УДК 378.147:004
DOI 10.52684/2312-3702-2025-53-3-64-71

DIGITALIZATION OF ENGINEERING EDUCATION: NEW PROGRAMS AND QUALITY ASSESSMENT TOOLS IN THE DIGITAL TRANSFORMATION ERA

A. V. Sinelshchikov, Ye. V. Ponomareva, O. A. Khokhlova

Sinelshchikov Aleksey Vladimirovich, Candidate of Technical Sciences, Associate Professor of Information Technologies Department, Astrakhan State University, Astrakhan, Russian Federation, phone: + 7 (927) 282-62-11; e-mail: laex@bk.ru;

Ponomareva Yelena Vladimirovna, Candidate of Physical and Mathematical Sciences, Associate Professor of General Engineering Disciplines and Ground Transportation Department, Astrakhan State Technical University, Astrakhan, Russian Federation, phone: + 7 (927) 566-50-32; e-mail: acmpax@rambler.ru;

Khokhlova Olga Aleksandrovna, Candidate of Technical Sciences, Associate Professor of General Engineering Disciplines and Ground Transportation Department, Astrakhan State Technical University, Astrakhan, Russian Federation, phone: + 7 (927) 566-50-32; e-mail: hohlova-mps@yandex.ru

This paper addresses the pressing issue of digitalization in engineering education within the context of the digital transformation of the economy. The study analyzes current trends in the development of digital technologies and their impact on the competency requirements for engineers. New educational programs aimed at fostering digital competencies among engineering students are examined, including the utilization of virtual and augmented reality, artificial intelligence, and big data. Particular attention is given to the development and application of quality assessment tools for these new educational programs, taking into account the specific characteristics of digital learning. Recommendations for enhancing engineering education in the face of digital transformation are proposed.

Keywords: *digitalization, engineering education, educational programs, digital competencies, Industry 4.0, educational quality assessment, digital tools, distance learning, virtual reality, artificial intelligence.*

ЦИФРОВИЗАЦИЯ ИНЖЕНЕРНОГО ОБРАЗОВАНИЯ: НОВЫЕ ПРОГРАММЫ И ИНСТРУМЕНТЫ ОЦЕНКИ КАЧЕСТВА В ЭПОХУ ЦИФРОВОЙ ТРАНСФОРМАЦИИ

А. В. Синельщиков, Е. В. Пономарева, О. А. Хохлова

Синельщиков Алексей Владимирович, кандидат технических наук, доцент кафедры информационных технологий, Астраханский государственный университет, г. Астрахань, Российская Федерация, тел.: + 7 (927) 282-62-11; e-mail: laex@bk.ru;

Пономарева Елена Владимировна, кандидат физико-математических наук, доцент кафедры общеинженерных дисциплин и наземного транспорта, Астраханский государственный технический университет, г. Астрахань, Российская Федерация, тел.: + 7 (927) 566-50-32; e-mail: acmpax@rambler.ru;

Хохлова Ольга Александровна, кандидат технических наук, доцент кафедры общеинженерных дисциплин и наземного транспорта, Астраханский государственный технический университет, г. Астрахань, Российская Федерация, тел.: + 7 (927) 566-50-32; e-mail: hohlova-mps@yandex.ru

В данной статье рассматривается актуальный вопрос цифровизации инженерного образования в контексте цифровой трансформации экономики. Исследуются современные тенденции развития цифровых технологий и их влияние на требования к компетенциям инженеров. Анализируются новые образовательные программы, направленные на формирование цифровых компетенций у студентов-инженеров, включая использование виртуальной и дополненной реальности, искусственного интеллекта и больших данных. Особое внимание уделяется разработке и применению инструментов оценки качества этих новых образовательных программ с учетом специфики цифрового обучения. Предлагаются рекомендации по повышению эффективности инженерного образования в условиях цифровой трансформации.

Ключевые слова: *цифровизация, инженерное образование, образовательные программы, цифровые компетенции, Индустрия 4.0, оценка качества образования, цифровые инструменты, дистанционное обучение, виртуальная реальность, искусственный интеллект.*

Introduction

The accelerating digital transformation, permeating all sectors of the modern economy, profoundly influences the qualification requirements for engineering professionals. Industry 4.0, characterized by the comprehensive integration of cyber-physical systems, the Internet of Things, big data, and artificial intelligence into production processes [1], urgently demands specialists capable of developing, implementing, and maintaining complex technological solutions. Traditional approaches to engineering education, often focused on the transmission of fundamental knowledge without sufficient emphasis on the practical application of digital technologies, fail to adequately address contemporary challenges. Consequently, a discernible discrepancy emerges between the competencies cultivated within existing educational programs and the evolving demands of the labor market, which inevitably leads to a shortage of highly qualified engineers capable of effectively operating within a digital environment.

