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ECONOMIC-SPATIAL MODEL OF THE COMPREHENSIVE SPATIAL DEVELOPMENT PLAN OF THE TERRITORIAL COMMUNITY AND THE STATE LAND CADASTRE

This paper aims to investigate the incorporation of functional zones, defined by the comprehensive spatial development plan, into the State Land Cadastre. To achieve this goal, the authors propose using geographic information systems (GIS) and, specifically, geospatial artificial intelligence (GeoAI). The research problem is addressed by developing a model that integrates artificial intelligence with GIS technologies. The findings offer significant value for spatial land management by ensuring construction transparency, predictable investment decisions, and the protection of community interests. The relevance of this study lies in demonstrating the potential of combining GIS and AI. It also substantiates the feasibility of integrating urban planning and land management documentation for post-war recovery.

Key words: *geoinformation system; artificial intelligence; functional zoning; state land cadastre; spatial planning; territorial community; land management; urban planning; normative monetary valuation.*

Formulation of the problem. The current stage of development of territorial communities in Ukraine requires a transition from fragmentary urban planning and land management to an integrated spatial development system. For a long time, land management and urban planning documentation were developed in parallel. This approach led to inconsistent decisions, duplication of functions, and complex managerial decision-making. Furthermore, the lack of legally binding functional zoning within the cadastre system creates prerequisites for uncontrolled construction, land-use conflicts, and non-transparent investment processes.

From an economic perspective, unresolved functional zoning leads to an unstable tax base for local budgets, undervalued market value of land assets, and elevated investment risk, as local authorities and investors cannot reliably link land-use regulations to cadastral value data.

This paper examines a practical mechanism for entering the functional zones of the comprehensive spatial development plan into the State Land Cadastre (SLC). This integration is performed using a GIS model. GIS models are already widely applied across various fields, including real estate and land relations.

GIS technologies, combined with econometric and machine-learning methods, are also increasingly used to model the market value of land and real estate for mass valuation and taxation purposes, underscoring the economic potential of integrating zoning data directly into cadastre systems.

However, the practical aspects of directly incorporating the functional zones of the comprehensive plan into

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the cadastre system remain insufficiently addressed in scientific research.

Analysis of recent research and publications. The integration of geoinformation technologies into the land administration system has been actively studied in Ukrainian scientific literature in recent years, with growing attention devoted not only to technological but also economic aspects of this process. For instance, Habrel M. et al. [1] examine local-level spatial planning in Ukraine as a tool for reconciling urban planning decisions with the interests of territorial communities, though without disclosing the mechanisms for the financial and economic evaluation of such decisions. Tretiak A. et al. [2] investigate the state of, and problems in, developing comprehensive plans for the spatial development of territories, emphasizing the need to harmonize land management and urban planning documentation, which directly affects the investment climate of territorial communities. Petrakovska O. and Mykhalova M. [3] analyze the transformation of concepts of territorial functional zoning, highlighting its role in regulating the land and real estate market. Butenko Y. et al. [4] examine spatial planning as a tool for managing the land resources of territorial communities, while acknowledging that the practical mechanisms for incorporating functional zones into the cadastre system remain insufficiently studied. Some studies lay the methodological groundwork for creating an intelligent expert system for real estate investment analysis based on machine learning and GIS, confirming the relevance of work in the economic-geospatial field.

In foreign scientific periodicals, a substantial body of research has accumulated on the economic aspects of the digitalization of land relations. Ibatullin S. et al. [5], based on a geospatial analysis of transactions covering more than 260,000 hectares, demonstrate that the market price of agricultural land in Ukraine practically does not deviate from its normative monetary valuation, indicating the undercapitalization of land as a factor of production and the need to improve market information support through cadastral mechanisms. Deininger K. et al. [6], based on a dataset of more than 175,000 land purchase-and-sale transactions, justify the transition from an administrative to a market-based (hedonic) model of mass land valuation as a precondition for transparent taxation and effective fiscal decentralization of communities in Ukraine. Tanashkin A. S. et al. [7] propose a methodology for building interpretable real estate market models based on machine learning for mass cadastral valuation purposes, which makes it possible to combine forecasting accuracy with transparency for taxation needs. Shulgan R. and Nikolaichuk K. [8] propose a GIS-based valuation database structure for the economic-statistical modeling of land plot market value, confirming the practical demand for combining geoinformation and econometric methods. Finally, in a comprehensive review, Mai G. et al. [9] define geospatial artificial intelligence (GeoAI) as one of the most dynamic areas of spatial data science, whose application in economic research (including real estate valuation, urban planning, and resource allocation) is rapidly expanding owing to the development of geospatial foundation models and the growth of computational capacity.

