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Features and Systematic Development of Digital Transformation in the Housing and Utilities Sector

Anna Y. Verenikina  , Alexey S. Budakov 

RUDN University, Moscow, Russian Federation

 verenikina_ayu@pfur.ru

Abstract. The article presents a systematic analysis of digital transformation in the housing and communal services (HCS) sector. Methods of comparative analysis, data synthesis, and a systemic approach were used to identify key directions of digitalization, such as the integration of BIM, IoT, and artificial intelligence platforms, as well as the automation of resource accounting and management. An analysis of the effectiveness of digital solutions was conducted, main barriers were identified, and recommendations for the development of the regulatory framework and personnel training were proposed. The results confirm the importance of a systematic approach to improving service quality and sustainable development of the HCS sector. This work contributes to expanding scientific understanding of digital transformation and may serve as a basis for further research and practical developments. **Keywords:** digital transformation, housing and communal services, BIM, Internet of Things, artificial intelligence, automation, quality management, systems analysis

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Introduction

Housing and communal services (HCS) face fundamental challenges related to infrastructure, digitalization, and fragmented management.

There is a need for transformation to improve service quality, energy and environmental efficiency, and institutional resilience.

The current digital context demands integrated cross-sectoral management models that unify processes and standardize data. Key barriers include the lack of unified legal frameworks, heterogeneous information systems, low digital literacy of personnel, resistance to organizational change, and high investment needs.

A comprehensive response requires creating a unified digital platform, standardizing energy efficiency assessment methods, and fostering partnerships among government, business, and academia.

Systematic adoption of digital technologies like BIM and IoT is crucial for better resource use and service quality. Research confirms that digital transformation reduces operational costs, enhances energy sustainability, and increases transparency.

Digitalization is recognized as a critical driver of HCS transformation, accompanied by multiple interrelated challenges.

As noted by R. Kh. Mutolapov [1], the global digitalization of housing and utilities facilities in advanced countries is at the stage of accumulating metadata and creating digital platforms, services and applications using IT solutions using artificial

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Bio notes:

Anna Y. Verenikina, PhD in Economics, Assistant Professor at the V.F. Stanis Department of Political Economy, RUDN University, 6 Miklukho-Maklaya St, Moscow, 117198, Russian Federation. ORCID: 0000-0003-0400-0799 E-mail: verenikina-ayu@rudn.ru

Alexey S. Budakov, Postgraduate Student at the V.F. Stanis Department of Political Economy, RUDN University, 6 Miklukho-Maklaya St, Moscow, 117198, Russian Federation. ORCID: 0000-0001-9216-3066 E-mail: budakovalexey@gmail.com

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intelligence. This basic technical trend is already forming new requirements for infrastructure and industry management.

The corresponding challenges of technological transformation are confirmed in the study by A.V. Bashkireva and T.V. Bashkireva [2], who indicate that digitalization contributes to the integration of HCS into a single state information space, optimizing reporting processes and increasing the accuracy of resource accounting.

Further development of challenges is noted in the work of S.P. Chernov and E.A. Lyashenko [3], who confirm that the level of digital maturity and the resource base differ significantly between municipalities and constituent entities of the Russian Federation. This requires a differentiated approach to the implementation of digital initiatives: regional indicators are focused on integration with federal platforms, and municipal indicators are focused on the development of local solutions.

Active interaction with the population, which together reduces risks and accelerates digital transformation. The market context of HCS is considered in detail by N.I. Voronina and O.A. Saprykina [4], which show that digitalization is becoming a tool for increasing the competitiveness of management companies through the expansion of additional services and the development of industry marketing.

This confirms that digital transformations are not limited to technical improvements, but are closely related to the economic and marketing strategy of companies. In this regard, the socio-environmental component of digitalization is reflected in the work of I.N. Tkachenko and I.A. Chechulin [5], where the sustainable development of HCS is understood as meeting current life needs without compromising future generations, which is associated with the quality of life of the population. This approach sets a broader context for assessing the effectiveness of digital initiatives and requires integration into the strategic objectives of the industry.

The effectiveness of business processes and economic mechanisms transformed under the influence of digital technologies is confirmed in the work of U.A. Kurbanova, D.R. Makhmudova and G.R. Gargatsev [6].

The study records a significant potential of digitalization for restructuring, demonopolizing the industry, reducing costs and improving the quality of services, but highlights the most important challenge — a low level of strategic management that limits the success of implementation. Practical aspects of improving management through digitalization are additionally disclosed by I.S. Zimina [7], which draws attention to the possibilities of optimizing cost planning, supplier selection, labor organization and the introduction of lean technologies. These measures create conditions for increasing economic efficiency, which directly correlates with the challenges voiced earlier in the field of management. An important systemic confirmation of the importance of the integrated approach is the study of N.A. Simchenko, S.P. Reus and V.I. Filonov [8], which shows that the combination of modern digital technologies with cross-industry interaction leads to a significant reduction in transaction costs and the creation of a synergistic effect.

The interaction of industrial corporations in the implementation of digital twins contributes to the acceleration of economic growth by “adopting” best practices through digital platforms, which emphasizes the need for cross-industry coordination as a key factor in the sustainable development of the industry.

Thus, the logic of the identified challenges and problems of digitalization of HCS is confirmed by the complexity and interconnectedness of factors — from technological innovations and organizational transformations to social and economic aspects.

