IRSTI 06.52.17 **https://doi.org/10.58805/kazutb.v.1.26-782**

CHALLENGES AND OPPORTUNITIES IN MANAGING SMART CITY PROJECTS: A CASE STUDY OF KAZAKHSTAN' S URBAN TRANSFORMATION

[1]A. Galymzhanova, [2]S. Singh, [3]Sh. Sarkambayeva, [1]A. Boranbayeva, [3]A.Zh. Turegeldinova

[1]Kazakh National University named after al-Farabi, Almaty, Kazakhstan,
[2]University of Fiju, Republic of Fiju,
[3]Kazakh National Research Technical University named after K.I. Satpayev, Almaty, Kazakhstan,
Correspondent-author: sh.sarkambayeva@satbayev.university

The article discusses the problems and opportunities of introducing smart city technologies in Kazakhstan through the prism of project management. Key aspects such as infrastructure quality, sustainable development, data protection, citizen participation, government support and the introduction of innovative technologies are analyzed. Examples of successful projects in Kazakhstan, such as transport and lighting management systems, as well as the experience of international practices, including Singapore and Germany, are given.

The study highlights the importance of integrating sustainable solutions, reducing digital inequality, and ensuring citizen participation in digitalization processes. In addition, the need to adapt international models of project management to the socio-economic and cultural characteristics of Kazakhstan is noted. Quantitative and qualitative analysis methods are used, including surveys, expert interviews and data visualization, which allows us to identify the interrelationships between various aspects of the implementation of smart city projects.

The practical significance of the article lies in the development of recommendations for public and private organizations aimed at improving the effectiveness of stakeholder interaction, stimulating citizen participation in digital transformation and creating conditions for sustainable urban development. The findings of the study can serve as a basis for strategic planning and decision-making in the field of smart city project management in Kazakhstan.

Keywords: smart cities, project management, urban transformation, Kazakhstan, sustainable development, governance models, technological innovation, stakeholder collaboration, public-private partnerships.

"АҚЫЛДЫ ҚАЛА" ЖОБАЛАРЫН БАСҚАРУДАҒЫ ҚИЫНДЫҚТАР МЕН МҮМКІНДІКТЕР: ҚАЗАҚСТАННЫҢ ҚАЛАЛЫҚ ТРАНСФОРМАЦИЯСЫНЫҢ ЖАҒДАЙЛЫҚ ЗЕРТТЕУІ

[1]А. Ғалымжанқызы, [2]С. Сингх, [3]Ш. Сарқамбаева, [1]А. Боранбаева, [3]А.Ж. Төрегелдинова

[1]Әл-Фараби атындағы Қазақ Ұлттық Университеті, Алматы, Казақстан,
[2]Фиджи университеті, Фиджи Республикасы,
[3]Қ.И. Сәтбаев атындағы Қазақ Ұлттық Техникалық Зерттеу Университеті, Алматы, Казақстан,
e-mail: sh.sarkambayeva@satbayev.university

Мақалада жобалық басқару призмасы арқылы Қазақстанда ақылды қала технологияларын енгізу мәселелері мен мүмкіндіктері қарастырылады. Инфрақұрылымның сапасы, орнықты даму, деректерді қорғау, азаматтардың қатысуы, мемлекетті қолдау және инновациялық технологияларды енгізу сияқты негізгі аспектілер талданады. Қазақстанда көлік пен жарықтандыруды басқару жүйелері сияқты табысты жобалардың мысалдары, сондай-ақ Сингапур мен Германияны қоса алғанда, халықаралық тәжірибелердің тәжірибесі келтіріледі.

Зерттеу тұрақты шешімдерді біріктірудің, цифрлық теңсіздікті төмендетудің және азаматтардың цифрландыру процестеріне қатысуын қамтамасыз етудің маңыздылығын көрсетеді. Бұдан басқа, жобалық басқарудың халықаралық модельдерін Қазақстанның әлеуметтік-экономикалық және мәдени ерекшеліктеріне бейімдеу қажеттілігі атап өтіледі. Сандық және сапалық талдау әдістері, соның

ішінде сауалнамалар, сараптамалық сұхбаттар және деректерді визуализациялау қолданылады, бұл ақылды қала жобаларын жүзеге асырудың әртүрлі аспектілері арасындағы байланысты анықтауға мүмкіндік береді.

Мақаланың практикалық маңыздылығы мүдделі тараптардың өзара іс-қимылының тиімділігін арттыруға, азаматтардың цифрлық трансформацияға қатысуын ынталандыруға және тұрақты қала дамуы үшін жағдай жасауға бағытталған мемлекеттік және жеке ұйымдар үшін ұсынымдар әзірлеу болып табылады. Зерттеу қорытындылары Қазақстандағы ақылды қалалардың жобаларын басқару саласында стратегиялық жоспарлау мен шешім қабылдау үшін негіз бола алады.

Түйін сөздер: ақылды қалалар, жобаларды басқару, қалаларды трансформациялау, Қазақстан, тұрақты даму, басқару модельдері, технологиялық инновациялар, мүдделі тараптардың ынтымақтастығы, мемлекеттік-жекеменшік әріптестік.

ПРОБЛЕМЫ И ВОЗМОЖНОСТИ В УПРАВЛЕНИИ ПРОЕКТАМИ ”УМНОГО ГОРОДА”: НА ПРИМЕРЕ ТРАНСФОРМАЦИИ ГОРОДОВ КАЗАХСТАНА

[1]А. Галымжанова, [2]С. Сингх, [3]Ш Саркамбаева✉, [1]А. Боранбаева, [3]А.Ж. Турегельдинова

[1]Казахский национальный университет имени аль-Фараби, Алматы, Казахстан,
[2] Университет Фиджи, Республика Фиджи,
[3]Казахский национальный исследовательский технический университет имени К.И. Сатпаева, Алматы, Казахстан,
e-mail: sh.sarkambayeva@satbayev.university

В статье рассматриваются проблемы и возможности внедрения технологий умного города в Казахстане через призму проектного управления. Анализируются ключевые аспекты, такие как качество инфраструктуры, устойчивое развитие, защита данных, участие граждан, поддержка государства и внедрение инновационных технологий. Приводятся примеры успешных проектов в Казахстане, таких как системы управления транспортом и освещением, а также опыт международных практик, включая Сингапур и Германию.

Исследование подчеркивает важность интеграции устойчивых решений, снижения цифрового неравенства и обеспечения участия граждан в процессах цифровизации. Кроме того, отмечается необходимость адаптации международных моделей проектного управления к социально-экономическим и культурным особенностям Казахстана. Используются методы количественного и качественного анализа, включая опросы, экспертные интервью и визуализацию данных, что позволяет выявить взаимосвязи между различными аспектами реализации проектов умных городов.

Практическая значимость статьи заключается в разработке рекомендаций для государственных и частных организаций, направленных на повышение эффективности взаимодействия заинтересованных сторон, стимулирование участия граждан в цифровой трансформации и создание условий для устойчивого городского развития. Выводы исследования могут служить основой для стратегического планирования и принятия решений в области управления проектами умных городов в Казахстане.

Ключевые слова: умные города, управление проектами, городская трансформация, Казахстан, устойчивое развитие, модели управления, технологические инновации, сотрудничество с заинтересованными сторонами, государственно-частное партнерство.

Introduction. Digital transformation of cities is an essential component of sustainable development, and its implementation through project management is the key to improving the efficiency and quality of the urban environment. With increasing urbanization and the need to optimize resource management, Kazakhstan is striving to create smart cities that integrate digital technologies to improve the quality of life, sustainability, and economic development.