The analysis conducted shows that, despite substantial scholarly work in the field of geoinformation support for land management and urban planning, on the one hand, and in the field of economic-statistical and intelligent modeling of the land and real estate market, on the other, these two directions are mostly studied separately. The question of the practical integration of the functional zones of a territorial community's comprehensive spatial development plan directly into the State Land Cadastre, as well as the assessment of the economic consequences of such integration for the investment attractiveness of territories, the replenishment of local budgets through land tax, and the reduction of corruption risks when changing the designated purpose of land, remains insufficiently addressed in the scientific literature. This constitutes the scientific problem that the present study seeks to address.

Formulation of the purpose of the article. The article aims to investigate the mechanism for entering information on the functional zones defined by the comprehensive spatial development plan of a territorial community into the State Land Cadastre using geographic information systems (GIS).

A GIS-based land cadastre model utilizing advanced technologies must ensure the following:

– direct display of functional zoning on the cadastral map;

– unification of construction and land-use regulations;

– prompt decision-making capabilities for local authorities;

– data openness for investors and citizens without disclosing sensitive information;

– creation of a reliable information base for the normative monetary valuation of land plots, underpinning fair land taxation and the forecasting of local budget revenues.

Based on these objectives, the essential operational stages of the model include:

– Data generation in compliance with the comprehensive plan requirements.

– Data preparation and structuring for entry into the State Land Cadastre (SLC).

– Integration of community data into the SLC.

– Interaction and data exchange between the territorial community GIS and state cadastres or registries.

The proposed GIS model will allow users to:

1. Plan community activities and make managerial decisions.

2. Integrate community data with the SLC.

3. Resolve legal issues regarding the processing and registration of land management documentation.

4. Ensure the practical application of the community comprehensive plan by local authorities and residents.

The sequence of steps presented in this paper will transform the comprehensive plan from an urban planning

document into an effective tool for territorial development management through SLC mechanisms.

Presentation of the main research material. The legal and methodological framework for studying the processes of development and implementation of a Comprehensive Spatial Development Plan for the territory of a territorial community is provided by the Law of Ukraine No. 711-IX of June 17, 2020, "On Amendments to Certain Legislative Acts of Ukraine Concerning Land Use Planning" [10]. The adoption of this Law represented an important stage in improving the spatial planning system in Ukraine, as it provided for the integration of urban planning documentation and land management documentation into a single planning document – the Comprehensive Spatial Development Plan for the Territory of a Territorial Community.

The practical implementation of the legislative provisions concerning the formation and incorporation of information on functional zones into the State Land Cadastre has become one of the key areas of digitalization of spatial planning processes. One of the first territorial communities to practically incorporate information on functional zones into the State Land Cadastre was the Rohanska Territorial Community in Kharkiv Region [11].

The proposed model for integrating the comprehensive spatial development plan of the territorial community and the State Land Cadastre is developed using GIS technologies and geospatial artificial intelligence (GeoAI) for data preparation and structuring.

This approach ensures:

– the integration of urban planning documentation and land cadastre data into a unified digital system;

– the direct visualization of functional zones, land-use regulations, and urban planning restrictions on the cadastral map;

– the harmonization of zoning and land-use regulations;

– the ability of local self-government bodies to make timely decisions;

– transparent access to information for investors and citizens.

The implementation of this model, using the Rohanska Territorial Community of Kharkiv Region as an example (Fig. 1), demonstrated that GIS application eliminates contradictions between the master plan, zoning, and land management documentation. Within this framework, planning constraints become an integral part of land cadastre information. This integration reduces corruption risks during land-use conversion, enhances the transparency of managerial decision-making, and improves the quality of strategic community development planning.

The presented GIS model (Fig. 2) illustrates a comprehensive information-technology cycle. It transforms the decisions of the community's comprehensive spatial development plan into legally binding SLC data and enables their subsequent utilization by all stakeholders.