The issue of the misalignment between graduate competencies and modern labor market demands, specifically the scarcity of skilled engineers adapted to the digital environment, has been explored in works such as [2] and [3]. Notably, studies by [4], [5], and [6] propose a model for the future engineer's competencies, which encompasses not only technical skills but also advanced digital proficiencies, including big data management, programming, and cybersecurity. However, current approaches to integrating digital technologies into engineering education are not without their shortcomings. For instance, Uvarov [7] critically assesses the fragmented implementation of digital tools in the educational process, noting a lack of proper methodological development and a comprehensive revision of educational paradigms. Similarly, [8] and [9] underscore the urgent need to shift from passive knowledge acquisition towards active project-based learning, leveraging modern digital platforms and simulators. In recent years, there has been increasing interest in applying virtual [10] and augmented [11] reality technologies in engineering education [12], which facilitates the creation of immersive learning environments [13] and enhances the effectiveness of students' practical training [14]. Nevertheless, the development of adequate quality assessment tools for new educational programs, particularly those tailored to the specific characteristics of digital learning, remains an open question. This critical issue underscores the necessity for developing and implementing novel educational programs aimed at cultivating essential digital competencies among students, alongside the creation of appropriate tools for assessing the quality of specialist training within the context of digital transformation [15, 16].

Merely incorporating digital technology-related disciplines into the curriculum is insufficient. A pivotal aspect involves the deep integration of digital tools and methodologies across all stages of the educational process, from curriculum design to practical training and the evaluation of learning outcomes. This implies not only students' mastery of specific software products and platforms, but also the development of systemic thinking, the ability to analyze big data, data-driven decision-making, and the capacity for effective teamwork and adaptation to rapidly changing technological conditions. Furthermore, the digitalization of education unlocks unprecedented opportunities for personalized learning, allowing for the adaptation of educational trajectories to individual student needs, and for the implementation of interactive and game-based learning methods that significantly enhance material retention.

The aim of this article is to comprehensively examine the key aspects of engineering education digitalization, analyze examples of new educational programs, and propose tools for assessing their quality, considering the specific nature of digital learning. To achieve this aim, the following objectives were defined: to systematize the key aspects of engineering education digitalization; to analyze examples of new educational programs in mechanics, construction, and broader engineering education; to determine criteria and tools for assessing the quality of digital learning; and to justify the necessity of developing digital competencies and their alignment with modern labor market requirements.

Methodology

The present study is theoretical and analytical in nature, aiming to identify, systematize, and critically comprehend current trends, approaches, and tools within the field of engineering education digitalization. The work is founded upon a comprehensive analysis and synthesis of data derived from a wide spectrum of scholarly sources.

A suite of theoretical methods was employed in this research. Systemic analysis facilitated the examination of engineering education digitalization as a complex, multi-component system, enabling the identification of intricate interconnections among its various elements, such as curriculum content, pedagogical methods, assessment instruments, and the dynamically evolving demands of the labor market. Subsequently, comparative analysis was utilized to juxtapose traditional educational paradigms with innovative, digital approaches, as well as to conduct a comparative evaluation of diverse educational programs and assessment tools. The methods of synthesis and generalization contributed to the formation of a holistic and integrated understanding of the research subject, thereby enabling the formulation of key conclusions and recommendations based on disparate data. Content analysis was applied to study and interpret the substance of scholarly publications, analytical reports, and descriptions of educational programs, which allowed for the identification of dominant trends, problematic areas, and successful practices in the field of digitalization. Finally, classification and systematization of information ensured the logical structuring of data pertaining to the key aspects of digitalization, the types of educational programs, and the quality assessment tools.

Data sources included scholarly articles by both domestic and international authors, monographs, analytical reports, textbooks, and conference materials, all addressing the broader issues of economic digital transformation, the Industry 4.0 paradigm, contemporary engineering education, competency development, and methods for assessing educational quality. Particular attention was given to sources reflecting practical experiences in implementing digital technologies in the educational process and responding to industry demands.

It is pertinent to underscore that this study does not involve empirical validation or primary data collection; rather, it focuses exclusively on the theoretical conceptualization and synthesis of existing knowledge and best practices within the specified domain.