The concept of a ”smart city” has become an important part of the strategy for the development

of cities around the world in recent decades. It involves the use of innovative technologies such as the Internet of Things (IoT), big data, blockchain and artificial intelligence to improve the quality of life, increase economic efficiency and ensure the sustainability of urban systems. In Kazakhstan, elements of a smart city include intelligent transport management projects, automated utility systems and e-government. For example, in Astana, the Smart Astana program is being implemented, which covers intelligent lighting, parking management and digitalization of public services.

However, the introduction of such technologies requires not only significant financial resources, but also high-quality project management. For Kazakhstan, where the process of transformation from a post-Soviet management system to a modern one is underway, this direction is especially relevant, since it intersects with the tasks of increasing transparency, strengthening citizens' trust and sustainable development.

According to McKinsey, cities that have implemented digital solutions can improve the quality of life of citizens by 10-30% by reducing emissions, improving safety and improving transport accessibility. Smart cities also contribute to sustainable development – they provide improved energy management, which can reduce energy consumption by 15-25% [1].

According to UN DESA, global investments in smart cities amount to about $124 billion and continue to grow by 18-20% annually. Kazakhstan, which actively attracts international investments, needs effective project management models to ensure sustainability and integration of innovations into the urban environment [2].

According to the World Bank, the level of urbanization in Kazakhstan reached approximately 58% in 2023, reflecting the rapid growth of the urban population and the need to modernize urban infrastructure. Forecasts show that by 2030 this figure could rise to 65%, which creates a serious burden on urban systems and increases the need for sustainable solutions [3].

In 2017, Kazakhstan adopted the Digital Kazakhstan program aimed at digitalization of all spheres, including urban governance. However, successful implementation requires design approaches that take into account complex challenges such as security, sustainable use of resources, digital inequality and public participation [4].

According to UN reports, cities generate more than 70% of global CO_2 emissions, and in Kazakhstan, greenhouse gas emissions also remain high due to the dominance of traditional energy. The use of smart city technologies, such as smart energy systems, can reduce emissions by 15-20%, which is in line with Kazakhstan' s sustainable development goals to reduce its carbon footprint.

According to IHS Markit estimates, global investments in smart cities will amount to more than $327 billion by 2025, and this area continues to develop rapidly. Kazakhstan is actively attracting investors, and projects within the framework of smart cities can increase capital inflows, as well as create up to 100,000 new jobs related to IT and engineering in the next 10 years.

According to the OECD, about 40% of Kazakhstanis in rural areas still do not have stable access to high-speed Internet, which is an obstacle to the full implementation of digital solutions. Eliminating digital inequality in cities and minimizing it in suburban areas are important aspects for successful digital transformation.

Pilot smart city projects have already been initiated in Uzbekistan and Kazakhstan, including projects on transport management and street lighting, which have shown an improvement in reducing energy consumption by 25% and reducing congestion by 10-15% in Almaty. The expansion of such projects, with the support of integrated project management, will allow Kazakhstan to take a leading position in digital transformation among the countries of Central Asia.

The main research question is formulated as follows: *How can international approaches to smart city project management be adapted for implementation in Kazakhstan, taking into account its socio-economic, cultural and infrastructural*

features?

The purpose of the research is to analyze the problems and opportunities that arise in the process of implementing smart city projects in Kazakhstan, as well as to develop recommendations for adapting international smart city project management models in order to increase their efficiency and sustainability in Kazakhstan cities.

The object of the study is the processes of smart city project management, including the introduction of innovative technologies and management systems into urban infrastructure, as well as their adaptation in the conditions of Kazakhstan.

The scientific novelty of this study lies in a systematic approach to analyzing problems and opportunities in the context of the specific realities of Kazakhstan, which allows for a deeper understanding of the specific barriers and opportunities for the successful implementation of smart cities in developing countries. The study also expands existing approaches in project management, offering additional strategies and recommendations for effective management of digitalization processes and sustainable urban development.

The practical value of the research lies in the development of proposals for public and private organizations that are engaged in the design and implementation of smart city initiatives. The proposed recommendations will help improve interaction between stakeholders, stimulate citizen participation in the digital transformation process and create conditions for sustainable urban development. It also contributes to improving the social and environmental sustainability of urban spaces and increasing the quality of life of citizens.

Literature Review. In order to improve the quality of life for its inhabitants and handle the complexity of persistent issues with urban settings, smart city initiatives are being supported globally [5]. Additionally, cities are being pressured to fulfill their part in tackling new global issues including resilience [6], decarbonization [7], and sustainability [8]. The creation of more sustainable infrastructure, new transportation paradigms [9,10], smart urbanism [11], public participation [12,13], municipal governance [14], or sustainability [15] are only a few of the many areas of activity that are included in smart city efforts. In terms of their goals, innovative methodologies, key technologies, priorities, or the characteristics of the urban environments in which they are implemented, these programs can take many different forms. Nevertheless, they all agree that digital technologies have the capacity to revolutionize urban life and serve as the primary facilitator for a constructive, forward-thinking, and long-lasting influence [16].

Nonetheless, there are indications of dissatisfaction with the tangible results of smart city projects [17,18] as well as opposition to what is increasingly thought to be an overabundance of corporate control over technology in urban areas [19]. Regardless of one' s overall political stance on smart cities, it appears reasonable to acknowledge that, thus far, the actual outcomes may be viewed as being rather constrained in relation to the corresponding investments and the stated aspirations. More precisely, it becomes evident from the standpoint of digital innovation that the rate of invention is substantially slower than in other fields where important characteristics of digital innovation, including generativity and convergence, have sparked swift and profoundly disruptive changes [20].

Trindade et al. [21] discussed the connection between the ideas of smart cities and sustainability, arguing that the latter can be effectively facilitated by the former as a concept and set of activities. In order for future investments to be justified by socioeconomic needs and environmental concerns rather than technological advancement and industrial competitiveness, Bibri and Krogstie [22] emphasize the necessity of connecting the development and innovation of information and communication technology (ICT) with sustainable development. According to Yigitcanlar et al. [8], cities cannot be smart unless they are sustainable. They explain a conflict between the objectives of sustainable urban development and the shared dreams of smart cities. Bibri [23] emphasizes the potential for using big data analytics to meet

sustainable development objectives, but she also recommends that researchers concentrate more on pinpointing practical problems and specific knowledge gaps. Ramaswami et al. [15] also discuss this link between data science and urban sustainability, arguing that smart city programs need to go beyond city-level data to a higher-order understanding of cities as transboundary systems with a variety of players, priorities, and solutions. A review by Ben Letaifa [24] indicates that when developing plans for smart cities, macro, mezzo, and micro aspects should be taken into account. It also offers a methodological framework for the implementation of smart cities.

Meijer and Bolívar' s review [14] discusses smart city administration. From straightforward institutional arrangements to more radical conceptualizations where the government itself must be changed to create a smart city, the authors identify various conceptualizations of smart city governance that vary in the degree of government transformation required to make cities smarter. Of the 20 drivers for smart city innovation and their prioritization identified in the analysis by Guedes et al. [25], 15 are mostly concerned with city government, while the remaining 5 are related to technology.

In order to better comprehend the difficulties faced by smart city programs, we examine a digital innovation lens in this study. In order to determine if smart city projects can truly create an environment of open and flexible affordances that fosters innovations that are characterized by convergence and generativity, we expand on the essential features of digital technology as suggested by Yoo et al. [20]. Understanding how much the primary obstacles to smart city initiatives might all be distinct expressions of a single issue stemming from a misalignment between smart city innovation practices and the fundamental ideas that drove digital innovation' s rapid success in other fields is the main driving force.

