УДК 332.2:332.6 https://doi 10.31548/economics15(1).2024.039

INFORMATION SYSTEMS FOR MODELING LAND PRICES UNDER THE URBANIZATION PROCESS

NAZARENKO VOLODYMYR,
PhD in Economics, lecturer of the Computer Systems, Networks and Cybersecurity department, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine
ORCID https://orcid.org/0000-0002-7433-2484
E-mail: volodnz@nubip.edu.ua
Tel.: +380661260476
MARTYN ANDRII,
Doctor of Economic Sciences, Professor, Corresponding member of the National Academy of Agrarian Sciences of Ukraine, Head of the Land-Use Planning Department, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine
ORCID https://orcid.org/0000-0002-6905-2445
E-mail: martyn@nubip.edu.ua

Abstract. *The dynamic shifts associated with urban growth or decline significantly influence both municipal and national economic policies. Urban expansion often necessitates substantial land resources allocation, whereas in regions with limited land availability or geographical restrictions, a innovative approach to urban planning is mandated. Key land value factors have been determined and classified. Each direct and indirect land prices key economic impact factor had been summarized and used to build information system model. Among these factors financial and economic data combined with geo-spatial information are considered the main input data sources for the digital information systems solution. An eight steps algorithm was constructed to enable information system output for economical assessment of land plot objects. The presented equations for economical assessment of a single land plot object can be used to calculate important parameters for the information system. Going one step further, a pyramid-shaped diagram denotes four stages of general economical valuation for prospective land object in context of investment opportunities. The price of each individual land slot can be efficiently calculated using an information system that relies upon pre-processed data, price impact factors and general land slot information. The findings underscore the necessity for adopting a more comprehensive approach towards the modeling of land prices in urbanized territories. This approach*

should adequately reflect the current delineation of urban and suburban boundaries, incorporate data pertinent to urban zones, and consider the spatial distribution of most significant industrial sites and business districts within larger urban zone (metropolitan region).

Keywords: *urbanization; information systems; system modeling; urban economics.*

Topicality

The necessity for an innovative methodology is imperative to elucidate the ramifications of urbanization processes and their subsequent impacts on the national economic framework. During phases of urban expansion, there is a notable increment in urban populations, augmented by the migration of labor forces from adjacent regions and countries. Conversely, in scenarios of urban economic stagnation or regression, there is a discernible migration of the labor force towards more economically vibrant cities, although a fraction remains. In megacities, inhabited by millions, the feasibility of migration is constrained by several factors, including land prices, as well as the cost and availability of residential real estate, which play pivotal roles in influencing individuals' decisions to relocate to or depart from these urban centers.

In this vein, it becomes essential to conduct rigorous analyses and develop comprehensive models forecasting the influence of urbanization on land use, pricing dynamics, and various aspects of regional economic development. Naturally, real estate price are divided into several components, one of them being land price.

Moreover, the urbanization process is intertwined with a spectrum of contemporary challenges, such as climate change exacerbated by rapid urban development and the unsustainable exploitation of natural resources. An exhaustive examination of spatial data pertaining to urban and suburban zones, exemplified by the city of Kyiv, reveals a transformation in the utilization of suburban land, now earmarked for residential construction projects and infrastructural enhancement. Furthermore, urban development indirectly precipitates environmental alterations in proximate areas, rendering them less amenable to specialized uses (e.g., agriculture or recreation), and necessitating significant financial investment and advanced technologies for soil fertility restoration.

