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Sustainable Urban Development in Kazakhstan Through Innovative Approaches to Resource Management

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ABSTRACT

The concept of the smart city is becoming increasingly important in light of contemporary challenges related to sustainable development and efficient resource utilization. This study focuses on the contribution of integrating digital technologies into urban infrastructure, which is critical for ensuring the sustainable development of urban areas. While advanced cities like Copenhagen and Singapore demonstrate successes in implementing smart practices, Kazakhstan faces significant challenges in this domain. The aim of the research is to analyze the gaps in urban development and explore global practices that can be adapted to the Kazakh context. Utilizing the leapfrog development model, the study evaluates strategies for implementing smart technologies in Kazakh cities, emphasizing their potential to enhance ecological sustainability, energy efficiency, and rational resource use. The main findings indicate that technological innovations are key to improving the quality of life for residents and promoting sustainable urban development. The research offers practical recommendations for urban planners and policymakers, highlighting the importance of integrating smart technologies into sustainable development strategies, particularly in the context of developing countries such as Kazakhstan.

1. INTRODUCTION

The concept of a smart city has gained significant relevance in recent times, driven by the rapid advancement of technologies based on the utilization of cutting-edge computer technologies on the one hand, and the necessity to reform the modern level of energy and resource consumption on the other [1]. The problem statement addressed by this study lies in the evolving concept of smart cities, driven by technological advancements and the imperative to reform energy and resource consumption. While the term 'smart city' is increasingly used to address urban management challenges, its precise definition remains relative, leading to diverse interpretations [2].

This study aims to address this gap by examining the dynamics of urban development and population growth, emphasizing the importance of integrating digital and smart technologies into urban infrastructure to enhance quality of life. The research contributes to the scholarly understanding of the effectiveness of smart city practices worldwide, highlighting the significance of technological advancement in improving the urban environment.

By considering examples from cities such as Copenhagen, Barcelona, New York, Singapore, and London, the study showcases a variety of strategies for integrating smart technologies into urban infrastructure, including transportation management and waste disposal systems. However, the implementation of smart city principles varies by region, which is particularly evident in Kazakhstan, where major cities such as Astana, Almaty, and Aqkol require significant development of digital technologies.

This research contributes to the scientific understanding of the effectiveness of smart city practices globally, highlighting the importance of technological advancement in improving urban inhabitation. The concept of smart cities has emerged as a crucial aspect of urban management, responding to the concentrated population dynamics and the ongoing growth trend observed in cities worldwide [3]. As cities grow more prominent, there is an increasing demand for intelligent digital urban development to improve infrastructure and effectively address societal needs. This paper adopts a perspective aligned with the leapfrog model of urban infrastructure development, emphasizing progressiveness and advancement in transforming cities from their foundational constituents.

In a world where urbanization continues to accelerate rapidly, the concept of smart cities becomes essential for achieving sustainable development. Smart cities integrate cutting-edge technologies to enhance resource management, encompassing community life's social, economic, and environmental dimensions. Amid population growth and climate change, innovative solutions are critically important for resource conservation and improving quality of life.

Sustainable development necessitates the implementation of smart technologies across all sectors, from energy to healthcare. For instance, smart lighting systems reduce energy consumption while enhancing safety. Active community involvement in decision-making processes ensures that the needs of local residents are addressed, fostering an environment of increased social responsibility.

An interdisciplinary approach to the development of smart cities, which includes collaboration among governmental entities, private companies, and academic institutions, lays the groundwork for a more resilient urban infrastructure. Research on smart cities within the context of sustainable development unveils new opportunities for enhancing the quality of life by providing effective and environmentally sustainable solutions in the face of global challenges.

The terminology 'smart city' has evolved to cater comprehensively to society's increasing demands, albeit with relative interpretations. Alternative designations such as digitalized, electronic, technological, flexi-city, and cyber-ville reflect the necessity of precise characterization for future city functions. Notably, certain cities have begun to stand out in various technological domains. Copenhagen and Barcelona exemplify advanced data exchange frameworks and intricate transportation networks managed through 'smart' infrastructure systems employing sensors for traffic management and energy-efficient street lighting [4].

Moreover, ecological preservation and rational resource consumption are integral to smart city practices. Cities implement active water conservation systems and waste management solutions, exemplified by New York's specialized waste containers and automated city lighting. Singapore and London have pioneered smart urban traffic distribution systems, showcasing substantial progress in autonomous vehicular transportation integration.

However, the implementation of smart city principles varies across regions. While cities like Astana, Almaty, Aqkol, represent fundamental technological principles, and the countries like Kazakhstan still require significant attention and development in digital technologies and their management [5, 6].

The novelty of this study lies in its examination of the dynamics of continuous urban and population development, emphasizing the integration of digital and 'smart' technologies into infrastructure to meet population needs effectively. By contributing to a scientific approach emphasizing the necessity of integrating innovative technology into urban infrastructure, this research substantiates the effectiveness of applying 'smart' city practices on both local and global scales. Ultimately, the study underscores the importance of technological advancement in enhancing urban inhabitation and sustainability.

By analyzing case studies such as Copenhagen, Barcelona, New York, Singapore, London, and Kazakhstan’s main cities, the study showcases diverse strategies employed to integrate smart technologies into urban infrastructure, ranging from transportation management to waste disposal systems.

Also, the study contributes to the scholarly discourse by emphasizing the necessity of integrating innovative technology into urban infrastructure for sustainable development and enhanced quality of life. Furthermore, the study considers the density, energy, and metabolism of a proposed smart city, reflecting on the intricate relationship between urban form, energy consumption, and sustainability [7]. By examining these diverse perspectives and incorporating insights from various contexts, this study offers a holistic understanding of smart city development and its implications for urban sustainability on a global scale.

The main findings of the research are about diverse interpretations of 'Smart City'. The term 'smart city' has multiple interpretations, ranging from digitalized and electronic to technological and cyber-ville. This relativity leads to varied implementations and understandings of smart city concepts across different regions. Global progress and disparities are also the most important issues in the research. Cities like Copenhagen, Barcelona, New York, Singapore, and London have made significant advancements in integrating smart technologies into their urban infrastructure. However, there is a notable disparity in technological integration in countries like Kazakhstan, where cities such as Astana, Almaty, and Aqkol show the foundational implementation of smart city principles but still require substantial development. The other findings include technological integration and urban development. Successful examples include Copenhagen's data exchange frameworks, Barcelona's smart transportation networks, New York's waste management systems, and Singapore’s and London's smart traffic distribution systems. Emphasis is placed on ecological preservation, energy efficiency, and rational resource consumption, which are integral to smart city practices. The study highlights the importance of integrating digital and smart technologies to improve living comfort and address urban governance challenges effectively [8].

The research uniquely focuses on the dynamics of continuous urban and population development, particularly in Kazakhstan, to showcase the potential and necessity of integrating innovative technologies into urban infrastructure. The significance of findings lies in the scientific understanding of smart city practices globally, emphasizing the need for technological advancements to improve urban living conditions and sustainability. By highlighting successful smart city implementations, the research provides a blueprint for other cities to follow, particularly those in developing countries like Kazakhstan, which face unique socio-economic and infrastructural challenges. The findings stress the importance of sustainable practices, such as energy-efficient lighting, waste management, and smart traffic systems, in the context of urban growth and development. This research bridges the gap between theoretical smart city concepts and practical implementations, offering actionable insights for urban planners and policymakers.

