Promising directions for the artificial intelligence development in the housing and utilities sector

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Abstract. Modern technologies require the improvement of automation and labour savings. Therefore, successful construction companies are everywhere introducing artificial intelligence into their business, which actually optimizes any processes without human intervention. At the same time, the final product quality increases. Investing in high technology may be a daunting task for many businesses, but in the long run, reducing waste and material consumption will have a positive impact on profitability. Investments in the technologies development in the housing and communal services are increasing around the world, and households are increasingly switching to smart metering devices. Artificial intelligence technologies allow organizations in housing and communal services to reduce the operators cost and automate the most frequent communications with residents. The innovative technologies introduction for the development of housing and communal services is aimed primarily at optimizing the services range in accordance with the population needs and rationalizing their use in the context of sustainable territories development. The authors analyse the prospects for the housing and communal complex development in the digitalization period, explores the possibilities and directions for the introduction and application of artificial intelligence in the field of housing and communal services in Russia and abroad.

1 Introduction

The article relevance is defined by accelerated technological development, which has changed the competition nature in world markets, increasing the importance of technological capabilities as a source of competitive advantage and identifying technology as a key factor in production. Nowadays smart technologies have the potential to solve problems in big cities. Progressive intelligent technologies are one of the engines for making «smart» decisions in this transformation. The challenge is to properly use data to create smart solutions that respond to the real needs of city residents.

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The study object is the housing and communal services and the prospects for its development in the digitalization era. The research subject is the artificial intelligence use in the field of housing and communal services. The goal is to study the possibilities and directions of using artificial intelligence in the field of housing and communal services. Tasks is considering the concept and main characteristics of artificial intelligence systems, studying modern trends in the implementation of artificial intelligence in housing and communal services, getting acquainted with foreign experience in the implementation of artificial intelligence in housing and communal services, finding out the actual problems of using artificial intelligence in the development of housing and communal services in Russia, suggesting ways for the development of the Russian housing and communal complex based on the artificial intelligence use.

The introduction of artificial intelligence in the housing and communal sector, as a rule, is not a sectoral priority of urban initiatives for the artificial intelligence development. Implementations occur pointwise, depending on the problems of urban development. Most of the projects are at the pilot stage [1-3].

2 Foreign experience

«LawnTap Technologies», a US company, has developed a smart lawn sensor that constantly monitors grass height, moisture and weather conditions. The system monitors performance in real time and, if necessary, automatically sends a service request to nearby lawn care providers. The AI bot accepts and analyzes the request, selecting an individual offer if the user needs to receive additional services. It is used for private application. An adapted platform for homeowners associations and management companies has also been launched. The complex of solutions allows to receive professional services for an adjacent territory without a long wait, search for contractors and service contracts.

Hong Kong-based «Hong Yip Service Company», which manages more than 1,600 residential and commercial buildings, including private and multi-apartment buildings, factories, shopping malls and government sites, using an artificial intelligence-based software and hardware solution consisting of sensors temperature and humidity, coupled with NB-IoT technology (Leveraging Softhard.IO’s Edge Lite), is piloting a system for monitoring the tightness of doors on rooftops and the presence of water leaks. The system is installed in 50 buildings. The company sees the solution as one of the most important tools for upgrading existing properties to smart buildings. The resulting data will automatically notify emergency teams of heat or water leaks, improve the user experience of residents and reduce operating costs [4].

Sound pickup sensors - hydrophones, are controlled by an artificial intelligence system and react to the water sound. In Canada, hydrophones are installed on fire hydrants. The sensors pick up the acoustic water vibrations and can «distinguish» which of the noises corresponds to an accident and which is the norm. The system is able to record the loss of water at a rate of 17 liters per minute. Testing was successful in November 2018, and 40 units were installed throughout Waterloo in 2019, led by the University of Waterloo, in collaboration with industry partners and the municipal administration. It contributes to an increase in the use efficiency of water resources, as well as the maintenance and repair of urban water supply communications [5].

The system of the Australian company «Melbourne Water» in partnership with «IBM» uses artificial intelligence and machine learning to control the water use at wastewater treatment plants. It analyzes many factors such as available water levels, available pumps, historical usage. The project is being piloted at one of the main drinking water treatment
plants in Melbourne. It helps to avoid budget losses due to wasteful energy consumption of treatment facilities by about 20% per year [6-8].