Analysis of recent research and publications

Urbanization is a complex and long-term process that is closely related to the economic development of territorial communities. In the short term, the rapid increase in the level of urbanization leads to an economic boom [1]. However, if such developments do not take into account environmental aspects and available natural resources with a view to the future, this is often a prerequisite for future problems [2, 3]. For example, decreasing levels of green space in cities and suburbs can lead to severe fires, droughts, and reduced air quality [4]. To overcome such phenomena, cities or communities are forced to spend significant financial resources, which does not benefit their development. Another aspect of the rapid development of cities

is a significant increase in the population, and, accordingly, an increase in the need for food and drinking water [5]. It is logical to assume that in this context, the land fund of the suburbs can serve as a resource base and be the center of the location of agricultural and food processing enterprises [6]. And forest zones can be a buffer for the protection and maintenance of a stable ecological situation [7]. For more robust economic modeling and land, real estate valuation, information systems and IT prove to be a reliable tool. The next wave to research work should aim to build upon current state-of-art by utilizing software and information systems not just as extras but as foundation for economic research.

The purpose of the work is to research and construct a robust land price system model that is part of a greater digital information system, with focus on urban and suburban land areas. The goal is to develop a suitable framework for economic land price modeling of any chosen land plot.

Presenting main material

Urbanization represents a multifaceted and enduring phenomenon intimately linked to the economic progression of territorial entities. Short-term observations indicate that a swift escalation in urbanization rates can catalyze economic prosperity. Nonetheless, such advancements, when neglecting the environmental implications and sustainable utilization of natural resources, invariably lay the groundwork for future adversities. For instance, the diminution of green spaces within urban and suburban areas can precipitate severe environmental calamities, including wildfires, droughts, and a decline in air quality. Addressing these challenges necessitates substantial financial investments from urban or community budgets, adversely affecting developmental trajectories. Furthermore, the rapid urban expansion is synonymous with a marked increase in population density, which, in turn, escalates the demand for essential resources such as food and potable water [8]. It is reasonable to postulate that, within this context, the suburban land reserve could function as a pivotal resource base, potentially hosting agricultural and food-processing industries [6]. Additionally, forested areas could serve as crucial buffers, safeguarding and sustaining environmental equilibrium [9].

Table 1 presents the results of the work carried out on the classification and distribution of selected data into categories that can be used in the information system to calculate the economic costs of land. The distribution of data by categories (Table 1) is directly related to the classification of the following areas: factors of direct and indirect economic costs of land use in the context of cities, among which it is worth highlighting important economic indicators.

The development of an information system for modeling land prices integrates findings and data analyses as outlined in Table 1. The dataset, derived from multiple sources, underpins the creation of economic models incorporated into a comprehensive land-use modeling framework (illustrated in Figure 1). This information system facilitates the assessment of prevalent economic metrics associated with urbanization, such as land prices in both urban and suburban settings. The model conceptualizes urbanization as a determinant factor influencing land value variations.

The outcomes of the modeling endeavor include both visual and quanti-

1. Land Value Factors, by data type and category classification

Impact Factors	Key Economic Indicator	Data Type	Sample Data
Location of the land plot Landmarks and relative location Natural Resources	the level of employment of the population by type of economic activity and by urban zones; the level of average income of the population by type of economic activity;	Geographic Location	Location coordinates Location of the site Land valuation Potential prospects Investment and Economic Growth Opportunities Water resources Mineral deposits Soil fertility Relative position of coordinates/spatial position
Type of land useLegal Documents	the level of employment of the population by type of economic activity and by urban zones; average median values of loans and deposits by type of bank; trade balance indicators;	Documents	Personal/Corporate/Public Agriculture/Industrial/ Construction/Farm/Natural Resources/Forest/Water Zone (Reserve) Terms of Use Lease or lease period

Land price
Economic growth
Interest rate
Property Value
Upkeep/maintenance cost
	the volume of GNP per capita and the dynamics of its changes;
	inflation rate and stability of the national currency;
		Financial	$ per unit area
			$ per unit of time
			National GDP Federal/ Municipal GDP,
			Investment, and Budget
			National rate
			Commercial Financial InstitutionsRate
			$ per unit of time

