Architecture of an event-driven serverless digital service for citizen participation in decision-making

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Abstract

As urban populations grow and urban governance systems become more complex, the need for digital services that enhance citizen engagement in decision-making is increasing. This article presents the architecture of an event-driven, serverless e-participation service implemented on the Amazon Web Services (AWS) cloud platform. The proposed solution combines the scalability and cost-effectiveness of serverless technologies with computer vision tools for biometric user identification, ensuring a high level of security and trust.

The service architecture includes modules for registration and authentication (Amazon Cognito), identity verification (Amazon Rekognition), business logic processing (AWS Lambda), data storage (DynamoDB, S3), and analytics (EventBridge, Athena, QuickSight). Empirical testing has shown that the proposed model provides high performance (up to 380 transactions per second) and reduces operating costs by 80–85% compared to traditional hosting models.

The scientific novelty of this work lies in the integration of an event-driven serverless architecture and artificial intelligence technologies for user identification, which has not previously been applied in the context of civic engagement platforms. The practical significance lies in the scalability of the solution for various cities in Kazakhstan and its integration with national digital platforms. The proposed approach facilitates the development of new forms of interaction between citizens and government agencies within the framework of the "Smart City" concept.

Keywords

Smart City, e-Participation, digital services, AWS, serverless architecture, citizen engagement

1. Introduction

Modern cities face the challenge of increasing citizen engagement in decision-making processes. Traditional offline formats (meetings, public hearings) are characterized by low efficiency, high costs, and limited accessibility. Within the Smart City concept, the implementation of digital services that ensure transparent and widespread participation is becoming increasingly important. This article examines the experience of developing a service architecture based on the event-driven serverless architecture of AWS.

The goal of the study was to create a digital service that would engage citizens in discussions and decision-making processes on key urban development issues. Particular attention was paid to ensuring ease of use and technological sustainability, which would contribute to the development of a new culture of interaction between society and government.

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To achieve this goal, several sequential tasks were formulated. First, it was necessary to analyze existing international and local e-participation practices to identify the strengths and weaknesses of existing solutions. Second, it was necessary to design the architecture of the future service, taking into account modern scalability and security requirements.

The scientific novelty lies in the use of an event-driven, serverless AWS architecture to build a digital urban service, as well as the integration of computer vision tools for user identification. The significance of the study lies in the feasibility of scaling the proposed architecture across various cities and integrating it with national information systems.

2. Materials and methods

The research methodology was structured as a sequential process moving from an analysis of existing practices to the design of a digital service architecture. It combines two interrelated areas: an analysis of best practices in e-Participation and the design of a digital service's technological architecture. This approach allowed for the development of a sustainable and scalable model adapted for use in a modern smart city.

The first stage involved a pre-project analysis, which included identifying citizen needs and expectations, as well as studying international and local e-participation practices. Practices such as Decidim Barcelona, Better Reykjavik, Consul Madrid, and the Kazakhstani initiatives OpenAlmaty and eOtinish were considered. The analysis revealed the key advantages of existing solutions (a wide range of engagement tools, integration with municipal processes) and their limitations (moderation difficulties, insufficient flexibility of architectural solutions, difficulties with user verification).

The second phase involved designing the service architecture. The event-driven serverless architecture of Amazon Web Services (AWS) was chosen as the underlying technology platform. This choice was driven by scalability, reliability, and cost-effectiveness. The architecture includes the following key modules: user registration and authentication using Amazon Cognito; citizen biometric verification via Amazon Rekognition; business logic implementation via AWS Lambda; data storage in Amazon DynamoDB and Amazon S3; content administration and management via AWS Amplify and API Gateway; and analytical processing and data visualization using Amazon EventBridge, Kinesis, Athena, and QuickSight.

Special attention was paid to security and reliability: protection from network attacks was provided by AWS WAF, access rights were controlled via IAM, and data transmission and storage were encrypted.

3. Literature review

Until recently, the global discourse surrounding the Smart City concept assumed that it should be centered on impersonal technological developments, big data, and algorithms capable of offering a single, supercomputer-calculated solution to the daily challenges facing modern cities [1].

In recent years, there has been a growing understanding in developed countries that cities, as complex and unique organisms, often cannot be contained within the confines of hardware and software. In-depth contextual research and consideration of the opinions and needs of urban stakeholders are essential [1].