The following content of the research work is presented below. Introduction with a background overview of the concept of smart cities and their relevance in modern urban management. Problem Statement descriptions in addressing the evolving concept of smart cities and the disparity in technological integration globally are mentioned in the introduction. The objectives of the section are the examination of the dynamics of urban development and the importance of integrating smart technologies.

Literature Review include the exploration of various definitions and interpretations of smart cities; the analysis of smart city implementations in Copenhagen, Barcelona, New York, Singapore, and London; examination of Kazakhstan’s main cities and their progress in smart city practices.

Research Methodology includes the description of the qualitative and quantitative methods used to gather data; sources of data, including case studies, surveys, and urban development reports; techniques used to analyze the collected data and draw conclusions.

Results section presents the detailed results from the analysis of the selected global cities as well as the identification of gaps and disparities in technological integration, particularly in Kazakhstan.

Discussion provides the interpretation of the results in the context of global and local smart city development; discussion of the challenges faced by cities like those in Kazakhstan and the opportunities for improvement; practical suggestions for urban planners and policymakers to enhance smart city practices.

The conclusion part includes the recapitulation of the main findings of the research; emphasis on the importance of integrating smart technologies into urban infrastructure; suggestions for future research to further explore smart city development and its implications for urban sustainability.

References include the list of all academic sources cited in the research.

This structure will ensure a comprehensive and detailed presentation of the research findings, their significance, and the broader context of smart city development.

1.1 Literature review

The literature review indicates a growing interest in the topic of smart cities and sustainable urban development among researchers, who emphasize the necessity of integrating technologies into urban management to achieve greater resilience and efficiency. One of the key works in this field is the study by Harrison and Donnelly [9], which underscores the importance of the smart city concept for the development of sustainable urban ecosystems. The authors argue that smart cities can address a range of social and environmental issues while simultaneously enhancing the quality of life for residents.

Another significant contribution is made by Caragliu et al. [10], who provide a definition of the term "smart city" and discuss its components. This research opens new perspectives on how technological innovations can be leveraged to improve the efficiency of urban systems and reduce their ecological impact.

It is also noteworthy that research related to the United Nations Sustainable Development Goals (SDGs) is beginning to receive increased attention. For example, analyses of the impact of smart cities on achieving the SDGs suggest that such cities can provide environmental sustainability, social integration, and economic development simultaneously. This is corroborated by findings from various studies indicating a growing connection between technological innovations and social change.

Moreover, contemporary research addresses the topic of digitalizing urban infrastructure and its role in mitigating the negative environmental impacts of urban living. The implementation of IoT technologies creates opportunities for more efficient resource management, such as water and energy, which, in turn, leads to reductions in emissions and energy expenditures.

The COVID-19 pandemic has served as a catalyst for the accelerated development of smart solutions, such as e-governance and digital services, enabling citizens to interact with municipal services without the need for physical presence. These changes have become crucial for fostering a "civil society" amid isolation, enhancing the accessibility of public services, and improving quality of life.

However, despite the numerous advantages that smart cities can offer, there is a pressing need for a more detailed analysis of the social efficacy of these initiatives. Defining and measuring social impact, particularly in the context of investments in smart city development, is critically important for assessing their sustainability and viability.

The concept of 'smart' cities is relatively novel, even though the foundations for developing such cities existed long before the emergence of contemporary digital technologies [11]. One study examined the primary facets of smart city advancement, with a specific focus on street lighting. Street lighting would be activated at dusk and deactivated at dawn [12]. Technologically, this seemingly minor facet yielded significant results in the continuous pursuit of electricity savings [13]. Moreover, this contributed to the advancement of other subsystems within the urban infrastructure [14]. Previous works also explored opportunities for digitalizing urban infrastructure, diminishing the detrimental impact of various urban activities on the ecological system of the city [15]. Consequently, one of the practices within a smart city can be applied as IoT Ecology. Other technological innovations aid in efficiently managing social challenges and technical issues (such as traffic regulation) through robotic systems [16].

One of the key characteristics of smart city development encompasses certain subsystem features, such as advancing the digital system to a level where routine tasks can be minimized, thus averting another potential cause of traffic congestion [17]. The evolution of the digital financial system has substantially enhanced the efficiency of financial institutions, enabling virtual queuing for services [18]. Innovative technologies have facilitated the emergence of the crypto market, providing a means to manage various forms of finance within 'smart' cities [19]. Certainly, the coronavirus pandemic has accelerated the pace of various service developments and increased social engagement [20]. Particularly, it has fostered the notion of 'civil society development, especially in the realms of finance and public services [21]. In particular, areas such as e-government have flourished, enabling numerous routine operations to be conducted from the comfort of one's home [22].

To a certain degree, these approaches result in relative measures of economic effectiveness, requiring a comparison between the expenses and the advantages stemming from the resultant effects [23]. Notably, the United Nations (UN) has outlined certain elements that constitute social impact indicators, including factors like food quality and quantity consumed by individuals in the studied area, clothing, housing, health, education, social security, and employment [24].

The relevance of this research, alongside its primary objective, lies in substantiating the efficacy derived from the implementation of practices and approaches inherent to the “smart city” concept, particularly in Kazakhstan [25]. The research tasks encompass examining assumptions concerning the significance and effectiveness of urban infrastructure development for the growing population [26], demonstrating the necessity of digital technology advancement within the city, and calculating public goods concerning the societal benefits of the city's overall utility and consumer preference favoring specific “smart” technologies [27]. A pivotal aspect of the research entails evaluating the social effectiveness stemming from investments in the development of a “smart” city, as well as considering the social impact using economic indicators [28]. This approach will culminate in achieving a pivotal research goal—demonstrating the feasibility of applying various conceptual practices of the “smart city” within their practical applications [29].

The literature gap of the study lies in the context of Kazakhstan’s smart cities, where digital technologies are still undergoing significant development. This unique focus on a country with distinct socio-economic and infrastructural challenges sets this study apart, offering insights into the potential for smart city practices to address urban development needs on a global scale. Overall, the study contributes to the scholarly discourse by emphasizing the necessity of integrating innovative technology into urban infrastructure for sustainable development and enhanced quality of life, thereby bridging the gap between theory and practice in the field of urban planning and management.

1.2 Case study example

In Kazakhstan, the concept of the 'smart' city has been progressively developing, drawing inspiration from advanced cities such as Singapore, Dubai, Lisbon, and Barcelona. Initially, the plan focused on transforming the capital of Kazakhstan, Astana, into a reimagined capital city by implementing the practices of the 'smart' city concept. According to this concept, such planning would reduce service delivery times at various levels (national and local), enhance city safety, and improve public transportation through 'smart traffic management.' However, the pace of 'digitalization' development is hindered due to urban planning system peculiarities, progressing at a slower rate [30]. The functional zoning of the city does not account for certain natural parameters. Factors like strong winds, steppe terrain, and summer droughts prevent standard engineering procedures and city greening, necessitating the development of a tailored approach (as exemplified during the construction of Expo'17). Favorable conditions for city development also exist (railroads, roadways); however, the absence of a metro system places a significant burden on a load of both private and public transportation systems. Although the city's expansive territory supports prospective residential and industrial development, it primarily adheres to the principle of functional division, with the capital city inadequately meeting the requirements for separating zones of work, daily life, and leisure [31]. Numerous gaps and challenges remain, necessitating further urban development efforts. Aqkol City stands out in this regard, progressing at a rapid pace toward becoming a 'digital city' featuring elements of automation. Here, technologies such as solar and wind energy utilization, intelligent transport stops, street cameras, smart lighting, and traffic signals are fully integrated. Emerging practical innovations are under development, holding the potential for future application in Astana and other cities exhibiting a comparable level of advancement. Examining the cryptocurrency market, which has gained significant momentum recently, has also contributed to a shift in citizens' consciousness. People are beginning to recognize the necessity of digitalization and are embracing the benefits of this domain. The citizens of the country, particularly the urban population, are becoming more engaged in the city's life and development. Additionally, various social projects are being implemented, effectively impacting society substantially.

