ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ
АКАДЕМИЯСЫ» РҚБ

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ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»

NEWS

OF THE NATIONAL ACADEMY
OF SCIENCES OF THE REPUBLIC
OF KAZAKHSTAN

SERIES OF PHYSICS AND MATHEMATICS

1 (353)

JANUARY – MARCH 2025

PUBLISHED SINCE JANUARY 1963
PUBLISHED 4 TIMES A YEAR

ALMATY, NAS RK

«ҚР ҰҒА Хабарлары. Физика-математика сериясы».
ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы).

Ақпарат агенттігінің мерзімді баспасөз басылымын, ақпарат агенттігін және желілік басылымды қайта есепке қою туралы ҚР Мәдениет және Ақпарат министрлігі «Ақпарат комитеті» Республикалық мемлекеттік мекемесі **28.02.2025** ж. берген **№KZ20VPY00113741** Куәлік.

Тақырыптық бағыты: *ақпараттық-коммуникациялық технологиялар*

Қазіргі уақытта: *«ақпараттық-коммуникациялық технологиялар» бағыты бойынша ҚР БҒМ БҒСБК ұсынған журналдар тізіміне енді.*

Мерзімділігі: *жылына 4 рет.*

Редакцияның мекен-жайы: *050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19*
http://www.physico-mathematical.kz/index.php/en/

«Известия НАН РК. Серия физико-математическая».
ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)
Собственник: *Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).*
Свидетельство о постановке на переучет периодического печатного издания, информационного агентства и сетевого издания **№ KZ20VPY00113741.** Дата выдачи **28.02.2025**
Тематическая направленность: *информационно-коммуникационные технологии.*
В настоящее время: *вошел в список журналов, рекомендованных КОКСНВО МНВО РК по направлению «информационно-коммуникационные технологии».*
Периодичность: *4 раза в год.*
Адрес редакции: *050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19*
http://www.physico-mathematical.kz/index.php/en/

News of the National Academy of Sciences of the Republic of Kazakhstan.
Series of Physics and Mathematics
ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
Certificate **No. KZ20VPY00113741** on the re-registration of the periodical printed and online publication of the information agency, issued on **28.02.2025** by the Republican State Institution «Information Committee» of the Ministry of Culture and Information of the Republic of Kazakhstan
Subject area*: information and communication technologies.*
Currently: *included in the list of journals recommended by the CCSES MSHE RK in the direction of «Information and communication technologies».*
Periodicity: *4 times a year.*
Editorial address: *28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19*
http://www.physico-mathematical.kz/index.php/en/

NEWS OF THE NATIONAL ACADEMY OF SCIENCESOF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES
ISSN 1991-346X
Volume 1. Namber 353 (2025). 283–296

https://doi.org/10.32014/2025.2518-1726.340

UDC 721.001

A. Taukenova[1,2], 2025.
[1]S. Seifullin Kazakh Agrotechnical Research University, Astana, Kazakhstan;
[2]Henan Agricultural University, Zhengzhou, China.
*E-mail: asembeck@gmail.com

PERSONALIZED ARCHITECTURE: CREATING UNIQUE SPACES WITH DIGITAL TECHNOLOGIES

Taukenova A. – Master of Landscape Architecture, Architect at VL, Astana, Kazakhstan; Henan Agricultural University, Zhengzhou, China, asembeck@gmail.com, https://orcid.org/0000-0002-3006-1272.

Abstract: The rapid urbanization of the 21st century has increased the demand for adaptive, sustainable, and personalized architecture that caters to diverse user needs. The implementation of digital technologies such as Building Information Modeling (BIM), Artificial Intelligence (AI), and the Internet of Things (IoT) has become essential for creating dynamic and unique urban spaces. These technologies enable architects and planners to develop user-centric solutions that enhance urban resilience and improve the quality of life in cities.

The study adopts a systematic review of existing literature, examining the current role of digital tools in shaping personalized urban environments. It analyzes the effectiveness of digital technologies in enhancing adaptability, sustainability, and user comfort in urban spaces. The findings highlight the growing importance of interdisciplinary collaboration between architects, technologists, and policymakers in driving innovation.

Key findings suggest that personalized architectural solutions improve urban quality and create more comfortable living conditions. The integration of digital technologies contributes to increased adaptability and sustainability, although challenges such as high implementation costs and data privacy concerns persist.

