specificities are more appropriate.

The Analytic Hierarchy Process (AHP) [5] provides such a mechanism. AHP involves constructing a hierarchical structure of evaluation criteria and performing pairwise comparisons of elements at each level. Criterion weights are calculated using eigenvectors of comparison matrices. A key advantage of AHP in multi-criteria decision-making lies in its ability to decompose a complex decision into hierarchical levels, thereby applying a systemic approach. The first level represents the overall utility relative to the decision-maker's goal, the second level contains evaluation criteria, each of which can be further divided into subcriteria forming subsequent levels of the hierarchy, and the final level consists of decision alternatives.

Another advantage of AHP is that criterion weights are determined not by assumption but through pairwise comparisons, which aligns more closely with natural human decision-making processes and cognitive reasoning. Through its consistency check mechanism, AHP allows verification of the logical coherence of the decision-maker's judgments, detecting inconsistencies that may distort results.

AHP is intuitive and user-friendly since pairwise comparisons require straightforward judgments about the relative importance of criteria, and it is flexible in combining qualitative and quantitative assessments. By employing a numerical scale for subjective qualitative evaluations, AHP allows expression of varying degrees of confidence, resulting in more realistic outcomes.

Modern researchers employ AHP to support decision-making in various domains: optimization and prioritization of sustainable urban development scenarios [6], and the selection of optimal cybersecurity architectures for critical infrastructure based on multi-criteria analysis [7]. In [6], a set-theoretic approach to multi-criteria decision-making is used, where criteria serve to describe alternative options and highlight distinctions among them from the decision-maker's perspective. In [7], a system of criteria was developed for evaluating security effectiveness to select the best architecture for critical infrastructure, with utility functions defined for each criterion and a software tool implemented to assess their interdependencies.

The presented evidence substantiates the selection of AHP as the mathematical foundation for developing a model of rational decision-making in the selection of information and technological tools under multiple criteria.

3. Formation of a System of Criteria for the Effectiveness of Information and Technological Tools

From the standpoint of a systems approach, the system of evaluation criteria should be developed in accordance with the goals of the subject in the field of scientific activity. The main objectives of such activity include: conducting scientific research aimed at formulating and validating hypotheses in fundamental sciences, or applying the results of fundamental research to solve specific practical problems in applied sciences; and implementing the results of scientific research in educational practice to familiarize students with the latest scientific achievements and to engage them in the academic community [8; 9].

When selecting criteria, it is also necessary to ensure the alignment of the goals of scientific activity with the global challenges of modern science, which have been previously identified as particularly relevant to the Ukrainian academic context: the globalization of science, the growing influence of digital technologies, and the migration of researchers.

Today, science is no longer local; research projects increasingly involve scientists from around the world, which intensifies competition for grants, citations, and positions in international rankings, while also increasing the degree of internationalization of scientific activity. The recognition of research results within the global academic space is achieved through publications in journals indexed by Scopus, Web of Science, and other scientometric databases. Integrating research outcomes into the global educational context enhances international visibility and reputation; therefore, a modern scholar and educator becomes not only a teacher but also a representative of their university's scientific achievements within the global academic community. Such outcomes, however, are unattainable without continuous learning and professional development.

The rapid transition toward digital tools, open databases, remote collaboration, and artificial intelligence in research creates a need for new digital competencies. For example, the use of modern digital platforms and technologies significantly improves the efficiency and quality of research. Simultaneously, digital libraries, databases, and analytical systems facilitate systematic literature reviews, thereby increasing the objectivity of findings. The integration of digital tools into educational processes fosters the creation of an innovative learning environment. Incorporating digital technologies into the research and educational process compels academic staff to continuously improve their proficiency in operating within digital scientific ecosystems.

The search for better working conditions, resources, and stability often leads modern scientists to relocate, resulting in the loss of national scientific potential. At the same time, transnational academic communities are evolving, allowing researchers to maintain professional connections regardless of their location. The use of digital technologies (online platforms, repositories, open conferences) enables remote collaboration without losing academic contact with Ukraine. The development of young researchers and doctoral students within the country, in turn, forms a talent pool and contributes to the gradual reduction of expert outflow.

The responsibilities of academic and research staff correlate with the globalization of science through active participation in international research networks, English-language publications, and grant programs. The digitalization of science reinforces these responsibilities, requiring the application of modern technologies for data analysis, communication, and learning. The migration of scientists underscores the importance of creating conditions for remote research collaboration and maintaining ties between researchers from different countries, transforming mobility into a driver of academic development.

