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KAZAKHSTAN

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ARCHITECTURE OF AN INTELLIGENT CHATBOT FOR SMART CITY: AI-BASED RECEIVING, ANALYSIS AND ROUTING OF CITIZEN REQUESTS

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Abstract. The paper addresses the development of an intelligent digital service for receiving, analysing and routing citizen requests within a Smart City ecosystem, in which a Telegram bot serves as the primary communication channel. The aim is to design a service architecture that combines a conversational interface, a multi-step submission scenario, storage of multimedia attachments, and an automatic thematic

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classification module followed by routing to responsible municipal departments. The service is built on a finite-state machine, SMS OTP authorisation and an S3-compatible store; classification quality was compared across three models. On a corpus of 3,260 Russian-language requests, a RuBERT-class model achieved the highest quality (accuracy 0.914; F1 0.907), outperforming linear baselines. Simulation of two processing scenarios showed a reduction of the average time to forward a request to the relevant department from 26.15 to 6.85 minutes.

Keywords: Smart City, chatbot, artificial intelligence, automatic text classification, complaint routing, service architecture

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SMART CITY ҮШІН ИНТЕЛЛЕКТУАЛДЫ ЧАТ-БОТ АРХИТЕКТУРАСЫ: АЗАМАТТАРДЫҢ ӨТІНІШТЕРІН ЖАСАНДЫ ИНТЕЛЛЕКТ НЕГІЗІНДЕ ҚАБЫЛДАУ, ТАЛДАУ ЖӘНЕ БАҒЫТТАУ

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Аннотация. Мақалада Smart City экожүйесінде азаматтардың өтініштерін қабылдау, талдау және бағыттау үшін Telegram-бот өзара әрекеттесу арнасы ретінде пайдаланылатын интеллектуалды цифрлық сервисті әзірлеу қарастырылады. Жұмыстың мақсаты — диалогтік интерфейсті, өтінішті берудің көпқадамды сценарийін, мультимедиалық тіркемелерді сақтауды және обращенияларды профильді бөлімшелерге кейіннен бағыттай отырып автоматты тақырыптық жіктеу модулін біріктіретін сервис архитектурасын жобалау. Сервис ақырлы автомат, SMS OTP арқылы авторизация және S3-үйлесімді қойма негізінде іске асырылды; жіктеу үш модель үшін салыстырылды. 3260 орыс тілді өтініштен тұратын корпуста RuBERT класындағы модель ең жоғары сапа көрсетті (accuracy 0,914; F1 0,907) және сызықтық әдістерден асып түсті. Өңдеудің екі сценарийін модельдеу обращенияны профильді бөлімге жіберудің орташа уақытын 26,15-тен 6,85 минутқа дейін қысқартатынын көрсетті.

Түйінді сөздер: Smart City, чат-бот, жасанды интеллект, мәтінді автоматты жіктеу, шағымдарды бағыттау, сервистік архитектура

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АРХИТЕКТУРА ИНТЕЛЛЕКТУАЛЬНОГО ЧАТ-БОТА ДЛЯ SMART CITY: ПРИЁМ, АНАЛИЗ И МАРШРУТИЗАЦИЯ ОБРАЩЕНИЙ ГРАЖДАН НА ОСНОВЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА

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Аннотация. В статье рассматривается разработка интеллектуального цифрового сервиса приёма, анализа и маршрутизации обращений граждан в экосистеме Smart City. Каналом взаимодействия с пользователями выступает Telegram-бот. Цель работы — спроектировать архитектуру сервиса, объединяющую диалоговый интерфейс, многошаговый сценарий подачи обращения, хранение мультимедийных вложений и модуль автоматической тематической классификации с последующей маршрутизацией в профильные подразделения. Сервис реализован на основе конечного автомата, авторизации через SMS OTP и S3-совместимого хранилища. Качество классификации сопоставлялось для трёх моделей. На корпусе из 3260 русскоязычных обращений модель класса RuBERT показала наибольшее качество (accuracy 0,914; F1 0,907), превзойдя линейные методы. Моделирование двух сценариев обработки показало сокращение среднего времени передачи обращения в профильный отдел с 26,15 до 6,85 минуты.

Ключевые слова: Smart City, чат-бот, искусственный интеллект, автоматическая классификация текста, маршрутизация жалоб, сервисная архитектура

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Конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

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Introduction.

In recent years, the development of the Smart City concept has increasingly been linked not only to sensor infrastructure and urban data analytics, but also to the emergence of new digital channels for interaction between residents and government agencies. Against this backdrop, services that allow for quick reporting of urban issues, attaching supporting materials, and receiving feedback as the request is processed are particularly important. For such tasks, interfaces with a low entry barrier, accessibility on mobile devices, and the ability to automatically process incoming messages are in demand. Messengers, and Telegram bots in particular, are becoming one of the most natural user channels and are increasingly being considered as a component of digital city services (Senadheera et al., 2024; Bono Rossello et al., 2025).