Conditions for the Use of Land PropertySite type Plot size Supply and demand (land slots)	volume of products sold by companies by type of economic activity and by territorial zoning; the general level of profit of companies by type of economic activity per capita of urban population and by territorial zoning;	Information	Sale/Rent/LeasingProtected /Agricultural/Municipal/ National Slot Area Slot boundaries coordinates Supply and demand of the commercial market Federal/Municipal City/ Building Plan
Environmental Costs and Factors	Green taxation rate and value Sustainability and restoration economic plan	Environmental	Land and soil degradation and restoration Deforestation and changes in green cover Waste management Sustainable development, environmental regulation

Source: prepared by the authors.

tative delineations of urban or territorial boundary shifts over periods of 5, 20, or more years, employing a methodical analytical approach to discern patterns and forecast spatial dynamics. This encompasses evaluations of anticipated growth, potential usage options for targeted land objects (including current valuations and price fluctuation analyses), and illustrations of principal economic and ancillary factors that affect land utilization and broader economic impacts. These analyses also consider local dynamics pertinent to urban expan-

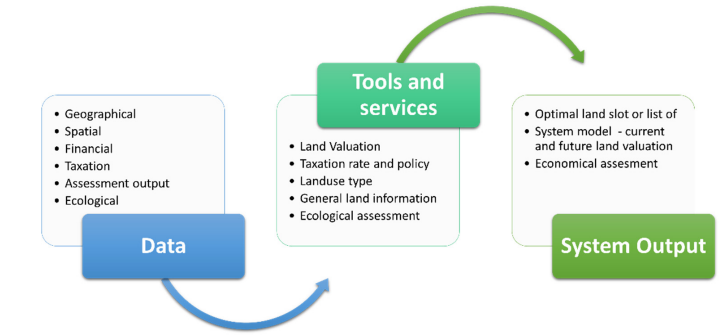

Fig. 1. Information System to Model Land Plot Price

Source: constructed by the authors.

sion, thereby elucidating the effects of urban sprawl on rural area diminution.

Additionally, the model scrutinizes key economic variables impacting urbanization, including segregation, as well as social and cultural dimensions. It encompasses a system for assessing the risks and fiscal repercussions stemming from the multifunctional conflicts of territorial use, encompassing ecological, construction, industrial, and agricultural domains.

To elucidate the formation of real estate prices, an examination of urban land lease rates is essential [10, 11]. Moreover, the classification system deployed in Table 1, predicated on economic variables such as interest rates, national GDP, and the real estate market dynamics, informs price determinations alongside supply and demand considerations. Legislative peculiarities and municipal land regulations, especially those pertaining to environmental standards, were integral to structuring the data presented in Table 1. Nonetheless, the availability of requisite data was constrained, limiting the scope of research.

The resultant architecture of the land price modeling information system, depicted in Figure 1, encompasses three pivotal stages: initial data aggregation and land category classification, data input processing, and, finally, output generation by the computational system. This system is designed not merely for price simulation but also to enable economic forecasting, generate land use documentation and management strategies, and provide visual aids for environmental modeling [12, 13].

The following outlines a systematic approach for the economic evaluation of a land use entity (plot), emphasizing the significance of a comprehensive framework that incorporates regulatory, environmental, and economic analyses. This framework assesses the current state and environmental impact of the land use entity, evaluates the technical condition of the entity, and considers spatial development alongside economic and investment strategies [14, 15].

The algorithm for determining the economic impact of urbanization encapsulates various data points and factors:

1. Estimation of the aggregate investment and financial outlay in new urban developments, categorized by territorial zoning, type of entity, and anticipated revenue generation from its operation.