One of the key means of overcoming these challenges and achieving the objectives posed by them is continuous learning in new methods and technologies. Such learning can take place within formal education frameworks but, due to various constraints, non-formal education is increasingly becoming a dominant form of professional development.

According to the Eurostat Adult Education Survey [10], conducted under the auspices of the EU statistical office, non-formal education significantly prevails over formal education in nearly all European countries in terms of adult participation in lifelong learning. Based on data from Eurostat, UNESCO, OECD, and national researchers, several periods of the most rapid growth in participation in non-formal education can be identified. The first period (2015–2019) coincided with the development of global online learning platforms such as Coursera, edX, and Udemy. Eurostat recorded an increase in the proportion of adults in the EU participating in non-formal education from 34% in 2011 to 40–45% in 2019. The second surge occurred during 2020–2021, driven by the COVID-19 pandemic: according to UNESCO and OECD, in 2020 the number of learners on global online platforms more than tripled. Since 2022, there has been a steady annual increase of 10–15% in participation in non-formal education, with a growing proportion of learners focusing on digital professional skills, artificial intelligence, cybersecurity, and language acquisition.

In Ukraine, the rapid rise in interest in online educational platforms was first observed in 2018–2019, driven by the appearance of numerous free online courses such as Prometheus, EdEra, and VUM online, as well as active integration with global platforms. According to Ukrainian IT community assessments, the number of registered users of online courses nearly doubled in the first year of the pandemic [11]. Non-formal education is now widely used for upskilling, reskilling, and remote learning during martial law.

The current level of informatization and the advancement of digital technologies provide access to an entire universe of opportunities for education and professional development outside traditional academic institutions. Online platforms, massive open online courses (MOOCs), digital libraries, video lectures, and interactive simulations allow learners to acquire knowledge anytime, anywhere, and at a pace suited to their individual needs. Education has thus become accessible to anyone with an Internet connection. However, alongside the expansion of educational opportunities arises the challenge of making conscious and rational choices among the vast number of available information resources and training programs. In non-formal education, clear quality standards are often absent, requiring learners to independently determine the relevance, reliability, and practical value of educational materials. This process demands critical thinking, information literacy, and self-organization – key competencies of the digital era. Therefore, the task of developing mechanisms and methodologies for the rational and conscious selection of learning resources in the non-formal education environment becomes particularly relevant.

To address this challenge, the AHP is proposed as a method for evaluating and selecting online learning platforms for non-formal education. AHP is designed for the hierarchical representation of evaluation criteria, whose consideration constitutes the essence of the rational decision-making process within a specific domain. The advantage of AHP lies in its ability to accommodate various aspects of the decision problem – both tangible and intangible, quantitatively measurable and qualitative, objectively determined data or subjective expert evaluations [12].

This approach enables the decision-maker to transform subjective judgments about the relative importance of evaluation criteria into a linear set of weight coefficients, which are subsequently used to rank decision alternatives or serve as objective functions in optimization problems under certainty. The transformation of qualitative evaluation criteria into quantitative parameters is implemented in several stages.

At the first stage, the structure of the specific decision problem is analyzed, and the most significant elements of the hierarchy – factors influencing decision outcomes – are identified. Hence, the process of forming a system of evaluation criteria for alternatives becomes crucial. In this study, the alternatives are represented by educational online platforms.

The evaluation and selection criteria at the lowest level of the hierarchy, as well as their grouping under second-level factors, are presented in Table 1.

The evaluation of online learning platforms requires a multidimensional approach that takes into account content, accessibility, and learning processes. Content-related factors emphasize the scope, accreditation, and quality of educational materials. Accessibility criteria reflect financial affordability and language options. Learning factors encompass the flexibility of formats, the presence of community and support, as well as the integration of innovative technologies. Collectively, these criteria form a comprehensive framework for assessing the effectiveness and relevance of online learning platforms in modern educational and scientific activities, determining the potential for creating an individualized lifelong learning trajectory.

