DOI 10.54596/2958-0048-2026-1-274-293
UDK 004.94
IRSTI 50.49.37

MODEL AND ARCHITECTURE OF A DECISION SUPPORT SYSTEM FOR ASSESSING MATERIAL RESOURCE PROVISION IN EDUCATIONAL ORGANIZATIONS

Ye.Sh. Utyubayev[1*]
[1]KSU Pavlodar Regional Center of Information Technologies of the Department of Education of Pavlodar Region, Pavlodar, Kazakhstan*
[*]Corresponding author: elnar87@mail.ru

Abstract
The aim of this study is to develop a model and architecture of a decision support system for assessing the material resource provision of educational organizations. The paper proposes the architecture of an information and analytical system that integrates the processes of data collection, storage, analytical processing, and visualization of information on the material resources of educational organizations. The system architecture includes subsystems for data acquisition from multiple sources, a centralized data warehouse, an analytical processing core, tools for visualizing indicators, and a module for generating management reports.
The methodological basis of the study is the application of mathematical modeling methods to formalize the processes of assessing the provision of educational organizations with equipment. A system of quantitative indicators is proposed, including the calculation of normative equipment demand, the provision coefficient, the resource deficit indicator, the integrated provision index, and the equipment retirement risk indicator. The developed model makes it possible to conduct a comprehensive assessment of the condition of the material and technical base of educational organizations.
Unlike traditional inventory accounting systems used in educational organizations, the proposed architecture integrates a mathematical model for calculating the equipment provision coefficient, the integrated provision index, and the equipment retirement risk indicator within a multi-level analytical decision support framework. This approach enables analytical monitoring of infrastructure provision rather than simple inventory accounting of equipment.

Keywords: decision support system; educational infrastructure monitoring; equipment provision coefficient; integrated provision index; equipment lifecycle risk; data-driven educational management.

БІЛІМ БЕРУ ҰЙЫМДАРЫНДАҒЫ МАТЕРИАЛДЫҚ РЕСУРСТАРМЕН ҚАМТАМАСЫЗ ЕТУДІ БАҒАЛАУ БОЙЫНША ШЕШІМДЕРДІ ҚОЛДАУ ЖҮЙЕСІНІҢ МОДЕЛІ МЕН АРХИТЕКТУРАСЫ

Утюбаев Е.Ш.[1*]
[1]Павлодар облыстық білім беру департаментінің Павлодар аймақтық ақпараттық технологиялар орталығы, Павлодар, Қазақстан*
[*]Хат-хабар үшін автор: elnar87@mail.ru

Аңдатпа
Бұл зерттеудің мақсаты-білім беру ұйымдарының материалдық ресурстармен қамтамасыз етілуін бағалау үшін шешімдерді қолдау жүйесінің моделі мен архитектурасын жасау. Жұмыста білім беру ұйымдарының материалдық ресурстары туралы мәліметтерді жинау, сақтау, аналитикалық өңдеу және визуализация процестерін біріктіретін ақпараттық-аналитикалық жүйенің архитектурасы ұсынылған. Жүйенің архитектурасына бірнеше көздерден деректерді жинауға арналған ішкі жүйелер, орталықтандырылған деректер қоймасы, аналитикалық өңдеу ядросы, индикаторларды визуализациялау құралдары және басқару есептерін шығаруға арналған модуль кіреді.

Зерттеудің әдіснамалық негізі білім беру ұйымдарын жабдықтармен қамтамасыз етуді бағалау процестерін ресімдеу үшін математикалық модельдеу әдістерін қолдану болып табылады. Жабдықтарға нормативтік сұранысты, қамтамасыз ету коэффициентін, ресурстар тапшылығының индикаторын, қамтамасыз етудің интеграцияланған индексін және жабдықтың зейнетке шығу қаупінің индикаторын есептеуді қамтитын сандық көрсеткіштер жүйесі ұсынылады. Әзірленген модель білім беру ұйымдарының материалдық-техникалық базасының жай-күйін кешенді бағалауды жүргізуге мүмкіндік береді.
Білім беру ұйымдарында қолданылатын тауарлық-материалдық қорларды есепке алудың дәстүрлі жүйелерінен айырмашылығы, ұсынылған архитектура көп деңгейлі аналитикалық шешімдерді қолдау шеңберінде жабдықты қамтамасыз ету коэффициентін, интеграцияланған қамтамасыз ету индексін және жабдықтың зейнетке шығу қаупінің индикаторын есептеудің математикалық моделін біріктіреді. Бұл тәсіл жабдықты түгендеудің қарапайым есебін емес, инфрақұрылымды қамтамасыз етуді аналитикалық бақылауға мүмкіндік береді.

Кілт сөздер: шешімдерді қолдау жүйесі; білім беру инфрақұрылымының мониторингі; жабдықтармен қамтамасыз ету коэффициенті; қамтамасыз етудің интеграцияланған индексі; жабдықтың өмірлік циклінің тәуекелі; деректерге негізделген білім беруді басқару.

МОДЕЛЬ И АРХИТЕКТУРА СИСТЕМЫ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ДЛЯ ОЦЕНКИ ОБЕСПЕЧЕННОСТИ МАТЕРИАЛЬНЫМИ РЕСУРСАМИ ОБРАЗОВАТЕЛЬНЫХ ОРГАНИЗАЦИЙ

Утюбаев Е.Ш.[1*]
[1]КГУ «Павлодарский областной центр информационных технологий» управления образования Павлодарской области, Павлодар, Казахстан*
[*]Автор для корреспонденции: elnar87@mail.ru

Аннотация
Целью настоящего исследования является разработка модели и архитектуры системы поддержки принятия решений для оценки материальной обеспеченности образовательных организаций. В работе предложена архитектура информационно-аналитической системы, обеспечивающая интеграцию процессов сбора, хранения, аналитической обработки и визуализации данных о материальных ресурсах образовательных организаций. Архитектура системы включает подсистемы получения данных из различных источников, централизованное хранилище данных, аналитическое ядро обработки информации, средства визуализации показателей и модуль формирования управленческой отчетности.
Методической основой исследования является применение методов математического моделирования для формализации процессов оценки обеспеченности образовательных организаций оборудованием. Предложена система количественных показателей, включающая расчет нормативной потребности в оборудовании, коэффициента обеспеченности, показателя дефицита ресурсов, интегрального индекса обеспеченности и показателя риска выбытия оборудования. Разработанная модель позволяет проводить комплексную оценку состояния материально-технической базы образовательных организаций.
В отличие от традиционных систем учета запасов, используемых в образовательных организациях, предлагаемая архитектура объединяет математическую модель для расчета коэффициента обеспеченности оборудованием, интегрального показателя обеспеченности и показателя риска выхода оборудования из строя в рамках многоуровневой системы аналитической поддержки принятия решений. Такой подход позволяет осуществлять аналитический мониторинг обеспеченности инфраструктурой, а не простой учет запасов оборудования.

Ключевые слова: системы поддержки принятия решений; мониторинг образовательной инфраструктуры; коэффициент обеспеченности оборудованием; интегральный индекс обеспеченности ресурсами; риск жизненного цикла оборудования; управление образованием на основе данных.

Introduction

In the context of the digitalization of the education system and the increasing requirements for the quality of the educational environment, effective management of the material and technical resources of educational organizations becomes increasingly important. The availability of modern equipment, educational laboratories, information and communication technologies, and other infrastructure elements is a key factor in ensuring the quality of the educational process and the implementation of educational programs. At the same time, the level of material resource provision of educational organizations must comply with established standards and regulatory requirements. In this study, material resource provision refers to the level of availability of equipment and technical infrastructure required to support the educational process in accordance with regulatory standards.