2. General Assessment of Land Plot Valuation

Score	Types of Objects	Data	Calculation
Market Valuation, R	Objects of commercial, profitable real estate, land objects	Annual profit from the object, UAH Estimated value of the object, UAH Profitability of the object, UAH	**R = P/Y,** P – Profit from the object for the year Y (Yield) – the ratio of income to the value of the object at the time of valuation
Permanent Rent Cost, P	Real estate and land plots	Is used to calculate the present value of the company's future projected cash flow and the final value of the object	**P = v/r,** v – Cash flow over a period of time r – Interest rate
Final cost of the plot, PF	Real estate and land plots	Calculated for periodic or ongoing year-end payments	**PF = (p*(1+g))/(d-g),** p – Cash flow over a period of time d – Key policy rate g – Projected growth rate
Residual value of land for residential development, R	Real estate and residential land	Factors that need to be worked out for the assessment: total area of the plot, projected rental price per sq. m., percentage of capitalization of the deposit, construction costs and taxes	**R = ((F-D)*r) – A,** F – Future income from land/object D – Developer's profit on the value of the land r – interest rate for a specified period of time A – The cost of purchasing a plot

Source: prepared by the authors.

2. Economic evaluation of the present condition of real estate within urban and adjacent zones, identifying factors that influence price formation, including supply and demand dynamics.

3. Analysis of the national taxation framework, including average banking loan interest rates, differentiated by the bank's ownership structure and the loan's purpose.

4. Examination of municipal taxation systems, including the spatial distribution of land rents, categorized by entity type and zoning regulations.

5. Valuation of real estate and assets, alongside an assessment of risks associated with their operational management.

6. Compilation of available capital and the cumulative volume of international investments, segregated by the intended application of the facility or zone.

7. Comprehensive descriptive and quantitative analysis of available land plots, with classifications based on intended use, territorial zoning, and economic valuation.

8. This algorithmic approach provides a structured methodology for the economic assessment of land use entities, facilitating informed decision-making and strategic planning in urban development contexts.

Utilizing the algorithm devised for the economic evaluation of urbanization processes, Table 2 delineates the mathematical formulations required for the market appraisal of various entities,

Fig. 2. General economic significance of the land object (investment prospects)

Source: constructed by the authors.

encompassing land plots, perpetual land lease rates, aggregate acquisition costs for purchasable land, and the residual valuation of plots designated for residential development projects. This table elucidates the types of data essential for executing the pertinent calculations.

Additionally, Figures 2 and 3 illustrate the methodological framework developed for the analysis and categorization of standard land use entities, emphasizing the importance of a thorough classification and comprehensive data acquisition concerning these entities. Presently, the scenario in Ukraine and other emerging economies is characterized by less-than-ideal conditions, with data exhibiting significant volatility. In order to calculate the general economic significance of the land object as a potential investment opportunity several important elements needs to be considered. The Figure 2 illustrates the main variables that are included when making generalized economic assessment of a potential land object – starting from the bottom is the foundational element the land plot characteristics, followed by ecological assessment and valuation. In addition, present legal condition and regulations must be included. The next step after evaluating general economic significance of the land object is to determine the actual real time price of the particular land slot.

Figure 3 shows the information system model that can be used to develop a software system for economic valuation. The presented models includes categorized data, important calculation functions, as well as descriptors classes for each individual land plot. Consequently, there is a compelling need to formulate a more resilient economic modeling structure. This proposed structure should integrate a sustainable development policy framework, aimed at the judicious utilization of land and natural resources, particularly within the ambit of metropolitan expansion.

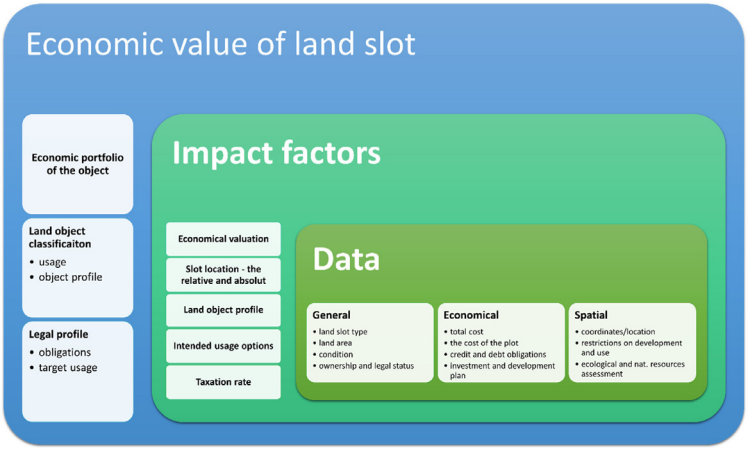

Fig. 3. The economic value price model of the land slot cost for future valuation