Results

Based on the comprehensive analysis conducted, key aspects of engineering education digitalization were systematized, examples of new educational programs were analyzed, criteria and tools for assessing the quality of digital learning were identified, and the requirements for engineers' digital competencies in modern conditions were generalized.

Key Aspects of Engineering Education Digitalization

The transformation of engineering education encompasses several pivotal aspects, each playing a decisive role in preparing a new generation of specialists capable of functioning effectively in the digital economy. Foremost among these is the profound integration of digital technologies directly into the educational process. This facet necessitates the extensive use of specialized software for modeling, design, and data analysis, alongside virtual reality (VR) and augmented reality (AR) technologies for creating immersive learning environments. The application of CAD/CAM systems in mechanical engineering, Building Information Modeling (BIM) technologies in construction, and simulators for managing complex technical systems enables students to gain invaluable practical experience with modern technologies, develop skills for solving real-world engineering problems, and prepare for professional activities in a digital environment [13, 14].

Equally significant is the evolution of educational program content, which must align with current industry demands and account for the rapid advancement of technologies. This entails the imperative to introduce specialized disciplines focusing on big data, artificial intelligence, the Internet of Things, cybersecurity, and digital manufacturing. Furthermore, the role of an interdisciplinary approach, integrating knowledge from various fields to address complex engineering tasks, such as in robotics where competencies in mechanics, electronics, programming, and data processing are all required, becomes increasingly prominent.

The development of digital competencies among faculty members stands as a cornerstone for the successful digitalization of engineering education [17]. Educators must not only master new teaching methodologies but also learn to effectively utilize digital tools in the instructional process and create interactive educational materials. It is equally crucial to foster competencies in digital communication and online interaction with students [18].

Concurrently, the establishment of a robust digital educational environmen becomes critically important. This presupposes the development of an infrastructure that ensures ubiquitous access to high-speed internet, modern computing equipment, specialized software, online platforms, and extensive databases. Particular attention must be paid to ensuring cybersecurity and data protection within this digital environment.

Finally, the strengthening of synergistic ties with the industrial sector is an indispensable condition for the successful adaptation of educational programs to labor market needs. This includes organizing internships and practical training at advanced enterprises, attracting leading industry specialists to teaching roles, and jointly developing educational programs and research projects. Such collaboration allows students to gain valuable practical experience in real-world settings and significantly enhances their competitiveness in the labor market.

New Educational Programs and Their Focus on Mechanics, Construction, and Engineering Education

Digitalization catalyzes the emergence of innovative educational programs, particularly in foundational fields such as mechanics, construction, and general engineering, where traditional disciplines gain new relevance within the context of digital transformation. These programs integrate advanced digital technologies, emphasizing the practical application of knowledge and the formation of competencies highly sought after in the modern labor market. Notably, mechanical disciplines, serving as a robust theoretical foundation, ensure a profound understanding of physical processes and the efficient utilization of digital tools.

Among such programs, the Master's program “Computational Mechanics and Computer Engineering” [19] stands out. It is tailored to train specialists capable of solving complex problems in structural mechanics using high-performance computing and advanced numerical modeling methods. The curriculum includes in-depth study of elasticity, plasticity, stability, and structural dynamics theories, alongside comprehensive mastery of specialized software such as ANSYS, Abaqus, and LS-DYNA. Students acquire skills in constructing finite-element models of buildings and structures, performing calculations for strength, stability, and dynamic loads, and conducting comprehensive analysis of simulation results to optimize structural designs. In this context, mechanical disciplines serve as an unshakable foundation for understanding the principles underlying numerical methods and for the accurate interpretation of simulation results.

Parallel to this, the program “Digital Design and Production in Mechanical Engineering” [20] exemplifies a holistic approach, focusing on the integration of digital technologies across all stages of a product's lifecycle – from initial design to direct manufacturing [21]. Students gain proficiency with CAD/CAM/CAE systems, study additive manufacturing technologies, robotics, and production management systems [22]. The integration of theoretical mechanics, strength of materials, and machine design principles enables students to develop optimal structural solutions while considering material strength characteristics and dynamic loads. Significant emphasis is placed on practical training, which includes hands-on experience with modern equipment, participation in real-world projects, and internships at industrial enterprises.

Equally pertinent is the program "Intelligent Control Systems in Robotics" which is designed to prepare specialists in the development and implementation of intelligent robot control systems. Here, students delve into theoretical mechanics, automatic control theory, artificial intelligence, and computer vision. The curriculum encompasses the development of robot control algorithms, the creation of navigation and motion planning systems, and the application of machine learning for adapting robots to changing environmental conditions. Mechanical disciplines provide the necessary groundwork for accurate robot dynamics modeling and the development of effective control algorithms.