The choice of Telegram as a channel for receiving requests is driven by a few practical considerations. The platform provides an open Bot API, supports the transfer of text, photos, videos, and documents, an Inline Keyboard, and conversation status. It does not require a separate app and is widely used among the region's population. These features lower the barrier to entry for residents while simultaneously providing the developer with a manageable software entry point to which server-side logic and an analysis module can be connected. Unlike web forms and call centers, the messenger's dialog interface allows the user to be guided step-by-step through the application process, ensuring the completeness of the entered data is verified on the client side.

However, interface convenience is not the only factor in demand. Research on digital dialogue in smart cities shows that resident satisfaction depends significantly on the timeliness of responses, the quality of government response, and the effectiveness of interactions (Shen et al., 2025). Citizens expect not only an accessible channel but also a noticeable reduction in the initial request processing time, transparency in the complaint flow, and more accurate recording of its content. Trust in the service itself plays a comparable role: the preferences of residents and front-office staff are also determined by the clarity of the operational logic, the accuracy of responses, and the ability to escalate to a human (Hemesath et al., 2024).

These expectations are driving a shift from passive message reception channels to intelligent services capable of automatically extracting meaning from text, identifying the subject of a complaint, and routing it to the appropriate department. Research on the automation of administrative procedures confirms that artificial intelligence can reduce routine workloads and speed up the initial processing of requests, but requires clear framework conditions related to data quality, accountability, and outcome control (Parycek et al., 2024). This leads to an important conclusion for city services: it makes sense to design request classification and routing not as an isolated NLP module, but

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as part of a managed service architecture (Rizun et al., 2025).

Data management requirements pose an additional constraint. A complaint reception service processes personal data, photographs, and video attachments, and therefore must consider not only the functional and algorithmic properties of AI but also infrastructural aspects. These include access control, file storage, action logging, and resilience to leaks and misrouting (König, 2021; Panahi et al., 2022). This study is part of a broader project to create an intelligent city system based on the Internet of Things and data analytics, in which the complaint reception service serves as a human-facing channel complementing sensory sources of city data.

A literature review shows that individual areas-AI support for digital participation, the use of chatbots in local government, automatic complaint classification, and data security requirements-have been studied in considerable detail. However, they are typically considered separately. A scenario in which a Telegram bot serves as the front-end interface for a city service, and an AI module is integrated into a unified architecture for receiving, analyzing, and routing requests, followed by experimental evaluation of classification quality, is poorly represented in the literature. Such solutions are even less frequently evaluated for Russian-and Kazakh-language request flows in a specific regional context (Rakhimzhanov et al., 2025). This gap determines the relevance of this study.

The need for automation is increasing as the volume of digital requests grows. With the expansion of electronic channels, the number of incoming messages increases, and manual sorting becomes a bottleneck. Operators are forced to read each request, assign it to the appropriate topic, and select the appropriate department, which slows response times and increases the risk of errors during peak loads. Transferring routine sorting to an algorithm allows for human intervention to be retained where it's truly needed while simultaneously speeding up the processing of the massive influx of typical complaints. This combination of automatic classification and the managed transfer of questionable cases to an operator forms the basis of the proposed service.

The research object is a digital service for receiving and processing citizen requests in a Smart City environment. The subject of the study is the architectural, algorithmic, and applied aspects of building a Telegram-based service with intelligent classification and routing of requests. The goal of the work is to develop an intelligent service architecture that integrates a dialog interface, service-based request processing, storage of multimedia attachments, and an artificial intelligence module into a reproducible model of an urban digital service. To achieve this goal, the following tasks were solved: designing a service architecture and data model; formalizing a request submission scenario based on a finite-state machine; implementing a thematic text classification and routing algorithm; deploying the service in a containerized environment and conducting functional, load, and usability testing; performing a comparative evaluation of classification models and assessing the impact of AI routing on initial processing time. The scientific novelty of this work lies in the integration of a dialog frontend, a managed service architecture, and a Russian-language request classification module into a reproducible urban service model, with an experimental

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evaluation of both the classification quality and the applied effect of routing.

Materials and methods.

The proposed approach combines a conversational user interface, a service architecture for data storage and processing, and an artificial intelligence module for thematic classification and automatic routing of requests. Methodologically, the work combines system analysis, design based on service-oriented architecture principles, design science with prototyping of a working service, formalization of user scenarios using finite-state machine theory, and experimental comparison of classification algorithms. This combination of methods allows us to simultaneously consider the solution at three levels-architectural, algorithmic, and applied-and link engineering solutions to measurable quality metrics.

The basic service architecture is shown in Figure 1. The entry point is the Telegram API, through which messages are received by a service bot implemented according to Clean Architecture principles. Separation into layers of domain, use cases, adapters, and infrastructure ensures the independence of the request processing business logic from specific external components and simplifies the replacement of storage, gateways, and models without rewriting the core. The service bot interacts with a PostgreSQL relational database for storing requests and metadata, with Redis for session management, state machine states, and caching, and with S3-compatible MinIO storage for file attachments. Authorization is performed through an external SMS OTP service. An administrative web interface is available for employees (Fig. 1).