According to a study published in the MDPI Smart Cities journal, smart cities use digital technologies and data analysis to improve the quality of life of citizens, improve the efficiency of infrastructure and services, and stimulate sustainable economic growth. The review examined the definition of smart cities, their advantages and disadvantages, as well as key implementation challenges, including issues of data privacy and digital inequality.

Research at IEEE Xplore analyzes key challenges and opportunities in smart city project management. Special attention is paid to the need for an integrated management approach that unites the public and private sectors. Among the main challenges are shortcomings in the regulatory framework, financial instability and poor coordination between stakeholders.

Other researches have noted that smart cities contribute to achieving sustainable development goals, including reducing carbon dioxide emissions, improving energy efficiency and improving transport accessibility. However, issues such as digital inequality and cybersecurity remain relevant.

Agueda Veloso, Fernando Fonseca, Ru Ramos (2024) analyze examples of the implementation of smart cities in Singapore, Barcelona, Helsinki and Medellin. The main focus is on sustainable development, where it is noted that most projects focus on management and environmental aspects. The study highlights the need for more holistic approaches to address the complex challenges of urbanization and the introduction of standardized assessment methods [26].

An analysis of the existing literature shows that smart city project management is a complex interdisciplinary field that requires the integration of technology, sustainable development, social participation and effective management. Research by foreign authors (Giffinger et al., Komninos, Allam) focuses on the general concepts of smart cities, such as technology adoption, urban sustainability and public participation [27]. They emphasize the importance of strategic planning and the availability of criteria for evaluating the effectiveness of smart cities.

Kazakh literature, on the contrary, focuses on the practical aspects of the implementation of the Digital Kazakhstan program and local challenges.

The main problems include a lack of resources, poor coordination between agencies, digital inequality, and low infrastructure availability.

A significant gap is the lack of unified approaches to managing smart city projects adapted to the conditions of Kazakhstan. Foreign studies offer examples of successful management models, but they require localization. Also, insufficient attention is paid to the integration of innovations into the social sphere, which is critically important for Kazakhstan with its high degree of urbanization.

Thus, further research should be aimed at developing adapted smart city project management models that take into account local challenges and international experience. This will create the basis for the sustainable and inclusive development of the urban environment.

The process of implementing smart city projects in Kazakhstan faces a number of problems, such as insufficient coordination between various public and private institutions, lack of qualified personnel, insufficient financing and technical immaturity of infrastructure. These problems create barriers to the effective implementation of innovative solutions in the urban environment and hinder the development of sustainable and smart cities, which requires the development of adapted project management models to improve management and ensure the sustainability of these projects in Kazakhstan.

Materials and methods. The study used methods of qualitative and quantitative analysis to study the problems and opportunities of smart city project management using the example of Kazakhstan. Interviews with experts, surveys of urban residents on their readiness to implement smart technologies, as well as an analysis of existing literature with an emphasis on local and international features were used to collect data. Additionally, a case method was used to analyze implemented projects, and a comparative analysis made it possible to compare successful initiatives of Kazakhstan with international experience. The data was processed using graphical visualization, including the construction of histograms, pie charts and tables, which made it possible to classify and rank key categories such as infrastructure, sustainable development, data security, digital inequality, government support and innovative technologies. This approach provided an in-depth analysis and identification of the interrelationships between various aspects of the implementation of smart city projects.

Results and discussions. Various methods suitable for the analysis of both qualitative and quantitative data were used to study the problem ”Problems and opportunities in the management of smart City projects: on the example of the transformation of cities in Kazakhstan”. The methods include interviews with experts, questionnaires, comparative analysis, case-stage method and analysis of existing literature. The following techniques were used to collect, process and analyze data.

A histogram showing the readiness of residents of different cities of Kazakhstan to implement intelligent technologies. The chart shows the percentage of respondents who are ready to implement smart city solutions in each city. Figure 1 shows the proportion of respondents who said that they were prepared to implement smart city technology from five different cities: Almaty, Nur-Sultan, Shymkent, Karaganda, and Aktobe. With 50% of respondents indicating a readiness to adopt smart city solutions, Aktobe has the highest rate among these cities. At 45%, Shymkent comes in second, showing a high level of preparation as well.

At 40%, Almaty, a significant Kazakh city, exhibits a moderate level of preparedness. The capital city of Nur-Sultan, on the other hand, has a somewhat lower ratio of 35%, indicating a less enthusiastic but still noticeable preference for smart city efforts. However, only 30% of respondents said they were in favor of using such technologies, making Karaganda the least prepared city in the study.

These discrepancies can be the result of disparities in local government initiatives, municipal infrastructure, public understanding of the advantages of smart cities, and technology accessibility. While places like Karaganda could need more focused efforts to raise awareness and

readiness, communities like Aktobe and Shymkent might have customized programs or favorable settings that spark greater enthusiasm.

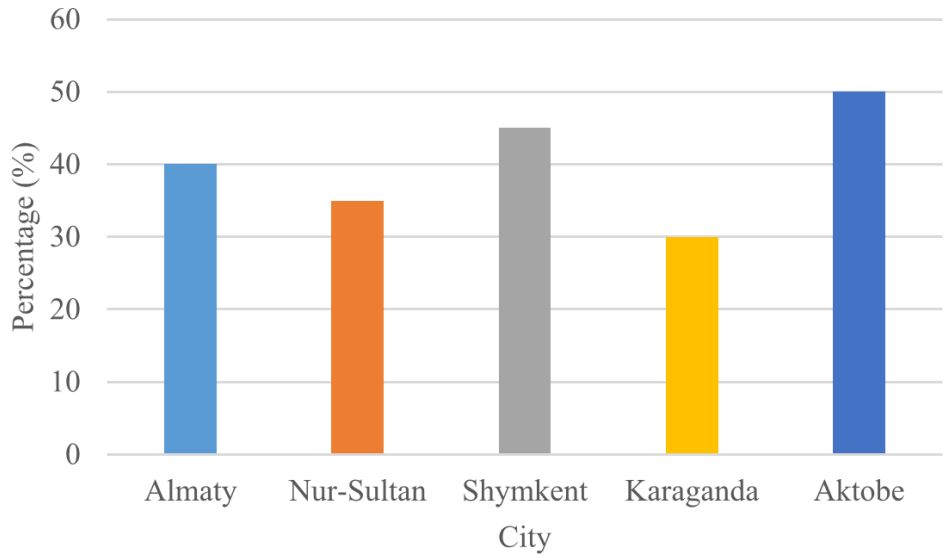

Fig. 1 - The percentage of respondents who said that they were prepared to implement smart city technology

(compiled by the authors based on [28])

Figure 2 shows a prioritizing of features depending on respondent preferences, highlighting the perceived relevance of different parts of smart cities. With 30% of respondents highlighting its significance, security stands out as the most important factor. This illustrates how safety, which includes emergency response systems, crime prevention technology, and surveillance systems, is widely acknowledged as a fundamental component of smart cities.