Source: constructed by the authors.

Conclusions

This study conducts a comprehensive analysis of the development dynamics within urban and suburban areas across various global regions. Stemming from this analysis, a model for the economic evaluation of land prices has been constructed. This model integrates a spectrum of factors influencing land value, encapsulating key economic, social, and financial dimensions categorized accordingly. The genesis of the presented model is rooted in an exhaustive examination of the land and real estate markets within Ukrainian cities and other major global urban centers. Furthermore, an information system designed for the simulation of land prices has been introduced. This system is capable of generating economic projections for the valuation of land use entities over future intervals of 5, 10, 20, and 25 years, within the context of accelerated urban and social development, while also considering the implications of climate change and its associated urbanization-related processes..

Список використаних джерел

1. Gollin D., Jedwab R., & Vollrath D. Urbanization with and without industrialization. *Journal of Economic Growth*. 2016. Vol. 21. Issue 1. No 2. Pp. 35–70. DOI: 10.1007/s10887-015-9121-4
2. Li S., & Ma Y. Urbanization, economic development and environmental change. *Sustainability.* 2014. № 6(8). Pp. 5143–5161. URL: https://doi.org/10.3390/su6085143
3. Bai X., McPhearson T., Cleugh H., Nagendra H., Tong X., Zhu T., & Zhu Y.G. Linking urbanization and the environment: Conceptual and empirical advances. *Annual review of environment and resources*. 2017. Vol. 42:215–240. URL: https://doi.org/10.1146/annurev-environ-102016-061128
4. Zhou X., & Wang Y. C. Spatial-temporal dynamics of urban green space in response to rapid urbanization and greening policies. *Landscape and urban planning*. 2011.

100(3):268–277. DOI:10.1016/j.landurbplan.2010.12.013
5. Oyeleye O.I. Challenges of urbanization and urban growth in Nigeria. *American Journal of Sustainable Cities and Society.* 2013. № 2. Pp. 79–96.
6. Nazarenko V. Research of the urban development in connection to food processing and agricultural companies in Ukraine. Publishing house «European Scientific Platform». 2021. Pp. 33–47. URL: https://doi.org/10.36074/hdsanzvvt.ed-1.04
7. DeFries R.S., Rudel T., Uriarte M., & Hansen M. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience.* 2010. № 3. Pp. 178–181. URL: https://doi.org/10.1038/ngeo756
8. Ebeke C.H., & Etoundi S.M.N. The effects of natural resources on urbanization, concentration, and living standards in Africa. *World Development. Elsevier*. 2017. Vol. 96(C). Pp. 408–417. DOI: 10.1016/j.worlddev.2017.03.026
9. Esbah H., Cook E.A., & Ewan J. Effects of increasing urbanization on the ecological integrity of open space preserves. *Environmental management.* 2009. 43(5):846–62. DOI:10.1007/s00267-009-9274-z
10. Shatkin G. The real estate turn in policy and planning: Land monetization and the political economy of peri-urbanization in Asia. Cities. 2016. Volume 53. Pp. 141–149. URL: https://doi.org/10.1016/j.cities.2015.11.015
11. Kresse K., & Van der Krabben E. Rapid urbanization, land pooling policies & the concentration of wealth. *Land Use Policy*. 2022. Volume 116. Pp. 106050. URL: https://doi.org/10.1016/j.landusepol.2022.106050
12. Nazarenko V. System Modeling of the Smart City in Context of Land Management E-Service. *Land Science.* 2021. Vol. 3. No 1. Pp. 22–35. URL: https://doi.org/10.30560/ls.v3n1p22
13. Nazarenko V.A., & Martyn A.G. Land management in urban and suburban areas: the case for sustainable development. In: V Міжнародна науково-практична конференція здобувачів вищої освіти і молодих учених «Перспективи розвитку територій: теорія і практика», 18–19 листопада 2021 року, м. Харків. С. 72–75.
14. Novakovskyi L., Martyn A., Novakovska I., & Skrypnyk L. Formation of land use restrictions by geoinformation analysis methods in spatial planning (On the example of territory around the airfields). *Ukrainskyi heohrafichnyi zhurnal.* 2021. N1:44–53. URL: https://doi.org/10.15407/ugz2021.01.044
15. Wu Y., Zhang X., & Shen L. The impact of urbanization policy on land use change: A scenario analysis. Cities. 2011. Volume 28. Issue 2. Pp. 147–159. URL: https://doi.org/10.1016/j.cities.2010.11.002