The aim of this study is to develop a model and architecture of a decision support system for assessing the material resource provision of educational organizations.

With the development of information technologies and digital platforms, the creation of information and analytical systems capable of automating the processes of monitoring material resources, analyzing provision indicators, and generating management reports becomes increasingly relevant. Decision Support Systems (DSS) play an important role in solving this problem, as they enable data integration, the application of analytical methods, and the presentation of analysis results in a form convenient for users.

The use of mathematical modeling methods within DSS makes it possible to formalize the processes of assessing the provision of educational organizations with material resources, determine quantitative indicators of compliance with regulatory requirements, and identify infrastructure deficits. The application of such models ensures the objectivity of analysis and increases the effectiveness of managerial decision-making in the development of educational infrastructure.

In the management practice of educational organizations, various information systems for resource accounting are widely used, including accounting and management systems (for example, solutions based on 1C), enterprise resource planning systems (ERP systems), and specialized information systems for educational management. The main function of such systems is the registration and accounting of material resources, reporting generation, and support of administrative processes. However, these systems are generally not designed to perform a comprehensive analytical assessment of the material resource provision of educational organizations.

Unlike traditional accounting systems, the approach proposed in this study is based on an analytical model for evaluating resource provision, including the calculation of normative equipment demand, the provision coefficient, the resource deficit indicator, the integrated provision index, and the equipment retirement risk indicator. The integration of these indicators into the architecture of a decision support system makes it possible to move from simple resource accounting to analytical monitoring of the condition of the material and technical base of educational organizations.

In addition, the proposed system architecture implements a multi-level analysis principle that provides data processing at the level of educational organizations, municipal administration, and regional administration. This makes it possible to aggregate analytical indicators and support managerial decision-making at different levels of the educational system. Thus, the proposed system complements existing accounting information systems with analytical tools for decision support in the management of educational infrastructure.

The scientific novelty of the study lies in the development of an analytical model for assessing the material resource provision of educational organizations integrated into the architecture of a decision support system for monitoring educational infrastructure. Unlike existing information systems focused primarily on inventory accounting of material resources, the proposed approach is based on a system of formalized analytical indicators, including the calculation of normative equipment demand, the provision coefficient, the resource deficit indicator, the integrated provision index, and the equipment retirement risk indicator. The proposed model enables a quantitative assessment of the condition of the material and technical base of educational organizations, allows the risks of decreasing provision due to equipment wear to be taken into account, and provides analytical support for managerial decision-making in planning the modernization of educational infrastructure at the institutional, municipal, and regional levels.

The theoretical significance of the study lies in the development of approaches to the application of decision support systems in the management of educational infrastructure. The study proposes a formalized system of analytical indicators for assessing the material resource provision of educational organizations, including the equipment provision coefficient, the integrated provision index, and the equipment retirement risk indicator. The proposed approach expands the application of analytical modeling and decision support systems for monitoring material and technical resources in the education system.

The practical significance of the study lies in the possibility of using the proposed architecture of the information and analytical system to automate the monitoring of the material and technical base of educational organizations and to support managerial decision-making. The implementation of the proposed system makes it possible to conduct comprehensive monitoring of the equipment provision of educational organizations, identify resource deficits, forecast the need for infrastructure renewal, and support evidence-based decisions on the modernization of the material and technical base at the level of educational organizations, municipal authorities, and regional administration.

The results of the study can be used in the development of regional information and analytical systems for monitoring educational infrastructure.

Literature Review

In recent years, increasing attention in the scientific literature has been devoted to the digital transformation of educational management systems. Studies show that the implementation of information and analytical systems contributes to greater transparency of management processes, improved monitoring, and more informed decision-making in the field of education.

International organizations also emphasize the importance of using data in the strategic management of education systems. Analytical reports by the OECD [1] and the World Bank [2] highlight the need to move from traditional reporting-based management models to analytical approaches based on systematic monitoring of indicators and the use of visualization tools for key metrics. Particular importance is attached to the development of digital platforms that ensure data comparability and their integration across different levels of educational system governance.

Research in the field of Learning Analytics also confirms the importance of analytical tools for supporting managerial decision-making in education [3]. It is noted that the use of data visualization methods significantly simplifies the interpretation of complex indicators and reduces the cognitive load on users of information systems.

A number of studies devoted to Decision Support Systems (DSS) emphasize the need to integrate mathematical data analysis models with tools for visualizing analytical results [4]. Modern DSS are focused not only on calculating analytical indicators but also on presenting information in a form convenient for managerial analysis and decision-making.

In research on infrastructure and resource management, risk-oriented approaches are actively developing [5], which make it possible to consider equipment degradation processes and forecast the need for infrastructure renewal. However, most existing studies focus on technical or industrial systems, whereas the application of such approaches to educational infrastructure requires adaptation to the specific characteristics of the social sector.

Researchers note that effective educational infrastructure management systems should ensure the coordination of analytical data at both the local level of educational organizations and the strategic level of regional governance. Recent studies [6–9] also demonstrate the application of multicriteria decision-making methods and hybrid analytical models in decision support systems for resource management.

Modern studies in the field of decision support systems demonstrate the extensive use of artificial intelligence methods, multicriteria optimization, and hybrid DSS models. For example, an integrated decision support architecture for inventory management is proposed in [10], combining fuzzy logic, genetic algorithms, and neural networks. Such approaches make it possible to consider environmental uncertainty as well as the dynamic nature of resource flows and inventory management processes.

Another research direction is related to the application of DSS for optimizing spare parts supply chains. In [11], the authors present a decision support system that considers various manufacturing technologies and logistics parameters in supply chain planning. In turn, the authors of [12] propose a decision support model for selecting spare parts suitable for additive manufacturing, demonstrating the expansion of DSS applications toward strategic resource management.

Recent studies in the field of decision support systems also demonstrate the rapid development of analytical data processing methods, the integration of artificial intelligence technologies, and the increasing importance of transparency in decision-making algorithms. In particular, study [13] addresses the problem of explainability of artificial intelligence models in decision support systems. The authors propose an expert-augmented supervised feature selection approach that improves the interpretability of analytical models and ensures greater transparency of analytical results in managerial decision-making.

Study [14] focuses on the analysis of decision-making mechanisms in digital platforms. The authors examine the influence of managerial response strategies to user feedback and demonstrate that adaptive information processing mechanisms can significantly improve the quality of managerial decisions. These findings confirm the importance of integrating analytical data processing tools into modern decision support systems.

Study [15] presents a review of decision support systems applied in intelligent supply chains based on Internet of Things technologies. The authors note that modern DSS actively use big data analytics, predictive analytics, and multicriteria decision-making methods to optimize resource allocation and manage complex infrastructure systems.

In study [16], a conceptual architecture of explainable and interactive decision support systems (DSS4EX) is proposed. This architecture is aimed at increasing the transparency of analytical models and improving interaction between the system and the user. The authors emphasize that modern DSS should provide not only the calculation of analytical indicators but also the possibility of interpreting analytical results to support strategic managerial decision-making.

Thus, modern research demonstrates that the development of decision support systems is closely associated with the integration of artificial intelligence methods, analytical models, and interactive visualization tools. Particular attention is paid to issues of algorithm transparency, interpretability of analytical models, and integration of data from multiple sources. These trends create a methodological foundation for the development of analytical decision support systems in various areas of management, including the management of infrastructure resources of educational organizations.

Issues related to the management of educational organizations through the analysis of material resources are considered in study [17]. The authors propose a methodological approach to managing general education institutions based on the assessment of material provision as an important factor influencing the effectiveness of the educational process.