The introduction of cross-industry digital projects is becoming a prerequisite for overcoming existing limitations and ensuring comprehensive, sustainable development of the industry in the long term. Scientific articles published after 2024 confirm that digitalization in HCS and related real estate is a sustainable global trend.

The study by B. Al-Haimi et al. [9] provides a systematic review of digital technologies in the real estate sector, including the application of artificial intelligence (AI), the Internet of Things (IoT) and big data to improve the efficiency of residential asset management and sustainable development. that digital transformation is fundamentally changing the way housing is maintained and operated, making them more adaptive and cost-effective. An article by Ab. Bhaker from the World Journal of Advanced Research and Review [10] highlights the impact of AI on technological change in residential real estate, which contributes to improving predictive models for maintenance and resource management, improving the quality of services and reducing costs.

This scientific approach is associated with the global trend of introducing digital platforms for energy management and monitoring the state of the housing stock.

To systematize research directions, about 70 publications on current issues and future prospects of HCS were analyzed, focusing on digital transformation, cross-sector management, regulatory frameworks, energy efficiency, and socio-environmental aspects. The analysis results are shown in Figure 1.

The scientific discourse highlights digital transformation with integration of intelligent management systems, including artificial intelligence, IoT, and big data technologies, as the research priority. This trend reflects the need to improve operational efficiency, reduce costs, and increase transparency amid a rapidly evolving economic and technological landscape. The significance of digital technologies is confirmed by their ability to enable continuous infrastructure monitoring and adaptive resource management, essential for sustainable sector development.

Significant attention is given to the legal and regulatory framework underpinning digitalization, as process standardization and legislative harmonization enable large-scale innovation adoption and reduce legal risks. These reforms foster a unified digital space that optimizes information exchange and organizational procedures, enhancing market participants' trust and ensuring institutional resilience in HCS.

Equally important is the development of platform solutions and cross-sector collaboration, integrating data and processes to promote coordination and synergy among economic sectors. Digitalization is thus seen as a socio-technical process requiring a holistic approach that considers technical, organizational, social, and environmental factors.

Energy and resource saving research occupies a key role, with digital technologies automating consumption accounting and optimization, critical for environmental policy and economic efficiency. The socio-environmental dimension, focusing on quality of life and sustainability, expands traditional management to address long-term impacts and balance societal and ecosystem interests.

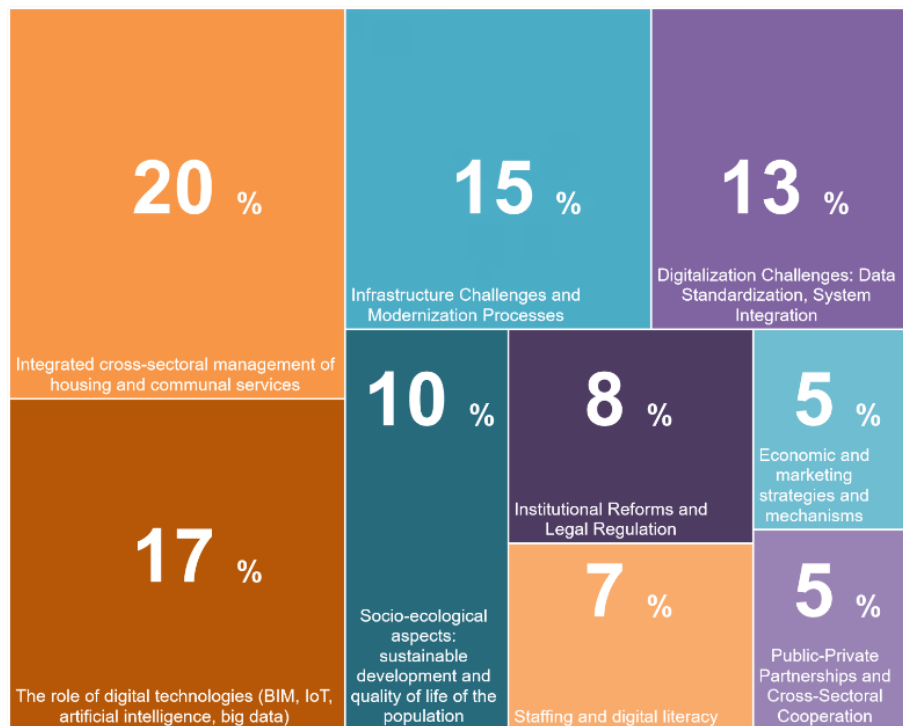


Figure 1. The Main Areas of Scientific Research and Priorities for the Digital Transformation of the HCS

Source: created by Anna Y. Verenikina, Alexey S. Budakov.

Future research and practice in HCS are expected to focus increasingly on developing integrated digital platforms with strong regulatory support that ensure technical, economic, and social sustainability. A systemic interdisciplinary approach involving stakeholders at all levels is vital for successful national digital economy programs and HCS modernization amid global challenges.

Current cross-sector coordination in HCS management involves building a comprehensive system integrating strategic and operational initiatives by government, utilities, and consumers. Central to this are unified management methodologies, digital platforms, and information-sharing mechanisms that enable flexible, adaptive governance aligned with digital economy demands and rising social-ecological expectations.

Pilot projects implementing cross-sector digital management models in communal infrastructure demonstrate high effectiveness by reducing operational and transactional costs, improving service quality control, boosting investment appeal, and strengthening the sector's financial stability.

Digitalization accelerates document flow, increases transparency and accountability, lowers administrative barriers, and improves payment discipline.

The theoretical basis for cross-sector management relies on a systems approach encompassing infrastructure, energy, construction, and social components of the communal sphere.