A significant niche within the construction industry is occupied by the BIM Technologies in Design and Construction stream [23]. Building Information Modeling (BIM) represents a transformative technology that redefines approaches to the design, construction, and operation of buildings and structures. Educational programs in this domain center on students' in-depth acquisition of specialized software, such as Autodesk Revit, ArchiCAD, and Tekla Structures. Learners acquire skills in creating information models of buildings, performing comprehensive analyses for energy efficiency, cost, and construction timelines, and effectively managing project documentation. Here, the mastery of principles and laws from mechanical disciplines is critically important for understanding structural behavior and for the correct interpretation of calculations performed within BIM systems.

Across all aforementioned programs, mechanical disciplines play a foundational role, providing students with essential knowledge of mechanical processes and enabling them to efficiently utilize modern digital tools for solving complex engineering problems.

Quality Assessment Tools for Digital Learning

Effective quality assessment of digital learning represents a complex and multifaceted challenge, necessitating a comprehensive approach that accounts for the specific characteristics of online environments. In contrast to traditional methods, digital learning presents novel opportunities for data collection and analysis, as well as for organizing interactive engagement among educational participants. However, alongside these advantages, new difficulties emerge concerning accessibility, student motivation, quality control of educational content, and the objectivity of learning outcome assessments. Consequently, the development and application of effective tools for assessing the quality of digital learning assume particular urgency.

Defining the criteria for digital learning quality constitutes a necessary preliminary step before the development and application of appropriate assessment tools. Prominent among these criteria are the relevance of educational program content, which must align with contemporary scientific advancements and practical needs, and their accessibility and ease of use for a broad range of learners, irrespective of their technical capabilities or geographical location. Equally vital are the levels of interactivity and engagement among students in the learning process, ensuring opportunities for active participation and interaction with instructors and peers. A crucial indicator is the effectiveness of learning in achieving stated educational objectives and fostering necessary competencies among students [24]. Furthermore, the quality of technical support, ensuring the uninterrupted functioning of digital resources, and, undeniably, the objectivity of learning outcome assessments, which must guarantee reliable measurement of students' knowledge and skills, are paramount. When selecting assessment tools, it is also critically important to consider the specific characteristics of the target audience; for instance, the necessity of access to specialized software for technical disciplines.

Several effective approaches stand out among the most impactful tools for assessing the quality of digital learning. Foremost is the systematic collection and subsequent analysis of student performance data, which not only allows for progress monitoring but also helps identify problematic areas in content mastery. Specialized online learning platforms can be effectively utilized for this purpose, as they automatically track student activity and analyze their engagement with educational content. A significant source of feedback comes from surveys and questionnaires administered to educational participants, including both students and faculty, which allows for an assessment of their satisfaction with the learning quality and the identification of both strengths and weaknesses of digital learning. Portfolio analysis offers a comprehensive means of evaluating students' practical skills and competencies acquired during their studies; portfolios can include project work, research outcomes, and certificates for completing online courses. Observation of the learning process directly allows for the evaluation of digital technologies' effectiveness in education and the documentation of both positive and negative aspects associated with the application of digital tools. Finally, the expert evaluation of educational programs, conducted by qualified specialists in engineering education and digital technologies, provides an in-depth analysis of curriculum content, pedagogical methods, and utilized digital tools, along with the formulation of recommendations for their improvement. The integrated application of these diverse tools enables a more comprehensive and objective understanding of digital learning quality and helps delineate strategic directions for its further enhancement.

Development of Digital Competencies and Alignment with Labor Market Requirements

The cultivation of digital competencies among future engineers represents a pivotal objective of contemporary engineering education, as these competencies constitute the aggregate of knowledge, skills, and abilities requisite for effective professional engagement with digital technologies. Modern digital technologies are evolving at an unprecedented pace, fundamentally altering the landscape of engineering professions and imposing new, continuously escalating demands on specialists' competencies.