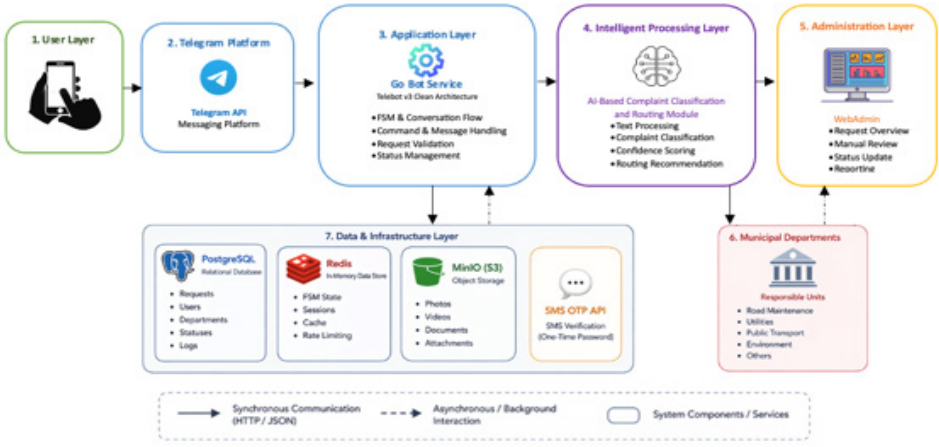


Fig. 1. Architecture of the intelligent service for receiving and routing citizen requests

Each component performs a separate function. The Telegram API is responsible for message delivery and attachment reception; the service bot implements user scenarios, input validation, and call orchestration; PostgreSQL stores structured request data and ensures its consistency during concurrent work by employees; Redis stores the rapidly changing state of a conversation and reduces the load on the database through caching; MinIO stores photos, videos, and documents, separating binary objects from relational data; and the administrative web interface provides employees with access to

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the list of requests, their statuses, and attachments. This separation of responsibilities is consistent with recommendations to consider request classification not as an isolated module, but as an element of a managed service infrastructure (Rizun et al., 2025).

The administrative web interface is designed for employees and complements the dialog channel with a processing function. The prototype features a dashboard with quantitative indicators of the request flow (total number, new, pending, resolved, and rejected), a breakdown of requests by subject category, a feed of recently received requests with status and date, and a card for each request with its text, change history, correspondence, and attached files. The interface supports language switching and request status management. This set of functions transforms the result of intelligent classification into a working tool: employees see the proposed category and responsible department, can confirm or adjust the decision, and track the entire complaint flow. Linking the dashboard to the same data entities used by the bot ensures a unified view of the request for both the requester and the operator and supports the transparency of processing that is essential for trust in city services (König, 2021).

The data model includes related entities reflecting the request lifecycle. The user entity stores the chat ID, phone number, name, interface language, role, and confirmation flag. A ticket contains a title, text, predicted category, status, responsible department, model confidence score, and spam flag, allowing the results of the intelligent analysis to be stored alongside the ticket itself. The ticket files are stored in a separate entity with a link to the storage object, type, and size, separating the management of attachments from the text data. User sessions record the current state of the state machine and the ticket draft, change history and discussion messages provide audit trails and communication between the requester and the operator, and department and employee entities define the organizational structure to which tickets are routed. Having a history and explicitly recording old and new field values increases the transparency of the complaint flow-a property that has been linked in the literature to trust in digital city services (König, 2021).

The ticket submission scenario is formalized as a deterministic finite-state machine (FSM) described by a tuple:

$$A = (S, E, \delta, s_0, F) \tag{1}$$

where S is a finite set of states, E is the set of input events (input alphabet), δ the transition function, s_0 is the initial state, $F \subseteq S$ is the set of final states. The set of states and the subset of final states are defined as:

$$S = \{s_0, s_1, \dots, s_n\}, F \subseteq S \tag{2}$$

with the states corresponding to authorization, title and text entry, attachment loading, confirmation, and call completion. The machine's response to a single event is determined by the transition function:

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$$\delta: S \times E \to S \tag{3}$$

and for the sequence of events $w = e_1, e_2, \ldots, e_k$, an extended transition function is introduced, defined recursively:

$$\delta^*(s, w \cdot e) = \delta(\delta^*(s, w), e), \delta^*(s, \varepsilon) = s \tag{4}$$

A completed request corresponds to a path from s_0 to one of the states of set F; if no further event arrives within the waiting time τ, the session is put into an interrupted state, preventing the accumulation of "stuck" drafts. The set of events E includes bot commands (/start, /new, /list, /cancel, /chat), text messages, inline button clicks, and file uploads with size restrictions. Data completeness control on the machine side reduces the number of requests without required fields and improves the suitability of the text for subsequent automatic classification.