Institutional analysis highlights norms, rules, and coordination mechanisms as key influences on market behavior and integration success. Coordinating investment, design, construction, and operation through a unified digital platform facilitates lifecycle management of infrastructure assets.

This integrated management relies on formalizing interagency procedures and forming network coalitions to enable information exchange, data and process standardization, and unified models for assessing economic, social, and environmental efficiency. This creates conditions for a systematic approach aimed at sustainable development of the communal sector and improved service quality.

Together, these methodologies and digital tools help overcome the sector's traditional fragmentation, ensuring coordinated and comprehensive management of resources, infrastructure, and key HCS processes amid a dynamic external environment and intensifying digital transformation.

Cross-sector management is crucial for sustainable HCS development by integrating resources, technologies, and management functions across economic sectors to ensure long-term system resilience.

Consolidating material, financial, and intellectual assets synergistically enhances infrastructure utilization, service process optimization, and cost reduction.

Digital technologies play a vital role, especially BIM, big data, and IoT. BIM integration provides precise virtual models of infrastructure with comprehensive engineering, energy, and environmental parameters, optimizing design, operation, and maintenance throughout the lifecycle. This approach reduces energy and material consumption, boosts energy efficiency and ecological sustainability, and lowers failure rates through predictive monitoring of technical conditions.

Intersectoral coordination (Figure 2) serves as a fundamental instrument aimed at the systematic minimization of redundant duplication of functional responsibilities and processes across the diverse entities involved in HCS.

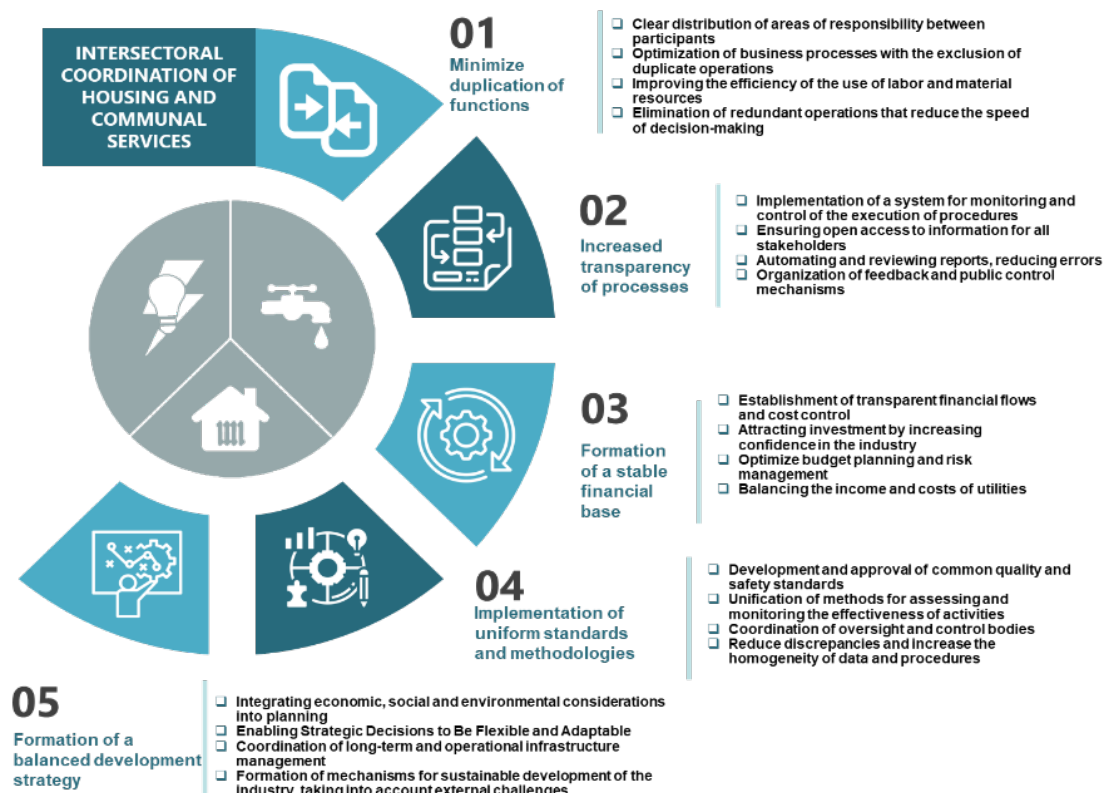


Figure 2. Key Directions of Intersectoral Coordination in the Sphere of the HCS

Source: created by Anna Y. Verenikina, Alexey S. Budakov.

This coordination leads to a substantial reduction of transactional costs, which typically arise from inefficient interaction and overlapping authorities among various stakeholders within the HCS market.

Enhanced transparency of operational and managerial processes, achieved through standardized control and reporting mechanisms, contributes to mitigating operational risks, thereby strengthening trust among investors and other interested parties.

Consequently, a stable financial foundation for the communal sector is established, which increases its investment attractiveness and supports the sector's long-term development. The implementation of unified standards and methodologies for evaluating effectiveness, sustainability, and management quality becomes an essential control mechanism, enabling regulation of the service level and quality provided.

This ensures the possibility to develop a balanced, multi-faceted development strategy for HCS that optimally accounts for economic parameters, social population needs, and environmental requirements.

Institutionalizing sustainable development principles in cross-sector management implies adopting a circular economy model focused on maximizing resource recycling, energy saving, and minimizing environmental impact. It integrates social responsibility to improve quality of life, increase accessibility and reliability of communal services, and promote equitable resource distribution.