Based on the conditions outlined for assessing the direction of the social impact and the influence of specific implemented practices immediately after their introduction, a fundamental issue arises, which constitutes a gap in the scientific context of this study. The challenges lie in gathering statistical data regarding the magnitude of the effects brought about by certain practices on the environment and to what extent they would be considered acceptable for use in Kazakhstan’s main cities from the point of smart development. One of the statistical insights that can be utilized in this study to address this scientific gap pertains to the urbanization trend of the population. Over approximately two decades, the urban population has increased from 50% to 65%, marking a notable shift.

2. RESEARCH METHODOLOGY

2.1 Hypothesis and testing

Several theoretical hypotheses were posited in this study. They were formulated based on practical observations of urban development in terms of its infrastructure, surveys conducted among the population regarding their preferences for digital urban development, and considerations of economic and ecological imperatives.

Thus, the study proposed three hypotheses:

H1: *The development of smart city practices influences overall city development.*
H2: *The development of Smart city practices enhances comfort and well-being for individuals and the population.*
H3: *The development of smart practices may lead to excessive expenses, impacting allocation for population needs and causing less comfort from the beginning of its implementation.*

According to the first hypothesis (H1), the development of smart city practices influences overall city development. This hypothesis will be assessed and substantiated through the methodology outlined in the paper.

The second hypothesis (H2) posits that through the development of all smart city practices, life within it becomes more comfortable, leading to an increased level of well-being and quality of life for both individuals and the growing population as a whole. This hypothesis will be further tested by calculating the social impact measured by the implementation of smart city practices in the city.

Furthermore, by the third hypothesis (H3), the implementation of smart practice and its functional maintenance result in excessive expenses that could have been allocated differently (via alternative means) to meet the needs of the population. This hypothesis will be tested through the method of determining the profitability of investments in innovative projects.

The hypothesis testing will be conducted using the case study of Kazakhstan’s main cities Astana and Aqkol.

2.2 Methods and materials

This research employed a comprehensive methodology to assess the innovation, social effectiveness, and public benefit derived from various technological advancements within the context of smart city development. The study focused on operational technological innovations in smart cities, considering both qualitative statistical indicators and individual participants. The main constraint was associated with using social efficiency indicators to assess quantitative factors in the operations of public organizations, particularly in obtaining precise quantitative data on the marginal utility of implemented innovations within smart city practices [32].

The social impact, viewed as an absolute measure, can be quantified using various methods, such as market-based and cost-benefit approaches.

As a result, the expected overall outcome of incorporating specific innovative technologies into a city within the framework of the “smart city” concept, along with the response received from the urban populace (whether positive or negative), will contribute to shaping the particular outcomes of the social impact. Overall, the study employed a robust methodology combining quantitative and qualitative approaches to assess the impact and effectiveness of smart city technologies, with a particular focus on Kazakhstan (Aqkol and Astana with its perspectives) [33].

The study focuses on the cities of Astana and Aqkol, which exemplify different aspects of smart city development in Kazakhstan. The selection criteria include population size, economic development, infrastructure level, and local government policies. This approach allows for an assessment of how scale and financial resources influence the implementation of innovations and the readiness of cities for smart technologies.

The evaluation of smart city practices is based on several criteria: social benefit is determined by the impact of technologies on the well-being of the population, economic efficiency is analyzed by comparing costs and benefits, environmental impact is assessed through reductions in emissions and improvements in air quality, and innovativeness is measured by the adoption of new technologies.

The main methodological limitations of the present research include data precision difficulties because of the lack of resources in social indicators and governmental reports. Time constraints and a few diverse data sources set boundaries in considering long-term impacts in the development of urban strategies effectively. Analytical tools such as ATLAS and SPSS Statistics were used during the quantitative and analytical part of the research.

In the context of the country’s main cities’ smart city development, ethical considerations in data collection and analysis are paramount to ensure the responsible and respectful treatment of individuals' data and privacy, as well as to uphold the principles of fairness, transparency, and accountability. Some of the main ethical considerations were closely related to informed consent, where all of the research participants while participating in polls and filling in questionnaires, had been fully informed about the purpose of the research, how their data would be used, and any potential risks or benefits associated with participation. Privacy Protection, Data Security, and Minimization of Harm, such as avoiding stigmatization, discrimination, or unintended consequences resulting from the use of data, particularly in a sensitive population of Astana. The need to keep fairness and equity, transparency, and accountability are also the main points that take a considerable role in this ethical review.

Survey design: To collect data, a structured survey was developed that allowed participants to express their opinions and evaluations regarding smart city development. The survey covered several key themes, including satisfaction with services, use of technologies, and expectations for smart city development.

Sample size: The study involved 400 respondents, selected through stratified sampling to ensure the representativeness of the results. The sample included respondents from various age groups, genders, and socio-economic statuses to reflect the diversity of the population.

Participant selection criteria: Participants in the survey were selected based on the following criteria:

Age: 18 years and older.

Place of Residence: Residents of the cities of Astana and Aqkol.

Experience: Participants had prior experience using technologies in their daily lives.

Willingness to provide feedback: Participants were willing to offer feedback on the implementation of smart city practices.

2.3 Data analyzing methodology

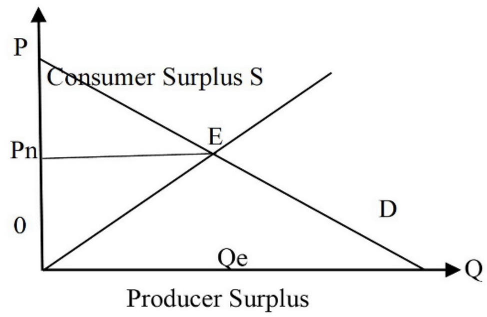

Figure 1. The public benefit from market equilibrium
Source: Compiled by the author

Throughout the study, the accrued societal benefit was examined. This benefit is calculated based on the advantages obtained by society after the implementation of innovative technology. In the application of this methodology, the Pareto principle served as the foundational principle (Figure 1). Pareto efficiency refers to a state in which resources are allocated in such a manner that it is impossible to improve the situation of one individual without worsening the situation of another. "Pareto efficiency" signifies that all potential improvements in welfare have been accounted for, and any enhancement for one party results in a loss for another.

In this case, consumers are urban residents, while producers encompass investors and governmental entities engaged in the implementation of smart technologies.

The external effect stemming from the utilization of a particular urban technology emanates from the public benefit it generates.