The primary goal of any Smart City initiative is to serve citizens, improve their quality of life, and simplify the solution of everyday and urgent problems. This is impossible without the active and organized participation of citizen communities and other stakeholders.

Urban governance is one of the most important development challenges of the 21st century – 54% of the world's population lives in cities, and this proportion is expected to increase to 66% by 2050 [2]. Urban governance encompasses new actions in infrastructure, energy sustainability, the natural environment, education, healthcare, and public safety, to name a few. However, challenges such as increasing resource demand and organizational and governance complexity make cities major sources of congestion, pollution, and waste, exacerbating a range of socio-economic problems such as poverty, unemployment, transportation, and crime. Smart city and smart government ideas have been conceived as approaches to addressing such complex urban issues. Smart city and smart government approaches utilize information and communications technology (ICT) to improve the interactivity, quality, and efficiency of urban services, reduce costs and resource consumption, and improve interactions between government, citizens, and businesses [3].

Technologically advanced countries place great importance on citizen engagement in smart city projects and strive to incorporate citizen participation into smart city strategies. This trend is based on numerous studies, the authors of which conclude that, in most cases, it is better to involve citizens in projects aimed at improving their well-being. If the population participates in decision-making, the laws and projects they have worked on are closer to reality and are easier to implement [4]. Moreover, citizen engagement in state and municipal governance increases their trust in the state and reduces their hostility. Decisions by state and municipal authorities become more legitimate. However, it is worth recognizing that citizen engagement has some negative consequences. For example, consultation with many interest groups significantly prolongs the decision-making process and can be costly [4]. These disadvantages can be minimized by using modern ICT to stimulate citizen participation.

The need to engage citizens in urban governance has been noted in many renowned academic works. Henri Lefebvre was the first to formulate the idea of the "right to the city." Its essence lies in the idea that citizens should have the right to shape the urban environment because they are the inhabitants of these spaces [5].

As part of the analysis of existing digital services and platforms, city portals, mobile applications, and web platforms worldwide and in Kazakhstan aimed at engaging with citizens were examined.

One of the most successful projects for engaging citizens in the life of a metropolis is the "Sydney: Your Say" program in Sydney, Australia [6].

As part of this strategy, city authorities created an online consultation platform, "Sydney: Your Say," to enable the public to contribute to decision-making. Every resident registered in the city can comment on draft government laws or propose amendments. However, this program is only used for citizen consultation on predetermined issues. Residents do not have the opportunity to propose their own development concepts for the city's districts.

Another successful example of citizen engagement in smart city decision-making is Barcelona. The Decidim Barcelona online platform for citizen participation is actively operating there. Besides Barcelona, Decidim is used for citizen engagement in 45 other cities and regions worldwide, including New York and Helsinki. The platform offers city residents various ways to express their opinions on public processes and transformations.

In the Netherlands, another form of citizen engagement is very popular: living laboratories. These are spaces that facilitate experimentation and the development of sustainable, long-term solutions.

Participants typically generate ideas for experiments, technological, and social innovations to test against the needs of end users of the urban environment. One such living laboratory is implemented by PLYGRND.city and is called the "Hoodlab" [7]. Its unique feature is that the lab can be moved from one location to another, as it is a standard shipping container. This allows the Neighborhood Lab to travel to areas where communities need to rally after events that have impacted residents. In these mobile locations, residents gather and brainstorm ways to improve their neighborhoods. The goal of the living lab is to create high-quality and close connections between residents.

The Consul platform was implemented in Madrid and has since been deployed in over 30 countries. Its advantage lies in its adaptability to various legal systems, but its limitations stem from its architecture, which relies on a classic client-server model, which reduces scalability.

In Scandinavia, the Better Reykjavik project, aimed at engaging citizens in the discussion of city initiatives and budget allocation, has gained widespread popularity. Its distinctive feature is its emphasis on participatory budgeting and integration with municipal processes.

Kazakhstan is not standing idle in matters of citizen engagement in urban development. The adopted "SMART ALMATY" Strategy for 2020-2025 highlights objectives 3 and 4, the purpose of which is to engage city residents in problems and ways to solve them [8].

An implemented example is the "Public Participation Budget" (hereinafter referred to as PPP) project on the OpenAlmaty portal [9]. PPP involves the population in the distribution of local budget funds as part of its formation. This is a digital process of interaction between local executive bodies and the population. According to it, residents can choose how to spend budget funds.