Thus, cross-sector management establishes an organizational and technological foundation for transforming HCS into an innovative, sustainable system aligned with national digital, ecological, and social strategies.

Key barriers to cross-sector management development in HCS are interconnected systemic factors hindering integration and digital initiatives.

Insufficient standardization of data, processes, and technological protocols leads to fragmented information systems among sector actors.

This fragmentation impedes effective information exchange, reduces transparency, raises transaction costs, and undermines management quality. Unified exchange standards and integration protocols are critical for building a unified HCS digital space.

Organizational resistance remains significant, driven by entrenched bureaucracy, cultural conservatism, and institutional hierarchies within utilities and government agencies. Lack of motivation, ineffective change management programs, and poor internal communication slow cross-sector collaboration and digital adoption.

Limited human capital due to low digital literacy and shortage of IT, systems management, and big data analysis specialists constrains digital integration. Comprehensive capacity-building programs, including professional training, retraining, and upskilling, are essential to overcome this barrier and enhance transformation effectiveness.

Legal and regulatory uncertainty further complicates the development of cross-sector management and digitalization in HCS. The lack of clear standards, innovation efficiency assessment methods, and requirements for information security and data protection creates significant legal and economic risks for market participants. This regulatory ambiguity reduces investment attractiveness,

slows cross-sector strategy development and scaling, and causes imbalances in technological and institutional governance.

Financial and investment constraints act as an overarching barrier, linking shortcomings in standardization, workforce development, and regulation.

High upfront costs for digital technology adoption, infrastructure modernization, and human capital development strain municipal budgets, especially in economically weak regions.

The absence of sustainable financial models and public-private partnership mechanisms impedes phased scaling of digital solutions and cross-sector coordination, limiting the sector's strategic growth and long-term sustainability.

The identified barriers form a complex, interconnected system requiring a comprehensive, systemic, and coordinated approach for effective HCS development and digital transformation.

To overcome structural and institutional challenges in cross-sector HCS management, a set of measures targets creating systemic conditions for sustainable growth.

A key priority is developing a unified legal framework that standardizes digital technologies, data exchange procedures, and interaction among sector participants.

This framework includes formalizing information system requirements, unifying data exchange protocols, and establishing clear rules for information security and personal data protection, thereby reducing legal risks and facilitating digital ecosystem expansion.

Strengthening human capital through comprehensive professional education, retraining, and upskilling programs focuses on building digital competencies and cross-sector collaboration skills.

These efforts address workforce shortages and improve digital literacy, forming the foundation for adopting advanced management and IT technologies.

To ensure coordinated and transparent market participant interaction, interagency procedures are formalized and data exchange processes standardized within a unified HCS digital platform.

This platform integrates data infrastructure, automates document flow, and supports collaborative decision-making based on accurate, up-to-date information, enhancing management quality and responsiveness.

State policy promotes active coordination of strategic and operational initiatives, stimulates investment, and supports public-private partnerships to attract funds and advance technological levels in the communal sector.

Support for research institutions and competence centers facilitates technology adaptation and best practice dissemination.

The introduction of digital platforms and integrated monitoring systems provides an integrated approach to managing the life cycle of infrastructure facilities — from design and construction to operation and modernization.

The use of analytical tools to assess the effectiveness and sustainability of ongoing projects is based on multidisciplinary methods using quantitative and qualitative indicators, which allows for continuous monitoring and adjustment of strategies in real time.

Practical testing of technologies and models of cross-sectoral management is carried out through pilot projects, the results of which serve as the basis for the formation of a methodological base and scaling up successful solutions, taking into account the specifics of regional conditions and the scale of infrastructure.

A comprehensive approach to assessing the effectiveness of these projects includes the analysis of economic, social and environmental indicators, contributing to the formation of a sustainable and innovative model for the development of HCS within the framework of national strategies for the digital economy and social modernization.

Foundations for further research in cross-sector management of HCS require a comprehensive, multifaceted approach aimed at in-depth analysis and systematic organization of the integrative processes underpinning the efficient functioning of the modern communal sector.

Advancing methodological and analytical toolsets is essential, emphasizing the application of multidisciplinary system analysis, mathematical modeling, and big data techniques. These approaches enable precise identification of integration bottlenecks, optimization of managerial decision-making, and reliable forecasting of the impacts from deploying innovative digital technologies.

The development and harmonization of the legal and regulatory framework remain a pivotal research priority. It is crucial to consider the unique regional characteristics of communal systems, advocating for the creation of flexible regulatory mechanisms with adaptive requirements and a differentiated approach to standardization.

Such a regulatory construct would facilitate more effective digital technology adoption and innovation stimulation across diverse territorial and infrastructural contexts.

Special focus should be placed on the adaptation and customization of digital technologies, taking into account technical, socio-economic, and environmental attributes of regional communal systems.

Enhancing inclusive governance involves broadening stakeholder participation — government agencies, utility providers, research institutions, and end-users — in decision-making processes through collective governance models founded on openness and transparency principles.

Ensuring continuity and replication of successful cross-sector management practices requires establishing effective knowledge and experience exchange mechanisms.

These include the formation of interaction networks, sector-specific competencies, and dedicated platforms for disseminating innovative solutions. Such mechanisms are vital for accelerating the adoption of leading global and national practices and fostering the development of collaborative innovation models uniting diverse stakeholders within the HCS domain.