Economic efficiency = amount of costs / obtained benefit (utility)

The concept of marginal utility entails qualitative attributes that can be expressed by the formula of marginal utility. Marginal utility refers to the additional satisfaction that a consumer derives from the consumption of one more unit of a good. For instance, the first slice of pizza provides the greatest level of enjoyment, while each subsequent slice yields diminishing satisfaction. This phenomenon is known as the law of diminishing marginal utility.

$$MUn = \mathrm{TUn} - \mathrm{TU_{n-1}} \quad (1)$$

where, MUn represents the increment of utility, TUn denotes the total utility (in the case of consuming the n-th quantity of goods), and TU_{n-1} signifies the total utility when consuming the previous quantity of goods (Figure 2).

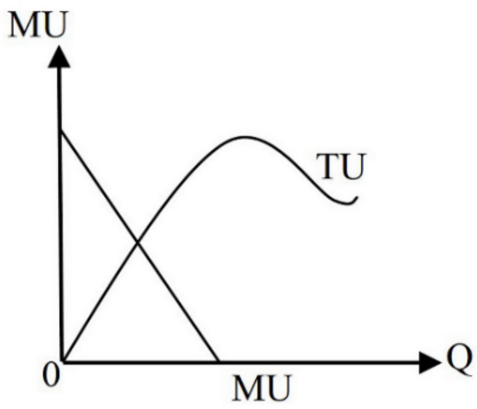

Figure 2. The relationship between changes in total and marginal utility
Source: Compiled by the author

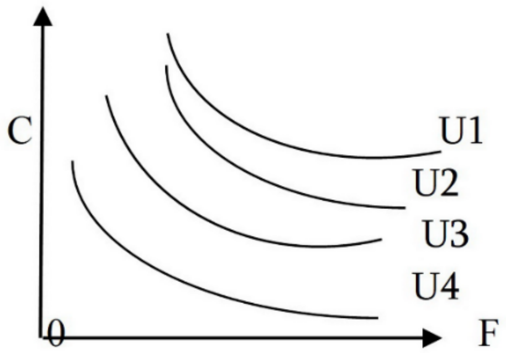

Figure 3. Indifference curves
Source: Compiled by the author

The indifference curve is also highly relevant in this context, as it reaches the point of satisfying the population's needs up to a certain level that is consistent with fulfilling various user requirements. When establishing the necessary threshold, a variety of indifference curves is considered instead of relying solely on a single curve.

The materials employed graphical representations and computer simulations for precise calculations of (U1, U2, U3, Un). The law of diminishing marginal utility also applied, albeit exerting a minor influence on the core indicators. In this context, a statistical measure of the mean squared deviation and average deviation were computed to determine deviations from the performance calculations (Figure 3).

A budget constraint was calculated to determine the composite good that the government could allocate from the budget for addressing other pressing issues rather than acquiring specific technological innovations for integration into urban life.

$$I = Px * Qx + \Sigma Pyi * Qyi \quad (2)$$

where, *I* represents disposable income, *Px * Qx* stands for expenditures on good X, and *ΣPyi * Qyi* denotes the composite good Y.

The consumer choice indicator examines relationships such as:

$$\mathrm{MRSfc} = \mathrm{Pf}/\mathrm{Pc} \quad (3)$$

$$MRS = MUf/MUc \quad (4)$$

In this context, by equating the expressions to each other, the following can be obtained:

$$\frac{\mathrm{Pf}}{\mathrm{Pc}} = MUf/MUc \quad (5)$$

This relationship is easier to visualize graphically (Figure 4).

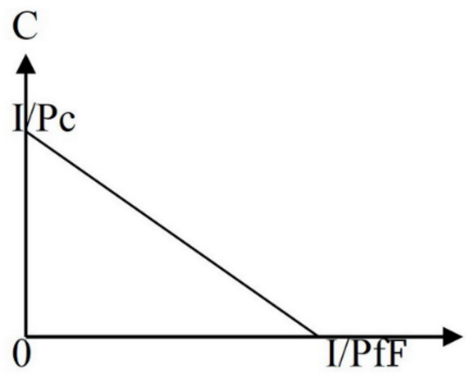

Figure 4. Graphical representation of the budget constraint line
Source: Compiled by the author

When examining marginal utility, it becomes evident how income and substitution effects, as proposed by J.R. Hicks and Slutsky, interact with each other regarding the implementation of smart city practices (Figure 5).

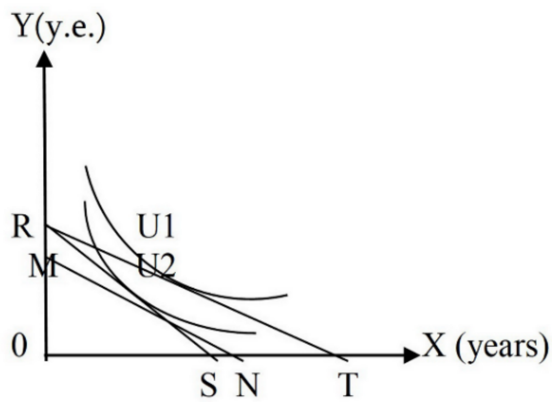

Figure 5. Interactions of effects
Source: Compiled by the author

Over time, a correlation between utility and years becomes evident, and the influence of income and substitution effects, which shifted from point Sv towards point N, then to T, and further from point M to point R, becomes apparent. This demonstrates an overall increase resulting from the utilization of technological innovations in the city, aligned with the development of the smart city concept. Along the Y-axis, there is also an observable intersecting growth of population incomes over time.

Taking into account the cumulative social effects linked to the execution of diverse investments within the current economic domain and the transparency of statistical data, analytical approaches were employed to evaluate the extent to which the introduced innovations and specific practices contribute to quality-of-life enhancement. These methodologies have been instrumental in evaluating the measure of social impact.

The methodology for expressing the social effect also encompassed economic formulas of the following nature:

$$E = ENP + ERPSF + ERTC + EIPL \quad (6)$$

where, *E* represents the social effect, *ENP* signifies the effect of preventing losses in net production due to environmental pollution, *ERPSF* denotes the effect of reducing social fund payments, *ERTC* stands for the effect of decreased healthcare expenses, and *EIPL* corresponds to the effect of enhanced labor productivity.

Next, it is imperative to compute the investment figures to ascertain profitability (calculate the rate of return (average)):

$$NP = \frac{100 * P(1 - N)}{(C_{\text{assets at the beginning of the period}} - C_{\text{assets at the end of the period}})/2} \quad (7)$$

where, *NP* represents the rate of return.

Calculations gauge city comfort via indirect indicators, correlating with social and economic standards. Sequentially analyzing public goods from smart city innovations, considering diminishing marginal utility, reveals social efficiency. Graphs depict qualitative data on social welfare, employment, culture, etc. Data sourced from governmental reports (2018-2022) informs computations.

Thus, economic formulas have been employed to calculate effectiveness and social effects, illustrating how investments in technology lead to improved social outcomes. The analysis of changes in social effects over time further underscores the positive impact of technological innovations on household income. The interrelationship of consumer behavior indicates how variations in marginal utility influence consumer decisions and the overall effectiveness of technologies. Therefore, these elements contribute to validating the findings regarding the positive influence of innovations on social welfare.

3. RESULTS

It is noteworthy that the study identified dynamics in specific indicators of social effect and the implementation of innovations despite the challenges associated with the lack of accessible quantitative and qualitative statistical data.