Table 1

Criteria for the Evaluation of Alternatives

Criterion Code	Name	Essence
1	2	3
Factor 1. Content		
C1	Course Content and Topics	Determines the degree to which a platform is universal or specialized. Some online platforms offer a wide range of disciplines (e.g., Coursera, edX), while others focus on specific fields such as IT (Udemy) or civic education (VUM online).
C2	Accreditation and Certification	Defines the extent to which the course content has official validation and recognition. For example, Coursera and edX cooperate with universities and companies, making their certificates recognized by employers. Ukrainian platforms such as *Prometheus* and *Diia.Osvita* often provide participation certificates that can be added to a resume when applying for a job.
C3	Content Quality	Reflects the professionalism of instructors, depth of material, and modernity of topics. High-quality content is often associated with partnerships with leading universities and the practical experience of course developers. From the perspective of knowledge acquisition, interactivity (presence of videos, graphics, practical tasks, simulations, etc.) plays a crucial role.
Factor 2. Accessibility		
C4	Cost	Assesses how financially accessible the learning process is. Courses may be completely free, conditionally free (*freemium*), or paid. Some platforms allow free course attendance, but certification requires payment.
C5	Language of Instruction	Defines the accessibility of course content for comprehension and the possibility of language skill acquisition. International platforms are primarily designed in English but often provide subtitles in other languages. Ukrainian platforms focus on native language instruction, which enhances accessibility for local users.
Factor 3. Learning Process		
C6	Learning Format	Determines the availability and convenience of various forms of content delivery and assessment, such as video lectures, interactive exercises, online tests, and group projects. Platforms like *edX* and *FutureLearn* form learning cohorts that progress through the same modules and tasks together, enabling collaboration and teamwork. Others, such as *Udemy* and *Prometheus*, support self-paced learning.

End toTable 1

1	2	3
C7	Flexibility and Usability	Reflects the availability of mobile applications and the ability to study offline from any location worldwide. A user-friendly interface and fast access to materials facilitate the learning process and make it more natural in everyday life.
C8	Community and Support	Defines the availability of assistance from organizers and peers and the possibility of receiving personal support. The presence of learner forums, group chats, and mentors or tutors enables participants to ask instructors questions or receive peer support at any stage. Peer-to-peer evaluation and collaborative project discussions allow for more detailed feedback and correction of individual work deficiencies.
C9	Innovation and Technology	Evaluates the use of artificial intelligence for personalized learning. Gamification of the learning process (badges, rankings, levels) and progress analytics enhance engagement and help adapt materials to learners' needs.

4. Development of a Conceptual Model of the Decision-Making Process

The problem of decision-making, in the general case, can be represented as a quintuple of sets [13]:

$$S = X, U, Y, F, R, \qquad (1)$$

where X – the set of possible environmental states that do not depend on the decision-maker;

U – the set of alternative decisions available to the decision-maker;

Y – the set of possible consequences (outcomes) of the decision;

$F : X \times U \rightarrow Y$ – the outcome function that assigns to each element of the Cartesian product of the sets of environmental states and decisions a corresponding result obtained by the decision-maker;

R – the preference relation or utility function that reflects the decision-maker's preferences over the set of outcomes.

The study examines a decision-making situation based on the subjective preferences of the decision-maker under conditions of complete awareness of the available alternatives. Therefore, the stochastic nature of the decision-making process is not considered; accordingly, the set of environmental states X is not defined. Instead, these states are implicitly taken into account by the decision-maker through the reflection of their own preferences over the set of outcomes and evaluation criteria. The elements of the set of alternative decisions *U* constitute the lowest level of the hierarchy when applying the Analytic Hierarchy Process AHP. The main objective of the method is to determine the preference relation or utility function *R*, which reflects the decision-maker's preferences over the set of outcomes.

Utility serves as an integral indicator of the overall value of an online learning platform for the user, determining how well the platform meets the learner's needs, expectations, and capabilities. This integral indicator forms the first (top) level of the hierarchy in the AHP model and consists of second-level factors that are interrelated as follows: the Content factor (F1) reflects the relevance, completeness, and quality of learning materials and directly influences learning effectiveness – represented by the Learning factor (F3), which, in turn, characterizes the learning experience, interaction, support, and technology, thereby enhancing the perception of content defined by F1. The Accessibility factor (F2) determines how accessible a course is in terms of language, format, and cost, creating the prerequisites for content assimilation (F1) and broader audience engagement (F3).

The relationship among the evaluation criteria described in Table 1 can be represented in the form of the following formulas:

Content (F1)	=	(Course Content and Topics (C_1), Accreditation and Certification (C_2), Content Quality (C_3));
Accessibility (F2)	=	(Cost (C_4), Language of Learning (C_5));
Learning (F3)	=	(Learning Format (C_6), Flexibility and Usability (C_7), Community and Support (C_8), Innovation and Technology (C_9)).

Such a relationship reflects the grouping of evaluation criteria, which constitute the penultimate level of the hierarchy, into evaluation factors that collectively determine the overall utility of the decision. This relationship is graphically illustrated in Figure 1.