Future development prospects are linked to the creation of an innovation stratosphere — a synergy of institutional, technological, and educational conditions promoting sustainable and efficient digital interaction among all communal sector actors. Designing this environment entails building adaptive digital ecosystems characterized by high integration, automation, and intelligent management processes, thereby laying the groundwork for implementing national strategies in digital economy, environmental security, and social modernization.

Integrated cross-sectoral management (Figure 3) of the housing and utilities sector forms a single digital ecosystem that unites government agencies, utilities and consumers.

The most important role in this scheme is played by normative regulation and standardization, which create the legal basis for unified management (25%).

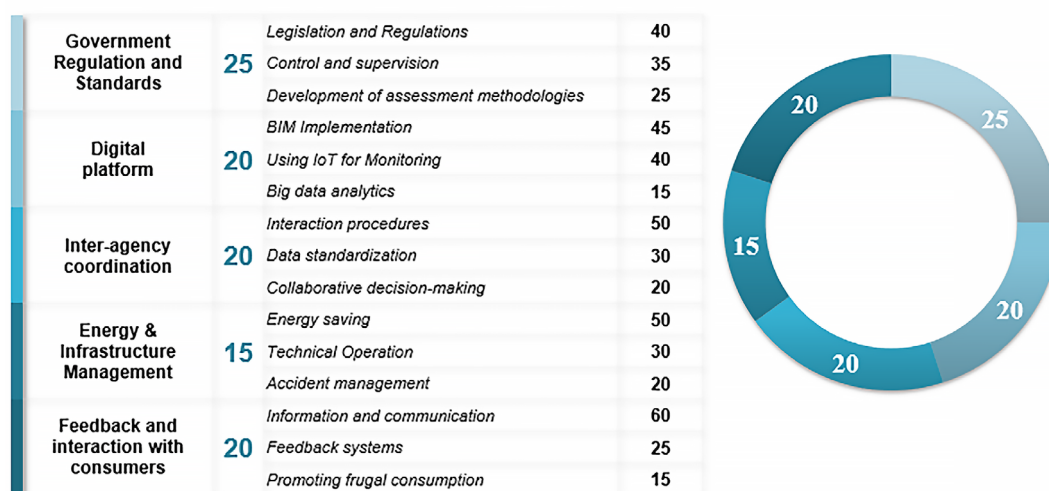


Figure 3. Framework for Integrated Cross-Sector Management in the HCS

Source: created by Anna Y. Verenikina, Alexey S. Budakov.

Judging by the estimates of management companies, the key sub-parameters — legislation and control — ensure the stability and transparency of processes.

Digital technologies, including BIM and IoT, are seamlessly integrated (20%) to improve monitoring and analysis.

Particular attention is paid to interdepartmental coordination, which optimizes information exchange and decision-making (20%).

Energy and infrastructure management (15%) aims to improve energy efficiency and prevent accidents. Interactive interaction with consumers (20%) helps to improve feedback and stimulate rational consumption. Such complexity provides flexibility and adaptability of management in a constantly changing environment of HCS.

Management companies identify key obstacles in the development of digitalization of HCS (Figure 4), of which the most significant is the lack of data standardization (30%). This leads to technical incompatibility of systems and complicates integration.

Fragmentation of information systems (20%) reduces the overall efficiency of management, creating silos and slowing down data exchange processes.

Low levels of digital literacy and resistance to new technologies (15%) hinder rapid innovation. Organizational barriers (15%), expressed in bureaucracy and lack of motivation, further reduce the speed of transformation.

Regulatory uncertainty (10%) and financial constraints (10%) create risks and discourage investment. Thus, the complex of these interrelated barriers requires comprehensive and strategically targeted solutions.

Digital transformation measures in the HCS sector (Figure 5) are based on the development and implementation of a regulatory framework and standards (25%), which ensures the orderliness and transparency of technological processes.

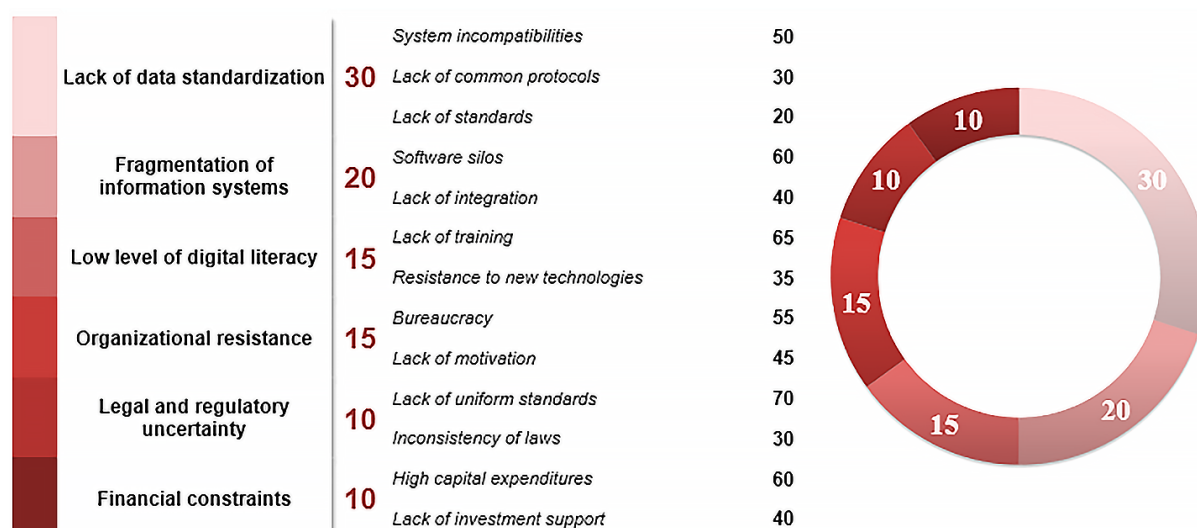


Figure 4. Main Barriers to Digitalization in the HCS

Source: created by Anna Y. Verenikina, Alexey S. Budakov.