The modern landscape of engineering professions is profoundly transformed under the influence of several key technological trends. Artificial Intelligence (AI) and Machine Learning (ML), penetrating all stages of the product lifecycle – from design to maintenance – demand that engineers possess a deep understanding of AI and ML principles, the ability to effectively utilize relevant tools and algorithms, and to interpret the results of big data analysis [24]. The proliferation of the Internet of Things (IoT) and Industrial Internet of Things (IIoT) necessitates proficiency in sensor technology, network architectures, cybersecurity, and analytics of data derived from connected devices, along with the ability to work with cloud platforms and develop IoT applications. The creation of digital twins, virtual replicas of physical systems, generates new demands for modeling, simulation, and data analysis skills, as well as a profound understanding of physical processes and the ability to translate them into virtual environments. The shift to cloud computing dictates a need for competencies related to cloud solution architectures, data security in the cloud, and the ability to work with various cloud platforms (such as AWS, Azure, GCP). The advancement of additive manufacturing technologies (3D printing) requires engineers to not only comprehend the principles of operation and select diverse technologies and materials but also to design parts optimized for additive production. Finally, the active application of augmented reality (AR) and virtual reality (VR) in training, design, visualization, and interaction with digital models mandates the acquisition of proficiency in corresponding tools and platforms.

In light of these trends, modern engineers must possess a comprehensive set of key competencies [25]. Foremost among these is digital literacy, implying confident command of a broad spectrum of specialized software tools, including CAD/CAM systems, modeling and data analysis tools, and software development instruments. Equally essential are analytical and systemic thinking, enabling engineers not only to process data but also to perceive the holistic picture of complex systems and the interconnections among their elements. Critically important is the ability to work with big data, encompassing its collection, processing, and analysis, as well as the application of machine learning and artificial intelligence methods for solving engineering problems. Beyond purely technical skills, creativity and innovativeness, manifested in the capacity to generate novel ideas and solutions, are increasingly valued, as are digital communication and collaboration skills for effective team interaction in distributed environments. Finally, amidst rapid technological changes, adaptability and continuous learning, coupled with knowledge of cybersecurity, become indispensable attributes of a competent specialist capable of protecting information systems from cyber threats. The alignment of graduates' digital competencies with the dynamically changing demands of the labor market is a critically important indicator of engineering education quality. The development of digital competencies among future engineers is an ongoing process that demands constant attention and effort from both educational institutions and the students themselves, as this is the only way to prepare highly qualified specialists capable of successfully operating in the digital economy.

Discussion

The analysis conducted convincingly demonstrates the complex nature of the digital transformation in engineering education and affirms the urgent necessity for its comprehensive reform to effectively address the challenges and leverage the opportunities presented by the current digital revolution. The new educational programs described in Section 3.2 and the proposed quality assessment tools presented in Section 3.3 represent a direct response to the contradiction identified in the introduction between traditional educational approaches and the dynamically evolving labor market demands for engineers' competencies.

The identified key aspects of digitalization, including technology integration, curriculum evolution, faculty competency development, the formation of a digital educational environment, and the strengthening of synergistic ties with industry, cannot be considered in isolation. They form an interconnected ecosystem where the success of one element critically depends on the coordinated development of others. For instance, the effective implementation of new educational programs, designed to cultivate digital competencies, is unfeasible without the simultaneous upskilling of faculty and the establishment of an adequate digital infrastructure.

Our findings align with the perspective of researchers like Uvarov [7], who emphasize the necessity of a systemic approach to integrating digital tools into the educational process, extending beyond mere fragmented implementation. The emphasis on project-based learning and the utilization of immersive technologies (VR/AR) [10, 11, 12, 13, 14] further corroborate the pressing need for a shift from passive knowledge acquisition towards the active development of practical skills. Moreover, the inclusion of fundamental disciplines, such as mechanics, within these new digital curricula, alongside the acquisition of advanced technologies, underscores the importance of maintaining a robust theoretical foundation for the modern engineer.

It should be acknowledged, however, that this study is theoretical and analytical in nature and does not include empirical validation of the effectiveness of the described programs or assessment tools. This constitutes a methodological limitation, as the true efficacy of digital initiatives can only be fully evaluated through long-term observation and the collection of objective quantitative and qualitative data on graduate performance and their subsequent adaptation to the labor market.

Nevertheless, the conducted analysis allows for the formulation of several strategic recommendations aimed at the comprehensive improvement of engineering education amidst digital transformation. These recommendations are designed not only to overcome identified challenges but also to maximize the utilization of digital technologies' vast potential.

Firstly, educational curricula and content must undergo a fundamental re-evaluation. This necessitates the mandatory inclusion of courses focusing on digital modeling, simulation, data analytics, artificial intelligence, and machine learning across all engineering specializations, tailored to their specific characteristics. Critically important is the active use of specialized software for engineering calculations and design (CAD, CAM, CAE, BIM) throughout all stages of learning. Furthermore, the integration of cloud technologies and platforms for collaborative project work and knowledge sharing is essential. Particular attention should be given to an interdisciplinary approach, implying the development of courses and projects that merge engineering disciplines with informatics, economics, management, and other relevant fields. Regular revision and updating of curricula, reflecting the latest scientific and technological advancements and evolving labor market demands, are vitally important.