Considering the analysis of formula (1) and based on the developed hierarchical model of relationships among the evaluation criteria, the decision-making process for selecting an online learning platform using the chosen mathematical framework can be presented as the following algorithm:

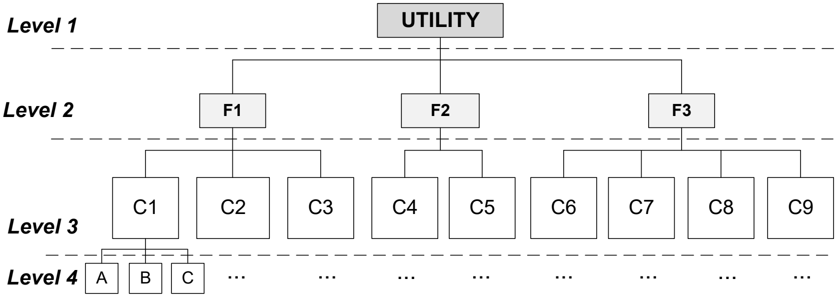

Figure 1. Evaluation Criteria Tree

Step 1. Expertly determine the preferences over the set of second-level evaluation factors.

Step 2. Calculate the priority vectors for each second-level factor.

Step 3. Expertly determine the preferences over the set of third-level evaluation criteria.

Step 4. Calculate the priority vectors for each third-level evaluation criterion, taking into account the priority values of the corresponding factor obtained in Step 2.

Step 5. Expertly determine the preferences over the set of alternatives according to each third-level evaluation criterion.

Step 6. Calculate the priority vectors for each alternative with respect to each third-level evaluation criterion, considering the priority values of the corresponding criterion calculated in Step 4.

Step 7. Compute the priority matrix of alternatives, taking into account the priority vectors of each alternative with respect to each criterion, calculated in Step 6.

Step 8. Calculate the utility function value for each alternative.

Step 9. Identify the best alternative as the one with the highest utility function value.

The given number of hierarchy levels is determined by the relatively low complexity of the decision-making problem, which involves a limited number of evaluation criteria and alternatives.

5. Construction of a Mathematical Model for Multi-Criteria Selection

At the second stage of the AHP, the relative importance of each element of the hierarchy is determined through pairwise comparisons of their subjective assessments. For this purpose, the following matrices are calculated:

– a pairwise comparison matrix of second-level evaluation factors, based on which the priority vector of factors is determined;

– pairwise comparison matrices of third-level evaluation criteria, which serve as the basis for calculating the priority vectors of criteria for each factor;

– pairwise comparison matrices of the alternative decisions at the lowest level, from which the priority vectors of alternatives for each criterion are derived;

– a composite matrix for determining the utility function value of each alternative decision.

The determination of the priority vector of factors is performed according to the mathematical model described below.

1. The pairwise comparison matrix of the second-level evaluation factors is completed using the following formula:

$$A = \left\{a_{ij}\right\}_{n\times n}, a_{ij} = \begin{cases} a_{ij}^{ВП}, i < j; \\ 1, i = j; \quad , i = \overline{1,n}, j = \overline{1,n}, \\ \dfrac{1}{a_{ji}^{ВП}}, i > j. \end{cases} \tag{2}$$

where $a_{ij}^{ВП}$ – the preference ratio determined by the decision-maker according to the Saaty ratio scale;

n – the number of second-level evaluation factors (n=3).

The normalized matrix is then calculated using the following formula:

$$H = \left\{\eta_{ij}\right\}_{n\times n}, \eta_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, j = \overline{1,n}. \tag{3}$$

The priority vector of factors is calculated using the following formula:

$$W=\{w_i\}_n, w_i=\frac{g_i}{\sum_{i=1}^{n}g_i}, g_i=\left(\prod_{j=1}^{n}\eta_{ij}\right)^{\frac{1}{n}}, i=\overline{1,n}, \qquad (4)$$

where g_i – the geometric mean values of the rows of the normalized matrix (3).

The determination of the priority vectors of criteria for each factor is carried out according to the mathematical model presented below.

n pairwise comparison matrices of third-level evaluation criteria are completed using the following formula:

$$\Theta_i=\{\theta_{kl}\}_{K_i\times K_i}, \theta_{kl}=\begin{cases}\theta_{kl}^{ВП}, k<l;\\ 1, k=l;\\ \frac{1}{\theta_{lk}^{ВП}}, k>l.\end{cases}, k=\overline{1,K_i}, l=\overline{1,K_i}, i=\overline{1,n}, \qquad (5)$$

where $\theta_{kl}^{ВП}$ – the preference ratios determined by the decision-maker according to the Saaty ratio scale;

K_i – the number of third-level evaluation criteria that constitute the *i*-th factor.