«Ecube Labs» has piloted the «Clean» program to address the lack of public trash cans – trash cans with full-tracking sensors connected to the «Clean City Networks» cloud platform in Seoul. 85 «Clean Cube» containers were installed for general waste and recyclables in especially crowded places in the city center (Figure 1). It was possible to reduce the frequency of collection by 66%, costs by 83% by eliminating the special equipment trips to empty tanks, and residents began to more actively comply with the rules for sorting garbage, which increased the share of waste sent for processing by 46%.

![Fig. 1. Containers with sensors for monitoring the filling](image)

In China «XiaoHuangGou» «smart» trash cans can automatically detect the type of trash, its average size and density using built-in cameras. A signal is transmitted to the sorting center when the tank is 80% full. Residents receive cash rewards for depositing metal, plastic and paper boxes into containers (the money received can be cashed out). «XiaoHuangGou» intends to develop an online shopping mall and a personal credit rating system so that users can purchase goods with digital credits. The company deployed more than 10,000 «smart» waste sorting containers in 33 cities in China, thereby gaining more than 2.6 million users of its application in less than a year with government support (as part of the national strategy for the development of waste-free cities). The plan is to deploy 1 million containers throughout China. It is expected to increase the level of waste disposal in cities up to 35%, improvement of waste management systems, transition to a zero-waste policy for the cities functioning.

«Oscar» is a waste sorting solution by Canadian company «Intuitive AI» with a 32-inch display and AI camera. The system uses computer vision and machine learning. In addition, «Oscar» is able to recognize the garbage in the hands of users in advance and make predictions about the correct sorting and the speed of filling the tanks. Testing has been carried out at various locations since the beginning of 2019- Vancouver Airport, universities (for example, Simon Fraser University), in the cities of Toronto and Vancouver - solutions for living quarters. Proper waste management could reduce the amount of recyclable waste sent to landfill by 10 tons per year, thereby reducing the seepage of toxic chemicals into the surrounding groundwater. It is equal to a reduction in CO₂ emissions of 29 tons per year.

The Chinese company «Shanghai Chengtou Group Corporation» has launched a digital household waste monitoring and management system that allows real-time tracking of the waste collection and transportation, analyzes its sources, and determines whether the waste has been properly sorted for further processing.

Startup «ZenRobotics» has partnered with «Ferrovial» to develop an AI waste sorting robot («The Zen Robotics Recycler») in Barcelona that is equipped with sensors and machine vision to continuously monitor the waste flow. The technology has demonstrated
its ability to separate large items weighing up to 30 kilograms, reaching rates of 2,000 items per hour, during testing with construction waste.

The US company «GE» in cooperation with «Intel», «AT&T Wireless», San Diego Police Department, San Diego Gas & Electric, Transportation and Engineering for the Internet of Things (IoT) project throughout the city 4,200 sensors are planned to be installed on lampposts to improve the efficiency of organizing urban space and street lighting. The sensors will be combined with both new applications within the smart city system and with existing ones (within the «Current» platform). An innovative system for measuring electricity consumption and calculating costs «LightGrid» has also been introduced (Figure 2). Nowadays more than 35 thousand LED lamps with sensors have been installed. Expected results are a 20% increase in street lighting efficiency, up to 90% increase in parking space efficiency, and about $2.5 million in annual savings in electricity costs and maintenance of the lighting system.

![Image](https://via.placeholder.com/150)

**Fig. 2. CityIQ: Universal intelligent node for all street lights**

Based on «Schneider Electric» platform solution and software from «Emerson», «EDF Energy» from West Burton, UK used the «Schneider EcoStruxure Maintenance Advisor» platform to prevent damage to equipment and production losses, as well as software for predictive maintenance «AMS Suite» by «Emerson» to optimize the maintenance strategy for combined cycle power plants. The solution was implemented at the «EDF» power plant in West Burton. The savings are over $1 million.

«Inspection Cloud» is an online platform from «EasyInspect» from Brennby, Denmark for visual inspection of infrastructure. Three-dimensional modeling of structures is performed in real time, marking the found damage due to drones and automatic damage detection using artificial intelligence. The technology is scalable and allows automatic damage detection on concrete, steel and masonry structures. It is a ready-made solution for integration into the urban environment. It is expected to increase in efficiency and decrease in the amount of time spent by engineering teams on surveying the urban infrastructure state. Artificial intelligence is able to process the same number of images in one day that a person can process in one year with a large-scale audit.