Secondly, a significant modernization of teaching methods and pedagogical approaches is required. This implies a decisive shift from passive knowledge absorption to active learning methods, such as project-based work, case studies, problem-oriented learning, and flipped classroom models, which foster deep material comprehension and critical thinking development. The expansion of interactive learning, encompassing Massive Open Online Courses (MOOCs), webinars, interactive simulators, and virtual laboratories, enables the creation of captivating and engaging learning environments. Personalized learning, achieved through the adaptation of the educational process to each student's individual needs and pace, should become standard practice, utilizing data analytics to track progress and provide individualized feedback [24]. Large-scale integration of Learning Management Systems (LMS), collaborative tools, and virtual and augmented reality (VR/AR) technologies will lead to the creation of more effective and engaging learning environments.

Thirdly, it is imperative to ensure a comprehensive update of educational institutions' infrastructure and resources. This entails providing ubiquitous access to modern computing equipment, specialized software, and laboratories, including high-speed internet access and reliable network connectivity at all levels. The establishment and continuous replenishment of digital libraries and databases with up-to-date educational materials, accessible 24/7, are crucially important. Moreover, systematic professional development programs for faculty in digital technologies and innovative pedagogical methods [17, 18] must be organized, enabling them to effectively utilize new tools and approaches.

Finally, strengthening cooperation with industry and business is strategically vital. This includes organizing regular internships and practical training for students at industrial enterprises, allowing them to gain real-world experience with digital technologies. Leading industry specialists should be actively engaged in curriculum development and teaching, ensuring that education aligns maximally with current industry demands. Furthermore, joint research projects with industrial partners should be expanded, fostering innovation and the development of highly qualified, in-demand personnel.

Further research could focus on the empirical validation of the effectiveness of specific educational programs and assessment tools developed within the context of digital transformation. It is also necessary to investigate the long-term implications of digitalization for engineers' professional development and their adaptation to the changing labor market, potentially through longitudinal cohort studies and analysis of career trajectories.

Conclusion

In conclusion, the digital transformation of engineering education is an inevitable and essential process, driven by the demands of Industry 4.0 and the rapid evolution of the digital economy. The analysis conducted within this article has convincingly demonstrated that successful adaptation to these global changes requires a comprehensive and holistic approach. This approach encompasses the updating of educational program content in response to new challenges, the implementation of innovative teaching methods, the targeted development of digital competencies among faculty, the systematic modernization of educational infrastructure, and the deepening and expansion of close collaboration with the industrial sector.

The implementation of these outlined measures will enable the preparation of a new generation of engineers who possess not only profound fundamental knowledge in their respective fields but also highly developed digital competencies. Such specialists will be capable of effectively operating within high-tech production environments, successfully solving complex interdisciplinary problems, and making a significant contribution to the innovative development of modern society. This study provides a substantial contribution to understanding the key aspects and challenges of engineering education digitalization, offering structured and well-reasoned recommendations for its ongoing strategic improvement.