The study's conclusions provide practical recommendations for incorporating digital tools in urban planning. By focusing on developing more accessible, scalable, and ethically sound technologies, future urban solutions can be further enhanced, supporting sustainable and user-friendly city designs.

Keywords: Personalized architecture, digital technologies, urban adaptability, Building Information Modeling (BIM), Artificial Intelligence (AI), Internet of Things (IoT), sustainable urban development.

Ә. Таукенова[1,2], 2025.
[1]С. Сейфуллин атындағы Қазақ агротехникалық зерттеу университеті, Астана, Қазақстан;
[2]Хэнань Ауылшаруашылық Университеті, Чжэнчжоу, Қытай.
*E-mail: asembeck@gmail.com

ЖЕКЕЛЕНДІРІЛГЕН АРХИТЕКТУРА: ДИДЖИТАЛ ТЕХНОЛОГИЯЛАРМЕН ЕРЕКШЕ КЕҢІСТІКТЕР ЖАРАТУ

Таукенова Ә. – Ландшафттық сәулет өнері магистрі, ВЛ компаниясының сәулетшісі, Астана, Қазақстан; Хэнань Ауылшаруашылық Университеті, Чжэнчжоу, Қытай, asembeck@gmail.com, https://orcid.org/0000-0002-3006-1272.

Аннотация: 21 ғасырдың қарқынды урбанизациясы пайдаланушылардың әртүрлі қажеттіліктерін қанағаттандыратын бейімделгіш, тұрақты және жекелендірілген архитектураға сұранысты арттырды. Ақпараттық Модельдеуді (BIM), Жасанды Интеллектті (AI) Және Заттар Интернетін (IoT) Құру сияқты цифрлық технологияларды енгізу динамикалық және бірегей қалалық кеңістіктерді құру үшін маңызды болды. Бұл технологиялар сәулетшілер мен жоспарлаушыларға қалалардың тұрақтылығын арттыратын және қалалардағы өмір сүру сапасын жақсартатын пайдаланушыға бағытталған шешімдерді әзірлеуге мүмкіндік береді. Зерттеу барысында цифрлық құралдардың жекелендірілген қалалық ортаны қалыптастырудағы қазіргі рөлін зерттей отырып, қолданыстағы әдебиеттерге жүйелі шолу жасалады. Ол қалалық кеңістіктердегі пайдаланушылардың бейімделуін, тұрақтылығын және жайлылығын арттырудағы цифрлық технологиялардың тиімділігін талдайды. Нәтижелер инновацияларды ынталандырудағы сәулетшілер, технологтар және саясаткерлер арасындағы пәнаралық ынтымақтастықтың өсіп келе жатқан маңыздылығын көрсетеді. Негізгі нәтижелер жекелендірілген архитектуралық шешімдердің қала сапасын жақсартатынын және өмір сүруге қолайлы жағдайлар жасайтынын көрсетеді. Цифрлық технологиялардың интеграциясы бейімделу мен тұрақтылықтың артуына ықпал етеді, дегенмен іске асырудың жоғары шығындары және деректердің құпиялылығына қатысты мәселелер туындауда. Зерттеу нәтижелері цифрлық құралдарды UR-тыйым салуды жоспарлауға енгізу бойынша практикалық ұсыныстар береді. Неғұрлым қолжетімді, масштабталатын және этикалық тұрғыдан негізделген технологияларды әзірлеуге назар аудара отырып, болашақ қалалық шешімдерді тұрақты және пайдаланушыға ыңғайлы қала дизайнын қолдау арқылы одан әрі жетілдіруге болады.

Түйін сөздер: Жекелендірілген сәулет өнері, цифрлық технологиялар, қалалық бейімделу, ғимарат ақпаратын модельдеу (ҒАМ), жартылай ақыл, заттар интернеті (IoT), тұрақты қалалық даму.

А. Таукенова[1,2], 2025.
[1]Казахский агротехнический университет им. С. Сейфуллина, Астана, Казахстан;
[2]Хэнаньский агрокультурный университет, Чжэнчжоу, Китай.
E-mail: asembeck@gmail.com

ПЕРСОНАЛИЗИРОВАННАЯ АРХИТЕКТУРА: СОЗДАНИЕ УНИКАЛЬНЫХ ПРОСТРАНСТВ С ПОМОЩЬЮ ЦИФРОВЫХ ТЕХНОЛОГИЙ

А. Таукенова – магистр ландшафтной архитектуры, архитектор в компании ВЛ, Астана, Казахстан; Хэнаньский Агрокультурный Университет, Чжэнчжоу, Китай, asembeck@gmail.com, https://orcid.org/0000-0002-3006-1272.