Then, n normalized matrices are calculated using the following formula:

$$N_i=\{\nu_{kl}\}_{K_i\times K_i}, \nu_{kl}=\frac{\theta_{kl}}{\sum_{k=1}^{K_i}\theta_{kl}}, k=\overline{1,K_i}, l=\overline{1,K_i}, i=\overline{1,n}. \qquad (6)$$

n priority vectors of the evaluation criteria are calculated using the following formula:

$$S_i=\{\sigma_k\}_{K_i}, \sigma_k=w_i\frac{\rho_k}{\sum_{k=1}^{K_i}\rho_k}, \rho_k=\left(\prod_{l=1}^{K_i}\nu_{kl}\right)^{\frac{1}{K_i}},$$
$$k=\overline{1,K_i}, l=\overline{1,K_i}, i=\overline{1,n}, \qquad (7)$$

where ρ_k – the geometric mean values of the rows of the normalized matrix (6).

The determination of the priority vectors of alternatives for each criterion is performed in the same manner as the calculation of the priority vectors of criteria (formulas (5)–(7)).

The utility of each alternative decision is determined by the normalized sum of its priority values across all criteria.

6. Results of the Software Implementation

To support decision-making regarding the selection of information and technological tools, a software implementation of the proposed mathematical model was developed within a spreadsheet environment.

Figure 2 presents the interface of the software implementation showing the pairwise comparison matrix of second-level evaluation factors and the determination of the corresponding priority vector.

The graphical representation of the distribution of priorities across the set of factors is shown in Figure 3.

	complete matrix			normalized matrix			Geometric mean	Weights
	Content	Accessibility	Learning	Content	Accessibility	Learning		
Content	1.000	3.000	5.000	0.652	0.730	0.333	0.541	0.239
Accessibility	0.333	1.000	9.000	0.217	0.243	0.600	1.442	0.637
Learning	0.200	0.111	1.000	0.130	0.027	0.067	0.281	0.124

Figure 2. Generalized table of paired comparisons

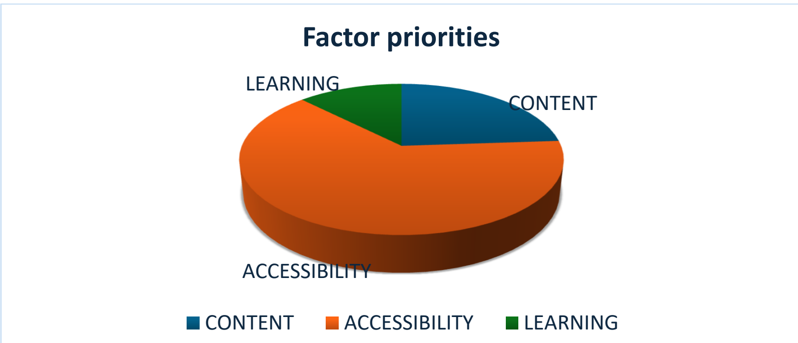

Figure 3. Distribution of Priorities over the Set of Factors

The interface forms displaying the results of the software implementation of the pairwise comparison matrices for the third-level evaluation criteria and the determination of the priority vectors of criteria for each second-level evaluation factor are presented in Figures 4–6.

Figure 7 presents the interface of the software implementation results for constructing the overall matrix used to determine the utility function value of each alternative decision, the priority vector of alternatives, and the conclusion regarding the selection of the best alternative based on the highest utility function value.

	complete matrix			**Geometric mean of the normalized matrix**	**Weights**
	Course Content and Topics	**Accreditation and Certification**	**Content Quality**		
Course Content and Topics	1.000	3.000	5.000	0.648	0.351
Accreditation and Certification	0.333	1.000	2.000	0.229	0.124
Content Quality	0.200	0.500	1.000	0.122	0.066

Figure 4. Table of paired comparisons by the factor CONTENT

	complete matrix		**Geometric mean of the normalized matrix**	**Weights**
	Cost	**Language of Learning**		
Cost	1.000	6.000	0.857	1.236
Language of Learning	0.167	1.000	0.143	0.206

Figure 5. Table of matched comparisons by the factor ACCESSIBILITY

	complete matrix				Geometric mean of the normalized matrix	Weights
	Learning Format	Flexibility and Usability	Value	Innovation and Technology		
Learning Format	1.000	3.000	4.000	5.000	0.438	0.123
Flexibility and Usability	0.333	1.000	8.000	2.000	0.239	0.067
Community and Support	0.250	0.125	1.000	7.000	0.108	0.030
Innovation and Technology	0.200	0.500	0.143	1.000	0.054	0.015