Figure 1. Fragment of the Comprehensive Spatial Development Plan for the Territory of the Rohanska Territorial Community, Kharkiv Region, showing functional zones

Source: Website "StroyObzor" [11]

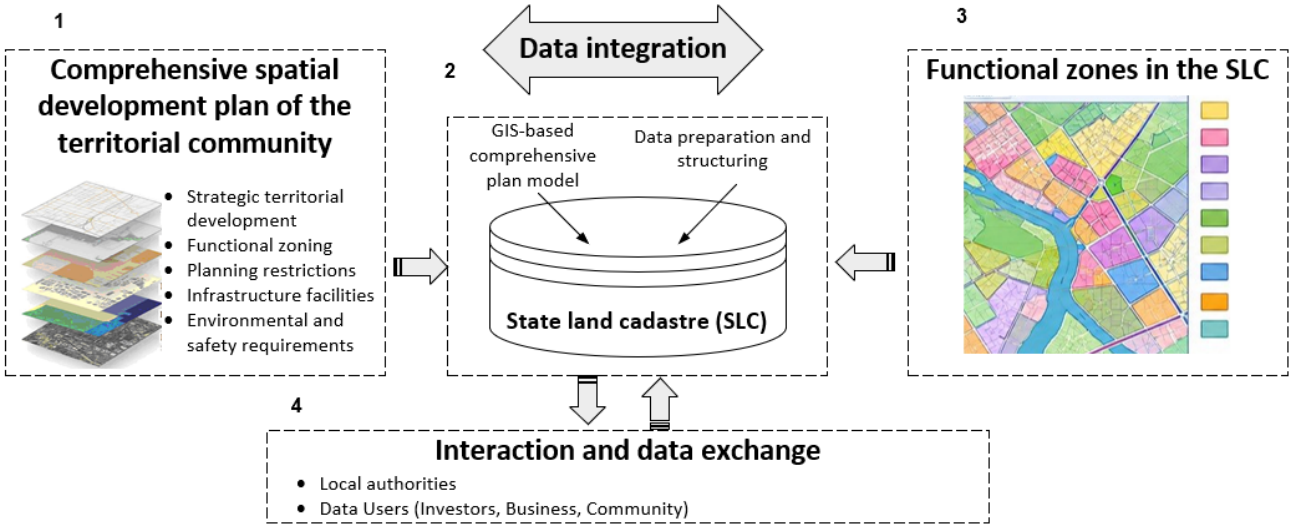

Figure 2. Schematic diagram of the GIS model for integrating the comprehensive spatial development plan of the territorial community and the State Land Cadastre

Source: developed by the authors based on research results

Data Generation under the Comprehensive Plan. Block 1 of the model presents the stage where the comprehensive spatial development plan of the territorial community is formed as an integrated document combining urban planning and land management components. This stage involves analyzing the natural, socio-economic, and urban planning conditions of the territory. It includes defining the community's development strategy and priorities, establishing functional zoning, and making planning decisions regarding infrastructure, transport, environment, and safety. Furthermore, the graphical and textual materials of the plan are generated. The output consists of a set of spatial objects and their attribute characteristics describing land-use regimes.

Preparation of Data for Entry into the State Land Cadastre. The data integration block *(Block 2)* is the core of the model. It adapts the comprehensive plan materials to the requirements of the cadastre system. During data preparation for the SLC, several processes occur: data transformation into an SLC-compatible format, creation of digital layers for functional zones with attributes and land-use codes, and topological and semantic data validation using GeoAI. At this stage, urban planning information takes a structured form suitable for uploading to the SLC. Once loaded into the SLC database, functional zones become part of official cadastral records. This ensures their display on the cadastral map of Ukraine, legally fixes land-use regimes, and provides information access. Thus, the decisions of the comprehensive plan acquire legal force through cadastral instruments implemented by means of GIS.

From an economic perspective, this data transformation converts previously implicit planning constraints into explicit, machine-readable input for the normative monetary valuation of land, thereby improving the accuracy of the land tax base and the transparency of asset pricing for investors [7].

Integration into the State Land Cadastre. The block of functional zones in the SLC *(Block 3)* integrates the functional zones of the comprehensive plan into the SLC structure, making them an integral part of the official cadastral map. Spatial functional zoning data are displayed as separate digital layers. These layers are linked to land plots, their designated purposes, and established land-use regimes. This ensures the synchronization of urban planning and land cadastre information within a unified GIS. Integrating functional zones into the SLC automates compliance verification between land plots and urban planning documentation. It also provides control over land-use conversion and builds a foundation for prompt managerial decision-making. Consequently, the SLC transforms into a tool for comprehensive spatial management of community territorial development.

Interaction and Information Exchange. Block 4, focusing on interaction and data exchange, demonstrates the informational interaction among local authorities, the SLC system, and data users. This block ensures continuous electronic exchange, updating, and utilization of spatial data without duplicating documentation [12].