Another example in Kazakhstan is the eOtinish project—an electronic system that was introduced in Kazakhstan on July 1, 2021, for submitting electronic citizen appeals to government agencies. Appeals can be submitted through the eGov portal, eOtinish, and eGov mobile applications.

The e-Otinish service allows you to: submit an official request for information from government agencies; submit an appeal or complaint; report problems you are facing; ask for assistance in exercising your rights and legitimate interests; demand the protection of your rights, freedoms, or legitimate interests.

On April 4, 2024, the state-run e-petition aggregator website, e-Petition, officially launched in Kazakhstan. The development and implementation of the e-Petition service was based on the e-Otinish service.

However, filling out the system's subsections can be problematic, as it is quite difficult to correctly formulate the petition's addressee (it is necessary to choose from multiple options, and it is easy to make a mistake). Furthermore, the e-Otinish service lists both the State Institution "Office of the Government of the Republic of Kazakhstan" and the State Institution "Administration of the President of the Republic of Kazakhstan" as possible addressees, whereas attempting to enter these addresses as addressees in the e-Petition service yields no result. When considering the implementation of the e-petition tool as a whole, it can be concluded that key issues remain unresolved. These include pre-moderation, user verification, and excessive centralization of the process.

Existing solutions demonstrate significant success in citizen engagement, but issues of scalability, accessibility, and reducing operating costs remain unresolved. The service presented in this article continues to develop this direction, offering an innovative approach using AWS serverless architecture and computer vision tools.

4. Digital service architecture

The digital service architecture was designed with modern scalability, security, and cost-effectiveness in mind. The solution was built on the Amazon Web Services (AWS) cloud infrastructure, enabling an event-driven, serverless approach. This choice ensured the system's flexibility and the ability to dynamically expand as the number of users grows.

A key element of the architecture is the registration and authentication module. Citizen identification is accomplished through a combination of Amazon Rekognition, which enables photo (selfie) verification, and Amazon Cognito, which manages access and accounts. This combination enhances security and reduces the likelihood of fraud.

Users interact with the service through API Gateway, which routes requests to a set of Lambda functions. These functions execute the application's business logic: processing survey data, generating QR codes for access, and managing user rights. Information is stored in a DynamoDB database and Amazon S3 file storage, ensuring high access speed and reliability.

AWS Amplify is used for content administration and management, providing a user-friendly interface for administrators and developers. The service's analytics module is built on EventBridge and Kinesis for streaming data processing, as well as Athena and QuickSight for analysis and visualization. This enables real-time reporting and prompt assessment of citizen activity levels.

Particular attention has been paid to security: IAM-based privilege differentiation mechanisms are implemented, AWS WAF provides attack protection, and data is encrypted both in transit and at rest. The service architecture combines technological reliability, adaptability, and cost-effectiveness, making it suitable for implementation in a modern smart city.

Figure 1 shows a simplified diagram of the digital service architecture.

