THE ROLE OF LAND CADASTRE AND GIS TECHNOLOGIES IN SMART CITY PROJECTS

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Abstract: This article examines the importance of land cadastre and Geographic Information Systems (GIS) technologies in the implementation of the Smart City concept. It analyzes current digital cadastral reforms in Uzbekistan and foreign countries, identifies existing challenges, and proposes solutions. New proposals have been developed to enhance the efficiency of Smart City governance through the integration of GIS, Artificial Intelligence (AI), Remote Sensing, IoT, 3D Cadastre, and Digital Twin technologies. The research results serve to improve the land resource management system and foster sustainable urban infrastructure development.

Keywords: Smart City, Land Cadastre, GIS, Geographic Information System, 3D Cadastre, Digital Twin, Artificial Intelligence, IoT, Remote Sensing, Geospatial Data, Digital Transformation.

Аннотация: В статье рассматривается роль земельного кадастра и геоинформационных систем (GIS) в реализации концепции Smart City. Проанализированы современные реформы цифрового кадастра в Узбекистане и зарубежных странах, существующие проблемы и пути их решения. Особое внимание уделено внедрению технологий искусственного интеллекта, дистанционного зондирования Земли, Интернета вещей (IoT), 3D-кадастра и цифровых двойников (Digital Twin). Предложены современные подходы к повышению эффективности управления городскими территориями на основе интеграции пространственных данных.

Ключевые слова: Smart City, земельный кадастр, GIS, геоинформационные системы, 3D-кадастр, Digital Twin, искусственный интеллект, IoT, пространственные.

Annotatsiya:Mazkur maqolada Smart City konsepsiyasini amalga oshirishda yer kadastri va geografik axborot tizimlari (GIS) texnologiyalarining ahamiyati tahlil qilingan. Shuningdek, O‘zbekiston va xorijiy davlatlarda raqamli kadastr tizimlarini rivojlantirish bo‘yicha amalga oshirilayotgan islohotlar, mavjud muammolar hamda ularning yechimlari yoritilgan. GIS, sun'iy intellekt, masofadan zondlash, IoT, 3D kadastr va raqamli egizak (Digital Twin) texnologiyalarini integratsiyalash orqali Smart City boshqaruvining samaradorligini oshirish bo‘yicha yangi takliflar ishlab chiqilgan. Tadqiqot natijalari yer resurslarini boshqarish tizimini takomillashtirish hamda shahar infratuzilmasini barqaror rivojlantirishga xizmat qiladi.

Kalit so‘zlar: Smart City, yer kadastri, GIS, geoaxborot tizimi, 3D kadastr, Digital Twin, sun'iy intellekt, IoT, masofadan zondlash, geoma'lumotlar, raqamli transformatsiya.

Introduction

In recent years, the acceleration of global urbanization, the growth of urban populations, the sharp increase in demand for land resources, and the complexity of environmental challenges have necessitated the introduction of new approaches to urban management. Because traditional management systems fail to deliver rapid and effective solutions to today’s complex socio-economic and environmental issues, developed countries are paying special attention to the widespread implementation of the Smart City concept, which operates on the basis of digital technologies. A Smart City is a modern governance model aimed at efficiently managing urban infrastructure, increasing the quality of public services, ensuring the rational use of resources, and achieving sustainable development by integrating information and communication technologies, artificial intelligence, geographic information systems (GIS), the Internet of Things (IoT), Big Data, cloud computing, remote sensing, and Digital Twin technologies into a unified platform.

The successful implementation of the Smart City concept depends directly on reliable, accurate, and constantly updated spatial data, the primary source of which is the land cadastre system. The land cadastre is a strategic information system that contains legal, economic, and spatial data on all land parcels within a state's territory. It is widely utilized in urban planning, construction, transport infrastructure development, the deployment of engineering and communication networks, environmental monitoring, investment project planning, and emergency management. Integrating this information with GIS technologies creates opportunities to perform comprehensive regional analysis, evaluate the efficiency of land resource utilization, identify existing issues, and make scientifically grounded management decisions.