Issues of regulatory and methodological support for the material and technical provision of educational programs are discussed in study [18]. The author analyzes the formation of a regulatory and methodological system for providing material and technical resources necessary for implementing educational programs in accordance with federal educational standards. The study emphasizes that the availability of appropriate infrastructure, equipment, and educational resources is a key condition for ensuring the quality of the educational process.

In particular, study [19] proposes a methodology for assessing the effectiveness of regional infrastructure facilities supporting scientific, technological, and innovation activities. The authors emphasize the importance of using integrated indicators that allow evaluating the contribution of infrastructure elements to regional development and identifying synergy effects arising from their interaction.

Another research direction is related to the development of regional monitoring systems and the use of hierarchical indicator aggregation mechanisms.

Issues related to performance evaluation and analytical monitoring in the public sector are examined in study [20]. The authors present a systematic review of approaches to performance measurement in local government and emphasize the importance of data-driven governance and the use of analytical indicators to improve public administration efficiency. The study highlights that modern public management systems increasingly rely on integrated information platforms and analytical tools that enable monitoring of key performance indicators, evaluation of resource allocation efficiency, and support for strategic decision-making.

Examples of existing analytical information systems in the education sector include the GIS «Kontingent» and GIS «Education» systems used in the Russian Federation. GIS «Kontingent» is a digital platform designed for centralized accounting of students in the education system and for integrating data on educational organizations, students, and educational programs. The system provides the collection, storage, and processing of information on student populations at different levels of educational management, including educational organizations, municipal authorities, and regional governance bodies. The use of GIS «Kontingent» enables the creation of a unified information space in the education system, improves transparency in educational management, and provides analytical support for managerial decision-making [21]. However, the functionality of the system is mainly focused on student accounting and administrative reporting, whereas the analytical assessment of material resource provision of educational organizations requires specialized information-analytical tools.

GIS «Education» represents a comprehensive digital platform designed to support information processes in educational system management [22]. The system integrates data on educational organizations, students, teachers, educational programs, and learning outcomes. The use of GIS "Education" enables the automation of data collection and processing, the generation of statistical and managerial reports, and the support of interaction between educational organizations and educational authorities. At the same time, the functional capabilities of the system are primarily oriented toward administrative accounting and information support of educational management, whereas the analytical assessment of material resource provision of educational organizations requires specialized information-analytical systems and mathematical modeling methods.

Despite the extensive research on decision support systems and infrastructure monitoring, most studies focus on industrial systems, supply chains, or technical infrastructure. The development of analytical models specifically aimed at assessing the material resource provision of educational organizations remains limited. In particular, there is a lack of integrated analytical approaches combining infrastructure monitoring indicators, provision coefficients and risk indicators for supporting management decisions in the development of educational infrastructure.

Materials and Methods

One of the key methods used in the development of the decision support system (DSS) for assessing the material resource provision of educational organizations is mathematical modeling. The application of this method makes it possible to formalize the processes of analyzing material resource provision, represent them in the form of quantitative relationships, and ensure the objectivity of managerial decisions.

Thus, the use of mathematical modeling is an essential component in the development of a decision support system. It enables the formalization of analytical procedures for assessing resource provision, improves the objectivity and accuracy of analytical calculations, and provides a foundation for automating monitoring and supporting managerial decision-making within the regional educational system.

To analytically assess the condition of the material and technical base of educational organizations, the decision support system uses a set of quantitative indicators that make it possible to determine the level of equipment provision, identify resource deficits, and assess the risks of decreasing provision in the future.

The normative demand for equipment of category c is denoted as *Nc* and represents the required number of equipment units necessary to ensure the proper functioning of the educational process in accordance with established standards (1):

$$N_c = n_c * S, \qquad (1)$$

where:

N_c– normative demand for equipment of category

n_c – equipment provision standard per student or per study group;

S – number of students in the educational organization.

If the standard is defined per study group or classroom, the corresponding number of groups or classrooms may be used instead of the number of students. The normative demand for equipment of category c is denoted by N_c and represents the required number of equipment units necessary to ensure the proper functioning of the educational process in accordance with established standards. This indicator is calculated based on the provision standard n_c,which defines the required amount of equipment per student or per study group, and the number of students Senrolled in the educational organization. The calculation of N_c allows the system to determine the normative level of resource provision and serves as the basis for comparing the required amount of equipment with its actual availability. As a result, the obtained value is used in subsequent calculations of the provision coefficient, the deficit indicator, and the integrated provision index within the decision support system.

The actual availability of equipment in category c is denoted as A_c and represents the number of equipment units that are in working condition within an educational organization. For each equipment category, the number of units in working condition is calculated as follows (2):

$$A_c = \sum_{i=1}^{k} a_i \ , \tag{2}$$

where:

A_c– actual number of equipment units of category c;

a_i – equipment unit in working condition;

k – total number of equipment units in this category.

This indicator is determined based on data from the registry of material resources and corresponds to the total number of operational equipment units of a given category. The value of A_c is used to assess the current level of resource provision and serves as a basis for the subsequent calculation of the provision coefficient and the equipment deficit indicator.

The provision coefficient determines the degree of compliance between the actual equipment quantity and the normative demand (3):

$$K_c = \frac{A_c}{N_c}, \tag{3}$$

where:

K_c– provision coefficient for equipment category c;

This coefficient reflects the degree to which the actual equipment availability meets the normative requirements and serves as a key indicator for identifying infrastructure deficits.The interpretation of the provision coefficient is as follows:

K_c<1– insufficient provision;

K_c=1 – normative provision;

K_c>1 – excessive provision.

The provision coefficient K_c characterizes the degree of compliance between the actual amount of equipment and the normative demand. This indicator is calculated as the ratio of the actual number of equipment units A_c to the normative demand N_c. The value of the coefficient makes it possible to determine the level of equipment provision in a particular category and is used to identify insufficient, normative, or excessive provision of resources.

If the actual amount of equipment is lower than the normative demand, the resource deficit is calculated as (4):

$$D_c = \max(0, N_c - A_c), \tag{4}$$

where:

D– deficit of equipment in category c.

The equipment deficit indicator D_c reflects the shortage of material resources relative to the normative demand. It is calculated as the difference between the normative demand N_c and the actual availability of equipment A_c when the normative demand exceeds the actual amount of resources. This indicator is used to identify the need for equipment procurement and to support planning of modernization of the material and technical base of educational organizations.

For a comprehensive assessment of the material and technical base of educational organizations, an integrated provision index is used. This index aggregates provision indicators across several equipment categories (5):

$$I = \sum_{c=1}^{m} w_c * K_c \ , \tag{5}$$

where:

I – integrated provision index;

w_c – weight coefficient representing the importance of equipment category

m – number of equipment categories.

The integrated provision index provides a normalized quantitative measure that allows comparison of the level of material resource provision between different educational organizations and supports prioritization of infrastructure development decisions. The integrated provision index I is used for the comprehensive assessment of the level of material and technical provision of an educational organization. This indicator is calculated by aggregating the provision coefficients across several equipment categories using weight coefficients w_c, which reflect the relative importance of each category for the educational process. This approach allows consideration of the different roles of equipment within educational infrastructure and provides a more objective assessment of the overall level of resource provision.

The w_c weighting coefficients used in the integrated provision index reflect the relative importance of different categories of equipment for the educational process. In the experimental calculations presented in this study, equal weights were assumed for all equipment categories in order to demonstrate the functionality of the analytical model. In practical applications, weighting coefficients may be determined using expert-based multicriteria decision-making methods, such as expert evaluation techniques or the Analytic Hierarchy Process (AHP), which allows accounting for the relative significance of infrastructure elements.

To forecast potential changes in the level of provision, an equipment retirement risk indicator is used. This indicator is based on the analysis of equipment service life (6):

$$R_c = \frac{E_c}{A_c}, \tag{6}$$

where:

R_c – retirement risk for equipment category c;

E_c – number of equipment units approaching the end of their normative service life;

A_c– actual number of equipment units in category c.