Список литературы

1. Рубанов В. А. Цифровая трансформация отраслей на основе использования ГИС, ДЗЗ И БАС : аналитический отчет / В. А. Рубанов, С. В. Серебряков, З. А. Кучкаров и др. – Москва, 2022. – 381 с. – Режим доступа: https://nti-aeronet.ru/wp-content/uploads/2022/12/AJeRONET_Cifrovaja_transformacija_otraslej_na_osnove_ispolzovanija.pdf, свободный. – Заглавие с экрана. – Яз. рус.
2. Kazaryan I. R. The mismatch between the university graduate competences and the employer requirements as a factor of the informal employment growth / I. R. Kazaryan, N. A. Kazantseva // Shadow Economy. – 2023. – Vol. 7, № 2. – С. 187–196. – Режим доступа: https://doi.org/10.18334/tek.7.2.117595, свободный. – Заглавие с экрана. – Яз. рус.
3. Цифровые технологии в развитии современных экономических систем (Digital technologies in the development of modern economic systems) : материалы Всероссийской научно-практической конференции, Липецк, 30 ноября 2022 года. – Липецк : Липецкий государственный технический университет, 2023. – 504 с.
4. Алексеенко А. В. Модель формирования профессиональной компетентности будущих инженеров / А. В. Алексеенко, А. Е. Алексеенко // Вестник Череповецкого государственного университета. – 2018. – № 3 (84). – С. 112–121.
5. Боровков А. И. Компьютерный инжиниринг : учеб. пособие / А. И. Боровков, С. Ф. Бурдаков, О. И. Клявин и др. – Санкт-Петербург : Санкт-Петербургский государственный политехнический университет, 2012. – 93 с.
6. Боровков А. И. Современное инженерное образование : учебное пособие / А. И. Боровков, С. Ф. Бурдаков, О. И. Клявин и др. – Санкт-Петербург : Санкт-Петербургский государственный политехнический университет, 2012. – 80 с.
7. Уваров А. Ю. Трудности и перспективы цифровой трансформации образования : монография / А. Ю. Уваров, Э. Гейбл, И. В. Дворецкая и др.. – Москва : ИД Высшей школы экономики, 2019. – 343 с.
8. Уваров А. Ю. Модель цифровой школы и цифровая трансформация образования / А. Ю. Уваров // Исследователь. – 2019. – № 1–2 (25–26). – С. 22–37.
9. Исмагилов Н. А. Современные технологии цифровой образовательной среды / Н. А. Исмагилов, И. Р. Хабибуллин, О. В. Азовцева // Молодой ученый. – 2023. – № 12 (459). – С. 155–158.
10. Дементьева А. В. Дополненная реальность в учебном процессе / А. В. Дементьева, И. А. Откупщикова, К. Н. Реськов // Научное сообщество студентов: Междисциплинарные исследования : сборник статей по материалам XLII Международной студенческой научно-практической конференции. – № 7 (42). – Режим доступа: https://sibac.info/archive/meghdis/7(42).pdf, свободный. – Заглавие с экрана. – Яз. рус.
11. Папагианнис Х. Дополненная реальность. Все, что вы хотели узнать о технологии будущего / Хелен Папагианнис ; пер. с исп. В. Г. Михайлова. – Москва : Эксмо, 2019. – 288 с.
12. Таран В. Н. Применение дополненной реальности в обучении / В. Н. Таран // Проблемы современного педагогического образования. – 2018. – № 60–2. – С. 333–337.
13. VR fire safety training // Luminous Group. – Режим доступа: https://www.luminousgroup.co.uk/project/premier-partnership-vr-fire-training/, свободный. – Заглавие с экрана. – Яз. рус.
14. Safety training meets virtual reality // Gravity Jack. – Режим доступа: https://gravityjack.com/simsafe-vr-training/, свободный. – Заглавие с экрана. – Яз. рус.
15. Аминов Р. И. Электронные информационно-управляющие системы в образовательном процессе вуза / Р. И. Аминов, Л. Х. Зайнутдинова // Инженерно-строительный вестник Прикаспия. – 2025. – № 1 (51). – С. 120–127.
16. Горовой Н. В. Формирование цифровых компетенций в сфере строительства посредством BIM-чемпионата Санкт-Петербургского государственного архитектурно-строительного университета / Н. В. Горовой, Д. В. Нижегородцев, А. А. Семенов, И. И. Суханова // Инженерно-строительный вестник Прикаспия. – 2024. – № 2 (48). – С. 89–94.
17. Зенкина С. В. Использование информационных и коммуникационных технологий в профессиональной деятельности преподавателя вуза / С. В. Зенкина, О. П. Панкратова, Е. А. Конопко // Конференциум АСОУ : сборник научных трудов и материалов научно-практических конференций. – 2016. – № 3. – С. 829–836.
18. Таран В. Н. Анализ компетенций профессорско-преподавательского состава при подготовке IT-специалистов / В. Н. Таран // Современные информационные технологии и ИТ-образование. – 2016. – Т. 12, № 4. – С. 20–24.
19. Прикладная механика // МГСУ. – Режим доступа: https://mgsu.ru/postupayushchim/Magistratura/Perechen-realizuemykh-programm/applied-mechanic/15-03-04-prikladnaya-mekhanika.php, свободный. – Заглавие с экрана. – Яз. рус.
20. Кармишин А. А. Цифровая подготовка производства в машиностроении / А. А. Кармишин, В. М. Макаров, П. Н. Морохин // РИТМ машиностроения. – 2022. – № 2. – Режим доступа: https://ritm-magazine.com/ru/public/cifrovaya-podgotovka-proizvodstva-v-mashinostroenii, свободный. – Заглавие с экрана. – Яз. рус.