After registration, the text of a request x is represented as a numeric vector. For linear models, TF-IDF features are constructed: the weight of a term t in a request x is defined by the product of the term frequency and the inverse document frequency,

$$w_{t,x} = tf(t, x) \cdot idf(t), idf(t) = log \frac{N}{1 + df(t)} \tag{5}$$

where N is the number of documents in the corpus, and d$f(t)$ is the number of documents containing term t. The resulting vector is subjected to L2 normalization

$$\hat{x} = \frac{\varphi(x)}{\|\varphi(x)\|_2} \tag{6}$$

The logistic (softmax) model estimates the posterior probability of each of the $K = 8$ categories using linear logits

$$z_c = w_c^T \hat{x} + b_c, P(c|x) = \frac{e^{z_c}}{\sum_{k=1}^{K} e^{z_k}} \tag{7}$$

A linear support vector machine is trained using the maximum margin principle in a one-versus-all scheme with a hinge loss function and L2 regularization

$$min \frac{1}{2} \|w_c\|^2 + C \sum_{i=1}^{N} \max(0, 1 - y_i^{(c)} (w_c^T \varphi(x_i) + b_c)) \tag{8}$$

The context model of the RuBERT class builds a text representation using the multi-headed attention mechanism of the transformer

$$Attention(Q, K, V) = softmax\left(\frac{QK^T}{\sqrt{d_k}}\right) V \tag{9}$$

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on top of the aggregated representation, the classification head of which forms the distribution by categories, and the additional training of the model is performed by minimizing the cross-entropy:

$$p = softmax(W_o h_{[CLS]} + b_o), L = -\frac{1}{N}\sum_{i=1}^{N}\sum_{c=1}^{K} y_{i,c}\, logP(c|x_i) \quad (10)$$

The final category of the appeal and the associated confidence assessment are determined as:

$$\hat{C} = \arg\max_{c \in C} P(c|x), p = \max_{c \in C} P(c|x) \quad (11)$$

The routing decision is given by a threshold rule that considers the spam filter $\sigma(x) \in \{0, 1\}$ and the mapping of categories to responsible departments μ:C→D:

$$R = \oint(\hat{C}, p) = \mu(\hat{C})\ if\ p \geq p_{min} \wedge \sigma(x) = 0; else \rightarrow operator \quad (12)$$

If the confidence score exceeds the p_{min} threshold and the request is not marked as spam, it is routed automatically; otherwise, it is passed to an operator for confirmation. Thus, the p_{min} threshold and the *σ(x)* filter jointly regulate the balance between the proportion of fully automated requests, routing accuracy, and robustness to noisy messages.

Classification quality is assessed using a $K \times K$ confusion matrix *M,* where element M_{ij} is equal to the number of requests of category *i* classified by the model into category *j.* The proportion of correct decisions, precision, and recall for category *c* are defined as:

$$Accuracy = \frac{\sum_{c=1}^{K} M_{cc}}{\sum_{i,j} M_{ij}}, Pr_c = \frac{M_{cc}}{\sum_i M_{ic}}, Re_c = \frac{M_{cc}}{\sum_j M_{cj}} \quad (13)$$

The measure balanced in precision and recall and its averaging over classes are calculated as:

$$F1_c = \frac{2Pr_c Re_c}{Pr_c + Re_c}, F1_{macro} = \frac{1}{K}\sum_{c=1}^{K} F1_c \quad (14)$$

Application efficiency is characterized by the share of automatically routed requests and the average routing time

$$AutoRate = \frac{1}{N}\sum_{i=1}^{N} 1[p_i \geq p_{min} \wedge \sigma(x_i) = 0], \bar{\tau} = \frac{1}{N}\sum_{i=1}^{N} \tau_i \quad (15)$$

where $\mathbb{1}[\cdot]$ is the indicator function, and τ_i is the routing time of the $i - th$ request. This set of metrics links the algorithmic quality of the model with the operational

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effectiveness of the service and is subsequently used in experimental evaluation.

Three approaches of varying complexity were compared as classification models: logistic regression on TF-IDF features, a linear support vector machine (Joachims, 1998), and a pre-trained language model of the RuBERT class (Kuratov et al., 2019). The choice of this particular set reflects a trade-off between interpretability, training cost, and quality: linear models on sparse features serve as strong and fast baseline solutions, while the language model evaluates the potential gain from taking into account context. The choice of RuBERT is due to the fact that the transformer architecture (Vaswani et al., 2017) and bidirectional pre-training (Devlin et al., 2019) make it possible to take into account the context and semantics of short Russian-language phrases typical of appeals; It is also known that retraining such models for a specific classification task yields a stable increase in quality (Sun et al., 2019; Minaee et al., 2021).

Text preprocessing included lowercase conversion, deletion of special characters, and tokenization; TF-IDF features were constructed for the linear models, and subword tokenization was used for the language model. The corpus was split into training, validation, and test sets (70/15/15), with the final metrics calculated on the holdout test set. Cross-validation was used to ensure the robustness of the estimates. Hyperparameter tuning (linear model regularization coefficient, learning rate, number of epochs, and batch size for RuBERT) was performed on the validation set. Linear models, metrics, and splitting procedures were implemented using the scikit-learn library (Pedregosa et al., 2011). The experiments were performed in a computing environment with the following configuration: Intel Core i7 processor, NVIDIA GeForce RTX 3060 graphics accelerator, 16 GB of RAM, Windows 11 operating system, Python 3.10, pandas 2.2.2, numpy 1.26.4, scikit-learn 1.5.0, matplotlib 3.9.0, PyTorch 2.3.0, and transformers 4.41.2 libraries. Fixing the versions, random seeds, and partitioning parameters ensures the reproducibility of the experiment.