The equipment retirement risk indicator R_c characterizes the probability of a decrease in the level of resource provision due to equipment approaching the end of its normative service life. This indicator is calculated as the ratio of the number of equipment units E_c whose service life is close to the normative limit to the total number of equipment units in this category A_c. The use of this indicator makes it possible to identify potential risks of decreasing provision in a timely manner and to plan the renewal of the material and technical base of educational organizations.

The calculated provision indicators are automatically generated by the analytical core of the system and are used for:

– monitoring the condition of the material and technical base of educational organizations;

– identifying equipment deficits;

– forming procurement and infrastructure modernization plans;

– building analytical dashboards and managerial reports.

Thus, the proposed methodology provides an objective quantitative assessment of the material resource provision of educational organizations and allows the integration of analytical results into a decision support system for managerial decision-making.

It should be noted that in the present study mathematical modeling is primarily used to formalize a system of analytical indicators characterizing the level of material resource provision in educational organizations. The proposed approach is based on the development of a system of indicators and metrics, including normative demand for equipment, the provision coefficient, the resource deficit indicator, the integrated provision index, and the equipment retirement risk indicator.

The use of this system of indicators makes it possible to perform a quantitative assessment of the condition of the material and technical base of educational organizations, identify resource shortages, and provide an analytical basis for managerial decision-making. Thus, the proposed model has an indicator-based analytical character and is intended for monitoring and assessing the level of infrastructure provision rather than solving optimization or dynamic forecasting problems.

The proposed system of indicators provides a reproducible analytical framework for assessing the level of material resource provision of educational organizations. All indicators are calculated based on formally defined parameters, including normative standards of equipment provision, the number of students, and the actual availability of resources. This ensures transparency of the analytical procedures and allows the model to be applied in different educational systems with similar regulatory standards.

The results of the study

Figure 1 illustrates the architecture of the decision support system designed to monitoring, analyze and evaluate the level of material resource provision in an educational organization.

The left side of the diagram represents the data sources that form the information basis of the decision support system. Operational sources include the register of equipment, information about events and statuses of technical facilities, repair requests, procurement and supply data, as well as information about the student body and the plans of the educational organization. Additionally, it is possible to download data from file sources and manually enter information through spreadsheets and troubleshooting forms.

The next step is data acquisition, which is implemented through various integration mechanisms. The system supports data import from Excel and CSV files with validation mechanisms, API integration with external information systems (for example, accounting systems or resource management systems), as well as web and mobile data entry. If necessary, event streaming can be used to ensure prompt information updates.

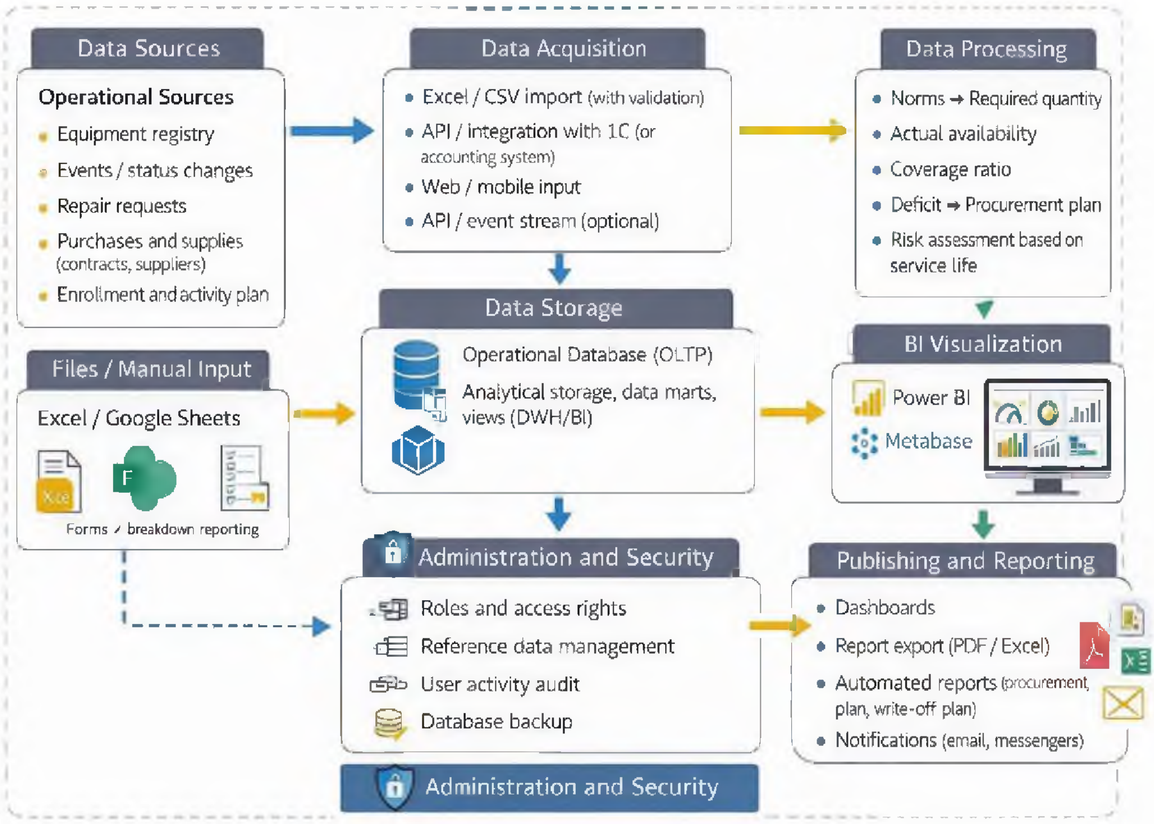

Figure 1. Architecture of the decision support system for assessing material resource provision in educational organizations

The central element of the architecture is the data storage subsystem, which includes an operational database (OLTP) designed to store current transactional data, and an analytical data warehouse (Data Warehouse) containing data marts and views for analytical processing and business intelligence.

After the data is received and saved, the analytical processing of the information is performed. At this stage, the analytical core of the system implements the proposed indicator-based model of material resource provision, including the calculation of normative demand, provision coefficients, deficit indicators, integrated provision indices and equipment retirement risks. An assessment of the risks associated with the life of the equipment and the likelihood of its disposal is also carried out.

The results of analytical processing are presented to users through a data visualization subsystem implemented using business intelligence tools such as Power BI and Metabase. Visualization includes interactive dashboards and graphical reports that allow analyzing indicators of educational infrastructure availability.

The final stage of the system's operation is publication and reporting, which includes the formation of analytical dashboards, exporting reports to PDF and Excel formats, automatic generation of management reports (for example, purchase plans or equipment write-offs), as well as sending notifications to users via email and other communication channels.

A separate functional unit of the system is the administration and security subsystem, which provides management of user roles and access rights, directory management, audit of user actions, and database backup. The presence of this block ensures data security and correct functioning of the system in multiuser operation conditions.

Thus, the presented architecture demonstrates the full technological cycle of the decision support system for assessing the availability of material resources of an educational organization and ensures the integration of data collection, analytical processing, visualization and formation of management decisions.

Figure 2 shows the architecture of a multi-level decision support system designed for monitoring, analyzing, and managing the material resources of educational organizations. The architecture of the system is based on a hierarchical principle and includes three levels: the level of an educational organization (school), the municipal level (district) and the regional management level.

The primary collection and processing of data on material resources is carried out at the educational organization level. This level includes subsystems for accounting for equipment, assessing the technical condition and wear of resources, as well as reporting on the provision of educational infrastructure. The system records data on the availability of equipment, its status and service life, which allows the formation of basic provision indicators.