The first hypothesis (H1) is confirmed through the analysis of the relationship between expenditures and the effectiveness of implementing various smart practices within the context of smart city development. An examination of residents' needs and the actions of public and private entities involved in the utilization of smart technologies reveals an equilibrium point indicative of an optimal choice for the public good.

Table 1 presents the data that served as the foundation for defining the public good. Four parameters were identified, which became the starting point for further analysis. Parameter P initially measured 0.05 and increased to 0.92 under the influence of various factors. Parameter Q, starting at 0.21, fluctuated between 0.21 and 0.19.

Table 1. Dependency of societal benefit on innovative technologies

Years	Index P	Price Index Q	Supply Consumer Surplus, c.u.	Producer Surplus, c.u.
2018 (1)	0.05	0.21	0.16	-0.16
2018 (2)	0.19	0.92	0.73	-0.73
2019 (1)	0.21	0.85	0.64	-0.64
2019 (2)	0.32	0.78	0.46	-0.46
2020 (1)	0.41	0.63	0.22	-0.22
2020 (2)	0.54	0.54	0.54	0.54
2021 (1)	0.63	0.41	-0.22	0.22
2021 (2)	0.78	0.32	-0.46	0.46
2022 (1)	0.85	0.21	-0.64	0.64
2022(2)	0.92	0.19	-0.73	0.73

Source: Compiled by the author by examining these indicators, it becomes evident how the Pareto principle operates in this case with an 80/20 ratio. The consumer and producer surpluses align precisely with this ratio.
c.u. – conventional unit, term used in the countries of the former USSR to denote a monetary amount in foreign currency or its equivalent amount at national currency at the official or exchange rate

The calculations of consumer and producer surplus are based on the difference between price and supply indicators. The consumer surplus, beginning at 0.16, increased until market equilibrium was reached, after which it gradually declined. Conversely, the producer surplus exhibited a reverse dynamic, varying from -0.16 to 0.46, increasing following the attainment of equilibrium.

Thus, the results underscore the significance of a clear relationship between expenditures, the effectiveness of innovation implementation, and public welfare within the context of smart city development.

In the implementation of smart city concepts, external effects are also observed, in addition to achieving an optimal level of public good. These effects directly arise from the creation of various public goods, such as bus stops with charging stations, electronic information displays with route schedules, and others. However, these external effects are so minimal that they were not considered in this study, as their impact on the results is negligible.

Nonetheless, it is possible to ascertain the economic efficiency that society can derive from technologies being implemented in smart cities. Economic efficiency depends on the comparison between the volume of expenditures and the magnitude of benefits received. Table 2 presents the dynamics of public efficiency development up to 2022, utilizing data on national and local income. The analysis was conducted over a time span of approximately five years, as this period is characterized by the influence of the COVID-19 pandemic and a sharp increase in online services and digital platforms.

The composition of Table 2 is based on statistical budget indicators, such as annual growth of national income, gross production volume, profit, and the payback period for capital investments, among others. The data were evaluated from two perspectives: economic efficiency in absolute terms. The values of the indicators gradually increased over the five-year period, ranging from 0.21 to 0.42, while other statistical values exhibited an upward trend (from 0.145 to 1.203, from 0.354 to 0.75, from 0.65 to 0.8, etc.). The value of capital investments within the framework of economic efficiency rose from 0.001 to 0.235 (correspondingly from 0.002 to 0.037, from 0.003 to 0.013, and so forth). Thus, during the selected time interval, the indicators of economic efficiency demonstrated growth.

Table 2. Relationship of the period during peak activity at the onset of implementing practices and approaches of the "smart" city concept and investments in innovative projects

Years	2018-2022								
Name of Economic Effect Indicators	Annual Growth of National Income	Annual Growth of Net Product Volume	Annual Growth of Normative Net Product Volume	Annual Growth of Profit	Annual Profit Volume	Cumulative Economic Effect over Capital Investment Payback Period	Annual National Income Volume	Annual Net Product Volume	Annual Profit Volume
Absolute Economic Efficiency Indicator Values	0.21-0.42	0.145-1.203	0.354-0.7488	0.65-0.794	0.36-1.2146	0.54-0.62	0.125-0.621	0.43-0.822	0.163-3.28
Capital Investment Efficiency Indicators	0.001-0.235	0.002-0.037	0.003-0.013	0.004-0.019	0.005-0.03	0.006-0.016	0.007-0.027	0.008-0.018	0.009-0.019

Source: Compiled by the author

Furthermore, effectiveness is also demonstrated in the context of considerations such as investment in human capital, safeguarding the health and well-being of employees, active participation in environmental development, civic responsibility, and fostering success, recognition, and respect.

Utilizing a particular innovation within society, its value diminishes over time due to wear and tear, the emergence of alternative technological advancements, and shifts in societal needs. Thus, by the law of diminishing marginal utility, one can observe how the marginal utility in Kazakhstan decreased in the case of bus stops, which deteriorated over time.

Table 3. Yearly data on the level of marginal utility from innovative technologies

T	MU	TU	Px*Qx	Pyi*Qyi
2018	0.0021	0.0035	0.02	0.03
2019	0.0045	0.0047	0.025	0.035
2020	0.0054	0.0052	0.046	0.046
2021	0.0052	0.0068	0.049	0.054
2022	0.0049	0.0059	0.057	0.067

Source: Compiled by the author

Hypotheses H1 and H2 are validated, indicating the interdependence between the quality of urban living and the social effectiveness of implemented technology. Additionally, external effects, such as an increased burden on public transportation due to the absence of a metro line, began to influence the establishment of a consequential correlation within a society according to the law of marginal utility (MU). In line with assumption H3, such adverse consequences arising from the implementation of new technologies, as guided by the law of diminishing marginal utility and reflected in the graph, can be depicted in Table 3. Table 3 encompasses data from 2018 to 2022, where computed indicators yielded marginal and total utility values, along with the respective products of good X in terms of price and quality, as well as good Y, corresponding to their respective prices and qualities (resulting in composite utility). For the initial calculation of marginal utility, values commencing at 0.0021 were taken as the starting point, gradually increasing in value to 0.0049. This illustrates that over time, through the utilization of various "smart" city practices, the marginal utility increased. The overall utility was measured from an initial point of 0.0035, reaching a value of 0.0059. Over time, this metric demonstrates increasing values, albeit at a less rapid pace (in comparison to the marginal utility indicator). This substantiates the law of diminishing marginal utility associated with the introduction of each innovation, where the overall utility, if not growing, remains constant. The indices representing the efficiency of innovations and investment activities within the realm of "smart" technologies are portrayed as the products of PxQx (depicting data along the X-axis) as well as PyiQyi (depicting data along the Y-axis), both of which symmetrically ascend in their values from 0.02 to 0.057 and from 0.03 to 0.067, respectively.

Over time, the economic efficiency of investing in innovative technologies can also become evident. According to the data presented in Figure 6.