Figure 6. Table of paired comparisons by the factor LEARNING

Online platforms for non-formal education	CONTENT (F1)			ACCESSIBILITY (F2)	
	Course Content and Topics	Accreditation and Certification	Content Quality	Cost	Language of Learning
A	0.221130588	0.08152652	0.031620058	0.851127107	0.133412146
B	0.08966406	0.030945316	0.019152486	0.197529104	0.049822819
C	0.036356995	0.006712015	0.008700594	0.091684888	0.014885081

Online platforms for non-formal education	LEARNING (F3)				TOTAL F1+F2+ F3	UTILITI
	Learning Format	Flexibility and Usability	Com-munity and Support	Innovation and Technology		
A	0.066704282	0.050058	0.0163909	0.008760732	1.46073	**0.70291**
B	0.028742004	0.010857	0.0095855	0.005193498	0.44149	**0.21245**
C	0.010320462	0.004121	0.0018685	0.001231515	0.17588	0.08464

The priority vector: 0.7*A+0.21*B+0.08*C

The most desirable (optimal) option is the option A for which the value of the utility function is equal 0.7029

Figure 7. Summary matrix of the priorities (UTILITI FUNCTIONS)

The graphical representation of the utility function of the alternatives is shown in Figure 8.

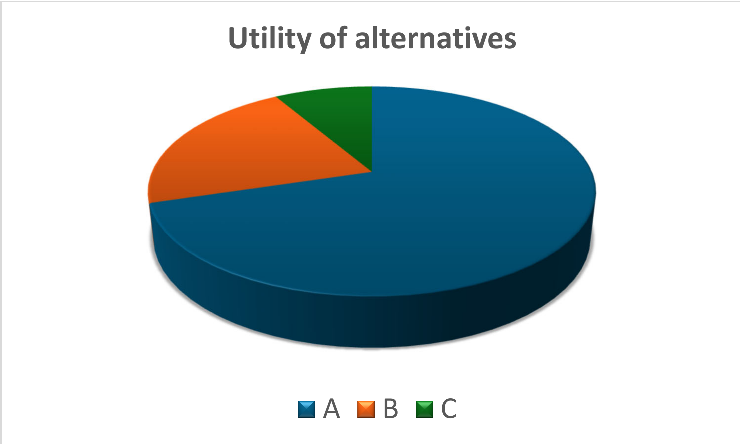

Figure 8. Distribution of utility among alternatives

The input data of the model are the numerical values located above the main diagonal in the pairwise comparison matrices (Figures 2, 4–6). The calculation of all other intermediate results, the generation of conclusions, and the graphical interpretation of outcomes are implemented using spreadsheet tools. It should be noted that the numerical data presented in the example reflect the subjective assessments of the authors. The alternative decisions, representing educational online platforms, are denoted by Latin letters to preserve anonymity, as this study does not pursue a promotional purpose. The model is universal with respect to the type of alternative selection.

The model parameters include: the number of alternatives, the number of hierarchy levels, the number of criteria at each level, and the number of criteria within each top-level factor. The latter two parameters determine the structure of the hierarchy tree of criteria; therefore, the model is universal concerning the form of the evaluation criteria hierarchy (Figure 1). Further development of this work, from the standpoint of software implementation, involves varying the model parameters.

7. Recommendations for the Formation of a System of Criteria

The formation of the set of evaluation criteria and their hierarchy in this study is subjective in nature and reflects the authors' perspective on the problem of selecting indicators for assessing the effectiveness of information and technological tools under the conditions of transformation of the scientific and educational environment. From a conceptual standpoint, further development of this work may involve a deeper investigation of the factors influencing the choice of evaluation criteria.

A general recommendation for the formation of a system of criteria is the application of the principles of the systems approach, educational analytics, and international standards in the development of digital education, analytics, and information technology management in educational and scientific activities.

Overall, the effectiveness of information systems in education can be characterized by multiple indicators, among which the following may be distinguished: technological efficiency (reliability, performance, security); functional completeness (compliance with educational and research objectives); pedagogical effectiveness (quality of the learning process); scientific productivity (integration into research activities); ergonomics and accessibility (usability, inclusiveness, multilingualism); economic efficiency (cost–benefit ratio); information security (protection of personal and research data); organizational maturity (integration of information technologies into strategic management); social and ethical components (academic integrity, inclusion); and innovation and scalability (development, adaptability, implementation of new technologies) [14].