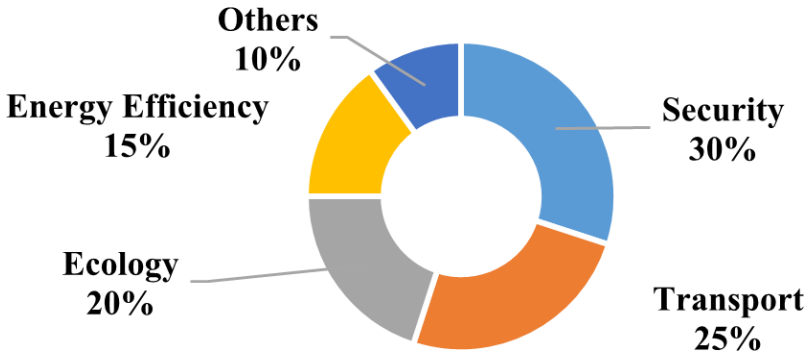

Fig. 2 - Prioritizing of features depending on respondent preferences

(compiled by the authors based on [28])

Transport received 25% of the replies, making it the second most important factor. Enhancing mobility and lowering urban congestion, a major issue for many cities, requires sophisticated and efficient transportation systems, such as integrated public transit options and real-time traffic management.

With 20% of respondents emphasizing its

importance, ecology comes in third. In order to solve environmental issues and guarantee a higher standard of living, smart city solutions aimed at ecological sustainability such as waste management, air quality monitoring, and green urban planning are essential.

15% of respondents said that energy efficiency was a top priority, which is consistent with the increased focus on lowering energy use through the use of smart grids and energy-efficient infrastructure. Both environmental preservation and economic viability depend on this factor.

Lastly, 10% of respondents said that other factors such as governance, healthcare, education, and cultural initiatives were important. Despite getting less emphasis, these components support a smart city' s overall growth.

In order to produce secure, effective, and livable urban places, the data highlights the complexity of smart city development and the necessity to balance security, mobility, ecological sustainability, energy efficiency, and other factors.

The number of successful smart city initiatives in the USA, Germany, Singapore, South Korea, and Kazakhstan is shown in Figure 3. The information highlights Kazakhstan' s comparative position and offers insight into the adoption and execution of smart city programs worldwide.

With 12 successful smart city initiatives, the USA leads the world and demonstrates its leadership in implementing cutting-edge urban technologies. These initiatives, which are supported by significant expenditures and a robust innovation environment, probably include a range of topics, including energy management, smart transportation, and security systems.

Germany comes in second with ten projects, demonstrating its focus on fusing environmental principles with smart technology. In keeping with its larger commitment to environmental sustainability, Germany frequently uses smart grids, eco-friendly urban planning, and green infrastructure.

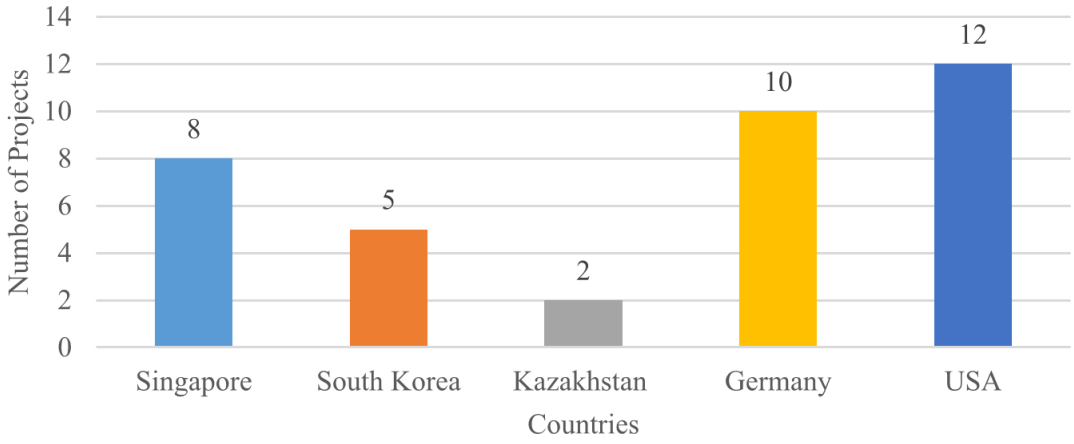

Fig. 3 - The number of successful smart city initiatives in the USA, Germany, Singapore, South Korea, and Kazakhstan

(compiled by the authors based on [28])

With eight initiatives, Singapore is a prime example of a tiny yet incredibly effective smart city deployment approach. Singapore, which is well-known for its extensive Smart Nation effort, positions itself as a global leader in urban innovation by utilizing technology for government, healthcare, and transportation.

With five projects, South Korea has made significant progress in incorporating technology into urban life. As evidenced by centers like Songdo International Business District, its initiatives frequently focus on building futuristic, highly connected cities.

Kazakhstan is just beginning to implement smart

city technologies, having completed two successful initiatives. Even if it behind the other countries, its efforts are a significant step in the direction of modernization and technical development. Kazakhstan might benefit from more funding, international cooperation, and laws that give priority to smart urban infrastructure in order to catch up.

The comparison emphasizes that although Kazakhstan has made only modest progress, there are important lessons to be learned from the experiences of nations like the USA, Germany, and Singapore. Kazakhstan has the ability to accelerate its smart city ambitions and support the global push towards smarter, more sustainable urban places by implementing best practices and customizing them to its local circumstances.

Figure 4 shows the frequency of mentions of various key categories related to the development of smart cities in the context of the transformation of cities in Kazakhstan. The following paragraphs summarize the conclusions drawn from the graph.

The quality of smart city infrastructure (The most frequently mentioned category):

This category is the most frequently discussed, which highlights the critical importance of infrastructure quality in the development of smart cities. It includes aspects such as transportation systems, power grids and urban services that are necessary for the successful implementation of any smart city initiative.

Sustainable development and ecology:

The frequent mention of sustainable development highlights the importance of integrating environmental issues into smart city projects. This includes addressing issues of clean energy, waste management, water conservation and other environmentally sustainable practices, which is a priority at the global level.

Data security issues:

Data security issues also occupy a prominent place, which indicates the difficulties associated with managing and protecting the huge amount of data generated by smart city systems. With the widespread use of the Internet of Things (IoT) and digital platforms, protecting citizens' data and ensuring privacy are becoming key issues.

Public participation and digital inequality:

Frequent mention of this category indicates the need to ensure broad access to smart city technologies and involve citizens in decision-making processes. It also raises issues of digital inequality, which may deepen if appropriate measures are not taken.

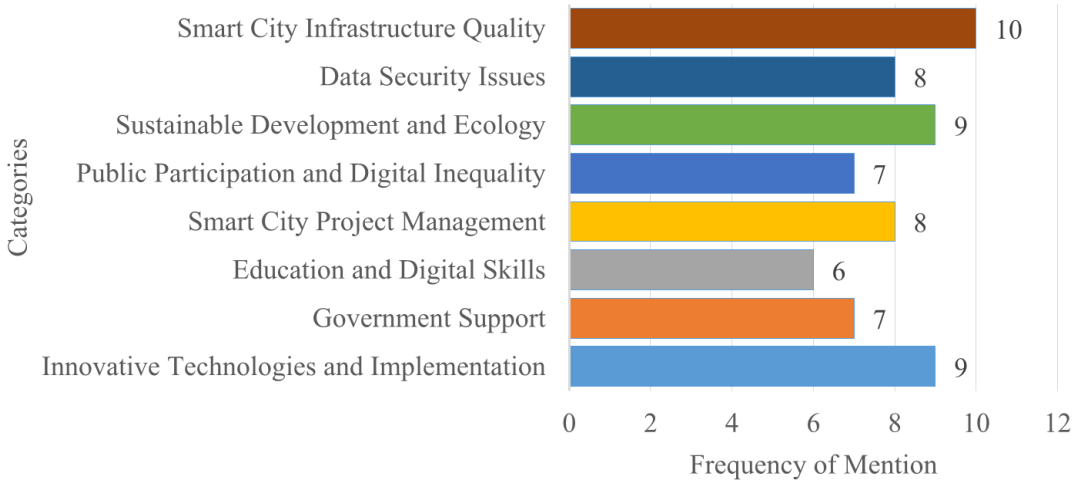

Fig. 4 - Frequency of mentions of various key categories related to the development of smart cities

(compiled by the authors based on [28])

Smart City Project Management:

The mention of project management suggests that effective management strategies are needed for the successful implementation of smart city projects, especially when integrating innovative technologies and coordinating between different sectors.