Practical Outcomes for the Territorial Community. The final component of the GIS model demonstrates the effects of implementing such an interaction:

– predictability of territorial development;
– transparent rules for businesses and investors;
– protection of the rights of community residents;
– effective infrastructure planning;
– consideration of environmental, safety, and transport requirements;
– reduction of conflicts and corruption risks in land use.

Thus, the GIS model demonstrates a logically complete chain:

community planning decision → implementation in the GIS model → integration into the State Land Cadastre → legal formalization → practical application.

From an economic perspective, the model is expected to broaden the local tax base through more accurate normative monetary valuation of land, reduce transaction costs for investors seeking reliable zoning information, and increase the capitalization of communities' land assets [5, 4].

The experience gained from this GIS model can serve as a framework for other territorial communities in Ukraine. Widespread implementation of comprehensive plans with functional zones entered into the SLC will establish a unified spatial information base. This base will support post-war recovery, investment growth, and environmentally balanced planning of territorial development.

Conclusions. This paper identifies the components of the GIS model for integrating the comprehensive spatial development plan of the territorial community and the SLC, along with the operational principles of its blocks. Entering the functional zones of the comprehensive plan into the SLC is a crucial step in reforming the spatial planning system in Ukraine. This approach enables a transition toward an integrated territorial management model. It ensures construction transparency, protects community interests, and creates conditions for sustainable development. Furthermore, the experience of applying this GIS model in the Rohanska Territorial Community demonstrates the high efficiency of this approach and the feasibility of scaling it at the national level.

From an economic standpoint, the proposed model creates the preconditions for a more accurate and transparent normative monetary valuation of land, a broader and more predictable tax base for local budgets, and reduced transaction costs for investors, which together strengthen the investment attractiveness of territorial communities during the post-war recovery period.

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ЕКОНОМІКО-ПРОСТОРОВА МОДЕЛЬ КОМПЛЕКСНОГО ПЛАНУ ПРОСТОРОВОГО РОЗВИТКУ ТЕРИТОРІАЛЬНОЇ ГРОМАДИ ТА ДЕРЖАВНОГО ЗЕМЕЛЬНОГО КАДАСТРУ

Статтю присвячено дослідженню організаційно-економічних і геоінформаційних засад інтеграції комплексного плану просторового розвитку території територіальної громади до Державного земельного кадастру (ДЗК) як інструменту вдосконалення управління земельними ресурсами та забезпечення сталого просторового розвитку. Обґрунтовано необхідність переходу від фрагментарного ведення містобудівної та землевпорядної документації до єдиного цифрового просторового середовища, що забезпечує узгодженість функціонального зонування, містобудівних обмежень, режимів землекористування та кадастрових даних. Актуальність дослідження зумовлена цифровою трансформацією територіального управління України, децентралізацією та потребами післявоєнного відновлення. Систематизовано підходи до формування геоінформаційної моделі інтеграції комплексного плану просторового розвитку з ДЗК. Запропоновано чотириблокову ГІС-модель із використанням геопросторового штучного інтелекту (GeoAI), що охоплює формування даних відповідно до комплексного плану, їх підготовку та структурування, інтеграцію функціональних зон до кадастрової системи, а також електронну взаємодію й обмін просторовою інформацією між органами місцевого самоврядування, ДЗК та користувачами. Практичну реалізацію підходу розглянуто на прикладі Роганської територіальної громади Харківської області. Встановлено, що інтеграція функціонального зонування з кадастровими даними сприяє узгодженню містобудівних і землевпорядних рішень, підвищує прозорість використання земель та створює передумови для автоматизованого контролю відповідності землекористування встановленим режимам. Такий підхід дає змогу знизити ризики земельних конфліктів і корупційних проявів під час зміни цільового призначення земель. Практичне значення результатів полягає в можливості масштабування запропонованої моделі на інші територіальні громади України. Її впровадження створює передумови для підвищення точності й прозорості нормативної грошової оцінки земель, стабілізації податкової бази місцевих бюджетів, зменшення інформаційної асиметрії та транзакційних витрат інвесторів, підвищення капіталізації земельних активів та інвестиційної привабливості територій. Результати можуть бути використані органами місцевого самоврядування, землевпорядними й містобудівними організаціями, фахівцями з кадастру та ГІС, інвесторами й науковцями.

Ключові слова: *геоінформаційна система; штучний інтелект; функціональне зонування; Державний земельний кадастр; просторове планування; територіальна громада; землеустрій; містобудування; нормативна грошова оцінка.*

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