When considering the systematization of evaluation criteria from the user's perspective of educational online platforms, the criteria should reflect not only the technical performance of information systems but, above all, the quality of user experience, learning convenience, and educational value. The following factors can therefore be highlighted:

Accessibility and system stability, described by such parameters as the average system response time, failure rate or percentage of downtime, compatibility with different devices, and ease of authentication and account recovery. Particular attention should be given to the accessibility of systems for users with disabilities.

User interface (navigation convenience), which reflects the degree of intuitiveness, usability, and visual appeal: the time required to complete standard tasks, interface consistency, and the possibility of personalization.

Content quality from the user's perspective, which indicates the relevance of materials, the share of interactive content, the availability of adaptive or personalized learning paths, and student feedback on clarity and value of materials.

Social interaction and user support, expressed through the availability of communication and feedback channels, such as forums, instructor or technical support responses, and accessible help services.

Motivational and emotional aspects of the learning experience, determining how effectively the system maintains user engagement and encourages continued learning.

Integration and personalization of the learning experience, reflecting the flexibility of the platform across various learning scenarios, integration with other systems (Zoom, MS Teams, Google Classroom, library resources), and the ability to build an individualized educational trajectory.

A quantitative criterion for assessing the effectiveness of information systems may be represented by the User Utility Index (UUI) – an integrated indicator that aggregates all the parameters mentioned above [14; 15].

$$UUI = w_1A + w_2U + w_3C + w_4S + w_5M + w_6B + w_7I ,$$

where A – accessibility,

U – usability,

C – content quality,

S – support,

M – motivation,

B – security,

I – integration,

w_i – the weighting coefficients determined by the expert evaluation method.

When forming a system of evaluation criteria, it is essential to focus on outcomes, which can be interpreted as a shift from assessing learning processes to evaluating the impact of information tools on the key results of these processes. The criteria should reflect the degree to which the implementation of information systems improves the quality of learning, as well as the extent to which such systems contribute to scientific productivity (e.g., number of publications, open data availability, international collaborations). Thus, an outcome-oriented focus ensures that the digital environment is directed toward the creation of educational and scientific value.

8. Conclusions

Based on the analysis of contemporary research, the relevance of addressing the problem of selecting information tools for learning under modern challenges has been substantiated, and the objective of the study has been formulated – to develop a model for rational decision-making in the selection of information and technological tools based on multiple criteria, followed by its software implementation. To achieve this goal, a comprehensive review of current approaches, models, and methods of multi-criteria decision-making for selecting information and technological tools was conducted. Their advantages, limitations, and areas of application were identified, which made it possible to justify the choice of the modeling method. A system of evaluation criteria for information tools was developed, taking into account the ongoing transformational challenges of the educational and scientific environment. Based on the obtained results, both conceptual and mathematical models of the decision-making process were designed, and a software implementation of the model was created using spreadsheet tools. The final stage of the study involved developing recommendations for constructing a system of criteria and indicators for assessing the effectiveness of information and technological tools within the context of transformation in the scientific and educational space.

The practical significance of the work lies in the creation of an automated decision-support tool for selecting information tools in the field of scientific and educational activity, using educational online platforms as an example. This tool is universal with respect to both the range of alternatives and the set of evaluation criteria. Further development of the research involves ensuring the universality of the model concerning the number of alternatives and the structure of the hierarchy tree of criteria – specifically, the number of hierarchy levels, the number of criteria at each level, and the number of criteria within each top-level factor.

The proposed approach provides adaptability of the evaluation criteria system, which is particularly important under the turbulent conditions surrounding the selection and use of educational online platforms. Such adaptability ensures the dynamism of the evaluation system, allowing modifications in response to rapid technological changes, the emergence of new educational formats (distance, hybrid, or asynchronous learning), evolving user needs for accessibility, mobility, and content personalization, and the necessity of integrating innovative services (artificial intelligence assistants, cloud laboratories, automated assessment systems). Adaptability also implies the ability to rapidly scale the system of criteria – from the individual, departmental, or faculty level to the institutional or university level as a whole.

Further development of this work envisions a deepening of research in the field of analysis and justification of evaluation criteria for information systems across various domains of scientific research, as well as the incorporation of stochastic aspects inherent in scientific and educational activities.