The service is deployed in a containerized environment. Bot images, PostgreSQL, Redis, and MinIO have been prepared; deployment is performed in a Kubernetes cluster (k3s distribution) with health checks and automatic component restarts, while the services are isolated on the internal network. The server side is configured with continuous integration and delivery via GitHub, Telegram update reception via webhook, secrets and environment parameter management, and logging. On the data side, a production PostgreSQL instance with applied schema migrations is used, along with Redis for the state machine, sessions, and cache, and regular scheduled database backups. This configuration meets the infrastructure requirements for city services processing personal data and files (Panahi et al., 2022).

The implemented functionality was tested in three areas, corresponding to the testing phase of the project schedule. Functional testing covered the correctness of state machine transitions and session expirations, the operation of all bot commands, one-time code authorization, and compliance with file size limits. Load testing assessed the service's resilience under high load, PostgreSQL's behavior during parallel queries, and the operation of multiple concurrent FSM sessions. Usability testing focused on

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the usability of inline buttons, the clarity of the status indicator, the correctness of the bilingual localization, and page-by-page navigation through the ticket list. At the time of preparation, the bot was deployed in a test environment, SMS OTP authorization was operational, and file submission, list and archive viewing, discussion mode, bilingual localization, and file storage in MinIO were implemented.

Since the service processes personal data and user files, the architecture incorporates security measures that meet smart city data management requirements (König, 2021; Panahi et al., 2022). Employee access is restricted by roles, and login is confirmed with a one-time code. Text data and binary attachments are separated into different storage locations: structured information is stored in PostgreSQL, while files are stored in isolated MinIO object storage, accessed through the service. Request actions are recorded in the change history, ensuring processing accountability, and regular backups reduce the risk of data loss. Network isolation of components and secret management through environmental parameters limit the attack surface. These solutions align with the principle that a smart city service should be assessed not only by algorithmic metrics but also by its infrastructural resilience and security (Parycek et al., 2024).

For the experimental evaluation, a set of metrics from two groups-classification quality and applied effectiveness-was used (Table 1). Quality metrics characterize the accuracy of request assignment to a category and the distribution of errors between classes, while applied metrics reflect the practical utility of the service: average routing time and the proportion of requests routed without operator intervention. This composition allows us to consider the service not only as a complaint reception interface but also as an intelligent component of the city's digital infrastructure, evaluating it simultaneously in terms of classification accuracy and operational effectiveness.

Table 1. Evaluation metrics of the intelligent request processing service

Evaluation Group	Metric	Purpose
Classification Quality	Accuracy	The proportion of correctly classified requests
Classification Quality	Precision	The accuracy of assignment to a specific category
Classification Quality	Recall	The completeness of request identification by category
Classification Quality	F1-score	A balanced assessment of classification quality
Classification Quality	Confusion Matrix	An analysis of errors between categories
Applied Efficiency	Mean Routing Time	The average request routing time
Applied Efficiency	Auto-routing Rate	The proportion of requests routed without an operator

To enhance the reliability of the findings, standard validation procedures were used. Models were compared using a single corpus split with fixed initial values, eliminating the influence of randomness of splitting on the relative order of methods. Error analysis complements aggregated metrics by revealing which categories are confounded, thereby shifting the discussion of quality from the overall quantity

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to the practical consequences of incorrect routing. This set of procedures meets the requirements for reproducibility and evidence-based evaluation of intelligent components and allows us to separate consistent differences between models from random fluctuations.

Quantitative evaluation was conducted in a controlled computing environment using a corpus of queries. The corpus included 3,260 Russian-language queries with variable text length, incomplete wording, colloquial expressions, and topics typical of urban affairs. The queries were distributed across eight categories: road infrastructure, lighting, garbage collection, housing and utilities, public transportation, yard improvement, security, and illegal dumping.

Discussion.

The use of chatbots in local and municipal government has emerged as a distinct field in recent years. Review studies show that such solutions are primarily used for information, consultation, transactional services, and complaint handling, and that their successful implementation depends on citizen-centered design, institutional readiness, and the quality of interactions (Senadheera et al., 2024). Experiments with the preferences of residents and front-office staff further emphasize that not only convenience but also public values-response accuracy, the ability to escalate to a human, and operational logic that meets user expectations-are important for e-government (Hemesath et al., 2024). These results support the approach chosen in this study, in which automatic routing complements, rather than replaces, human interaction in cases of low model confidence.

The second area of research involves text analytics of requests. A review of text analytics tools in the public sector documents the rapid growth of machine learning, topic modeling, and short text classification methods. However, it is noted that a significant portion of solutions remains experimental or exists as separate analytical modules without tight integration into application services (Rizun et al., 2025). Research on real-world datasets of complaints confirms that automatic classification reduces the workload of operators and accelerates subsequent processing. A comparison of intelligent analysis algorithms on crowdsourced complaints revealed significant differences in accuracy between k-nearest neighbors, random forest, support vector machines, and boosting (Madyatmadja et al., 2023); the integration of an attention mechanism into the task of classifying complaints in government-citizen interaction systems yielded an increase in quality by taking into account significant text fragments (Zhang et al., 2025); a mixed-method analysis of complaints to a city hotline confirmed the dependence of the result on the subject taxonomy and the nature of the messages (Zhou et al., 2025). Deep learning-based solutions are also applied in urban complaint mobile applications, where categorization is performed based on the image of the urban problem (Shama et al., 2024).