References

1. Gollin D., Jedwab R., & Vollrath D. Urbanization with and without industrialization. *Journal of Economic Growth*. 2016. Vol. 21. Issue 1. No 2. Pp. 35–70. DOI: 10.1007/s10887-015-9121-4
2. Li S., & Ma Y. Urbanization, economic development and environmental change. *Sustainability.* 2014. № 6(8). Pp. 5143–5161. URL: https://doi.org/10.3390/su6085143
3. Bai X., McPhearson T., Cleugh H., Nagendra H., Tong X., Zhu T., & Zhu Y.G. Linking urbanization and the environment: Conceptual and empirical advances. *Annual review of environment and resources*. 2017. Vol. 42:215–240. URL: https://doi.org/10.1146/annurev-environ-102016-061128
4. Zhou X., & Wang Y. C. Spatial-temporal dynamics of urban green space in response to rapid urbanization and greening policies. *Landscape and urban planning*. 2011. 100(3):268–277. DOI:10.1016/j.landurbplan.2010.12.013

5. Oyeleye O.I. Challenges of urbanization and urban growth in Nigeria. *American Journal of Sustainable Cities and Society.* 2013. № 2. Pp. 79–96.
6. Nazarenko V. Research of the urban development in connection to food processing and agricultural companies in Ukraine. Publishing house «European Scientific Platform». 2021. Pp. 33–47. URL: https://doi.org/10.36074/hdsanzvvt.ed-1.04
7. DeFries R.S., Rudel T., Uriarte M., & Hansen M. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience.* 2010. № 3. Pp. 178–181. URL: https://doi.org/10.1038/ngeo756
8. Ebeke C.H., & Etoundi S.M.N. The effects of natural resources on urbanization, concentration, and living standards in Africa. *World Development. Elsevier*. 2017. Vol. 96(C). Pp. 408–417. DOI: 10.1016/j.worlddev.2017.03.026
9. Esbah H., Cook E.A., & Ewan J. Effects of increasing urbanization on the ecological integrity of open space preserves. *Environmental management.* 2009. 43(5):846–62. DOI:10.1007/s00267-009-9274-z
10. Shatkin G. The real estate turn in policy and planning: Land monetization and the political economy of peri-urbanization in Asia. Cities. 2016. Volume 53. Pp. 141–149. URL: https://doi.org/10.1016/j.cities.2015.11.015
11. Kresse K., & Van der Krabben E. Rapid urbanization, land pooling policies & the concentration of wealth. *Land Use Policy*. 2022. Volume 116. Pp. 106050. URL: https://doi.org/10.1016/j.landusepol.2022.106050
12. Nazarenko V. System Modeling of the Smart City in Context of Land Management E-Service. *Land Science.* 2021. Vol. 3. No 1. Pp. 22–35. URL: https://doi.org/10.30560/ls.v3n1p22
13. Nazarenko, V.A., & Martyn, A.G. Land management in urban and suburban areas: the case for sustainable development. In: V Mizhnarodna naukovo-praktychna konferentsiia zdobuvachiv vyshchoi osvity i molodykh uchenykh «Perspektyvy rozvytku terytorii: teoriia i praktyka», 18–19 lystopada 2021 roku, m. Kharkiv, 72–75.
14. Novakovskyi L., Martyn A., Novakovska I., & Skrypnyk L. Formation of land use restrictions by geoinformation analysis methods in spatial planning (On the example of territory around the airfields). *Ukrainskyi heohrafichnyi zhurnal.* 2021. N1:44–53. URL: https://doi.org/10.15407/ugz2021.01.044
15. Wu Y., Zhang X., & Shen L. The impact of urbanization policy on land use change: A scenario analysis. Cities. 2011. Volume 28. Issue 2. Pp. 147–159. URL: https://doi.org/10.1016/j.cities.2010.11.002.