References:

1. Triantaphyllou, E. (2000). *Multi-Criteria Decision Making: A Comparative Study*. Dordrecht, The Netherlands: Kluwer Academic Publishers (now Springer). P. 320. ISBN 0-7923-6607-7. Available at: https://www.csc.lsu.edu/trianta/Books/DecisionMaking1/backup/Book_DM1.htm?utm_source=chatgpt.com
2. Peretyatko M. V. (2020) Zastosuvannia metodu zvazhenykh sum pry proektuvanni modulia vyboru robochoho mistsia prohramno-aparatnoho zabezpechennia dlia pidtrymky funktsionuvannia kovorkinh-zon [Application of the weighted sum method in designing a workplace selection module for coworking-zone software and hardware support]. *Radioelektronika ta molod u XXI stolitti – Radio Electronics and Youth in the XXI Century: Proceedings of the 24th International Youth Forum* (Kharkiv, April 7–9, 2020). Kharkiv: KhNURE, vol. 6, pp. 177–178. Available at: https://openarchive.nure.ua/handle/document/22545
3. Behzadian M., Khanmohammadi Otaghsara S., Yazdani M., Ignatius J. A state-of-the-art survey of TOPSIS applications. Expert Systems with Applications. Volume 39, Issue 17, 1 December 2012, Pages 13051-13069. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0957417412007725
4. Balali A., Yunusa-Kaltungo A., Edwards R. A systematic review of passive energy consumption optimisation strategy selection for buildings through multiple criteria decision-making techniques. *Renewable and Sustainable Energy Reviews*. 2023. №171. Available at: https://www.sciencedirect.com/science/article/abs/pii/S1364032122008942; DOI: https://doi.org/10.1016/j.rser.2022.113013
5. Saaty R.W. The analytic hierarchy process – what it is and how it is used. *Mathematical Modelling.* Volume 9, Issues 3–5. 1987, Pages 161-176. URL: https://www.sciencedirect.com/science/article/pii/0270025587904738

6. Mikhno O., Patrakeiev I., Levinskova N. (2023) Bahatokryterialnyi vybir alternatyv na osnovi metodu analizu iierarkii [Multi-criteria selection of alternatives based on the analytic hierarchy process]. *Viiskovo-spetsialni nauky – Military Special Sciences,* no. 4(56), pp. 57–63. Available at: https://miljournals.knu.ua/index.php/visnuk/en/article/view/1126/1031

7. Dolgova N. H., Shapovalova O. O., Solodovnyk H. V. (2025) Systema pidtrymky rishen u zavdanniakh proektuvannia kiberbezpeky krytychnoi infrastruktury [Decision support system in the tasks of designing cybersecurity of critical infrastructure]. *Kiberbezpeka: osvita, nauka, tekhnika – Cybersecurity: Education, Science, Technology,* no. 1(29), pp. 348–372. Available at: https://www.csecurity.kubg.edu.ua/index.php/journal/article/view/884/741

8. Mironchuk O. A. (n.d.) Transformatsiia mizhnarodnoho naukovoho spivrobitnytstva v umovakh hlobalizatsii [Transformation of international scientific cooperation under globalization]. Available at: https://www.researchgate.net/ublication/342202572_Transformacia_miznarodnogo_naukovogo_spivrobitnictva_v_umovah_globalizacii

9. Holuk V. Ya., Lutsenko I. S., Nahorna I. I. (2022) Suchasni tendentsii ta spetsyfika naukovo-doslidnoi diialnosti [Current trends and specifics of research activity]. *Ekonomika ta suspilstvo – Economy and Society,* no. 40.

10. Eurostat. Adult education surve. 2022. Available at: https://ec.europa.eu/eurostat/web/microdata/adult-education-survey

11. Sabadyshyna Yu. (2024) Prometheus pro onlain-navchannia ukraintsiv [Prometheus about online education of Ukrainians]. *Developers.Org.UA*. Available at: https://dou.ua/lenta/news/prometheus-in-2023/?utm_source=chatgpt.com

12. Cherkasy State Technological University. (n.d.). *Decision Support System "Decisioner": Analytic Hierarchy Process (AHP) help page.* Available at: https://dss.knsa.chdtu.edu.ua/ahp-help

13. Hullman, J., Hildreth, J., & Kim, Y. (2024). Decision theoretic foundations for experiments. *arXiv preprint arXiv:2401.15106.* Available at: https://arxiv.org/abs/2401.15106

14. Miya, T. K., & Govender, I. (2022). *UX/UI design of online learning platforms and their impact on learning: A review. International Journal of Research in Business and Social Science*, 11(10), 316-327.

15. Holt, C. J. (2023). Evaluating and expanding usability and user satisfaction of online research supervision*. Australian Journal of Educational Technology*.