The district level performs the functions of aggregating and analytically processing data received from educational organizations. At this level, modules of the regulatory framework, analytics and calculation of integrated security indices, as well as spatial analysis (GIS monitoring) tools are implemented. The district analytical platform ensures comparability of indicators between organizations and allows identifying schools with an increased risk of infrastructure shortages.

The regional level performs strategic functions of educational infrastructure management. It implements modules for the formation of regional standards of security, analysis of the current state of material resources, forecasting the need for equipment and scenario modeling of the development of educational infrastructure. The results obtained are used to prepare management decisions, plan budget programs, and develop strategic reports.

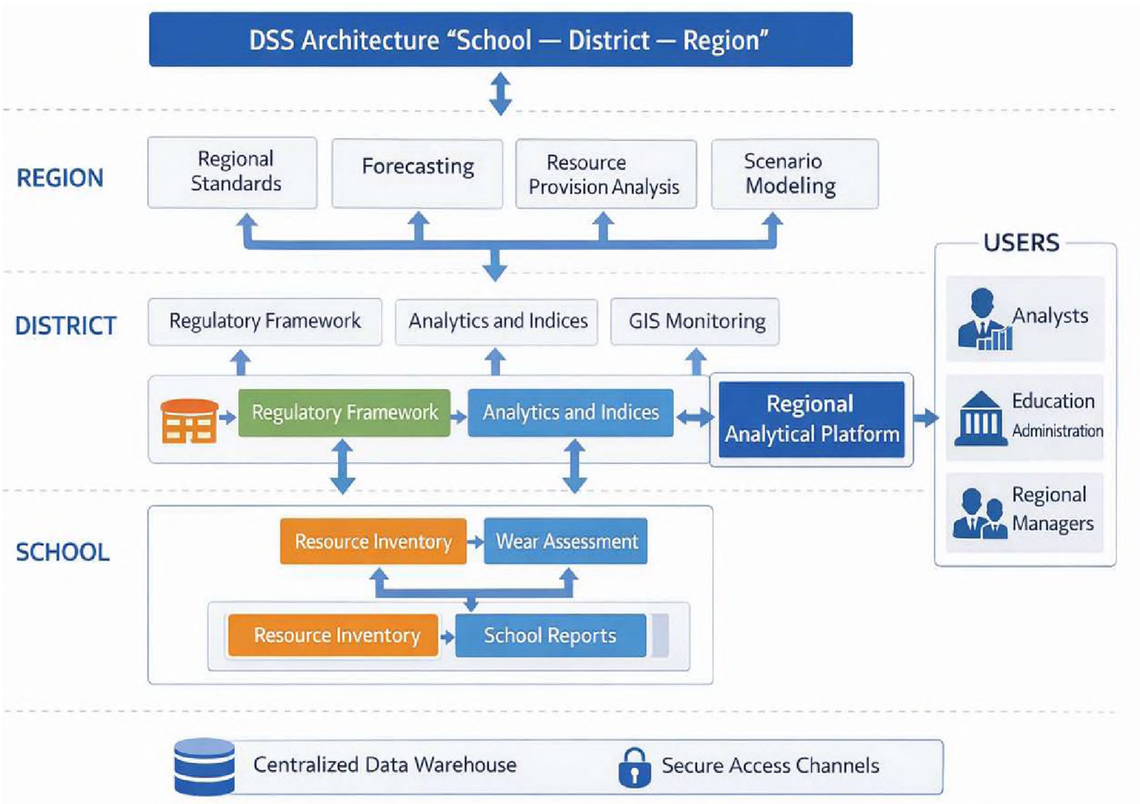

Figure 2. Architecture of the information and analytical system for assessing material resource provision in educational organizations at the regional level

The lower part of the architecture contains the basic infrastructure components of the system, including a centralized data warehouse and mechanisms for secure access to information resources. The centralized database ensures the integration of information from all levels of the system, and access control mechanisms allow the system to be used by various categories of users, including analysts, representatives of educational authorities and regional leaders.

Thus, the proposed architecture provides integration of the processes of monitoring, analytical processing and strategic management of the material resources of the educational system, allowing for a comprehensive assessment of security and support for managerial decision-making at all levels of the educational infrastructure.

The proposed architecture provides a unified analytical framework for monitoring educational infrastructure resources and enables data-driven management of material resource provision at school, municipal and regional levels.

Approbation

To demonstrate the applicability of the proposed decision support model, an experimental calculation was performed using a simulated dataset representing an educational organization with 500 students. In the experiment, five categories of equipment were considered: computers, interactive boards, laboratory equipment, multimedia devices, and network infrastructure.

Based on the proposed mathematical model, the normative demand for equipment was calculated using formula (1), taking into account the established provision standards per student or per educational group. The actual availability of equipment was determined using a simulated register of material resources reflecting the current state of the organization's infrastructure.

Using formulas (3) and (4), the provision coefficient and equipment deficit indicator were calculated for each equipment category. The obtained values made it possible to identify categories with insufficient provision and to assess the scale of infrastructure shortages. For example, the calculations showed that although the total number of equipment units may appear sufficient from an inventory perspective, the provision coefficient revealed shortages in specific categories such as laboratory equipment and interactive boards.

To obtain a comprehensive assessment of the infrastructure condition, the integrated provision index was calculated using formula (5). The use of weighted aggregation made it possible to account for the relative importance of different equipment categories for the educational process. The results showed that the integrated index provides a more balanced assessment of infrastructure provision compared to a simple count of equipment units.

In addition, the equipment retirement risk indicator was calculated using formula (6), taking into account the proportion of equipment approaching the end of its normative service life. This indicator made it possible to identify equipment categories requiring priority modernization.

The calculations of equipment provision based on normative demand and actual availability are presented in figure 3. The Figure 3 shows the normative demand for equipment, the actual availability of equipment in the educational organization, the calculated provision coefficient, and the resource deficit indicator.

1	**Assessment of Equipment Provision Based on Normative Demand and Actual Availability**				
2					
3	**Equipment category**	**Normative demand**	**Actual availability**	**Provision coefficient**	**Deficit**
4	Computers	50	48	0,96	2
5	Interactive boards	20	15	0,75	5
6	Laboratory equipment	30	18	0,6	12
7	Multimedia devices	25	27	1,08	0
8	Network equipment	10	9	0,9	1
9					

Figure 3. Assessment of equipment provision based on normative demand and actual availability

Figure 4 shows the results of analytical calculations used to assess the level of equipment provided by an educational organization based on the proposed mathematical model.

	A	B	C	D	E	F	G	H	I	J
1	Equipment category	Normative	Actual ava	Provision c	Deficit (Dc	Weight coefficient (w		Integrated	provision index (I)	
2	Computers	50	48	0,96	2	0,2		0,858		
3	Interactive boards	20	15	0,75	5	0,2				
4	Laboratory equipment	30	18	0,6	12	0,2				
5	Multimedia devices	25	27	1,08	0	0,2				
6	Network equipment	10	9	0,9	1	0,2				
7										

Figure 4. Model calculation of equipment provision indicators

For each equipment category, the table includes the normative demand for equipment (N_c), the actual availability of equipment in operational condition (A_c), the calculated provision coefficient (K_c), the deficit indicator (D_c), and the weight coefficient (w_c) used in the calculation of the integrated provision index.

The provision coefficient is determined as the ratio of the actual availability of equipment to the normative demand, allowing the level of provision to be evaluated in relative terms. The deficit indicator reflects the shortage of equipment compared to the established normative requirement. In the presented example, equal weight coefficients are assigned to all equipment categories in order to demonstrate the calculation of the integrated provision index in a simplified experimental scenario.