21. Селиванов С. Г. Инновационное проектирование цифрового производства в машиностроении : учебное пособие / С. Г. Селиванов, А. Ф. Шайхулина, С. Н. Поезжалова и др. – Москва : Инновационное машиностроение, 2016. – 264 с.

22. Кутин А. А. Прогноз развития цифровых машиностроительных производств / А. А. Кутин, С. С. Ивашин // Инновации. – 2016. – № 8 (214). – С. 9–13.

23. BIM-технологии в строительстве // НИТУ МИСиС. – Режим доступа: https://misis.ru/applicants/admission/magistracy/faculties/informatikaivtmag/bim-teh/, свободный. – Заглавие с экрана. – Яз. рус.

24. Груздева М. Л. Возможности использования цифровых платформ в образовании / М. Л. Груздева, Т. Д. Феофанова // Современные наукоемкие технологии. – 2022. – № 6. – С. 104–108. – Режим доступа: https://top-technologies.ru/ru/article/view?id=39208, свободный. – Заглавие с экрана. – Яз. рус.

25. Poszytek, P. Digital transformation in educational organizations: leadership, innovation and industry 4.0. – Abingdon, oxon : Routledge, 2024. – 288 C.25.

Ссылка для цитирования:
Sinelshchikov A. V., Ponomareva Ye. V., Khokhlova O. A. Digitalization of engineering education: new programs and quality assessment tools in the digital transformation era // Инженерно-строительный вестник Прикаспия : научно-технический журнал / Астраханский государственный архитектурно-строительный университет. Астрахань : ГБОУ АО ВО «АГАСУ», 2025. № 3 (53). С. 64–71.

УДК 681.5
DOI 10.52684/2312-3702-2025-53-3-71-76

СИСТЕМА ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ДЛЯ ПЛАНИРОВАНИЯ РЕМОНТА ОБОРУДОВАНИЯ ЖИЛИЩНО-КОММУНАЛЬНОГО ХОЗЯЙСТВА

А. Н. Черемин

Черемин Александр Николаевич, магистрант, Астраханский государственный технический университет, г. Астрахань, Российская Федерация, тел.: + 7 (961) 654-91-27; e-mail: aleks08-02@mail.ru

Представлена система для поддержки принятия решений, предназначенная для планирования ремонтных работ в рамках системы водоснабжения жилищно-коммунального хозяйства. Обоснованием для разработки системы послужила высокая аварийность и значительный износ инфраструктуры. В работе применяются вероятностные модели, направленные на прогнозирование отказов оборудования, и математическая модель, служащая для оптимизации ремонтной программы. Учитываются как ресурсные, так и финансовые ограничения. Применение данной системы прогнозирует снижение количества аварий на 20–30 %, уменьшение эксплуатационных расходов и увеличение надежности водоснабжения. Разработанная система предоставляет возможность перехода от практики реагирования на аварии к стратегии превентивного обслуживания инфраструктурных объектов.

Ключевые слова: *система поддержки принятия решений; техническое обслуживание; ремонт; водоснабжение; надежность; прогнозирование отказов; предиктивное обслуживание; оптимизация; жилищно-коммунальное хозяйство.*

DECISION SUPPORT SYSTEM FOR PLANNING REPAIR OF HOUSING AND COMMUNAL SERVICES EQUIPMENT

A. N. Cheremin

Cheremin Aleksandr Nikolaevich, postgdraduate student, Astrakhan State Technical University, Astrakhan, Russian Federation, phone.: + 7 (961) 654-91-27; e-mail: aleks08-02@mail.ru

A decision support system designed for planning repairs within the water supply system of housing and communal services is presented. The rationale for the development of the system was the high accident rate and significant deterioration of the infrastructure. The work uses probabilistic models aimed at predicting equipment failures and a mathematical model used to optimize the repair program. Both resource and financial constraints are taken into account. The use of this system predicts a reduction in the number of accidents by 20–30 %, a reduction in operating costs and an increase in the reliability of water supply. The developed system provides an opportunity to move from the practice of responding to accidents to a strategy of preventive maintenance of infrastructure facilities.

Keywords: *decision support system; maintenance; repair; water supply; reliability; failure prediction; predictive maintenance; optimization; housing and communal services.*

Введение

Система водоснабжения является критически важной составляющей жилищно-коммунального хозяйства (ЖКХ), от надежности которой зависит комфорт и безопасность населения. В настоящее время многие элементы этой инфраструктуры серьезно изношены, что приводит к учащению аварийных ситуаций. По данным исследований, средний износ трубопроводных сетей в ряде россий-