Назаренко В.А., Мартин А.Г. (2024).
ІНФОРМАЦІЙНІ СИСТЕМИ МОДЕЛЮВАННЯ ЦІН НА ЗЕМЛЮ ПРИ ПРОЦЕСІ УРБАНІЗАЦІЇ
ЕКОНОМІКА І УПРАВЛІННЯ БІЗНЕСОМ, 15(1): 45-55.
https://journals.nubip.edu.ua/index.php/bioeconomy/article/view/49050
https://doi 10.31548/economics15(1).2024.039

Анотація. *Динамічні зрушення, пов'язані з розвитком або занепадом міст, суттєво впливають як на муніципальну, так і на національну економічну політику. Розширення міст часто вимагає виділення значних ділянок землі (або земельних площ), тоді як у регіонах із обмеженою доступністю землі або географічними обмеженнями є обов'язковим інноваційний підхід до міського планування.*

Мета роботи – дослідження й побудова надійної моделі системи цін на землю, яка є частиною більшої цифрової інформаційної системи, з акцентом на міські та приміські земельні ділянки. Окрім того, завдання полягало в розробці відповідної системи для економічного моделювання цін на землю будь-якої обраної земельної ділянки.

Визначено й класифіковано ключові фактори вартості землі. Кожен прямий і непрямий фактор економічного впливу цін на землю був узагальнений і використаний для побудови моделі інформаційної системи. Серед цих факторів фінансово-економічні дані в поєднанні з геопросторовою інформацією вважаються основними джерелами вхідних даних для інформаційної системи підтримки прийняття рішень. Побудовано восьмиступінчастий алгоритм, який застосовується головною функцією інформаційної системи в процесі представлення економічної оцінки земельних ділянок.

Наведені рівняння для економічної оцінки окремо взятого об'єкта земельної ділянки можуть бути використані для розрахунку важливих параметрів для даної інформаційної системи. Якщо іти ще далі, то діаграма в формі піраміди позначає чотири етапи загальної економічної оцінки перспективного земельного об'єкта в контексті інвестиційних можливостей. Ціна кожної окремої земельної ділянки може бути ефективно розрахована за допомогою інформаційної системи, яка спирається на опрацьовані дані, фактори впливу на ціну та загальну інформацію про земельні ділянки. Отримані результати підкреслюють необхідність більш комплексного підходу до моделювання цін на землю на урбанізованих територіях. Цей підхід повинен адекватно відображати поточне розмежування міських і приміських територій, включати дані, що стосуються міських зон, враховувати просторовий розподіл найбільш значущих промислових об'єктів і ділових районів у межах великої міської зони (урбанізованого регіону).

Ключові слова: *урбанізація; інформаційні системи; системне моделювання; міська економіка.*