3 **Russian experience**

Nowadays the following projects using artificial intelligence in the field of housing and communal services have been implemented in Russia at the implementation stage and in the long-term plans - automated accounting of snow volumes at snow melting points and building shipping routes based on artificial intelligence technologies, violations recognition of housing and communal services at road facilities and adjacent territories, smart dispatcher based on the Unified Dispatch Center, smart accounting system, management
support system for the urban utilities complex, digital employee twin of the urban utilities complex: «smart» watch and «smart» suit, robotic cleaning of yard territories, water consumption volumes forecasting, critical situations forecasting, territorial waste management scheme modeling based on telemetric information and video analytics, green spaces control using artificial intelligence technologies, Maryino smart quarter, digital substation «Medvedevskaya» in Skolkovo [9-14].

Accounting for snow volumes at snow melting points and building shipping routes based on artificial intelligence technologies. Nowadays the vehicles registration that arrived for the shipment of snow to the snow melting point is carried out using machine vision: numbers recognition, brands, vehicle models from two points: at the entrance, at the exit. Laser recognition of snow volumes has been installed at all Mosvodokanal and Mosvodostok snow melting points, which makes it possible to measure the exact amount of snow in the car body both at the entrance and at the exit. Errors video analytics in the measuring equipment: due to the driver fault for technical reasons. Electronic notifications about the results of snow shipment are generated directly to the driver via a mobile phone (chat bot in Telegram) based on the system of video analytics and laser volume measurement. The project was awarded at the international level in November 2021: the automated snow tracking system at snow rafting points was shortlisted for the IoT Global Awards.

Smart dispatcher based on the Unified Dispatch Center. Artificial intelligence technologies are used to receive feedback from residents on the implementation quality, notify residents about the application rejection by the managing organization, register new applications from residents, and consult residents on typical issues based on the developed knowledge base.: New mobile application «Gosuslugi Moskvy», Portal of the Moscow Mayor «mos.ru», «Electronic home» are implemented. The mobile workplace for an employee of the managing/service organization has been implemented. Artificial intelligence technologies are used to process incoming calls for the targeted notification of residents about scheduled or emergency shutdowns of utility services, routing applications to the appropriate dispatch centers for registration using a virtual operator, pre-filling the applicant's application card before switching to the single dispatch center operator. Information about the performed work is transferred to the cloud accounting department, the workload of performers and payments and payment for applications from a single dispatch center through a personal account (viewing estimates, invoices and payments) on the Mayor's portal, to the mobile application «Gosuslugi Moskvy», payment by bank transfer on the spot.

Smart metering system. «STRIZH» devices and modems transmit data packets via the XNB wireless protocol. The base station receives and processes signals from «STRIZH» devices within a radius of up to 10 km, then it transmits the data to the server. The user receives information in the «STRIZH.Cloud» personal account or via API. The system capabilities - consumption control of electricity, gas, water, heat, smoke control, parking, temperature, fires, leaks, breaking doors, breaking windows, fullness of garbage cans.

Also in May 2022, MTS, one of the first telecom companies, developed a comprehensive IoT solution for automatically collecting data from electricity meters. It actually allows to provide a full cycle of collecting data on the consumption of utility resources and includes electricity meters with a built-in radio module of the NB-IoT standard (Narrow Band IoT is a communication standard used by smart devices, it is used by telecom operators when deploying their networks), automated accounting systems electricity in the MTS cloud, a traffic package, as well as artificial intelligence systems for analyzing the collected data. In addition to smart electricity meters, MTS also has water,
gas and so on meters in the smart housing and communal complex technology stack. The solution core is the «Energosbyt-service» product, which reduces the costs of guaranteeing electricity suppliers for the creation and maintenance of the metering system, as well as simplifies the readings collection and significantly reduces the costs of energy sales companies when accounting for electricity consumption.