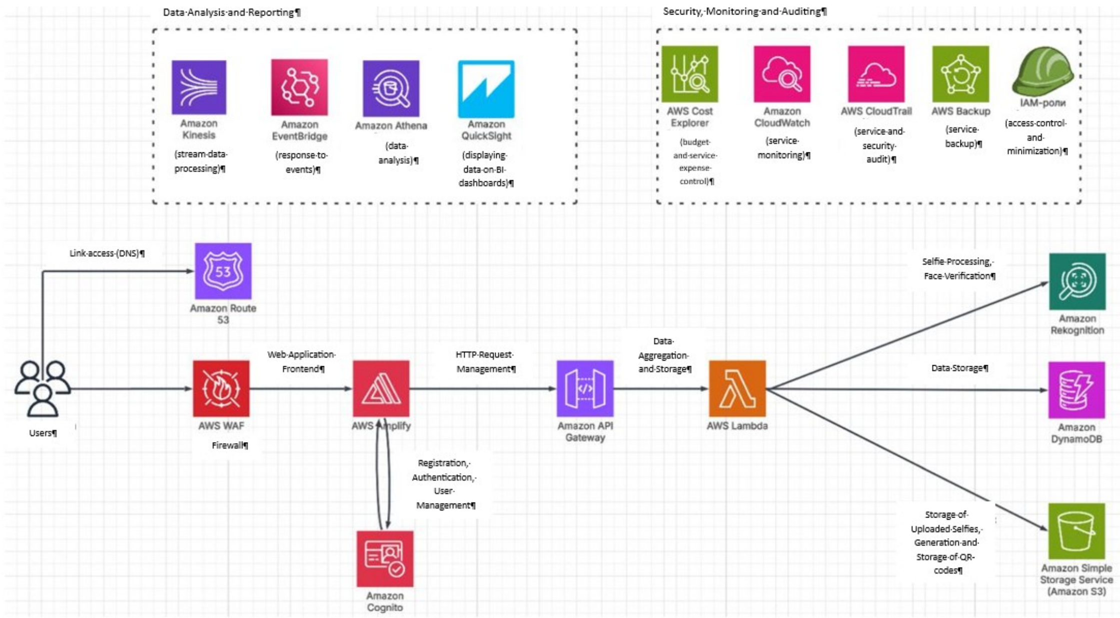

Figure 1: Digital service architecture.

Choosing an event-driven serverless architecture offers a few advantages. First and foremost, it allows the system to automatically adapt to changing operating conditions: as the number of users increases, resources scale without administrator intervention, and resource consumption is reduced as the load decreases. This approach makes the service flexible and cost-effective.

A key advantage is high reliability and fault tolerance. Thanks to the distributed nature of AWS cloud services, the system remains operational even if individual components fail. Security is ensured using multi-level authentication, data encryption, and protection from network attacks.

Cost efficiency is achieved through the pay-per-use model, which allows payment only for the resources consumed. This reduces barriers to implementation and operation of such solutions in municipal structures. Taken together, these advantages make the service architecture resilient, secure, and efficient.

5. Comparison of the chosen approach with existing alternatives

Table 1 presents a comparison that summarizes the results of the architectural approach selection for the digital service and compares it with viable alternatives. The comparison is based on the developed architecture (serverless model on AWS), the results of MVP development and tests, as well as considering data localization constraints in the Republic of Kazakhstan and expected operational scenarios (variable load peaks, rapid releases, limited operational resources).

Table 1 is designed for engineering and management decision-making and evaluates options along the following axes: brief description, key benefits and risks/limitations, scalability and total cost of ownership (TCO), suitability for service objectives, and a final recommendation. Columns are interpreted based on the status of the service (MVP) and the target operational model; as scaling and/or regulatory requirements change, the criteria prioritization can be refined.

The chosen serverless approach on AWS is optimal for our scenario (variable peaks, fast MVP rollout, minimal operational overhead), subject to the Republic of Kazakhstan's data localization requirements (a two-loop approach: a sovereign loop in Kazakhstan + only anonymized data outside Kazakhstan). Containers/Kubernetes are a fallback strategy for specific, long-term tasks; open-source platforms are useful as functional references, but lack elasticity and rollout speed.

Table 1.
Comparison of the chosen approach with existing alternatives

Approach/ alternative	Brief description	Key benefits	Key disadvantages/ risks	Scalability and TCO	Compliance with service objectives	Recommen-dation
Serverless on AWS (Chosen Approach)	Lambda + API Gateway + DynamoDB + S3 + EventBridge + Cognito + Athena/QuickSight	Auto-scaling; pay-per-call; fast MVP; tight service integration; low operational load; high availability	Cold starts (mitigated by provisioned concurrency); vendor lock-in; data localization requirements (requires a Kazakhstani circuit)	Very high; low TCO under variable load	High - Ideal for peak engagement campaigns	Use as a basic technical standard; supplement with a localization scheme in the Republic of Kazakhstan
Containers / Kubernetes (or ECS/Fargate)	Microservices in containers, cluster autoscaling	Flexible environments; control over runtime; no cold starts; portability	Higher DevOps costs; cluster management; need to reserve capacity for peaks	High, but with operational costs; TCO is higher with rare peaks	Average - justified for specific calculations /long tasks	Consider specifically for "long" or specialized workloads
VPS / traditional hosting (monolithic)	Multiple VMs + Web Application + Database	Simple model; predictability	Poor elasticity; manual scaling; downtime risks; harder to provide HA/DR	Low at startup, but TCO rises rapidly as load increases	Low - does not correspond to peak scenarios	Not recommended for urban scale
VPS / traditional hosting (monolithic)	Multiple VMs + Web Application + Database	Simple model; predictability	Poor elasticity; manual scaling; downtime risks; harder to provide HA/DR	Low at startup, but TCO rises rapidly as load increases	Low - does not correspond to peak scenarios	Not recommended for urban scale
On-premise / own data center	Placement in the city's infrastructure	Full control; simplified legal compliance agenda	Capital expenditures; long lead times; difficult scaling and fault tolerance	Dependent on investments; elasticity is limited	Average - useful for sovereign data	A hybrid approach is possible: personal data in the Republic of Kazakhstan, processing/showcases in the cloud using anonymized data
Other clouds (Azure/GCP, on-premises providers)	Similar managed services	Reduced lock-in to a single vendor; sometimes better jurisdictional compliance	Differences in service/ecosystem maturity; migration costs	High	Medium–high – depends on the availability of local regions/services	Consider as a strategic backup or for a hybrid scheme