Management companies emphasize the need for training through training and advanced training (20%), which creates the foundation for the development of digital tools.

The implementation of BIM, IoT and digital platforms (20%) expands monitoring and analysis capabilities, contributing to improving the quality of services.

Stimulating public-private partnerships and investments (15%) is seen as key to ensuring the financial sustainability of projects. Scaling and regional adaptation (20%) allow us to take into account territorial features and increase the efficiency of solution implementation. The combination of these measures is aimed at improving energy efficiency, reducing costs and sustainable development of the industry, which becomes the basis for a comprehensive modernization of HCS.

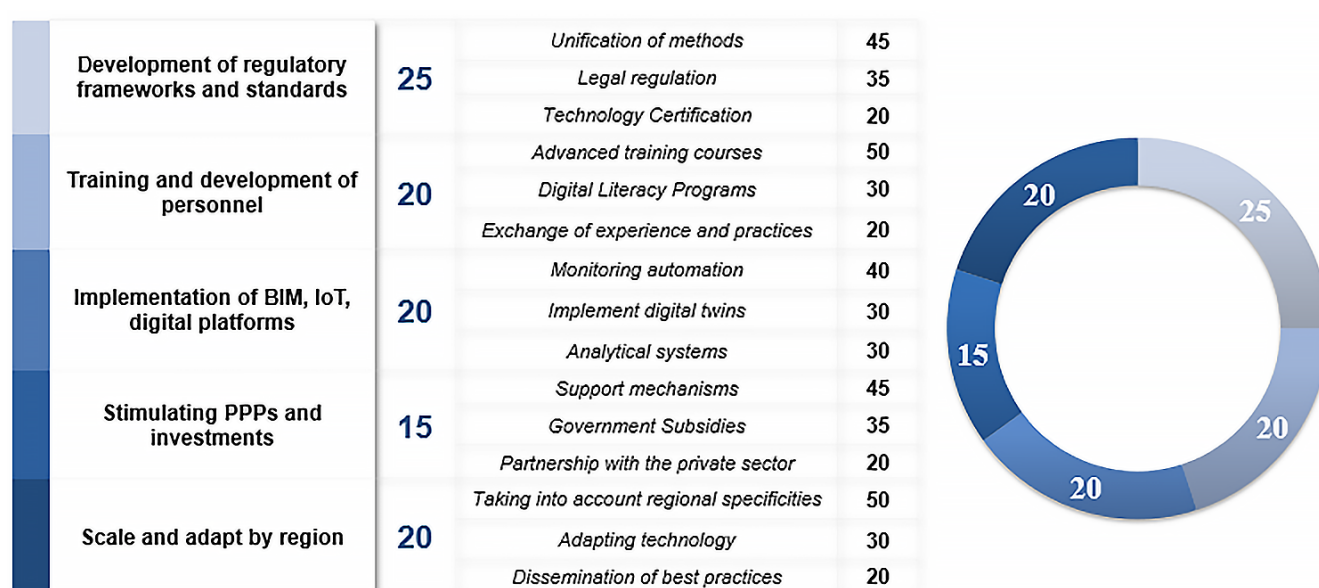


Figure 5. Measures and Prospects for Digital Transformation in the HCS

Source: created by Anna Y. Verenikina, Alexey S. Budakov.

In order to assess the development of the prospects for digital services, HCS also analyzed official statistics reflecting the dynamics of key indicators of the functioning of digital platforms (Figure 6).

INDEX	2021	2022	2023	2024	COMMENT
 USER SATISFACTION (%)	81,36	81,43	81,16	81,16	A STABLE LEVEL OF SATISFACTION INDICATES THAT THE QUALITY OF SERVICE IS MAINTAINED AT A HIGH LEVEL.
 NUMBER OF SERVICES RECEIVED (THOUSAND UNITS)	206,93	393,24	527,64	—	THE SIGNIFICANT GROWTH REFLECTS THE SCALING AND EXPANSION OF THE REACH OF DIGITAL SERVICES.
 NUMBER OF SERVICES (UNITS) IMPLEMENTED	21	29	31	31	THE INCREASE IN THE NUMBER OF SERVICES CONFIRMS THE DEVELOPMENT OF THE FUNCTIONALITY AND CAPABILITIES OF THE DIGITAL PLATFORM.

Figure 6. Key Indicators of Digital Platform Adoption

Source: created by Anna Y. Verenikina, Alexey S. Budakov based on data from fedstat.ru.

The current state of digitalization in the HCS sector is a comprehensive process aimed at increasing operational efficiency, transparency, and service quality through the implementation of integrated digital technologies.

The stability of user satisfaction indicators amidst a rapid growth in the number of services and offerings reflects a systemic success in maintaining service quality and adapting the population to emerging digital interaction formats.

Satisfaction serves as a crucial indicator of consumer adaptation and the digital maturity level of the platform, which is vital for strategic management of digital transformation initiatives.