For the Russian-language and regional context, a comparison of modern approaches to complaint classification is particularly revealing: the application of large language models and instructionally tuned embeddings to public transport complaints demonstrated performance sensitivity to the choice of model, instruction language,

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and subject taxonomy (Rakhimzhanov et al., 2025). This is consistent with the choice of a pre-trained Russian-language model of the RuBERT class (Kuratov et al., 2019) in this study, based on a transformer architecture (Vaswani et al., 2017) and bidirectional pre-training (Devlin et al., 2019); the accumulated experience of pre-training similar models and reviews of text classification methods indicate a consistent advantage of contextual representations over sparse features in tasks with short messages (Sun et al., 2019; Minaee et al., 2021).

The third area is formed by requirements for data management and security. Literature on Smart City platforms emphasizes that digital city services cannot be designed without considering accountability for data processing, transparent rules for its use, and protection of the digital environment (König, 2021), while systematic reviews of privacy technologies document a wide range of threats and solutions for protecting citizens in smart cities (Panahi et al., 2022). Work on the automation of administrative procedures provides a framework for the responsible use of AI, in which automation must be accompanied by outcome control and the preservation of human intervention in disputed cases (Parycek et al., 2024). These requirements are directly reflected in the architecture of the proposed service-in access control, dedicated file storage, action logging, and threshold logic that transfers uncertain decisions to the operator.

An architectural approach to digital participation deserves special attention. Research on the design of AI-enabled civic participation services formulates principles for constructing collective intelligence architectures in which technological components are linked to organizational and value requirements (Bono Rossello et al., 2025). In this logic, the contribution of this work lies not so much in a single classification model as in the way it is integrated: a dialog frontend, service processing, data and file storage, and a classification module with threshold routing are assembled into a reproducible architecture, where each component has clear responsibilities. This engineering approach, implemented through prototyping, complements the predominantly analytical research on request classification and brings their results closer to the conditions of real-world use in municipal services.

Comparison of these areas reveals a significant gap. AI support for digital participation (Bono Rossello et al., 2025), the use of chatbots in management, request classification, and data security requirements are considered largely in isolation. There are significantly fewer studies in which a Telegram bot serves as a front-end interface, and an AI module is integrated into a single, controlled architecture for receiving, analyzing, and routing data, with experimental evaluation of quality and processing time, and these rarely consider the Russian-language regional context. This paper addresses precisely this gap by considering classification and routing not as a standalone module, but as an element of a holistic service with a reproducible architecture and measurable practical impact.

Results.

The structure of the corpus is shown in Figure 2. The largest share of requests concerned road infrastructure, housing and utilities, and courtyard improvement. Requests concerning public transportation, safety, and illegal dumping were less

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numerous.

Hadoop delivered stable batch processing but struggled with latency in real-time tasks due to its disk-based model. Spark excelled in real-time analytics and iterative machine learning due to in-memory caching. The Hybrid system outperformed both, combining Hadoop's storage with Spark's speed-especially in multi-step workflows-delivering the fastest and most balanced performance across all tasks (Figure 2).

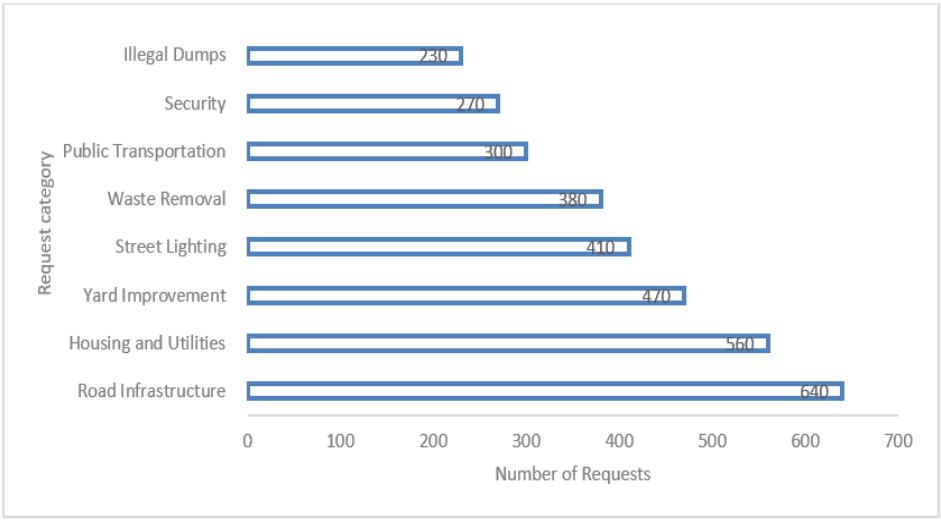


Fig. 2. Distribution of the synthetic request corpus by thematic categories (3,260 in total)

The next step involved comparing three classification models using the Accuracy, Precision, Recall, and F1-score metrics (Figure 3). The RuBERT class model demonstrated the highest quality: accuracy was 0.914, and F1-score was 0.907. Linear methods-logistic regression on TF-IDF features and linear SVM-were inferior to the language model, with the support vector machine being closer to it than logistic regression. The advantage of the transformer model is evident across all four metrics and is consistent with its ability to account for the context and semantics of short statements, whereas linear models rely primarily on the co-occurrence of individual words and are therefore less effective at distinguishing between similar but substantively different phrases. The balanced Precision and Recall scores of the best model indicate the absence of a pronounced bias toward certain categories. At the same time, the gap between the models is moderate, which is important to consider when choosing a solution for operation: linear methods, with significantly lower training and inference costs, remain a practically acceptable alternative where computing resources are limited (Figure 3).