The presented calculations illustrate the application of the proposed analytical model for evaluating the material resource provision of educational organizations and serve as the basis for the subsequent visualization of results in the dashboard interface of the decision support system.

To illustrate the analytical capabilities of the proposed decision support system, a prototype of an analytical monitoring dashboard was developed based on the calculated indicators. The dashboard visualizes key equipment provision metrics and supports analytical monitoring of the educational infrastructure.

The first visualization of the dashboard, Figure 5, shows a comparison of the regulatory need for equipment and the actual availability of equipment in different infrastructure categories in an educational organization.

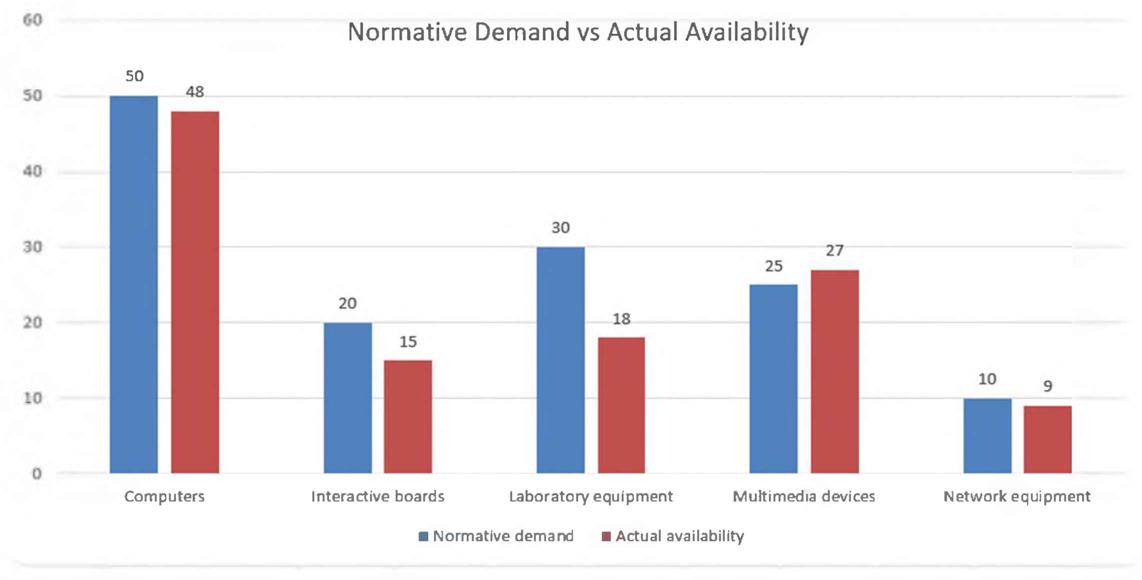

Figure 5. Comparison of normative demand and actual availability of equipment across categories.

Visualization allows you to identify categories of equipment with insufficient inventory and supports analytical monitoring of infrastructure deficiencies.

The second visualization of the dashboard, Figure 6, reflects the calculated availability ratio for each category of equipment.

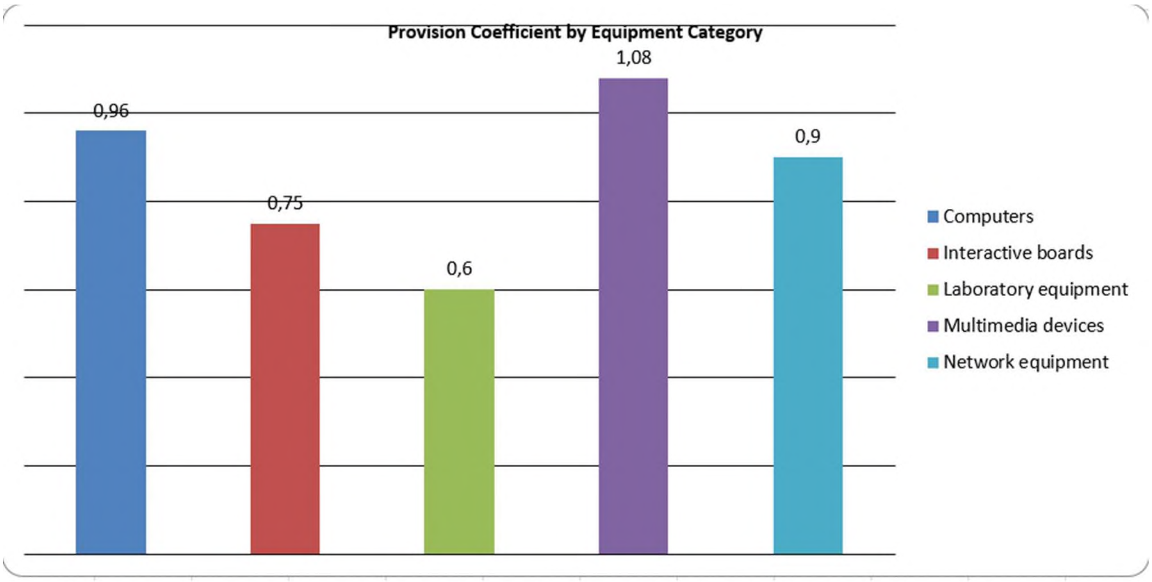

Figure 6. Provision coefficient by equipment category

This indicator provides a normalized assessment of the level of availability and allows you to compare the availability of equipment between categories with different regulatory requirements.

In addition, the dashboard, Figure 7, includes an analytical visualization combining the safety factor and the risk of equipment disposal.

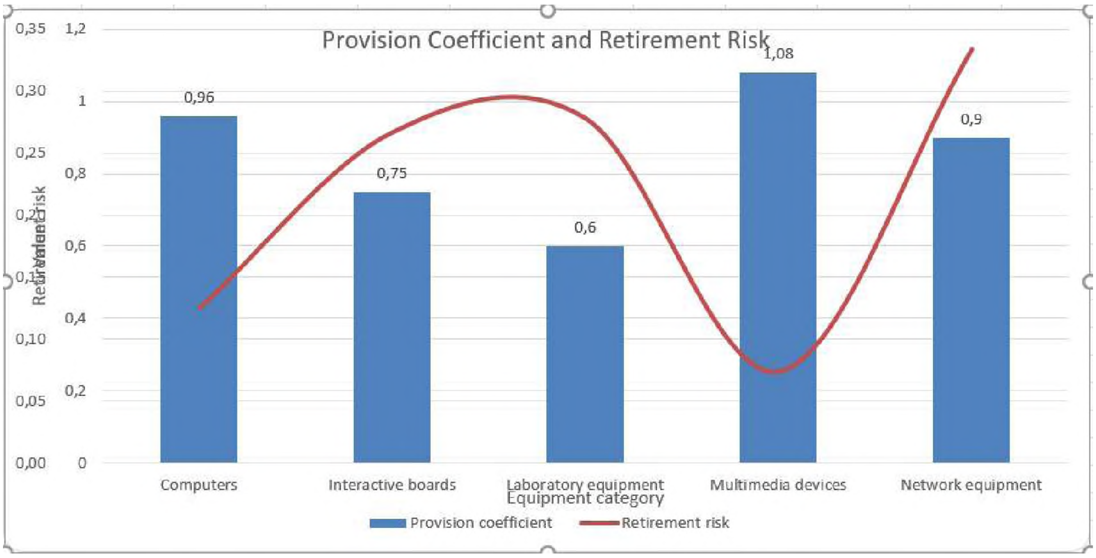

Figure 7. Provision coefficient and equipment retirement risk

This graph allows you to identify categories of equipment that are characterized by both a low level of availability and a high risk of equipment loss due to the expiration of the standard service life.