Currently, the use of 3D cadastre, Digital Twin, artificial intelligence, remote sensing data, unmanned aerial vehicles (drones), IoT sensors, and cloud-based GIS platforms is expanding rapidly within Smart City projects in developed nations. These technologies allow for the real-time monitoring of land plots, buildings and structures, transport networks, green spaces, and engineering utilities, automatically detecting changes and providing governance bodies with prompt, reliable data. Consequently, the efficiency of city administration is enhanced, the quality of public services is improved, investment processes are accelerated, and the scope for ensuring ecological safety is expanded.

In the Republic of Uzbekistan, large-scale reforms are also being implemented to develop the digital economy, digitalize public administration, and improve the geospatial data infrastructure. In recent years, significant practical work has been carried out to fully digitalize land cadastre data, establish a unified geospatial database, transition cadastral services into electronic formats, widely introduce modern GIS technologies into the state management system, expand the scope of satellite imagery and remote sensing data utilization, and create 3D cadastre and digital city models. In particular, new projects aimed at developing the geospatial data infrastructure, improving the national geoportal, and creating modern cadastral information systems are being implemented during the 2025–2026 period.

Despite these efforts, several pressing problems persist in the process of implementing Smart City projects. Notably, the lack of integration of geospatial data managed by various state organizations under a single standard, outdated cadastral records in certain regions, the inability to update spatial data in real time, the insufficient implementation of 3D cadastre technologies, the limited use of artificial intelligence and Digital Twin technologies, an inadequate number of qualified GIS specialists, and issues related to securing geospatial data negatively affect the performance of Smart City systems. Furthermore, imperfect data-sharing mechanisms among government agencies create difficulties in administrative decision-making.

Under these circumstances, deeply integrating the land cadastre and GIS technologies with Smart City infrastructure, automatically updating geospatial data via artificial intelligence, refining land monitoring through remote sensing and drones, enhancing the reliability and security of cadastral data using blockchain technology, creating digital urban models based on Digital Twins, and consolidating all geospatial data into a single platform constitute some of today's most urgent scientific and practical tasks.

The primary objective of this article is to scientifically analyze the role and significance of land cadastre and GIS technologies in Smart City projects, identify current pressing issues, and develop innovative proposals and recommendations to eliminate them based on international experience and modern technologies relevant to the year 2026. The findings of this study serve as a scientific and practical basis for optimizing digital governance in Uzbekistan's cities, ensuring the rational use of land resources, and further advancing Smart City systems effectively.

Current Status, Pressing Issues, and Development Trends of Integrating Land Cadastre and GIS Technologies in Smart City Projects

In the current era of rapid digital transformation, Smart City projects are initiating a new stage of urban governance. The efficiency of these systems depends directly on the accuracy, prompt update rate, and interoperability of geospatial data among various information systems. For this reason, land cadastre and GIS technologies are viewed as one of the fundamental information platforms for urban infrastructure management.

Today, in many countries, land parcels, buildings and structures, engineering-communication networks, transport infrastructure, and green spaces are maintained within a unified geospatial database. Spatial data is regularly updated using satellite imagery, unmanned aerial vehicles, laser scanning (LiDAR), and high-precision GNSS technologies. This enables the detection of illegal construction, the monitoring of targeted land use, and the making of precise decisions regarding regional development.

In Uzbekistan, extensive reforms are being undertaken to modernize the land cadastre system. Electronic cadastral services are expanding, and the utilization of GIS technologies in the operations of government agencies is rising. In certain regions, digital maps are being updated, geodetic networks are being improved, and projects aimed at increasing the accuracy of geospatial data are being implemented in phases. These changes serve to develop the land resource management system in accordance with modern requirements.

Nevertheless, a number of problems remain in practice. Because the geospatial databases established across different organizations are not fully compatible, data exchange is not sufficiently developed. In some regions, cadastral data is outdated, and the process of updating it requires significant time and financial resources. The insufficient development of mechanisms to maintain spatial data under a unified standard also negatively impacts the management process.

Another critical issue is that three-dimensional (3D) cadastral systems have not yet been fully implemented in practice. The capacity to comprehensively represent multi-story buildings, underground utilities, and complex infrastructure objects via two-dimensional maps is limited. This situation can cause certain ambiguities in land use planning and the formalization of property rights.