For detailed analysis, Figure 4 shows the error matrix of the best model. Requests related to roads, housing and utilities, and yard improvement-categories with relatively stable and specific vocabulary-are recognized most reliably. Pairs of categories with semantic overlap proved more challenging: «garbage removal» and «illegal dumps,» as well as «lighting» and «safety.»

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Fig. 3. Comparison of request classification model quality

The nature of the errors suggests that the main source of inaccuracies is not the rarity of the classes themselves, but the closeness of their verbal expressions, with residents describing problems of varying severity using similar wording. The practical conclusion is that quality improvement should be sought not only by increasing the model's complexity but also by refining the subject taxonomy: combining difficult-to-distinguish categories, introducing a hierarchical classification, or adding clarifying features, such as the geolocation of the request.

Reducing initial processing time has a direct organizational impact. When request assignment to a category and department selection are performed automatically, the operator is freed up from the time previously spent reading and manually sorting each message; the operator is left primarily with uncertain and questionable cases, filtered by a threshold rule. All other things being equal, this increases front office throughput and smooths out peak loads when the number of requests increases. Importantly, however, the gains are not simply a matter of multiplying the average time by the number of requests: the actual effect depends on the proportion of automatically routed requests, the error rate and the cost of their correction, as well as the operator workflow. Therefore, the estimates provided should be considered as an indication of the potential for workload reduction.

The obtained estimates are consistent with the results of related studies. The achieved classification quality is at a level characteristic of transformer models on short Russian-language texts and confirms the feasibility of their use in the task of topic-based request routing. Unlike studies that consider the classifier as a standalone analytical module (Rizun et al., 2025; Zhou et al., 2025), in this study it is embedded in a managed service architecture, which allows us to link model quality with the applied effect-reduced initial processing time and reduced operator workload. A comparison

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with approaches based on large language models and embeddings (Rakhimzhanov et al., 2025) shows that the selected RuBERT model provides a reasonable compromise between quality and cost for Russian-language request flow, although direct comparison requires a single corpus and a unified taxonomy.

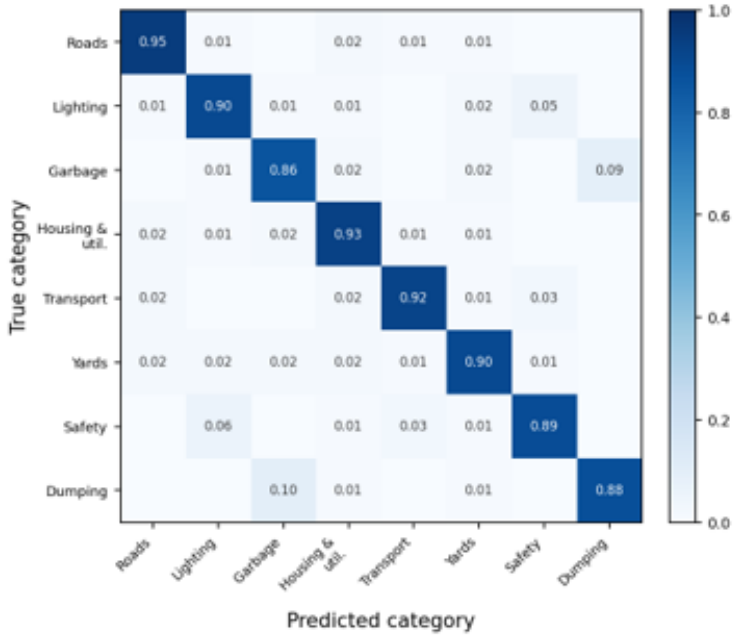


Fig. 4. Confusion matrix of the best classification model (row-normalized shares

The distribution of errors across categories is useful to compare with the corpus structure. The most common categories-roads, housing and utilities, and yard improvement-are recognized with high recall, as expected given the larger volume of training examples and more consistent vocabulary. Less-represented categories are generally classified less reliably, but the reduced recall is determined not only by their rarity but also by the overlap of wording with adjacent classes. For example, reports about illegal dumps are most often mistakenly attributed to garbage collection, and some safety reports are attributed to lighting, as residents often associate dark areas with a feeling of unsafety. This means that simply aligning the classes in the training set will not eliminate the majority of errors; refining category boundaries and incorporating additional report features appears more effective.