Beyond technical enhancements, analyzing and considering user experience provides essential feedback that guides the refinement and development of digital services, taking into account regional and social peculiarities.

Scaling digital platforms consistently requires ongoing monitoring and the enhancement of digital literacy among the population, alongside timely identification and elimination of technological and organizational barriers.

In this context, user satisfaction is a systemic element integrated into comprehensive efficiency metrics and the broader institutional stability of the sector.

Balanced attention to user satisfaction levels facilitates resource and economic mechanism optimization, elevates investment attractiveness, reduces administrative barriers, and fosters trust among all stakeholders in the HCS market.

Collectively, these factors underpin the formation of a sustainable and innovative development model for the housing and utilities sector, supporting environmental security and social well-being over the long term.

Materials and Methods

In the present study, a systematic approach was employed, encompassing a comprehensive analysis of scientific literature, regulatory documents, official statistics, and results from pilot projects on digital transformation in the HCS sector.

The methodology was based on comparative analysis, data synthesis, and identification of patterns, which allowed for the formulation of generalized conclusions and the determination of key development trends.

Data sources included publications in peer-reviewed scientific journals, official reports from government bodies, conference materials, as well as open databases.

To assess the effectiveness of digital solutions, both quantitative indicators (such as the level of automation, the share of digital platforms, and trends in the user satisfaction index) and qualitative criteria (including the degree of process standardization, the level of digital maturity, and the integration of BIM, IoT, and AI-technologies) were applied.

Results and Discussion

The results presented herein are based on a comprehensive and consolidated analysis of the current state and trends within the digital transformation in the HCS. The analysis allowed for the identification of critical pathways and essential factors influencing the modernization of the industry.

In this regard, it is necessary to emphasize the following key outcomes:

- Key directions of digital transformation in the HCS were identified, including the implementation of integrated digital platforms such as BIM, IoT, and artificial intelligence, alongside the automation of resource accounting and service processes;
- It was demonstrated that digitalization significantly enhances management efficiency by increasing processing speeds of requests severalfold, reducing incident rates by approximately 30%, and raising the level of automation up to 40%;
- A positive trend in user satisfaction was confirmed, with a CSI of 4.7, indicating growing loyalty and trust of consumers in the HCS;
- Significant barriers to digitalization were revealed, including fragmentation of information systems, lack of unified regulatory frameworks, low digital literacy among personnel, and financial constraints;
- The importance of developing unified legislation, standardizing data and processes, and implementing training programs was substantiated to successfully scale digital initiatives;

- The role of cross-sector collaboration and integrated management models was emphasized as essential for sustainable and innovative sector development aligned with national digital and environmental strategies;
- These results collectively confirm that a systematic approach to digital transformation in housing and utilities contributes to enhanced service quality, improved economic efficiency, and sustainable sector development.

Main parameters of the results achieved and the main areas of focus are shown in Figure 7.