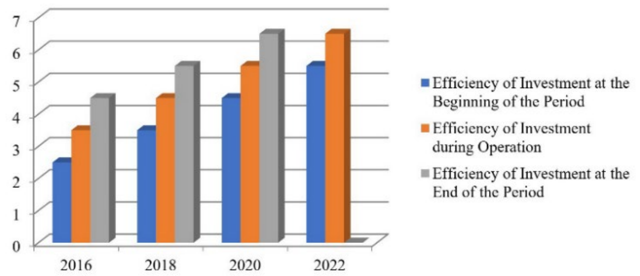

Figure 6. Dependency of economic effect on innovative activity
Source: Compiled by the author

In this graphical representation, the ordinate axis displays the values of investment efficiency, while the abscissa axis represents the years of observation. The investment efficiency, expressed in monetary units, as depicted in the figure, was measured using Eq. (2) concerning disposable income, along with the assessment of composite goods and analysis of Eq. (7) about the rate of profitability, which affects both qualitative and quantitative characteristics.

Assumption H3 cannot be substantiated because investment activity consistently increased its measurements. However, this contradicts the assumption that the adoption of smart technologies in the city would be more influenced by the law of diminishing marginal utility, as well as by prevailing external effects or the existence of composite goods to a greater extent than postulated. Nevertheless, the growth of innovative activity (attributable to the observed quantitative expansion of investment activity as one of the growth factors) and the expansion of public welfare exhibit a contrary response. In this context, by Eq. (2), this hypothesis does not find its reflection in the prospective outlook.

Table 4. Social effectiveness in the application of smart practices

Years	ENP-the Effect of Preventing the Loss of Clean Products due to Environmental Pollution	ERPSF -the Effect of Reducing Payments from the Social Fund	ERTC- the Effect of Reducing Treatment Costs	EIPL- the Effect of Increasing Labor Productivity	E- Social Effect
2018 (1)	0.012	0.021	0.036	0.011	0.065
2018 (2)	0.032	0.031	0.06	0.036	0.075
2019 (1)	0.015	0.041	0.084	0.061	0.085
2019 (2)	0.016	0.054	0.108	0.086	0.095
2020 (1)	0.0178	0.065	0.132	0.111	0.105
2020 (2)	0.0189	0.075	0.156	0.136	0.115
2021 (1)	0.0195	0.082	0.18	0.161	0.125
2021 (2)	0.029	0.085	0.204	0.186	0.135
2022(1)	0.032	0.087	0.228	0.211	0.145
2022 (2)	0.042	0.089	0.252	0.236	0.155

Source: Compiled by the author

Subsequently, social effects, in conjunction with the economic dimension of societal well-being, interplay with each other, yielding a comprehensive depiction of their interactions. Furthermore, different effects, in combination with Eq. (6), contribute to an aggregate social effect, culminating in the population's contentment with the proposed smart city technologies. Thus, upon scrutinizing the table of social effects, one can observe the evolving needs of the urban population and the ensuing social effect following the utilization of various technologies. Table 4 takes into account all parameters influencing overall social effectiveness. Initial data were extracted for each year's semesters (1st and 2nd semesters) from statistical indicators such as ENP, ERPSF, ERTC, and EIPL, which possessed values of 0.012, 0.021, 0.036, and 0.011, respectively. Over the years, these values gradually increased, reaching final readings of 0.042, 0.089, 0.252, 0.236, and 0.155, respectively. Consequently, the ultimate result, which is the summation of all types of effectiveness, also ascends in value from 0.065 to 0.155.

According to the obtained results, the level of integration of smart approaches within the city significantly influences its socio-economic development. When executing socially-oriented projects within the urban context, issues such as the accrued societal benefit (stemming from activities associated with the adoption of innovative technologies) are addressed. This benefit is realized both by those who financially contributed to it and those who did not. Furthermore, citizens experience external effects due to additional savings and the elimination of costs that could impact the outcomes of implementing practices aligned with the concept of a “smart” city. In such circumstances, residents should undergo changes that encompass their lifestyle, their connections with the community (since the incorporation of cutting-edge technologies leads to modifications in societal interactions), culture, any fears or aspirations, and influences on intricate categories such as health and overall well-being.

The expansion of research on Kazakhstani cities within the context of global smart city practices can significantly enrich the understanding of their potential. The primary findings of our study indicate that Kazakhstani cities face unique challenges and opportunities that can be integrated into a broader global context.

First, examining the implementation of technologies in Kazakhstani cities may be beneficial for comparison with global trends. For instance, the experience of Astana in deploying "smart" lighting and air quality monitoring systems can be aligned with similar initiatives in other countries. By comparing these practices, it is possible to identify which elements are most effective under varying conditions.

Second, analyzing the successes and failures of Kazakhstani cities in implementing innovations can provide a foundation for strategic recommendations aimed at optimizing resource management and improving services. Investigating, for example, energy efficiency projects in Kazakhstan may reveal how the adaptation of international technologies leads to cost reductions and environmental improvements.

Furthermore, it is crucial to consider the role of the community in the processes of urban transformation. Engaging local residents in the development and implementation of smart city projects is a key element that underscores the importance of public participation in shaping their environment. The experiences of Kazakhstani cities in this regard can serve as a model for other countries seeking effective methods of community engagement.

Thus, data pertaining to Kazakhstani cities not only illustrate the local context but also create opportunities to expand knowledge about global smart city practices. By integrating these findings into a broader context, it is possible to form a comprehensive understanding of how to adapt successful solutions to the specific conditions faced by cities in Kazakhstan. This, in turn, will contribute to their sustainable development and the enhancement of residents' quality of life.

4. DISCUSSIONS

This study meticulously examines the qualitative and quantitative determinants that influence the implementation of smart technologies in contemporary urban environments. The use of various hypothesis-testing methods, supported by formulas, graphical representations, and tabular data presentations, underscores the effectiveness of adapting urban infrastructure to new technological approaches that meet the needs of the population. As noted by the authors [34], the integration of new technologies into the urban environment can significantly enhance the quality of life; however, the actual impact often depends on specific contexts and conditions.

The results of our research corroborate the findings of other scholars who emphasize the importance of tailoring smart solutions to the unique characteristics of each city. For instance, Popova and Zagulova [35] highlight the necessity of considering socio-economic factors when implementing smart technologies. Particularly for Astana, the facilitation of transportation routes has proven to be crucial, although this issue remains unresolved at present. The introduction of smart traffic systems, such as intelligent traffic lights and cameras, aims to reduce congestion on the roads, as supported by research findings [36]. However, the results indicate limitations in conducting comparative analyses due to the lack of available quantitative and qualitative data, which complicates a comprehensive understanding of the impact of smart technologies on society. Similarly, the authors [37] stress that data unavailability may restrict opportunities for in-depth analysis. Although the primary hypotheses have been validated, the generalized conclusions are constrained by data accessibility and assumptions. Ethical considerations, such as confidentiality, equity, and community engagement, necessitate a cautious approach to interpreting the obtained results.

The findings of this research indicate a significant increase in the overall social benefit resulting from the implementation of smart city practices. The observed Pareto principle suggests exponential growth in efficiency with modest increases in income and investment in innovative technologies. This aspect is further corroborated by studies [38], which highlight the growing popularity of public smart resources that enhance the safety and attractiveness of urban environments.

The integration of innovative technologies into urban infrastructure substantially saves time, particularly concerning traffic congestion and bureaucratic procedures. E-government systems improve operational efficiency and accessibility by expediting governmental processes and engaging citizens in the formation of civil society. Innovations in the healthcare sector demonstrate increased efficiency by bypassing queues and enhancing emergency response systems [39].