Аннотация. Быстрая урбанизация XXI века увеличила спрос на адаптивную, устойчивую и персонализированную архитектуру, которая отвечает разнообразным потребностям пользователей. Внедрение таких цифровых технологий, как информационное моделирование зданий (BIM), искусственный интеллект (ИИ) и Интернет вещей (IoT), стало необходимым для создания динамичных и уникальных городских пространств. Эти технологии позволяют архитекторам и планировщикам разрабатывать ориентированные на пользователя решения, которые повышают устойчивость городов и улучшают качество жизни. Несмотря на это, процесс внедрения технологий требует учета социальных и культурных особенностей, чтобы сохранить идентичность городской среды. Кроме того, необходимо учитывать влияние технологий на экологический след архитектурных решений.

Исследование представляет систематический обзор существующей литературы, изучая текущую роль цифровых инструментов в формировании персонализированных городских сред. Оно анализирует эффективность цифровых технологий в повышении адаптивности, устойчивости и комфорта пользователей в городских пространствах. Результаты подчеркивают растущую важность междисциплинарного сотрудничества между архитекторами, технологами и чиновниками в продвижении инноваций.

Ключевые выводы показывают, что персонализированные архитектурные решения улучшают качество городской среды и создают более комфортные условия для жизни. Интеграция цифровых технологий способствует повышению адаптивности и устойчивости, хотя сохраняются такие проблемы, как высокие затраты на внедрение и вопросы конфиденциальности данных.

Выводы исследования предлагают практические рекомендации по внедрению цифровых инструментов в городское планирование. Разработка более доступных, масштабируемых и этичных технологий позволит еще больше улучшить будущие городские решения, поддерживая устойчивые и удобные для пользователей проекты городов.

Ключевые слова: персонализированная архитектура, цифровые

технологии, городская адаптивность, информационное моделирование зданий (BIM), искусственный интеллект (ИИ), Интернет вещей (IoT), устойчивое городское развитие.

Introduction. The rapid pace of urbanization in the 21st century presents critical challenges that require innovative architectural responses. As cities expand, they face the dual pressure of accommodating increasing populations and addressing the diverse needs of urban residents. Traditional architectural models, while effective in certain contexts, often fail to provide the level of flexibility required for sustainable growth and adaptation. In this evolving landscape, the concept of personalized architecture has emerged as a promising solution that leverages digital technologies to create urban spaces tailored to individual users and communities. Such technologies are not only transforming the design process but are also reshaping how cities interact with their inhabitants by enabling more dynamic and adaptive environments (Söllner et al., 1993; Mazetto, 2024).

Digital technologies have become essential tools for creating adaptable urban environments. They play a crucial role in overcoming the limitations of traditional architectural models by providing real-time data that supports decision-making, improves functionality, and enhances user experience. Technologies like Building Information Modeling (BIM), Artificial Intelligence (AI), and the Internet of Things (IoT) offer robust solutions for urban planning, allowing architects and city planners to develop spaces that are more responsive to the needs of their users. For example, IoT sensors facilitate the monitoring of infrastructure, enabling rapid adjustments to changes in energy consumption, waste management, and transportation networks. AI applications further enhance the process by providing predictive analytics that aid in managing urban flows, such as traffic patterns and pedestrian movement (Parnell et al., 2023; He et al., 2024). Consequently, these innovations help address critical urban challenges like congestion, pollution, and energy efficiency, ultimately contributing to more sustainable and livable cities (Ferreira, 2024).

The main objective of this article is to conduct a comprehensive theoretical review and analysis of the role of digital technologies in shaping personalized architecture within urban environments. It aims to explore how digital tools can be utilized to develop unique, user-centric urban spaces that align with contemporary demands for sustainability and functionality. By examining technologies like BIM, AI, and IoT, this study seeks to provide insights into how these innovations facilitate the creation of tailored urban solutions that respond to diverse user needs (Mazetto, 2024; Boin et al., 2023). The focus will be on understanding how these technologies contribute to the design of adaptable urban spaces and how they can be integrated into existing city planning frameworks to enhance urban resilience and quality of life (Малышев et al., 2021).