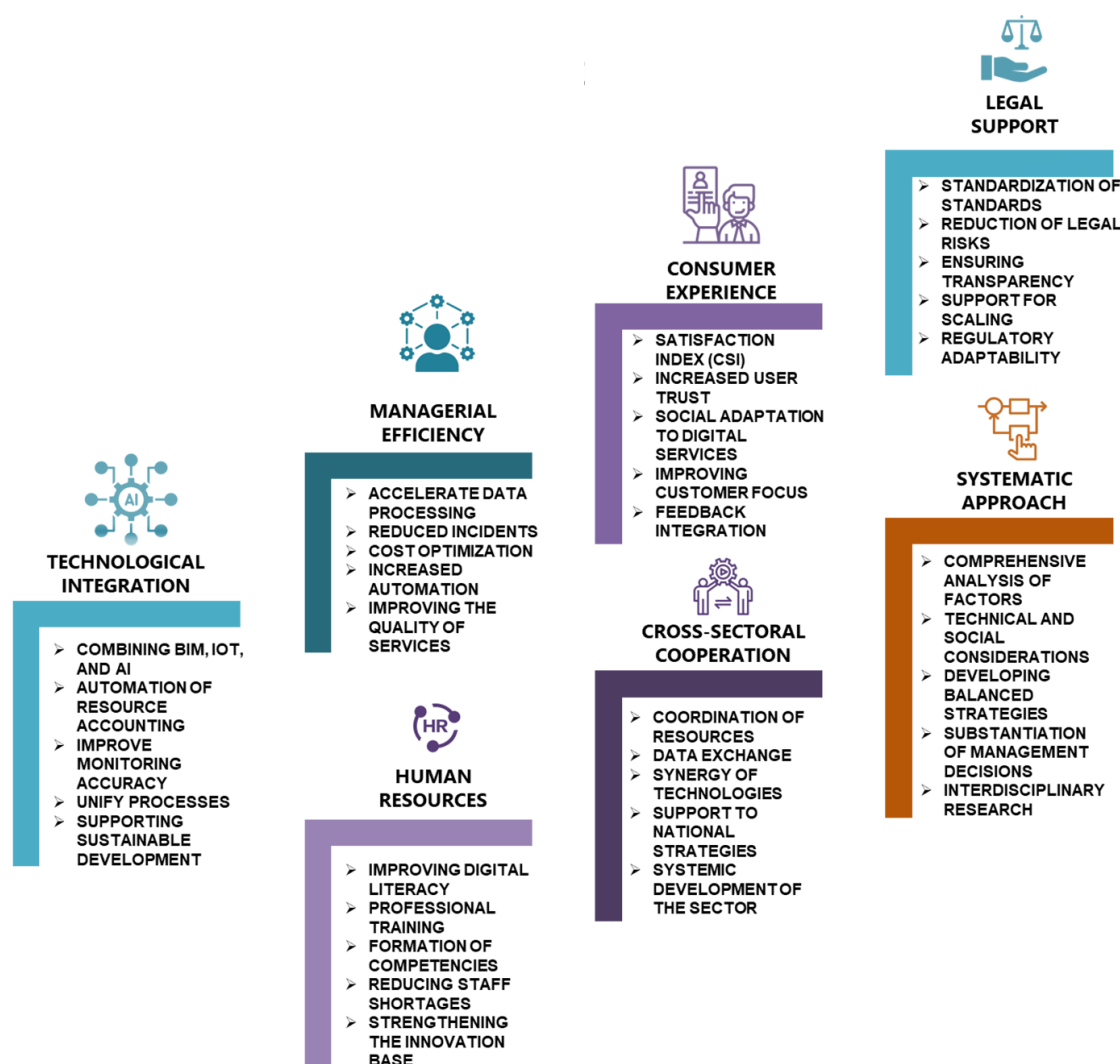


Figure 7. Main Parameters of the Results Achieved and the Focus of the Main Attention

Source: created by Anna Y. Verenikina, Alexey S. Budakov.

The comprehensive analysis corroborates prevailing trends identified in extant literature and emphasizes the imperative integration of digital platforms such as BIM, IoT, and artificial intelligence for the systematic modernization of the housing and utilities sector.

The observed augmentation in automation levels and concomitant reduction in incident rates substantiate the beneficial effects of digitalization; nonetheless, persistent challenges including information system fragmentation, absence of unified regulatory frameworks, deficiencies in digital literacy among personnel,

and fiscal constraints remain notable impediments. Future research endeavors should prioritize the formulation of cohesive legal and regulatory frameworks alongside specialized professional training programs.

Particular emphasis is warranted on investigating cross-sectoral collaboration and integrated management models, which are pivotal for fostering sustainable development and enhancing the sector's innovative capacity. Furthermore, empirical inquiries into user adaptation to digital services and rigorous evaluations of pilot projects implementing integrated platforms represent critical avenues for forthcoming scholarly investigation.

Conclusion

Digital transformation in the HCS is a systemic change in management approaches that enhances service quality, transparency, and environmental sustainability. The implementation of technologies such as BIM, the Internet of Things, and artificial intelligence enables optimization of infrastructure operations, automation of resource accounting, and predictive maintenance, reducing failures and costs. However, significant systemic barriers must be addressed, including fragmented information systems, lack of data standardization, low digital literacy among personnel, and regulatory uncertainty. Strengthening cross-sector cooperation, developing unified digital platforms, and implementing comprehensive training programs are critical for scalable and sustainable sector development. This transformation not only fosters economic efficiency but also builds consumer trust, improving the socio-environmental living conditions of the population.

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Особенности и системное развитие цифровой трансформации в сфере жилищно-коммунального хозяйства

А.Ю. Вереникина  , А.С. Будаков 

Финансирование. Настоящее исследование не получало внешнего финансирования.

Заявление об информированном согласии: не применимо.

Вклад авторов. Разработка концепции и методологии исследования, создание программного обеспечения, валидация и формальный анализ данных, проведение эксперимента, курирование и визуализация данных, подготовка черновика рукописи, а также администрирование проекта — А.С. Будаков. Разработка концепции исследования, валидация результатов, предоставление ресурсов, рецензирование и редактирование, общее научное руководство — А.Ю. Вереникина. Все авторы прочли и одобрили окончательную версию рукописи.

Конфликт интересов. Авторы заявляют об отсутствии конфликта интересов.

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Сведения об авторах:

Вереникина Анна Юрьевна, кандидат экономических наук, доцент кафедры политической экономики им. В.Ф. Станиса, Российский университет дружбы народов, Российская Федерация, 117198, Москва, ул. Миклухо-Маклая, д. 6.
ORCID: 0000-0003-0400-0799
E-mail: verenikina-ayu@rudn.ru

Будаков Алексей Сергеевич, аспирант кафедры политической экономики им. В.Ф. Станиса, Российский университет дружбы народов, Российская Федерация, 117198, Москва, ул. Миклухо-Маклая, д. 6.
ORCID: 0000-0001-9216-3066
E-mail: budakovalexey@gmail.com

Российский университет дружбы народов, Москва, Российская Федерация
 verenikina-ayu@rudn.ru

Аннотация. Представлен системный анализ цифровой трансформации в жилищно-коммунальном хозяйстве (ЖКХ). С использованием методов сравнительного анализа, синтеза данных и системного подхода выявлены ключевые направления цифровизации, включая интеграцию технологий BIM, IoT и платформ на базе искусственного интеллекта, а также автоматизацию учета и управления ресурсами. Проведен анализ эффективности цифровых решений, обозначены основные барьеры и предложены рекомендации по развитию нормативной правовой базы и кадровой подготовки. Результаты подтверждают значимость системного подхода для повышения качества услуг и устойчивого развития сектора ЖКХ. Данное исследование способствует расширению научного понимания цифровой трансформации и может служить основой для дальнейших теоретических и прикладных разработок.
Ключевые слова: цифровая трансформация, жилищно-коммунальное хозяйство, BIM, Интернет вещей, искусственный интеллект, автоматизация, управление качеством, системный анализ

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