The integrated provision index calculated based on the proposed model provides an aggregated assessment of the level of material and technical resource provision of an educational organization. This indicator allows evaluating the overall condition of the material and technical base and can be used as an analytical metric to support managerial decision-making in planning infrastructure modernization and resource allocation.

Thus, the results of the approbation demonstrate that the proposed analytical model and the decision support system architecture enable the automated calculation of equipment provision indicators, visualization of analytical results, and identification of infrastructure resource deficits. The integration of these indicators into the analytical dashboard interface supports data-driven decision-making in the management of educational infrastructure at the level of educational organizations, municipal authorities, and regional administration.

The conducted approbation shows that the use of a system of analytical indicators makes it possible to identify imbalances in the provision of educational infrastructure that may remain unnoticed when using traditional inventory accounting systems. In particular, the comparative analysis of provision coefficients demonstrates differences between equipment categories, making it possible to identify priority areas for modernization of the material and technical base of educational organizations. The integrated provision index provides an aggregated quantitative assessment of infrastructure conditions and can be used for comparative analysis of provision levels across different educational organizations at the municipal or regional level. Thus, the proposed model creates a foundation for the development of analytical tools for monitoring educational infrastructure and improving the justification of managerial decisions in the development of the material and technical base of educational organizations.

Conclusion

The study proposes a model and architecture of a decision support system designed to assess the material resource provision of educational organizations and to support analytical monitoring of educational infrastructure. The proposed approach integrates a system of quantitative indicators, including normative equipment demand, the equipment provision coefficient, the resource deficit indicator, the integrated provision index, and the equipment retirement risk indicator. The integration of these indicators within a decision support system architecture enables a transition from simple inventory accounting of material resources to analytical monitoring of the condition of the material and technical base of educational organizations.

The architecture of the proposed system is based on a multi-level analytical model that supports data aggregation at the level of educational organizations, municipal authorities, and regional administration. This structure allows the integration of data from multiple educational institutions and ensures comparability of analytical indicators across different levels of the educational management system. As a result, the system can be used to support managerial decision-making in planning infrastructure modernization and resource allocation.

The approbation of the proposed analytical model on a simulated dataset demonstrated the practical applicability of the developed indicators for assessing the level of equipment provision and identifying infrastructure deficits. In particular, the use of the integrated provision index made it possible to obtain a more comprehensive assessment of the condition of the material and technical base compared with simple inventory-based indicators. The analytical dashboard developed as part of the study illustrates the possibility of visualizing key indicators of infrastructure provision and supports the monitoring of equipment lifecycle risks.

The implementation of the proposed architecture can significantly improve the efficiency of monitoring educational infrastructure. In particular, the integration of automated data aggregation mechanisms allows reducing the time required to collect and analyze reports from educational organizations and municipal authorities. The use of analytical indicators enables a more objective assessment of infrastructure needs and supports evidence-based planning of modernization activities.

Future research may focus on extending the analytical capabilities of the proposed system. In particular, the integration of predictive analytics and machine learning methods may enable forecasting of infrastructure demand and optimization of resource allocation at the regional level. In addition, further development of the risk model may include consideration of additional parameters, such as the criticality of equipment for the educational process, the relative age of equipment compared with its normative service life, and maintenance history. These developments may further improve the effectiveness of analytical decision support in the management of educational infrastructure.

Литература:

1. OECD (2023), Education at a Glance 2023: OECD Indicators, OECD Publishing, Paris, https://doi.org/10.1787/e13bef63-en.
2. World Bank. (2020). Realizing the Future of Learning: From Learning Poverty to Learning for Everyone, Everywhere. World Bank. https://doi.org/10/Realizing-the-Future-of-Learning-From-Learning-Poverty-to-Learning-for-Everyone-Everywhere. Available at https://docs.edtechhub.org/lib/X7NW3DD4
3. Viberg O., Hatakka M., Bälter O., Mavroudi A. The current landscape of learning analytics in higher education // Computers in Human Behavior. 2020. Vol. 89. P. 98-110. https://doi.org/10.1016/j.chb.2018.07.027
4. Sarker, I.H. Machine Learning: Algorithms, Real-World Applications and Research Directions. SN COMPUT. SCI. 2, 160 (2021). https://doi.org/10.1007/s42979-021-00592-x
5. Li D-P, Cheng S-J, Cheng P-F, Wang J-Q, Zhang H-Y (2018) A novel financial risk assessment model for companies based on heterogeneous information and aggregated historical data. PLoS ONE 13(12): e0208166. https://doi.org/10.1371/journal.pone.0208166
6. Taheri M. et al. A fuzzy programming model for optimizing the inventory management problem // Expert Systems with Applications. – 2023. https://doi.org/10.1016/j.eswa.2023.119766
7. Alinezhad, M., Mahdavi, I., Hematian, M. et al. A fuzzy multi-objective optimization model for sustainable closed-loop supply chain network design in food industries. Environ Dev Sustain 24, 8779-8806 (2022). https://doi.org/10.1007/s10668-021-01809-y
8. Gulia, P., Kumar, R., Kaur, G. et al. Numerical modelling using fuzzy multi-objective optimisation for environmental sustainability in green supply chain manufacturing. Int J Interact Des Manuf 19, 2061-2076 (2025). https://doi.org/10.1007/s12008-024-02043-2
9. Alkahtani, B.S.T., Simic, V., Anjum, M. et al. Decision Support System for Financial and Accounting Performance Assessment in Manufacturing Industries. Int J Comput Intell Syst 18, 314 (2025). https://doi.org/10.1007/s44196-025-01066-1
10. Vidal G.H. de Paula, Caiado R.G.G. Decision support framework for inventory management combining fuzzy multicriteria methods, genetic algorithm and neural network // Computers & Industrial Engineering.– 2022. – https://doi.org/10.1016/j.cie.2022.108777
11. Cantini, A. (2022). A decision support system for configuring spare parts supply chains considering different manufacturing technologies. International Journal of Production Research. https://doi.org/10.1080/00207543.2022.2041757
12. Cardeal G., Ribeiro I., Leite F. Decision-support model to select spare parts suitable for additive manufacturing // Computers in Industry. – 2023. – https://doi.org/10.1016/j.compind.2022.103798
13. Ojo, A., Rizun, N., Walsh, G., Mashinchi, M. I., Venosa, M., & Rao, M. N. (2024). Prioritising national healthcare service issues from free text feedback: A computational text analysis & predictive modelling approach. *Decision Support Systems, 181*, 114215. https://doi.org/10.1016/j.dss.2024.114215
14. Xiaochao Wei, Yanfei Zhang, Xin (Robert) Luo, Modeling the evolution of collective overreaction in dynamic online product diffusion networks, Decision Support Systems, Volume 181,2024, 114232, https://doi.org/10.1016/j.dss.2024.114232.