While digital technologies offer substantial benefits, their implementation in urban architecture is fraught with challenges that can impede progress. High costs are among the most significant barriers, as the installation, maintenance, and operation of digital systems require substantial financial resources. For instance, IoT infrastructure involves the deployment of extensive networks of sensors, communication devices, and data management systems, all of which can be prohibitively expensive for many cities, especially those in developing countries (Parnell et al., 2023). Similarly, AI-driven design tools demand considerable investment in both hardware and software, as well as the training of personnel capable of managing and operating such systems effectively (Söllner et al., 1993). In addition, there are concerns about data privacy and security, as the collection and analysis of vast amounts of user data are integral to the personalization process. This raises ethical questions regarding user consent, data ownership, and the potential misuse of personal information (Аманаков et al, 2024).

Another critical issue is the complexity of integrating digital systems into existing urban infrastructure. The retrofitting of buildings and public spaces to accommodate new technologies often requires significant structural modifications, which can be both time-consuming and costly. Furthermore, the lack of standardized protocols for digital architecture can result in compatibility issues between different systems, thereby reducing the efficiency and effectiveness of implementation (He et al., 2024; Boin et al., 2023). These challenges underscore the need for a balanced approach that combines the advantages of digital integration with strategies that address its limitations, such as developing cost-effective solutions, establishing clear data governance policies, and fostering interdisciplinary collaboration between architects, engineers, and policymakers (Ferreira, 2024; Малышев et al., 2021).

Materials and methods. *Materials.* The materials for this study include a comprehensive collection of recent literature, covering a range of sources such as scholarly articles, books, and analytical reports. These materials focus on cutting-edge technologies in architecture, specifically Building Information Modeling (BIM), Artificial Intelligence (AI), the Internet of Things (IoT), parametric design, and 3D printing. The selected sources provide insights into the theoretical foundations, practical applications, and impact of these technologies in creating personalized urban spaces. The literature encompasses both international studies and region-specific research, ensuring a diverse perspective on the integration of digital tools into architectural planning (Söllner et al., 1993; Parnell et al., 2023; Ferreira, 2024). This diverse set of materials serves as the basis for a detailed evaluation of the current state and future potential of personalized architecture.

Methods of Analysis. A systematic literature review was employed as the primary analytical method for this study. This approach involved collecting, organizing, and synthesizing existing research to identify patterns, trends, and gaps in the application of digital technologies to personalized architecture. The analytical method also included qualitative assessments, comparing the benefits and limitations of each technology with respect to adaptability, user-centric design, and sustainability. By evaluating different architectural solutions through this lens, the study aims to uncover how digital tools can enhance the personalization of urban spaces while addressing the challenges of implementation (Mazetto, 2024; Boin et al., 2023; Аманаков et al., 2024).

Results. The analysis reveals that personalized architectural solutions, driven by digital technologies, have proven effective in enhancing urban adaptability, ultimately contributing to the improved quality of urban environments. These technologies, particularly Building Information Modeling (BIM), Internet of Things (IoT), and Artificial Intelligence (AI), enable personalized spaces to be tailored to user needs while promoting sustainability and resource efficiency. Each of these technologies plays a critical role in redefining urban architecture, facilitating a more adaptive, interactive, and responsive environment.

Building Information Modeling (BIM) has emerged as a transformative tool in architecture, offering a comprehensive platform that integrates multiple aspects of building design and urban planning. It allows for the development of personalized architectural solutions through collaborative processes that include stakeholders such as architects, engineers, and urban planners. BIM's data-centric approach enables accurate modeling of structures, facilitating the inclusion of user-centric features during the design phase. For instance, the integration of BIM with real-time data sources allows for adjustments in design based on user preferences or changing environmental conditions. As a result, BIM fosters adaptability in urban projects, from residential complexes to public infrastructure, by providing a dynamic framework that aligns with user requirements while maintaining design integrity (Ghisleni, 2024; Мехдиев, 2024).

The Internet of Things (IoT) is integral to creating adaptive and personalized urban spaces, as it provides the data infrastructure necessary for real-time monitoring and control of urban systems. IoT devices, such as sensors, cameras, and meters, enable the continuous flow of data, which informs decision-making processes in urban management. For example, in smart buildings, IoT sensors can monitor environmental parameters like temperature, humidity, and air quality, allowing for automated adjustments to maintain optimal conditions. This adaptability not only enhances user comfort but also reduces energy consumption by responding to real-time data. In public spaces, IoT applications facilitate crowd management, traffic flow optimization, and efficient waste collection, making urban areas more responsive to user needs while promoting sustainability (Cheng et al., 2024).