Government support:

Government support plays an important role in the development of smart cities, including the creation of regulatory norms, financing and promotion of public-private partnerships. Without stable government support, such projects are difficult to implement and maintain for a long time.

Innovative technologies and their implementation:

The mention of innovative technologies confirms the importance of using advanced technologies such as artificial intelligence, big data and the Internet of Things to solve urban problems. However, their successful implementation requires careful adaptation to local conditions and effective application.

Education and digital skills (A less frequently mentioned category):

Interestingly, education and digital skills are mentioned less frequently, which may indicate that although technology plays an important role, there is a certain gap in the field of digital literacy of the population. Providing the necessary training for the workforce and citizens is critical for the successful implementation of smart city technologies.

The graph illustrates that the key challenges in the development of smart cities in Kazakhstan are focused on infrastructure, sustainable development and data security. However, there are also areas that require more attention, such as education and digital inequality. These findings can serve as a basis for future policy decisions and research aimed at a more balanced and inclusive approach to smart city development.

Within the framework of the study on the problems and opportunities of smart city project management using the example of the transformation of cities in Kazakhstan, several key aspects were analyzed, including infrastructure quality, sustainable development, data security issues, public participation, project management and government support. Both qualitative and quantitative data presented in the form of tables, graphs and diagrams were used to interpret the results.

1. The quality of the smart city infrastructure

Table 1 - Frequency of mentioning factors related to infrastructure quality

Category	Frequency of mention
Transport systems	35
Energy supply and energy saving	28
Water supply and sanitation	22
Smart buildings and residential complexes	18

Table 2 - Frequency of mentioning data security issues in smart cities

Data security issue	Frequency of mention
Protection of personal data	40
Cyber threats and hacks	33
IoT Infrastructure Protection	25
Threats of information leaks	22

We analyzed the frequency of mentioning factors related to infrastructure quality (Table 1). The greatest attention in the context of infrastructure quality is paid to transport systems, which is explained by the need to solve transport problems such as traffic jams and the lack of environmentally friendly transport. Energy supply and energy conservation occupy the second place, due to the growing interest in sustainable and energy efficient solutions in cities.

2. Sustainable development and ecology

Sustainable development is an important topic in the development of smart cities, which is confirmed by the high frequency of mentioning environmental technologies. The greatest attention is paid to the introduction of green technologies, such as solar panels and waste recycling systems. This is also due to the need to minimize the impact on the environment in conditions of rapid population growth and urbanization.

3. Data security issues

The list of data security issues in smart cities with their frequency of mention are presented in Table 2. Data security issues are central to the challenges faced by smart cities. The protection of citizens' personal data is especially important, which is becoming critical due to the increased use of the Internet of Things (IoT) and the collection of big data. Problems with cyber threats and infrastructure protection also require increased attention, given the vulnerability of digital systems in smart cities.

4. Public participation and digital inequality

Public participation and digital inequality are important aspects in the management of smart city projects. It is important to ensure access to technology for all segments of the population in order to avoid a widening digital divide. The high frequency of mentioning these issues indicates the need to create inclusive and accessible solutions for all citizens.

5. Smart City Project Management

Table 3 - Frequency of mentioning project management issues

The problem of project management	Frequency of mention
Coordination between sectors	38
Lack of qualified personnel	30
Development of implementation strategies	25
Risk and cost assessment	20

Table 4 - Frequency of mentioning innovative technologies

Innovative technology	Frequency of mention
Artificial intelligence and machine learning	45
Big Data and Analytics	40
Internet of Things (IoT)	35
Smart sensors and monitoring	30

The main challenge in managing smart city projects is coordination between different sectors such as transport, energy, ecology and security (Table 3). The lack of qualified personnel and the lack of clear technology implementation strategies also play a significant role in the successful implementation of such projects.

6. Government support

Government support plays an important role in the successful implementation of smart city projects. In particular, financing, regulatory creation and support for public-private partnerships play a crucial role. The emergence of new forms of government support, such as subsidies for environmental technologies or tax incentives for start-ups, contributes to the acceleration of digitalization processes.

7. Innovative technologies and their implementation

Innovative technologies play a key role in creating smart cities. According to Table 4, the greatest attention is paid to artificial intelligence and machine learning, which make it possible to effectively manage resources and make decisions based on big data analysis. The Internet of Things (IoT) is also an integral part of smart cities, creating a network of connected devices for data collection and processing.

Kazakhstan' s Energy consumption that comes from renewables [28]**.** The information supplied about Kazakhstan' s principal energy contributions from nuclear and renewable sources has important ramifications for the growth of smart cities. Figure 5 shows the dynamics of Kazakhstan' s Energy consumption that comes from renewables since 1985. Renewable energy has demonstrated a more dynamic trajectory, whereas nuclear energy has played a minor role, with minimal contributions throughout the early 1990s and total absence after 1999. The percentage of renewables started out slowly in 1985 at 1.94%, reached a peak of 6.12% in 2002, and then fluctuated before stabilizing at 4.52% in 2023.

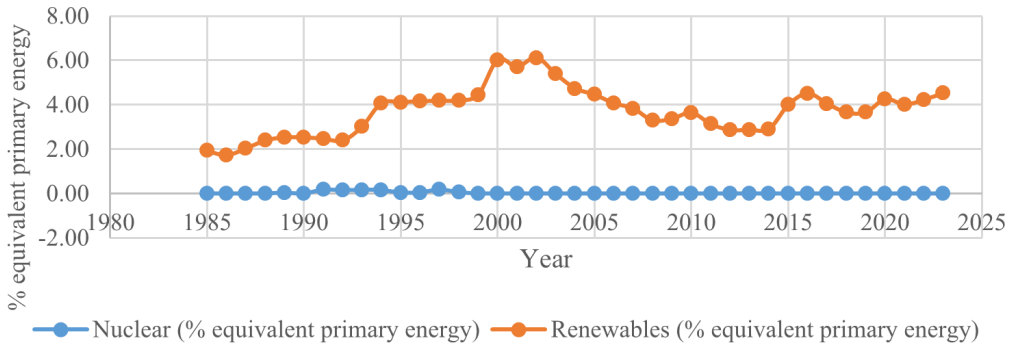

Fig. 5 - Kazakhstan' s Energy consumption that comes from renewables

(compiled by the authors based on [28])

The growing focus on renewable energy is a crucial component of smart cities, which place a high priority on sustainability, energy efficiency, and low-carbon solutions. The 2002 peak points to early investments in renewable energy, which may have been prompted by legislative measures or advances in technology. The ensuing drop and patchy expansion, however, point to difficulties in growing and maintaining renewable infrastructure, maybe as a result of financial or regulatory limitations.