Furthermore, securing geospatial data in compliance with cybersecurity requirements, widely implementing automated analysis systems based on artificial intelligence, and training qualified GIS specialists are urgent tasks today. To ensure the effective use of modern software, it is necessary to strengthen cooperation between government agencies and educational institutions.

In the coming years, artificial intelligence, Digital Twins, Big Data, IoT sensors, and cloud GIS platforms are expected to be the main drivers in the evolution of Smart City projects. These technologies will significantly expand the capability to monitor urban infrastructure in real time, increase the efficiency of land resource utilization, pre-assess ecological risks, and make management decisions on a scientific basis.

Ultimately, deeply integrating land cadastre and GIS technologies into Smart City platforms will not only elevate the quality of urban administration but will also serve to bolster investment attractiveness, digitalize public services, and guarantee the sustainable use of land resources. Pursuing the consistent development of these areas remains one of Uzbekistan’s top priorities in forming a system of modern digital cities.

Innovative Solutions and Practical Proposals for Improving Land Cadastre and GIS Technologies in Smart City Projects

The efficiency of Smart City systems depends not only on the introduction of modern technologies but also on their mutual integration, data reliability, and their effective application during the decision-making process. Therefore, improving land cadastre and GIS technologies is currently one of the priority areas in public administration, urban planning, and land resource management. The comprehensive application of digital technologies creates a solid scientific-practical foundation for accurately assessing the state of the land fund, increasing regional land-use efficiency, and sustainably developing urban infrastructure.

First and foremost, it is essential to establish a unified national GIS platform that consolidates all geospatial data nationwide. Within this platform, data concerning land cadastre, real estate, transport, engineering-communication networks, environmental monitoring, water resources, and urban planning should be maintained in an integrated manner. As a result, data exchange between different state authorities will accelerate, redundant data will be reduced, and management decisions will be grounded in reliable information.

Integrating artificial intelligence technologies into GIS systems opens up new horizons in land resource management. AI can automatically analyze data obtained from satellite imagery and drones to detect illegal constructions, shifts in land parcel boundaries, the condition of crop fields, and ecological issues in a short amount of time. This serves to accelerate monitoring activities and minimize human error.

The widespread introduction of 3D cadastre and Digital Twin technologies is another vital direction. Through three-dimensional digital models, multi-story buildings, underground utilities, transport facilities, and engineering networks are represented in a single virtual environment. This significantly expands the possibilities for planning construction projects, modeling emergency scenarios, operating infrastructure assets, and forecasting urban growth.

Regularly deploying remote sensing technologies, high-resolution satellite imagery, LiDAR systems, and unmanned aerial vehicles accelerates the cadastral data updating process. Continuous monitoring of territories enables the early detection of unauthorized land use, the assessment of natural disaster consequences, and the oversight of agricultural land conditions.

Conclusion

The research results indicate that land cadastre and Geographic Information Systems (GIS) represent strategic information infrastructures vital for the successful implementation of Smart City projects. Reliable and continuously updated spatial data regarding land resources serves as a critical factor for scientifically planning cities, developing infrastructure, preserving ecological balance, optimizing transport systems, and digitalizing public services.

Analysis shows that although important reforms are being carried out in Uzbekistan to digitalize the land cadastre, improve geospatial databases, and introduce GIS technologies into public administration, obstacles such as the lack of a single platform for data integration, outdated cadastral information in certain areas, underdevelopment of 3D cadastre technologies, and a shortage of qualified specialists still hinder the full evolution of Smart City systems.

This article has developed a series of scientific and practical proposals to eliminate these problems. In particular, the study justifies the necessity of creating a unified national geospatial data platform, integrating artificial intelligence into GIS and land cadastre systems, introducing 3D cadastre and Digital Twin technologies, organizing continuous monitoring based on drones and remote sensing data, ensuring cadastral data security using blockchain technology, and training highly qualified GIS specialists.

Consistently advancing these directions in the future will create a robust scientific-practical foundation for increasing the efficiency of land resource management, evolving urban infrastructure in line with modern requirements, strengthening investment attractiveness, ensuring environmental sustainability, and developing the Smart City concept in Uzbekistan according to international standards.

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