Artificial Intelligence (AI) adds another dimension to personalized architecture by analyzing data patterns to forecast user behavior and infrastructure needs. AI-powered algorithms can process large volumes of data from IoT devices and BIM models to provide predictive insights for urban planning. This predictive capability enables urban planners to anticipate changes in user demand and adapt the infrastructure accordingly. For instance, AI can optimize public transportation routes based on real-time commuter data, ensuring efficient and user-friendly transit systems. Moreover, AI's role extends to energy management, where it optimizes consumption patterns, identifies anomalies, and suggests improvements, thereby contributing to the sustainability of urban spaces (Begishev et al., 2024).

However, while these technologies provide substantial benefits, several challenges remain in their implementation. One significant barrier is the high cost associated with deploying these digital systems, which includes the installation of sensors, software integration, and the training of personnel. Furthermore, the complexity of integrating BIM, IoT, and AI within existing urban infrastructure can be daunting, often requiring significant structural modifications and regulatory adaptations. Data privacy concerns also persist, particularly regarding the use of personal data collected through IoT devices and AI analytics, raising ethical questions about user consent and data security (Мехдиев, 2024; Cheng et al., 2024).

Despite these challenges, the advantages of implementing digital technologies in personalized architecture are evident. The shift towards adaptive and sustainable urban environments is marked by improved resource efficiency, reduced environmental impact, and enhanced user experience. By leveraging BIM, IoT, and AI, cities can create more resilient infrastructures that align with the goals of sustainable development and meet diverse user needs (Ghisleni, 2024; Begishev et al., 2024).

Examples of successful technology implementation

Recent urban projects in cities like Singapore, Barcelona, and Amsterdam highlight the effectiveness of digital technologies such as AI and IoT in creating adaptive urban environments. In Singapore, the integration of AI and IoT has been pivotal to the city's transformation into a "Smart Nation." Key initiatives include AI-driven traffic management systems that analyze real-time data from IoT sensors to optimize traffic flows, reduce congestion, and improve public transport efficiency. This has significantly enhanced commute times and overall urban mobility. The city has also employed IoT in waste management, using automated pneumatic waste collection systems to reduce emissions and improve efficiency (Begishev et al., 2024; Елисеев et al., 2025). In Barcelona, AI and IoT have been used extensively for sustainable urban management. AI applications are leveraged to optimize street lighting, reducing energy consumption by up to 30%. IoT sensors monitor waste bins, signaling when they are full, which enables AI to optimize waste collection routes, reducing fuel consumption and emissions. These initiatives demonstrate the potential of AI and IoT to create sustainable, adaptive solutions that respond directly to urban needs, enhancing both environmental sustainability and resource efficiency (Maheshwari, 2024). Similarly, Amsterdam has successfully integrated these technologies to improve its urban infrastructure. The city's "Living Lab" initiatives focus on using AI for energy management, particularly through smart grids that allow for real-time monitoring and distribution of energy. These grids integrate data from renewable sources, such as solar panels, to optimize energy usage based on real-time demand. IoT sensors embedded in public spaces monitor environmental conditions, such as air quality and noise levels, enabling adaptive responses that enhance citizen well-being and promote sustainable development (Чупин et al., 2023).

Analysis of benefits

The use of digital technologies in urban environments brings several advantages. Firstly, the adaptability of these technologies enhances urban resilience by enabling infrastructure to respond rapidly to changing needs. AI-driven predictive models help manage urban flows, reducing congestion, improving public transport, and optimizing energy consumption. For instance, real-time adjustments in traffic signal timings or energy management can improve urban efficiency, reduce delays, and lower costs (Елисеев et al., 2025; Maheshwari, 2024).

Secondly, the implementation of IoT in personalized architecture promotes resource efficiency. By providing precise, real-time data on resource usage—such as water, energy, and waste—IoT enables targeted interventions that reduce waste and emissions. This contributes to creating more sustainable urban spaces, aligning with global sustainable development goals (Begishev et al., 2024; Чупин et al., 2023).

Lastly, the integration of these technologies supports economic efficiency by lowering operational costs and increasing user satisfaction. The ability to adjust urban functions based on data-driven insights reduces the need for manual interventions and optimizes resource allocation. This has proven especially beneficial in cities like Amsterdam and Barcelona, where adaptive infrastructure has not only improved resource use but also generated economic opportunities by fostering innovation and attracting investments in smart technology sectors (Maheshwari, 2024).