The success of Kazakhstan' s smart cities depends on a more comprehensive and varied energy plan. Energy efficiency and dependability may be improved by incorporating cutting-edge technology like smart grids, IoT-based energy management, and AI-driven renewable forecasting. Furthermore, the lack of nuclear energy represents a lost chance for reliable, low-carbon baseload electricity that might be used in conjunction with renewable energy sources in a smart city framework.

In the future, Kazakhstan' s cities must make steady investments in renewable energy a top priority while investigating cutting-edge options like decentralized energy generation and energy storage systems. By lowering reliance on fossil fuels and ensuring a robust and sustainable energy base, these actions would support global smart city goals.

Table 5 - Share of various energy sources in Kazakhstan

Year	Nuclear (% equivalent primary energy)	Renewables (% equivalent primary energy)	Fossil fuels (% equivalent primary energy)
1985	0.00	1.94	98.06
1986	0.00	1.74	98.26
1987	0.00	2.04	97.96
1988	0.00	2.40	97.60
1989	0.03	2.54	97.43
1990	0.00	2.53	97.47
1991	0.18	2.48	97.34
1992	0.16	2.40	97.45
1993	0.17	3.02	96.82
1994	0.16	4.07	95.77
1995	0.04	4.11	95.85
1996	0.05	4.16	95.79
1997	0.19	4.18	95.63
1998	0.06	4.19	95.75
1999	0.00	4.46	95.54
2000	0.00	6.02	93.98
2001	0.00	5.70	94.30
2002	0.00	6.12	93.88
2003	0.00	5.38	94.62
2004	0.00	4.73	95.27
2005	0.00	4.46	95.54
2006	0.00	4.07	95.93
2007	0.00	3.83	96.17
2008	0.00	3.30	96.70
2009	0.00	3.38	96.62
2010	0.00	3.64	96.36
2011	0.00	3.13	96.87
2012	0.00	2.87	97.13
2013	0.00	2.88	97.12
2014	0.00	2.92	97.08

2015	0.00	4.00	96.00
2016	0.00	4.51	95.49
2017	0.00	4.05	95.95
2018	0.00	3.66	96.34
2019	0.00	3.66	96.34
2020	0.00	4.26	95.74
2021	0.00	4.01	95.99
2022	0.00	4.23	95.77
2023	0.00	4.52	95.48

The information on Kazakhstan' s energy mix (Table 5) that has been supplied emphasizes the country' s heavy reliance on fossil fuels and its gradual decline over time, highlighting both the opportunities and significant obstacles in the country' s transition to sustainable energy systems for the development of smart cities. Up until the early 2000s, fossil fuels continuously supplied more than 95% of the equivalent primary energy, reaching a high of 98.26% in 1986. During the same time span, fossil fuel dependence decreased slightly to 93.88%, while renewable energy contributions climbed steadily from 1.94% in 1985 to 6.12% in 2002. Since then, the percentage of fossil fuels has remained dominant, dropping just marginally to 95.48% in 2023.

Fossil fuel dependence presents serious sustainability issues for smart cities, such as resource depletion, air pollution, and greenhouse gas emissions. Reducing reliance on fossil fuels is crucial because smart cities seek to use cutting-edge technologies to maximize energy efficiency and make the switch to low-carbon systems. The data shows that although there has been some progress in integrating renewable energy, it has not happened quickly enough to significantly reduce dependency on fossil fuels.

The following are important tactics for smart cities to hasten the elimination of fossil fuels:

1. Improved Renewable Integration: Reliance on fossil fuels can be decreased by increasing the use of renewable energy sources including solar, wind, and hydroelectric power in conjunction with cutting-edge energy storage systems.

2. Energy Efficiency Measures: To maximize energy use, smart cities can implement smart grids, IoT-based systems, and energy-efficient technologies.

3. Policy and Incentives: Strict laws governing the use of fossil fuels, tax breaks, and subsidies are some ways that governments might encourage the growth of renewable energy.

4. Public Awareness and Participation: Promoting renewable energy adoption and lowering dependency on practices that heavily rely on fossil fuels.

The information emphasizes how urgently strategic actions are needed to hasten Kazakhstan' s energy transformation. As centers of sustainability and innovation, smart cities must spearhead this shift by putting in place comprehensive, tech-driven solutions that allow for a substantial and long-term decrease in reliance on fossil fuels while increasing the proportion of renewable energy in the energy mix.

Mobile cellular subscriptions in Kazakhstan [9]

A key component of the creation of smart cities is the use of mobile cellular technologies. The trend of mobile cellular subscribers per 100 population in Kazakhstan between 1960 and 2022 demonstrates a significant shift and underscores the vital role that telecoms play in promoting digital infrastructure for smart city projects (Figure 6).

A figure of 0.00 per 100 people indicates that Kazakhstan had no mobile cellular subscriptions

between 1960 and 1994. During this time, the Soviet Union' s centralized system of fixed-line telephones constituted the majority of the country' s communication infrastructure. The absence of mobile technology draws attention to the early phases of digital connectivity, which prepared the way for later developments in telecommunications.

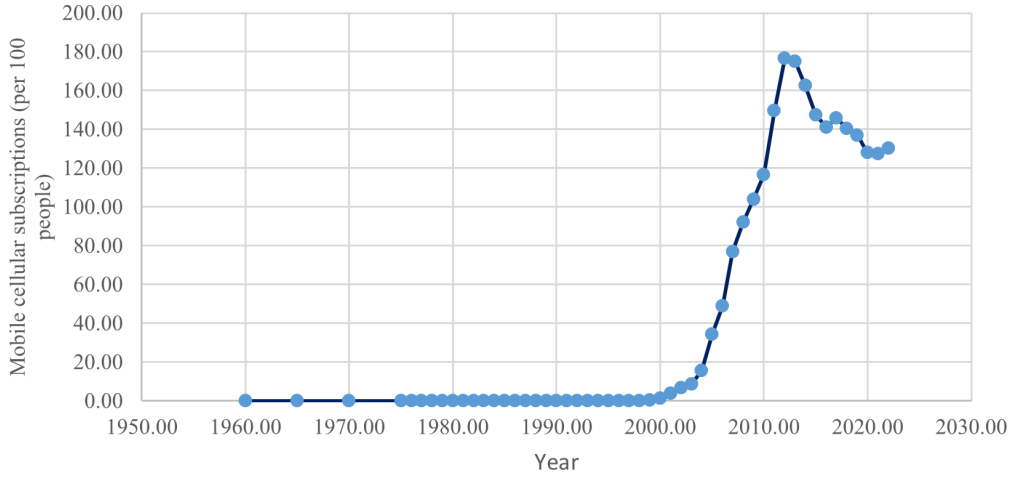

Fig.6 - Mobile Cellular subscriptions in Kazakhstan

(compiled by the authors based on [28])

A significant change occurred with the advent of mobile cellular technology in 1995; by 2003, the subscription rate had risen steadily from 0.03 per 100 persons to 8.63. Initial investments in mobile infrastructure and the steady uptake of mobile devices are responsible for this increase. During this time, basic connectivity, a crucial need for the development of smart cities, particularly in metropolitan areas was made possible by mobile technology.

Mobile subscriptions increased exponentially between 2004 and 2012, rising from 15.76 to a peak of 176.79 per 100 persons. Technological developments, the introduction of 2G and 3G networks, and telecom carriers' aggressive pricing strategies are all responsible for this quick uptake. Real-time communication, data exchange, and the establishment of digital services were made possible by the increase in mobile connectivity, which made Kazakhstani cities attractive targets for smart city projects. The extensive use of mobile devices, which are essential for Internet of Things (IoT) applications in smart city sectors including transportation, energy, and governance, is reflected in high subscription rates.