6. Empirical testing and performance evaluation

To validate the functionality and effectiveness of the proposed architecture, a pilot test of the digital e-participation service was conducted in the AWS test environment (Table 2). Response time, scalability, throughput, and system stability were assessed.

Load testing was conducted using AWS CloudWatch, Apache JMeter, and Kinesis Data Generator. The test configuration included 12 AWS Lambda functions, one DynamoDB table, an API Gateway, and S3 storage. User activity was simulated with an uneven distribution of requests over the course of a day – from 5 to 50 requests per second, which corresponds to the dynamics of real-world opinion gathering and voting campaigns.

Table 2.
Results of empirical testing of the proposed architecture

Load level	Number of concurrent users	Average response time	Peak response time	Throughput (TPS)	Comments
Low	100	0,7s	0,9s	~80	The system operates without delays; the load is distributed evenly
Average	500	0,95s	1,2s	~140	Optimal state, minimal delays in event queues
Increased	1 000	1,3s	1,6s	~210	Slight increase in response time, the system scales steadily
High	2 000	1,8s	2,1s	~290	There is an increase in delays with frequent requests, the system compensates for this through autoscaling
Peaks	5 000	2,2s	2,6s	~340	When provisioned concurrency is activated, the response time is reduced to 1.7s, stability is maintained

The graph (Fig. 2) illustrates the dependence of the average system response time on the number of concurrent users in the range from 100 to 5,000. Without provisioned concurrency (orange line), latency increases after 2,000 users. Enabling provisioned concurrency (blue line) stabilizes performance and reduces the average response time to 1.1–1.7 seconds, even under peak loads. The green line reflects a theoretical model confirming the linear scalability of the architecture.

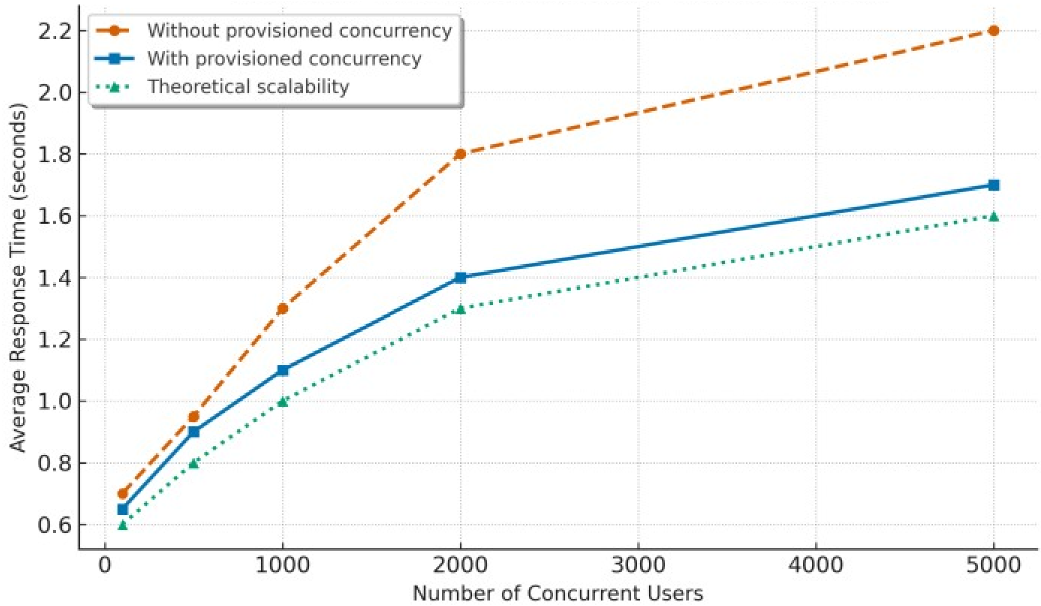

Figure 2: Dynamics of response time with increasing load.