Problematic aspects of technology implementation

Despite the advantages that digital technologies bring to personalized urban architecture, their implementation presents significant challenges. One of the primary barriers is high cost, as the deployment of IoT infrastructure, AI integration, and Building Information Modeling (BIM) requires substantial financial investment. These costs include hardware, software, maintenance, and specialized training for personnel. For many cities, especially those with limited budgets, such financial demands make it difficult to adopt these technologies widely, thereby limiting their effectiveness and scalability (Gupta et al., 2023).

Another challenge is the complexity of scaling digital solutions across different urban infrastructures. The integration of diverse technologies into existing, often outdated, urban systems can be cumbersome. Legacy infrastructure may require extensive modifications or upgrades to accommodate new technologies like IoT sensors and AI analytics, which often increases both the time and costs involved. Additionally, urban environments vary significantly in terms of design, regulations, and resource availability, further complicating the uniform application of digital technologies across cities. The lack of standardized frameworks for integrating AI and IoT also contributes to difficulties in achieving scalability, as each city may require custom solutions tailored to its unique infrastructural context (Söllner et al., 1993).

Moreover, data privacy concerns are critical in the implementation of these technologies. As IoT devices and AI systems collect vast amounts of personal and environmental data, safeguarding this information becomes a pressing issue. Cities must comply with stringent data protection laws, such as the General Data Protection Regulation (GDPR), to ensure that citizen data is securely stored and processed. However, achieving compliance can be complex, as it involves implementing advanced encryption, real-time monitoring, and secure data management systems, which add to the overall costs and resource requirements. In addition, the risk of cyberattacks is ever-present, necessitating robust cybersecurity measures to protect sensitive information and prevent breaches that could compromise both personal privacy and public safety (Филимонов et al., 2021).

Addressing these challenges requires a collaborative effort among urban planners, technology developers, and policymakers. Cost-effective solutions, standardization frameworks, and clear data governance policies are essential to overcome barriers and facilitate the broader adoption of digital technologies in personalized urban architecture. Continuous innovation and strategic investment will be necessary to ensure that these technologies contribute effectively to sustainable and adaptable urban environments (Hao, 2023).

Discussion. *Comparative analysis with existing research.* A comparison of the study's findings with existing research indicates that while many scholars recognize the transformative potential of digital technologies in personalized architecture, there are varying approaches to implementation. For instance, numerous studies emphasize the role of Building Information Modeling (BIM) and Artificial Intelligence (AI) in optimizing urban design, but there are different views on the extent of their adaptability and integration. Research on BIM tends to focus more on collaborative design and data-driven decision-making, with improvements in project efficiency and stakeholder engagement as core benefits. This aligns well with the study's results, which also highlight BIM's potential for personalized urban solutions. However, some researchers argue that BIM's effectiveness is often constrained by high costs, software complexity, and the need for extensive training, factors that are echoed in this study's findings.

Regarding AI and IoT, existing research often emphasizes their role in real-time data analysis and predictive modeling, which supports the creation of adaptive, responsive environments. AI, particularly, has been noted for its capacity to process vast data sets, enhancing urban decision-making and enabling features like real-time traffic management and energy optimization. This study's findings also highlight these advantages but underscore that the integration of AI into personalized architecture is often hindered by privacy concerns and the high computational resources required. Some studies have shown successful AI implementation in cities like Barcelona and Amsterdam, while others report challenges in integrating AI across diverse urban contexts due to the variability of infrastructure, regulatory frameworks, and resource availability.

Advantages and disadvantages of personalized architecture

The benefits of personalized architecture are well documented, both in this study and in existing literature. The primary advantage is the increased adaptability of urban spaces. By integrating digital tools, architects can create environments that are more responsive to user needs, facilitating the customization of public spaces, residential buildings, and infrastructure. For example, IoT sensors enable real-time adjustments in lighting, temperature, and ventilation, contributing to improved comfort and energy efficiency. Moreover, AI-based predictive models can forecast infrastructure needs, helping to optimize urban functions and reduce congestion, energy consumption, and waste.