The management support system for the urban economy complex. The management support system for the urban economy complex is aimed at creating a tool for centralized analysis of the urban economy complex and combining information on the activities of the Moscow executive authorities, integrating several dozen information systems containing data from the urban economy complex, more than 200 resource-supplying and subordinate organizations of the urban economy complex, creating tools to increase the level of customer orientation in the municipal economy complex: centralized and comprehensive notification of residents about ongoing work (planned and to eliminate incidents) even before they apply (complaints) to a single dispatch center or «Our City», minimizing negative events in the housing and communal complex, automatic work planning and execution control, assistance in resource management and incident management, centralized dynamic activity analysis of the urban complex organizations (events, incidents, activities, characteristics of urban facilities, etc.) regardless of a specific department or organization (cross-organizational) based on machine learning to identify anomalies, hidden relationships between incidents and the city services activities, systemic violations analysis. Figure 3 shows an example of the automatic information system «Management Center of the urban economy complex» work.

**Fig. 3.** Automatic information system «Management Center of the urban economy complex»

The digital twin of an urban complex employee: «smart» watch and «smart» suit. The devices are used to collect reference data on how employees perform their daily tasks and generate digital models for monitoring specialties using artificial intelligence methods, including determining a specific action performed by an employee, estimating active work time and idle time, calculating labor productivity efficiency, continuous monitoring and visualization using 3D models of workers.

Digital intelligent service for recognizing the eliminating violations results. The service task is to automate the work that is now carried out manually by the supervisory authorities, namely, after the order is issued and after the set time, the supervisory authorities check the actual elimination of the comments issued as a audit result, depending on the violation and the measures that were required to be performed by the subject control inspectors. The report provided by the subject of control on the elimination of comments (most often a scanned copy) is checked. Through the system of urban video surveillance, as well as screenshots from the object of control (for example, roofs), the actual comments
elimination (for example, cleaning the roof), manually comparing this video camera and photographs is checked.

**Green spaces using artificial intelligence technologies monitoring.** The specialists from the laboratory of the Peoples' Friendship University of Russia (PFUR) in Moscow began to use a new monitoring system for green spaces «Tree Talkers». Now about two dozen trees on the territory of this educational institution have been equipped with sensors that record their condition. The sensor looks like a small box that is attached to a tree trunk above human height with a belt. The height here is important for the device safety: so that none of the passers-by would have a desire to remove an incomprehensible box. The «Tree Talkers» mechanism is quite simple: the device scans vital processes - the sap flow and photosynthesis intensity. The additional device «TT-G» determines the slope and elasticity of a tree. All data is sent once an hour to a computer program that analyses all data and displays a result.

**Critical situations prediction.** A unified system for monitoring incidents and controlling the accidents elimination at housing and communal facilities has been launched in all Russia regions since September 1, 2020. It allows to accumulate operational and reliable data on incidents, as well as establish a clear procedure for monitoring troubleshooting. The platform provides for information exchange with the Ministry of Emergency Situations and the Ministry of Energy. The Ministry of Construction approved a unified approach to the accidents and incidents classification in the summer of 2021, so now the incidents assessment at housing and communal facilities follows the same rules in all regions. The incident is automatically classified in the system as an accident if the resolution time is long. For example, interruption of gas supply or sewage disposal starts to be considered an accident if it was not eliminated within four hours, water supply - within eight hours, and interruption of heat supply to consumers of the first category receives the accident status immediately.

**The territorial scheme of waste management modeling based on telemetric information and video analytics based on data generated in real time, taking into account the actual operator activities at all stages of waste management and disposal.** Remote monitoring of activities and compliance with the regional operator requirements based on video analytics data (actual time of collection, transportation), forecasting for 10 years or more, forecasting of capacity shortages, overflow planning, a mathematical modeling service for the territorial scheme of waste management using artificial intelligence technologies, including: the tool implementation for creating any options for territorial schemes and their comparison, taking into account macroeconomic indicators and regional characteristics, automatic calculation of waste removal logistics, taking into account logistics restrictions, traffic, weather conditions (Figure 4).

![Fig. 4. The territorial scheme of waste management modeling](image_url)
Positioning Robotic cleaning of yard areas. Robotic cleaning of yard areas is used in Moscow. The Russian company «Avtonomika» unveiled a fully autonomous, unmanned electric street sweeper called «Pixel», in early 2023 (Figure 5). As expected, about 15 such cleaning robots will soon be tested on the Moscow roads. «Pixel» is described on the manufacturer's website as «a small communal robot», which is designed for silent and high-quality cleaning of landscape gardening and other areas. The developers confirm that replaceable attachments will ensure the maintenance of a clean and comfortable urban environment, regardless of the weather, time of day, season or free «working hands». It is alleged that the all-wheel drive car works almost silently, it is oriented in space due to the computer vision system. «Avtonomika» has already received orders for the supply of «Pixel» to the UAE.