By 2022, the subscription rate had marginally decreased from its peak in 2012 to 130.42 per 100 individuals, indicating market saturation and the rationalization of numerous subscriptions. The penetration rate held steady in spite of this drop, demonstrating Kazakhstan' s preparedness for cutting-edge digital solutions. The decrease is in keeping with the global trend toward integrated communication systems, where mobile networks support smart city technologies by enhancing Wi-Fi and internet.

One of the main factors facilitating smart city initiatives in Kazakhstan is the country' s high rate of mobile penetration. IoT solutions, such as e-governance platforms, intelligent transportation systems, and smart metering, are made possible by mobile networks in smart cities. According to the trends shown, Kazakhstani cities are in a good position to embrace these technologies, taking use of the widespread use of mobile devices to link people, companies, and government services.

Even though mobile connectivity is a major factor in smart city programs, issues including

digital literacy, rural-urban connectivity gaps, and infrastructure upgrades to 5G networks still exist. The modest drop in subscription prices over the past few years also points to the necessity of diversifying digital services in order to keep users interested. There are opportunities to use mobile networks for smart city applications, especially in the fields of public services (e.g., e-health and e-education), energy (e.g., smart grids), and transportation (e.g., traffic management).

It will be crucial to integrate mobile cellular networks with cutting-edge technologies like 5G, AI, and IoT as Kazakhstan moves forward with its smart city goal. To guarantee fair access to the advantages of smart cities, policymakers should give mobile infrastructure improvements top priority, especially in rural areas with poor connectivity. Furthermore, encouraging public-private collaborations can help achieve socioeconomic and environmental objectives while hastening the implementation of smart city solutions.

ICT Technology adoption-per-100-people in Kazakhstan

The rapid advancement of mobile cellular technology defined the 2000s (Figure 7). In 2012, mobile subscriptions reached a peak of 176.79 per 100 individuals, indicating the quick uptake of 2G and 3G networks. During this decade, internet usage also increased, and by 2012, it had surpassed 61% of the population. Despite being adopted more slowly than mobile services, fixed broadband grew steadily, reaching 12.21 per 100 by 2014.

With mobile cellular subscriptions stable between 127 and 147 per 100 persons, signifying market saturation, the ICT sector developed starting in 2015. In the meantime, internet penetration reached a remarkable 92.3% of the population, and fixed broadband subscribers increased to 15.35 per 100 persons by 2022. This illustrates how Kazakhstan is becoming more and more dependent on broadband internet in order to get improved digital services.

The steady increase in internet usage demonstrates how well Kazakhstan has incorporated ICT into daily life, thanks to developments in broadband and mobile infrastructure. The country is well-positioned to use ICT for greater digital transformation as it continues to embrace it, bolstering projects like e-governance, smart cities, and an increasingly digital economy.

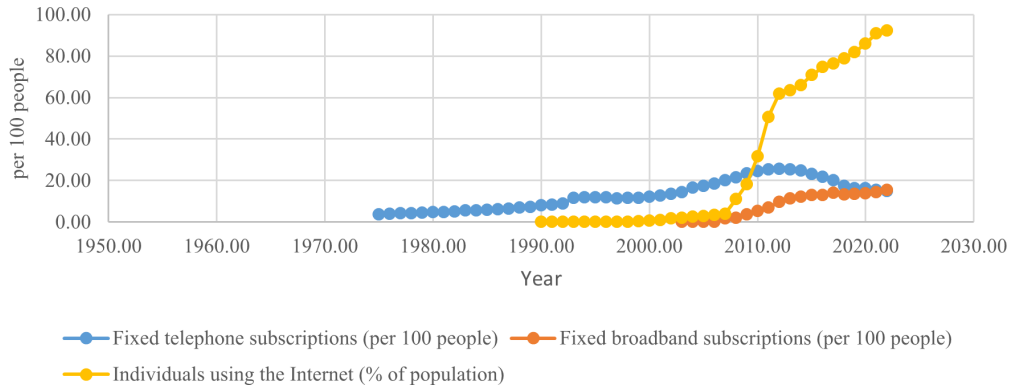

Figure 7 - ICT Technology adaptation in Kazakhstan

(compiled by the authors based on [28])

Comparing the results obtained with international experience, it can be noted that Kazakhstan is at the stage of active implementation of its projects similar to those of other developing countries, however, thanks to programs such as Digital Kazakhstan, the country has already begun to successfully solve many of these problems. It is expected that in the future, increased government funding and the introduction of innovative technologies, combined with international cooperation, will help accelerate

this process.

Conclusion Based on the conducted research of problems and opportunities in the management of smart city projects, several important conclusions can be drawn on the example of the transformation of cities in Kazakhstan. Firstly, the development of smart cities in Kazakhstan faces a number of key challenges, such as the need to implement sustainable environmental solutions, ensuring public participation in the digitalization process, overcoming digital inequality, as well as the need for government support and the creation of appropriate regulatory conditions for the implementation of such projects. These problems turned out to be systemic, requiring an integrated approach and integration into the existing urban infrastructure.

Secondly, the results of the study demonstrated a high interest in the issues of sustainable development and ecology in the design of smart cities. Environmental aspects such as the use of green technologies, solar panels, waste recycling and energy conservation occupy an important place in urban plans. This trend is confirmed by an increase in the frequency of mentioning environmental aspects in modern design studies, which also indicates an increasing attention to the issue of sustainability at the level of public and private initiatives.

Thirdly, despite active efforts on the part of the Government and the private sector, the challenges of ensuring broad public participation and eliminating digital inequality remain important obstacles to the effective introduction of technology into the urban environment. Citizen participation in the digitalization process requires the creation of more open platforms for communication and participation in decision-making, as well as more accessible educational and technical solutions for all segments of the population. Digital inequality, in turn, limits citizens' access to the latest technologies, which reduces the overall potential for creating effective and inclusive smart cities.

Funding. *This research has been funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR24993051 "Development of an intelligent city system based on IoT and data analysis")*

References

1. Tehnologii umnyh gorodov: chto vlijaet na vybor gorozhan? [Electronic resource] // McKinsey & Company. -2018. URL: https://www.mckinsey.com . Date of application: 06.12.2024. [in Russian]

2. Worldwide Spending on Public Cloud Services is Forecast to Reach $1.35 Trillion in 2027, According to New IDC Spending Guide [Electronic resource] // IDC. -2023. URL: https://www.idc.com . Date of application: 12.12.2024.

3. Cities Across Central Asia Can Unlock Full Economic Potential by Implementing Low-Carbon and Climate-Resilient Development Strategies, [Electronic resource] //World bank group. -2023. URL https://www.worldbank.org Date of application 10.12.2024.