To evaluate the practical effect of the AI module, two processing scenarios were simulated: a completely manual route and a route with intelligent classification and automatic assignment of the responsible department. The average time to complete the main stages is shown in Figure 5. Under the simulated conditions, the average total time to transfer a request to the relevant department decreased from 26.15 to 6.85 minutes-more than 3.8 times. The distribution of savings across stages is uneven: the time to register a request remains virtually unchanged, while the main benefit is achieved at the initial analysis and routing stages, where automatic classification replaces manual

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review, categorization, and department selection. This indicates that the value of the intelligent module is primarily due to the reduction of operators' workload on routine sorting, rather than to the acceleration of user data entry (Figure 5).

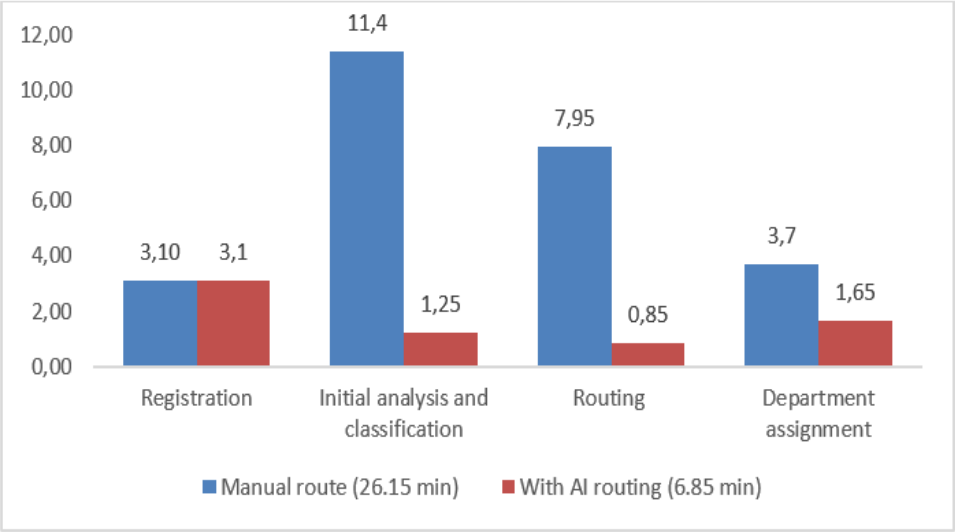


Fig. 5. Average request processing time by stage: manual and AI-assisted scenarios

The results should be interpreted considering the limitations of the study. First, only Russian-language material was considered, while the service supports a bilingual interface, and the classification quality of Kazakh-language queries requires separate evaluation. Second, the comparison is limited to three models and does not include modern approaches based on large language models and instructional embeddings. Third, the applied time estimates were obtained under model conditions, while the quantitative metrics from the service's load testing require separate presentation on a real infrastructure. These limitations limit the scope of the conclusions and simultaneously suggest directions for future work.

Conclusion.

This paper proposes the architecture of an intelligent Smart City service for receiving and routing citizen inquiries based on a Telegram bot using artificial intelligence methods. The following objectives were achieved: the service architecture and data model were designed; a request submission scenario was formalized using a finite-state machine; thematic text classification and a threshold routing algorithm were implemented; the service was deployed in a containerized environment and tested through functional, load, and usability testing; a comparative evaluation of classification models was conducted, and the impact of AI routing on initial processing time was assessed. Thus, the goal of the paper was achieved.

The results of the simulation experiment showed that the use of AI improves the quality of initial request classification and reduces routing time compared to manual processing: on the corpus, the RuBERT-class model achieved an accuracy of 0.914

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and an F1-score of 0.907, while the average time to transfer a request to the relevant department decreased from 26.15 to 6.85 minutes. An error analysis revealed that the main inaccuracies were not due to class imbalances, but to the semantic proximity of individual categories, highlighting the role of subject-based taxonomy as a classification mechanism. It was also established that the choice of the model's confidence threshold influences the balance between routing accuracy and the level of service automation.

The scientific significance of this work lies in examining the Telegram bot as a fully-fledged component of the Smart City digital infrastructure and in integrating the dialog frontend, managed service architecture, and Russian-language request classification module into a single, reproducible model with experimental evaluation. The practical significance lies in the potential application of the proposed approach in creating municipal request processing services that can improve the availability of city services, reduce operator workload, and shorten routing times. Further research should focus on incorporating Kazakh-language and multimodal data (including classification based on attached photographs), comparison with approaches based on large language models, and evaluating the service's performance in production conditions, including load testing, external quality validation, and integration with the city's sensor data sources.

From a practical perspective, the proposed solution demonstrates that intelligent request triage can be implemented using an accessible technology stack and integrated into residents' familiar communication channels, without requiring them to learn a separate application. The manageability of the confidence threshold and the preservation of the operator's role in questionable cases make the approach applicable to real-world municipal practice, where the cost of erroneous routing is high. The obtained results confirm the feasibility of further developing the service from a prototype to production operation, subject to its validation on real data and as part of a broader city data collection and analysis system.

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МЕЖДУНАРОДНЫЙ ЖУРНАЛ ИНФОРМАЦИОННЫХ И КОММУНИКАЦИОННЫХ ТЕХНОЛОГИЙ

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