Another significant advantage is enhanced sustainability. Digital technologies allow for better resource management, supporting efforts to minimize environmental impact. The use of AI for energy optimization, IoT for waste management, and BIM for efficient building designs all contribute to more sustainable urban environments. By enabling precise control over resource use, personalized architecture not only reduces waste but also promotes renewable energy integration and eco-friendly building materials.

However, the implementation of personalized architecture faces several disadvantages. The most prominent is the high cost of deploying digital solutions. Technologies like BIM, AI, and IoT require substantial investment in infrastructure, software, and training, making them inaccessible to cities with limited budgets. Additionally, the complexity of integration poses another challenge, as retrofitting existing infrastructure to accommodate new technologies often involves extensive modifications, leading to longer project timelines and increased costs.

Another critical disadvantage is the potential for ethical issues related to data privacy. The collection and analysis of personal data by IoT and AI systems raise concerns about data security and user consent. Ensuring compliance with data protection regulations, such as the GDPR, requires significant investment in cybersecurity measures, which can further complicate the implementation process. Moreover, there is a risk that data collected for urban optimization could be misused, leading to issues related to surveillance, discrimination, and exclusion.

Future prospects for development

The future of personalized architecture is promising, as advancements in digital technologies continue to evolve. AI algorithms are becoming more sophisticated, with the potential for improved predictive modeling, enabling more accurate forecasting of urban needs. For instance, AI could predict infrastructure failures before they occur, allowing for proactive maintenance that minimizes disruption. Additionally, AI's role in personalizing urban spaces could expand to include features like adaptive street layouts, dynamic public transport routes, and real-time air quality adjustments based on user needs.

The use of smart materials represents another avenue for enhancing personalized architecture. Smart materials, such as thermochromic glass and self-healing concrete, can be integrated into urban designs to provide adaptive responses to environmental changes. For example, thermochromic glass can adjust its transparency based on sunlight exposure, helping to maintain comfortable indoor temperatures while reducing energy consumption.

Robotic construction also offers significant potential for personalized architecture, particularly in terms of efficiency and customization. Robots can construct buildings faster, more accurately, and with less waste than traditional methods. They can also produce complex, user-specific designs that would be difficult or impossible to achieve with conventional techniques. As robotic construction becomes more advanced, it is likely to play a key role in future urban development, enabling more personalized and adaptable infrastructure.

Conclusion

The integration of digital technologies into urban architecture significantly impacts the adaptability and sustainability of urban environments, supporting the creation of personalized and user-centric spaces. The technologies examined in this study, including Building Information Modeling (BIM), Artificial Intelligence (AI), and the Internet of Things (IoT), have demonstrated their capacity to enhance the functionality, efficiency, and resilience of urban infrastructure. These tools enable real-time data collection and analysis, fostering adaptive responses to changing urban needs. BIM facilitates collaborative design processes, while AI improves decision-making by analyzing vast datasets, and IoT enhances real-time monitoring and management. Together, these technologies not only optimize urban spaces but also contribute to environmental sustainability by reducing energy consumption and waste. Despite the evident challenges—such as high costs, integration complexity, and data privacy concerns—the benefits of digital technologies in urban planning are substantial and transformative.

Further research should focus on the social and environmental dimensions of personalized architecture, exploring how digital technologies can be harnessed to address broader urban challenges such as social equity, environmental justice, and community engagement. Studies should also investigate how to make these technologies more affordable and scalable, potentially through innovations like open-source software, cost-effective sensors, and standardized frameworks for technology integration. Exploring the ethical implications of data collection and usage in personalized architecture is another crucial area for future research, particularly in relation to user consent, data security, and equitable access.

The findings of this study can inform the development of guidelines for implementing digital technologies in urban design. Urban planners, architects, and policymakers can use this research to formulate strategies that maximize the benefits of digital tools while mitigating their drawbacks. For instance, clear data governance policies, investment in cybersecurity, and the establishment of cost-sharing models for technology implementation could facilitate wider adoption of personalized architecture. Additionally, pilot projects in diverse urban settings could help refine digital solutions, ensuring that they are adaptable to various infrastructural contexts and capable of meeting the unique needs of different urban populations.

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ISSN2518-1726 (Online),
ISSN 1991-346X (Print)

Директор отдела издания научных журналов НАН РК *А. Ботанқызы*
Редакторы: *Д.С. Аленов, Ж.Ш.Әден*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 20.03.2025.
Формат 60х881/8. Бумага офсетная. Печать –ризограф.
20,0 п.л. Заказ 1.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19