The practical application of smart technologies supports hypotheses regarding social benefits and efficiency. However, the specific characteristics of each city influence the effectiveness of these technologies, necessitating tailored implementation strategies. As noted by Zumofen et al. [40], factors such as persistent winds and transportation issues require unique approaches to integrating smart technologies in various regions of Kazakhstan.

Thus, the findings of the study underscore practical implications for the development of smart cities, emphasizing the interplay between costs, efficiency, and social benefits. However, a critical analysis reveals limitations related to data accessibility and the complex nature of social impacts. Similar constraints are noted by Zamponi and Barbierato [41], who advocate for the exploration of alternative data sources to enrich the analysis.

A more nuanced examination of the results concerning the hypotheses uncovers intricacies in the relationship between the implementation of smart technologies and societal well-being. While hypotheses H1 and H2 are supported, contradictions arise regarding assumption H3, highlighting the necessity for deeper investigation into the mechanisms underlying technological adoption and its impacts.

The practical implications include enlightening policymakers and urban planners about the potential advantages and barriers associated with smart city initiatives. Understanding the dynamic nature of social influences can facilitate decision-making processes and promote more inclusive and sustainable urban development strategies.

5. CONCLUSIONS

The conducted research has revealed that the concept of the "smart city" holds significant potential for socio-economic development in Kazakhstan, particularly concerning the integration of technologies aimed at enhancing the quality of life. The implementation of infrastructure projects focused on adopting "smart" solutions has demonstrated a positive impact on reducing energy and resource costs, thereby alleviating the economic burden on household budgets. Specifically, the introduction of smart traffic and public transportation management systems has helped mitigate congestion, which in turn has positively influenced the reduction of pollutant emissions.

Furthermore, the findings indicate that smart water resource management technologies have led to more rational water usage in the agricultural sector, a critical aspect in the context of climate change. These innovations have not only improved water supply efficiency but have also contributed to enhancing the environmental situation in regions facing challenges related to the depletion of water resources.

However, despite the positive results, the research also identified several challenges faced by developing countries in implementing the "smart city" concept. First, insufficient data transparency and limited access to information complicate decision-making based on data analysis. Second, the uneven distribution of financial resources and technologies between urban and rural areas exacerbates social inequalities. This highlights the need for comprehensive strategies that ensure equitable access to technology and information for all segments of the population.

The practical application of the research findings may include the development of innovation clusters that bring together businesses, government agencies, and academic institutions to collaboratively design and implement new technologies and solutions.

Thus, the research confirms that the integration of the "smart city" concept represents a crucial step toward sustainable development in Kazakhstan. The implementation of innovative technologies in urban management can not only enhance the quality of life for residents but also create new opportunities for economic growth, which is particularly relevant in the current context of globalization and environmental challenges.

Future research should further explore smart city development and its implications for urban sustainability. Key suggestions include:

– Optimization of smart city infrastructure: Investigate ways to optimize smart city infrastructure for maximum efficiency and effectiveness.

– Assessment of surveillance systems: Evaluate the efficacy of smart surveillance systems in ensuring safety and reducing crime rates.

– Impact of digitization on government services: Examine the broader societal implications of digitizing government services, particularly in reducing time and administrative burdens.

– Technological advancements for socio-economic growth: Study the role of technological advancements in fostering socio-economic growth and addressing urban challenges.

– Applying the pareto principle: Explore the application of the Pareto principle in smart city contexts, considering complex interrelationships involving environmental and economic factors.

– Sustainable development strategies: Develop strategies for sustainable development that integrate smart city practices and technologies.

– Comparative studies: Repeat the study in other Central Asian metropolises with similar socio-economic backgrounds to validate findings and explore regional variations.

– Marginal utility and effectiveness: Investigate the correlation between diminishing marginal utility and effectiveness for sustainable development.

By focusing on these areas, future research can further substantiate the importance of implementing smart city practices to foster socio-economic growth and enhance urban sustainability.

REFERENCES

[1] Arcas, G.I., Cioara, T., Anghel, I., Lazea, D., Hangan, A. (2024). Edge offloading in smart grid. Smart Cities, 7(1): 680-711. https://doi.org/10.3390/smartcities7010028

[2] Zhou, H., Zhang, Z., Wu, Y., Dong, M., Leung, V.C. (2022). Energy efficient joint computation offloading and service caching for mobile edge computing: A deep reinforcement learning approach. IEEE Transactions on Green Communications and Networking, 7(2): 950-961. https://doi.org/10.1109/TGCN.2022.3186403

[3] Shingare, H., Kumar, M. (2023). Whale optimization-based task offloading technique in integrated cloud-fog environment. In Soft Computing for Problem Solving. Lecture Notes in Networks and Systems, pp. 459-469. Springer, Singapore. https://doi.org/10.1007/978-981-19-6525-8_35

[4] Rahamathunnisa, U., Sudhakar, K., Murugan, T.K., Thivaharan, S., Rajkumar, M., Boopathi, S. (2023). Cloud computing principles for optimizing robot task offloading processes. In AI-Enabled Social Robotics in Human Care Services, pp. 188-211. IGI Global, Hershey, Pennsylvania. https://doi.org/10.4018/978-1-6684-8171-4.ch007

[5] Zhang, Y., Yu, H., Zhou, W., Man, M. (2022). Application and research of IoT architecture for End-Net-Cloud Edge computing. Electronics, 12(1): 1. https://doi.org/10.3390/electronics12010001

[6] Bilyalova, M., Amandykova, S., Musilimova, K., Ilyassova, G., Nukusheva, A. (2019). Some questions of improvement of electoral legislation in the Republic of Kazakhstan. Journal of Legal, Ethical and Regulatory Issues, 22(2): 1-10.

[7] García, M.A., García, A.I.M., Karatzas, S., Chassiakos, A., Ageli, O. (2023). SGAM-based analysis for the capacity optimization of smart grids utilizing e-mobility: The use case of booking a charge session. Energies, 16(5): 2489. https://doi.org/10.3390/en16052489

[8] Menci, S.P., Valarezo, O. (2024). Decoding design characteristics of local flexibility markets for congestion management with a multi-layered taxonomy. Applied Energy, 357: 122203. https://doi.org/10.1016/j.apenergy.2023.122203

[9] Harrison, C., Donnelly, I. (2011). A theory of smart cities. In Proceedings of the 55th Annual Meeting of the ISSS - 2011, Hull, UK, pp. 1-15.