An empirical test confirmed that the proposed event-driven serverless architecture ensures high performance when implementing e-participation services. The results provide the basis for further field pilots using real municipal data and integration with national digital platforms of the Republic of Kazakhstan.

7. Discussion

The transition from a traditional client-server architecture to an event-driven serverless model has demonstrated a significant increase in the efficiency of e-participation services. Pilot tests confirmed that the proposed solution provides linear scalability, high fault tolerance, and cost-effectiveness for loads of up to 5,000 users without performance degradation.

The proposed architecture differs from existing platforms, such as Decidim (Spain) and Consul (Spain, Latin America), primarily in its technological paradigm.

Decidim and Consul are based on the classic client-server model and require constant computing power, administration, and manual scaling, making them vulnerable to peak loads and increasing operating costs.

In contrast, the proposed solution implements an event-driven serverless architecture, where computing functions are activated by events, and the infrastructure scales automatically. This enables high flexibility without the capital expenditures of maintaining servers. The system also integrates, for the first time, a computer vision-based identity verification module (Amazon Rekognition), ensuring reliable citizen identification while minimizing the risk of fraud and abuse.

Furthermore, the architecture includes a streaming analytics module (EventBridge + Kinesis + QuickSight), which enables near-real-time analysis of citizen activity, identifying peaks of interest, and automatically adapting the interaction interface. The developed system creates a new class of intelligent participation platforms capable of not only recording activity but also adaptively responding to social dynamics.

Particular attention is paid to the confidentiality of personal data and the legal requirements of the Republic of Kazakhstan for its localization. The architecture provides for a dual-loop data storage model: user personal data is stored in a national data center, while analytical processing is performed in the cloud using anonymized data. All operations are encrypted both in transit and at rest, and access to data is regulated through AWS IAM and WAF mechanisms. The use of facial recognition technologies adheres to the principles of ethical AI use: users are informed about the nature of their data processing, and participation is possible only after agreeing to the terms of service. This approach strikes a balance between security, transparency, and respect for citizens' digital rights.

Despite technological advances, challenges remain related to digital inequality and accessibility for socially vulnerable groups. In particular, older users and residents of rural areas may face limited access to high-speed internet or low digital literacy. Therefore, interface development is focused on universal design: adaptive fonts, voice prompts, and streamlined navigation.

The architecture combines innovation and social awareness, creating conditions for inclusive citizen participation, regardless of age, technical skills, or location.

The proposed architecture defines a new research vector in the field of e-participation. Theoretically, it describes digital participation as a flow system of events, where each act of citizen interaction becomes an element of a dynamic model of social activity. The practical contribution lies in the proven feasibility of scaling the architecture at the city or regional level without significant cost increases or performance losses.

Empirical testing confirmed the architecture's feasibility and its potential as a foundation for national digital participatory services.

8. Conclusion

The study demonstrated that an event-driven serverless architecture can serve as an effective foundation for building modern citizen e-participation systems. Implementation of a prototype on the AWS platform confirmed the high performance, stability, and cost-effectiveness of the developed solution.

The scientific novelty of this work lies in the integration of serverless technologies and computer vision in the context of civic participation, which enables scalability and reliable user identification. The architecture forms a new theoretical approach to modeling citizen engagement as a self-adaptive process driven by events and data.

From a practical perspective, the system ensures stable operation under changing workloads, a high level of data security and privacy, and the ability to integrate with national digital platforms of the Republic of Kazakhstan.

In the long term, the study's results pave the way for the creation of hybrid Smart City services combining artificial intelligence, streaming analytics, and digital democracy mechanisms. The development of such solutions will improve the transparency of public administration, citizen trust, and quality of life in Kazakhstan's cities.

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Declaration on Generative AI

During the preparation of this work, the authors used OpenAI-GPT-5 to: Grammar and spelling check. After using this tool, the authors reviewed and edited the content as needed and takes full responsibility for the publication’s content.

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