![Figure 5. «Avtonomika» small communal robot](image)

Digital solutions for water utilities. Digital solutions for water utilities are, first of all, automated process control systems that allow to effectively manage water supply and sanitation facilities. «Mosvodokanal» is the leader in the water supply and sanitation industry digitalization. Information about the operation of all water supply and sanitation systems, the operation of water treatment stations, the operation parameters of the distributing water supply system, control units, as well as sewer pumping stations and wastewater treatment plants are collected in the central dispatching office. It controls and eliminates excess pressure in wells and pumps. Applications for emergency situations in water supply and sanitation systems can be submitted not only by phone, but also through the «Our City portal» and the «112» system. In addition, 400 pressure control points installed in the water supply system and 180 filling control points in the main channels of sewerage collectors installed in the city make it possible for quick response to emergency situations. Figure 6 shows the forecasting example based on the project of a subject in the Russian Federation. Data for 10 years show a downward trend in water consumption in the study area.
The pilot project «Smart-quarter» in Maryino. The pilot project «Smart-quarter» in Maryino is being implemented by «UNECOMOSCOW», «SAURES». Houses and adjacent territories are equipped with intelligent lighting, security and energy systems, namely, new generation intercoms that allow residents to control doors using a smartphone and receive information from surveillance cameras. Smart wireless meters for better resource accounting and energy efficiency. Advanced video surveillance cameras in entrances and elevators for communication with the dispatcher or track the vandals actions. Outdoor lighting poles with individual control modules and energy-saving lamps with extended service life (~15 years). Waste bins equipped with fire alarms and fullness sensors that report utility workers when they need to be emptied. Gas stations are provided in the yard for owners of electric cars. The introduction of advanced technologies into existing buildings will improve the life quality, ensure comfort and safety, and optimize the costs of the city and residents [15-17].

Automated monitoring of power grid facilities. If Automated monitoring of power grid facilities is implemented by the united central point of Moscow Cable Networks. Dispatch center with a single digital mnemonic diagram of the city's power grid, which monitors the state of the real network and monitors the emergencies. The project also provides for equipping transformer substations and other network facilities with sensors as part of the subproject «Digital Electricity District». Therefore, dispatchers will be able to obtain the most accurate information about the location and extent of incidents. And the «Dispatcher's Advisor» complex will help people to choose the fastest way to remotely localize the area where the failure occurred. The dispatch center has been created, and the subproject «Digital District of Electric Grids» and the «Dispatcher's Advisor» system are being piloted. It is expected to increase efficiency and reduce the time for surveying urban infrastructure. Artificial intelligence is able to process the same number of images in one day that a person can process in one year with a large-scale audit [16-20].

Conclusions

Strategic planning and forecasting in the housing and communal services requires further development based on digital and information technologies. This need is due to the growing information, the algorithms complexity for calculating and interpreting the results, the high requirements for the quality and accuracy of forecasts in this economic branch. The advantages of using artificial intelligence in the housing and communal services are, of course, a reduction in the status in employment: robots are able to perform the most
physically difficult, as well as harmful to humans, work; improving the safety and efficiency of the housing and communal complex employees, reducing utility and operating costs, as well as reducing the errors associated with the human factor. In addition, robots will help to reduce production costs by eliminating the internal costs of compensating workers' wages, resulting in increased economic efficiency. The artificial intelligence introduction in the sphere of housing and communal services will help to update the outdated resource base, reduce the labor and time costs, will optimize housing and communal services processes, thereby increasing the communal services efficiency. States that will introduce artificial intelligence technologies will take a leading position and reach a new development level.

References


17. V., Telichenko, V., Rimshin., E., Ketsko *Design and Calculation Solutions for Designing Biological Treatment Facilities on The Pumping Station Example* AIP Conference Proceedings, **2497**, 020009 (2023)


19. V., Telichenko, V., Rimshin., E., Ketsko *Engineering structures stability against progressive collapse* E3S Web of Conferences **410**, 02037 (2023)