[10] Caragliu, A., Del Bo, C., Nijkamp, P. (2011). Smart cities in Europe. Journal of Urban Technology, 18(2): 65-82. https://doi.org/10.1080/10630732.2011.601117

[11] Krishankumar, R., Ravichandran, K.S., Aggarwal, M., Pamucar, D. (2023). An improved entropy function for the intuitionistic fuzzy sets with application to cloud vendor selection. Decision Analytics Journal, 7: 100262. https://doi.org/10.1016/j.dajour.2023.100262

[12] Allam, Z., Dhunny, Z.A. (2019). On big data, artificial intelligence and smart cities. Cities, 89: 80-91. https://doi.org/10.1016/j.cities.2019.01.032

[13] Bajaj, K., Jain, S., Singh, R. (2023). Context-aware offloading for IoT application using fog-cloud computing. International Journal of Electrical and Electronics Research, 11(1): 69-83. https://doi.org/10.37391/ijeer.110110

[14] Almalki, F.A., Alsamhi, S.H., Sahal, R., Hassan, J., Hawbani, A., Rajput, N.S., Saif, A., Morgan, J., Breslin, J. (2023). Green IoT for eco-friendly and sustainable smart cities: Future directions and opportunities. Mobile Networks and Applications, 28(1): 178-202. https://doi.org/10.1007/s11036-021-01790-w

[15] Yang, H., Ding, W., Min, Q., Dai, Z., Jiang, Q., Gu, C. (2023). A meta reinforcement learning-based task offloading strategy for IoT devices in an edge cloud computing environment. Applied Sciences, 13(9): 5412. https://doi.org/10.3390/app13095412

[16] Cernisevs, O., Popova, Y. (2022). ICO as crypto-assets manufacturing within a smart city. Smart Cities, 6(1): 40-56. https://doi.org/10.3390/smartcities6010003

[17] Auwalu, F.K., Bello, M. (2023). Exploring the contemporary challenges of urbanization and the role of sustainable urban development: A study of Lagos City, Nigeria. Journal of Contemporary Urban Affairs, 7(1): 175-188. https://doi.org/10.25034/ijcua.2023.v7n1-12

[18] Bokhari, S.A.A., Myeong, S. (2022). Artificial intelligence-based technological-oriented knowledge management, innovation, and e-service delivery in smart cities: Moderating role of e-governance. Applied Sciences, 12(17): 8732. https://doi.org/10.3390/app12178732

[19] Bokhari, S.A.A., Myeong, S. (2022). Use of artificial intelligence in smart cities for smart decision-making: A social innovation perspective. Sustainability, 14(2): 620. https://doi.org/10.3390/su14020620

[20] Alharbi, N.S., AlGhanmi, A.S., Fahlevi, M. (2022). Adoption of health mobile apps during the COVID-19 lockdown: A health belief model approach. International Journal of Environmental Research and Public Health, 19(7): 4179. https://doi.org/10.3390/ijerph19074179

[21] Ding, J., Xu, J., Weise, T., Wang, H. (2022). Community services and social involvement in COVID-19 governance: Evidence from China. International Journal of Environmental Research and Public Health, 19(22): 15279. https://doi.org/10.3390/ijerph192215279

[22] Hariguna, T., Rahardja, U., Sarmini, S. (2022). The role of E-government ambidexterity as the impact of current technology and public value: An empirical study. Informatics, 9(3): 67. https://doi.org/10.3390/informatics9030067

[23] Haque, A.B., Bhushan. B., Dhiman. G. (2022). Conceptualizing smart city applications: Requirements, architecture, security issues, and emerging trends. Expert Systems, 39(5): e12753. https://doi.org/10.1111/exsy.12753

[24] Mhatre, J., Lee, A., Nguyen, T.N. (2023). Toward an optimal latency-energy dynamic offloading scheme for collaborative cloud networks. IEEE Access, 11: 53091-53102. https://doi.org/10.1109/ACCESS.2023.3280415

[25] de Sena, A.S., Ullah, M., Nardelli, P.H. (2022). Edge computing in smart grids. In Handbook of Smart Energy Systems. https://doi.org/10.1007/978-3-030-72322-

4_106-1

[26] Pallewatta, S., Kostakos, V., Buyya, R. (2023). Placement of microservices-based IoT applications in fog computing: A taxonomy and future directions. ACM Computing Surveys, 55(14s): 1-43. https://doi.org/10.1145/3592598

[27] Ismail, S., Dawoud, D.W., Ismail, N., Marsh, R., Alshami, A.S. (2022). IoT-based water management systems: Survey and future research direction. IEEE Access, 10: 35942-35952. https://doi.org/10.1109/access.2022.3163742

[28] Kraemer, T., Weiger, W.H., Trang, S., Trenz, M. (2023). Deflected by the tin foil hat? Word-of-mouth, conspiracy beliefs, and the adoption of innovative public health apps. Journal of Product Innovation Management, 40(2): 154-174. https://doi.org/10.1111/jpim.12646

[29] Lim, Y., Edelenbos, J., Gianoli, A. (2023). Dynamics in the governance of smart cities: Insights from South Korean smart cities. International Journal of Urban Sciences, 27(s1): 183-205. https://doi.org/10.1080/12265934.2022.2063158

[30] Nam, H., Nam, T., Oh, M., Choi, S. (2022). An Efficiency measurement of e-government performance for network readiness: Non-parametric frontier approach. Journal of Open Innovation: Technology, Market, and Complexity, 8(1): 10. https://doi.org/10.3390/joitmc8010010

[31] Nastjuk, I., Trang, S., Papageorgiou, E.I. (2022). Smart cities and smart governance models for future cities: Current research and future directions. Electronic Markets, 32(4): 1917-1924. https://doi.org/10.1007/s12525-022-00609-0

[32] Noori, N., Hoppe, T., De Jong, M., Stamhuis, E. (2023). Transplanting good practices in Smart City development: A step-wise approach. Government Information Quarterly, 40(2): 101802. https://doi.org/10.1016/j.giq.2023.101802

[33] Owczarek, T., Sojda, A., Wolny, M. (2022). The study of the interdependencies of areas and aspects of smart city in Polish cities. Zeszyty Naukowe. Organizacja i Zarządzanie/Politechnika Śląska, 161: 203-214. https://doi.org/10.29119/1641-3466.2022.161.14

[34] Popova, Y., Popovs, S. (2022). Impact of smart economy on smart areas and mediation effect of national economy. Sustainability, 14(5): 2789. https://doi.org/10.3390/su14052789

[35] Popova, Y., Zagulova, D. (2022). UTAUT model for smart city concept implementation: Use of web applications by residents for everyday operations. Informatics, 9(1): 27. https://doi.org/10.3390/informatics9010027

[36] Secinaro, S., Brescia, V., Lanzalonga, F., Santoro, G. (2022). Smart city reporting: A bibliometric and structured literature review analysis to identify technological opportunities and challenges for sustainable development. Journal of Business Research, 149: 296-313. https://doi.org/10.1016/j.jbusres.2022.05.032

[37] Shenkoya, T. (2023). Can digital transformation improve transparency and accountability of public governance in Nigeria? Transforming Government: People, Process and Policy, 17(1): 54-71. https://doi.org/10.1108/tg-08-2022-0115

[38] Vishnu, S., Ramson, S.J., Rukmini, M.S.S., Abu-Mahfouz, A.M. (2022). Sensor-based solid waste handling systems: A survey. Sensors, 22(6): 2340. https://doi.org/10.3390/s22062340

[39] Vujković, P., Ravšelj, D., Umek, L., Aristovnik, A. (2022). Bibliometric analysis of smart public governance research: Smart city and smart government in comparative perspective. Social Sciences, 11(7): 293. https://doi.org/10.3390/socsci11070293

[40] Zumofen, R., Kakpovi, B.G. Mabillard, V. (2022). Outcomes of government digitization and effects on accountability in Benin. Transforming Government: People, Process and Policy, 16(3): 305-317. https://doi.org/10.1108/tg-10-2021-0173

[41] Zamponi, M.E., Barbierato, E. (2022). The dual role of artificial intelligence in developing smart cities. Smart Cities, 5(2): 728-755. https://doi.org/10.3390/smartcities5020038