15. Fehrenbacher, D. D., & Weisner, M. (2024). Avatars and organizational knowledge sharing. *Decision Support Systems, 182*, 114245. https://doi.org/10.1016/j.dss.2024.114245
16. Rinaldi, G., Theodorakos, K., Garcia, F. C., Agudelo, O. M., & De Moor, B. (2025). DSS4EX: A decision support system framework to explore artificial intelligence pipelines with an application in time series forecasting. *Expert Systems with Applications, 269*, 126421. https://doi.org/10.1016/j.eswa.2025.126421
17. Богданов А. Д., Щепкин А. В. Методический подход к управлению организацией общего образования через материальное обеспечение // Вестник ЮУрГУ. Серия: Компьютерные технологии, управление, радиоэлектроника. – 2025. – № 2. – URL: https://cyberleninka.ru/article/n/metodicheskiy-podhod-k-upravleniyu-organizatsiey-obschego-obrazovaniya-cherez-materialnoe-obespechenie.
18. Назарова Т. С. Создание нормативно-методической системы материально-технического обеспечения основных образовательных программ ФГОС: проблемы и перспективы // Вестник Московского университета. Серия 20. Педагогическое образование. – 2017. – № 1. – URL: https://cyberleninka.ru/article/n/sozdanie-normativno-metodicheskoy-sistemy-materialno-tehnicheskogo-obespecheniya-osnovnyh-obrazovatelnyh-programm-fgos-problemy-i.
19. Byvshev, V., Parfenteva, K., Panteleeva, I. *et al.* Methodology for assessing the effectiveness of regional infrastructure facilities to support scientific, technical and innovation activities in the context of the synergy effect: analysis, formation and study. *J Innov Entrep* 11, 65 (2022). https://doi.org/10.1186/s13731-022-00257-w
20. Satria, T. F. ., Hadiguna, R. A. ., Henmaidi, H., & Arief, I. . (2025). Performance measurement in local government: A systematic review towards efficient public sector management. International Journal of Innovative Research and Scientific Studies, 8(4), 1417–1428. https://doi.org/10.53894/ijirss.v8i4.8093
21. ГИС «Контингент»: официальный сайт. – URL: http://gis-kontingent.ru/
22. ГИС «Образование» Челябинской области: официальный сайт. – URL: https://chiro74.ru/p/gis-obrazovanie

References:

1. OECD (2023), Education at a Glance 2023: OECD Indicators, OECD Publishing, Paris, https://doi.org/10.1787/e13bef63-en .
2. World Bank. (2020). Realizing the Future of Learning : From Learning Poverty to Learning for Everyone, Everywhere. World Bank. https://doi.org/10/Realizing-the-Future-of-Learning-From-Learning-Poverty-to-Learning-for-Everyone-Everywhere. Available at https://docs.edtechhub.org/lib/X7NW3DD4
3. Viberg O., Hatakka M., Bälter O., Mavroudi A. The current landscape of learning analytics in higher education // Computers in Human Behavior. 2020. Vol. 89. P. 98-110. https://doi.org/10.1016/j.chb.2018.07.027
4. Sarker, I.H. Machine Learning: Algorithms, Real-World Applications and Research Directions. SN COMPUT. SCI. 2, 160 (2021). https://doi.org/10.1007/s42979-021-00592-x
5. Li D-P, Cheng S-J, Cheng P-F, Wang J-Q, Zhang H-Y (2018) A novel financial risk assessment model for companies based on heterogeneous information and aggregated historical data. PLoS ONE 13(12): e0208166. https://doi.org/10.1371/journal.pone.0208166
6. Taheri M. et al. A fuzzy programming model for optimizing the inventory management problem // Expert Systems with Applications. – 2023. https://doi.org/10.1016/j.eswa.2023.119766
7. Alinezhad, M., Mahdavi, I., Hematian, M. et al. A fuzzy multi-objective optimization model for sustainable closed-loop supply chain network design in food industries. Environ Dev Sustain 24, 8779-8806 (2022). https://doi.org/10.1007/s10668-021-01809-y
8. Gulia, P., Kumar, R., Kaur, G. et al. Numerical modelling using fuzzy multi-objective optimisation for environmental sustainability in green supply chain manufacturing. Int J Interact Des Manuf 19, 2061-2076 (2025). https://doi.org/10.1007/s12008-024-02043-2
9. Alkahtani, B.S.T., Simic, V., Anjum, M. et al. Decision Support System for Financial and Accounting Performance Assessment in Manufacturing Industries. Int J Comput Intell Syst 18, 314 (2025). https://doi.org/10.1007/s44196-025-01066-1
10. Vidal G.H. de Paula, Caiado R.G.G. Decision support framework for inventory management combining fuzzy multicriteria methods, genetic algorithm and neural network // Computers & Industrial Engineering.– 2022. – https://doi.org/10.1016/j.cie.2022.108777

11. Cantini, A. (2022). A decision support system for configuring spare parts supply chains considering different manufacturing technologies. International Journal of Production Research. https://doi.org/10.1080/00207543.2022.2041757
12. Cardeal G., Ribeiro I., Leite F. Decision-support model to select spare parts suitable for additive manufacturing // Computers in Industry. – 2023. – https://doi.org/10.1016/j.compind.2022.103798
13. Ojo, A., Rizun, N., Walsh, G., Mashinchi, M. I., Venosa, M., & Rao, M. N. (2024). Prioritising national healthcare service issues from free text feedback: A computational text analysis & predictive modelling approach. *Decision Support Systems, 181*, 114215. https://doi.org/10.1016/j.dss.2024.114215
14. Xiaochao Wei, Yanfei Zhang, Xin (Robert) Luo, Modeling the evolution of collective overreaction in dynamic online product diffusion networks,Decision Support Systems,Volume 181,2024, 114232, https://doi.org/10.1016/j.dss.2024.114232.
15. Fehrenbacher, D. D., & Weisner, M. (2024). Avatars and organizational knowledge sharing. *Decision Support Systems, 182*, 114245. https://doi.org/10.1016/j.dss.2024.114245
16. Rinaldi, G., Theodorakos, K., Garcia, F. C., Agudelo, O. M., & De Moor, B. (2025). DSS4EX: A decision support system framework to explore artificial intelligence pipelines with an application in time series forecasting. *Expert Systems with Applications, 269*, 126421. https://doi.org/10.1016/j.eswa.2025.126421
17. Bogdanov A. D., Shhepkin A. V. Metodicheskij podxod k upravleniyu organizaciej obshhego obrazovaniya cherez material`noe obespechenie // Vestnik YuUrGU. Seriya: Komp`yuterny`e texnologii, upravlenie, radioe`lektronika. – 2025. – № 2. – URL: https://cyberleninka.ru/article/n/metodicheskiy-podhod-k-upravleniyu-organizatsiey-obschego-obrazovaniya-cherez-materialnoe-obespechenie
18. Nazarova T. S. Sozdanie normativno-metodicheskoj sistemy` material`no-texnicheskogo obespecheniya osnovny`x obrazovatel`ny`x programm FGOS: problemy` i perspektivy` // Vestnik Moskovskogo universiteta. Seriya 20. Pedagogicheskoe obrazovanie. – 2017. – № 1. – URL: https://cyberleninka.ru/article/n/sozdanie-normativno-metodicheskoy-sistemy-materialno-tehnicheskogo-obespecheniya-osnovnyh-obrazovatelnyh-programm-fgos-problemy-i.
19. Byvshev, V., Parfenteva, K., Panteleeva, I. *et al.* Methodology for assessing the effectiveness of regional infrastructure facilities to support scientific, technical and innovation activities in the context of the synergy effect: analysis, formation and study. *J Innov Entrep* 11, 65 (2022). https://doi.org/10.1186/s13731-022-00257-w
20. Satria, T. F. ., Hadiguna, R. A. ., Henmaidi, H., & Arief, I. . (2025). Performance measurement in local government: A systematic review towards efficient public sector management. International Journal of Innovative Research and Scientific Studies, 8(4), 1417-1428. https://doi.org/10.53894/ijirss.v8i4.8093
21. GIS «Kontingent»: oficial`ny`j sajt. – URL: http://gis-kontingent.ru/
22. GIS «Obrazovanie» Chelyabinskoj oblasti: oficial`ny`j sajt. – URL: https://chiro74.ru/p/gis-obrazovanie

Information about the author

Ye.S. Utyubayev – corresponding author, Head of the Pavlodar Regional Center of Information Technologies, Pavlodar Region Department of Education, Pavlodar, Kazakhstan; e-mail: elnar87@mail.ru.