4. Urdabayev M, Kireyeva A, Vasa L, Digel I, Nurgaliyeva K, Nurbatsin A Discovering smart cities' potential in Kazakhstan: A cluster analysis // PLoS ONE. -2024. -Vol. 19(3). DOI 10.1371/journal.pone.0296765

5. Camero A., Alba E. Smart City and information technology: A review // Cities– 2019. –Vol. 93. - P. 84-94. DOI 10.1016/j.cities.2019.04.014

6. Cartalis C. Toward resilient cities - a review of definitions, challenges and prospects // Adv. Build. Energy Res. -2014. -Vol. 8(2). -P. 259-266. DOI 10.1080/17512549.2014.890533

7. Voytenko Y., Mccormick K., Evans J., Schliwa G. Urban living labs for sustainability and low carbon cities in Europe: towards a research agenda // J. Clean. Prod. -2016. -Vol. 123. -P. 45-54. DOI 10.1016/j.jclepro.2015.08.053

8. Yigitcanlar T., Kamruzzaman M., Foth M., Sabatini-Marques J., da Costa E., Ioppolo G. Can cities become smart without being sustainable? A systematic review of the literature // Sustain. Cities Soc. -2019. -Vol. 45. -P. 348-365. DOI 10.1016/j.scs.2018.11.033

9. Noy K., Givoni M. Is 'smart mobility' sustainable? Examining the views and beliefs of transport's technological entrepreneurs // Sustainability. -2018. -Vol. 10(2):422. DOI 10.3390/su10020422

10. Young M., Farber S. Ride-hailing platforms are shaping the future of mobility, but for whom? // In The Platform Economy and the City: Urban Peril and Promise in the New Digital Economy / Zwick, A., Spicer, Z., Eds. Montreal, QC, Canada: McGill-Queens University Press, 2021. DOI 10.31219/osf.io/pz7fk

11. Verrest H., Pfeffer K. Elaborating the urbanism in smart urbanism: distilling relevant dimensions for a comprehensive analysis of Smart City approaches // Inf. Commun. Soc. -2019. -Vol. 22(9). -P. 1328-1342. DOI:10.1080/1369118X.2018.1424921

12. Nguyen H.T., Marques P., Benneworth P. Living labs: Challenging and changing the smart city power relations?//Technol. Forecast. Soc. Change.-2022. -Vol. 183. DOI 10.1016/j.techfore.2022.121866

13. Parygin D., Sadovnikova N., Gamidullaeva L., Finogeev A., Rashevskiy N. Tools and Technologies for Sustainable Territorial Development in the Context of a Quadruple Innovation Helix // Sustainability. - 2022. -Vol. 14(15):9086. DOI 10.3390/su14159086

14. Meijer A., Bolívar M.P.R. Governing the smart city: a review of the literature on smart urban governance // Int. Rev. Adm. Sci. -2016. -Vol. 82(2). -P. 392-408. DOI 10.1177/0020852314564308

15. Ramaswami A., Russell A.G., Culligan P.J., Rahul Sharma K., Kumar E. Meta-principles for developing smart, sustainable, and healthy cities // Science. -2016. -Vol. 352(6288). -P. 940-943. DOI 10.1126/science.aaf7160

16. Weber-Lewerenz B., Traverso M. Navigating Applied Artificial Intelligence (AI) in the Digital Era: How Smart Buildings and Smart Cities Become the Key to Sustainability // Journal of Artificial Intelligence and Applications. -2023. -Vol. 1(4). -P. 214-227. DOI 10.47852/bonviewAIA32021063

17. Yigitcanlar T., Kamruzzaman M., Buys L., Ioppolo G., Sabatini-Marques J., da Costa E.M., Yun J.H.J. Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework //Cities. -2018. -Vol. 81. -P. 145-160. DOI 10.1016/J.CITIES.2018.04.003

18. Mora L., Deakin M., Reid A. Combining co-citation clustering and text-based analysis to reveal the main development paths of smart cities // Technol. Forecast. Soc. Change. -2019. -Vol. 142. - P. 56-69. DOI 10.1016/j.techfore.2018.07.019

19. Robinson, P.; Coutts, S. 16-The case of Quayside, Toronto, Canada // In Smart City Emergence; Elsevier: Amsterdam, The Netherlands. -2019. -P. 333-350. DOI 10.1016/B978-0-12-816169-2.00016-X

20. Yoo, Y., Boland R.J., Lyytinen K., Majchrzak A. Organizing for innovation in the digitized world // Organ. Sci. -2012. -Vol. 23. -P. 1398-1408. DOI 10.1287/orsc.1120.0771

21. Trindade E.P., Hinnig M.P.F., Costa E.M., Marques J.S., Bastos R.C., Yigitcanlar T. Sustainable development of smart cities: a systematic review of the literature // Journal of Open Innovation: Technology, Market, and Complexity. - 2017.-Vol.3(3) - P.1-14. DOI 10.1186/s40852-017-0063-2.

22. Bibri S.E., Krogstie J. Smart sustainable cities of the future: An extensive interdisciplinary literature review //Sustain. Cities Soc. -2017. -Vol. 31(25). -P. 183-212. DOI 10.1016/j.scs.2017.02.016

23. Bibri S.E. On the sustainability of smart and smarter cities in the era of big data: an interdisciplinary and transdisciplinary literature review // J. Big Data. -2019. -Vol. 6(1). DOI 10.1186/s40537-019-0182-7

24. Ben Letaifa, S. How to strategize smart cities: Revealing the SMART model // J. Bus. Res. -2015. -Vol. 68(7). -P. 1414-1419. DOI 10.1016/j.jbusres.2015.01.024

25. Guedes, A.L.A.; Alvarenga, J.C.; Goulart, M.d.S.S.; y Rodriguez, M.V.R.; Soares, C.A.P. Smart cities: The main drivers for increasing the intelligence of cities // Sustainability. -2018. –Vol. 10(9):3121. DOI 10.3390/su10093121

26. Veloso, Á., Fonseca, F., & Ramos, R. Insights from Smart City Initiatives for Urban Sustainability and Contemporary Urbanism. Smart Cities. -2024. -Vol. 7(6). -P. 3188-3209. DOI 10.3390/smartcities7060124

27. Giffinger, R., Haindlmaier, G. Benchmarking the Smart City: A Sound Tool for Policy-Making? // Scienze Regionali. - 2018. - Vol. 17(1). -P. 115-122. DOI 10.14650/88820.

28. Statistical Review of World Energy [Electronic resource] //Energy Institute. – 2024. URL: https://www.energyinst.org .Date of application 14.12.2024.

Information about the authors

Galymzhanova A.- Doctoral Candidate, Kazakh National University named after al-Farabi, Almaty, Kazakhstan, e-mail: aiddaanaa07@gmail.com;

Singh S.- Ph.D., Professor, University of Fiju, Republic of Fiju, e-mail: satyanand.singh@fnu.ac.fj;

Sarkambayeva Sh. -Ph.D., Kazakh National Research Technical University named after K.I. Satpayev, Almaty, Kazakhstan, e-mail: sh.sarkambayeva@satbayev.university;

Boranbayeva A. - Ph.D., Kazakh National University named after al-Farabi, Almaty, Kazakhstan, e-mail: boranbaeva7777@gmail.com;

Turegeldinova A. - PhD, Candidate of Economic Sciences, Kazakh National Research Technical University named after K.I. Satpayev, Almaty, Kazakhstan, e-mail: a.turegeldinova@satbayev.university

Сведения об авторах

Галымжанова А. - докторант, Казахский национальный университет имени аль-Фараби, Алматы, Казахстан, e-mail: aiddaanaa07@gmail.com;

Сингх С. -Ph.D., профессор, Университет Фиджи, Республика Фиджи, e-mail: satyanand.singh@fnu.ac.fj;

Саркамбаева Ш.Г. - Ph.D., Казахский национальный исследовательский технический университет им. К.И. Сатпаева, Алматы, Казахстан, e-mail: sh.sarkambayeva@satbayev.university

Боранбаева А. - Ph.D., Казахский национальный университет имени аль-Фараби, Алматы, Казахстан, e-mail: boranbaeva7777@gmail.com;

Турегельдинова А. - к.э.н., PhD, Казахский национальный исследовательский технический университет им. К.И. Сатпаева, Алматы, Казахстан, e-mail:a.turegeldinova@satbayev.university