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DISTRICT PLANNING AND HOUSING INFRASTRUCTURE SYSTEM AS A FRAMEWORK FOR SUSTAINABLE REGIONAL ECONOMIC DEVELOPMENT

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Abstract: The article examines the systemic interconnection between housing infrastructure, district planning, and the regional economy using the city of Tashkent as a case study. Housing infrastructure is presented as the fundamental element of territorial development, ensuring the formation of quality of life and setting the direction for planning decisions. It is shown that district planning serves as a mechanism for integrating housing construction, engineering networks, and social infrastructure into the city's spatial structure. The study analyzes the impact of housing infrastructure on the regional economy, identifying both direct and indirect effects. The application of demographic and economic–mathematical models for forecasting housing needs and optimizing planning solutions is substantiated. Examples from Tashkent's practice (2010–2025) are provided and compared with international experience (Germany, Turkey, South Korea). The conclusions highlight that the integrated development of housing infrastructure within the district planning system is a key factor for sustainable regional development.

Key words: housing infrastructure, district planning, regional economy, urbanization, demography, optimization.

Annotatsiya: Maqolada Toshkent shahri misolida turar joy infratuzilmasi, tuman rejalashtirishi va mintaqaviy iqtisodiyot o'rtasidagi tizimli o'zaro bog'liqlik ko'rib chiqilgan. Turar joy infratuzilmasi hududiy rivojlanishning boshlang'ich bo'g'ini sifatida taqdim etilgan bo'lib, aholi turmush sifati shakllanishini ta'minlaydi va rejalashtirish yechimlarining yo'nalishini belgilaydi. Tuman rejalashtirishi turar joy qurilishi, muhandislik kommunikatsiyalari va ijtimoiy infratuzilmani shaharning fazoviy tuzilishiga integratsiya qilish mexanizmi sifatida namoyon bo'lgan. Turar joy infratuzilmasining mintaqaviy iqtisodiyotga ta'siri tahlil qilinib, to'g'ridan-to'g'ri va bilvosita ta'sirlar aniqlangan. Demografik va iqtisodiy-matematik modellardan turar joy ehtiyojlarini prognoz qilish va rejalashtirish yechimlarini optimallashtirishda foydalanish asoslangan. Toshkent amaliyotidan (2010–2025 yy.) misollar keltirilgan va Germaniya, Turkiya, Janubiy Koreya tajribalari bilan taqqoslangan. Xulosalarda ta'kidlanishicha, tuman rejalashtirishi tizimida turar joy infratuzilmasining kompleks rivojlanishi barqaror mintaqaviy rivojlanishning asosiy omili hisoblanadi.

Kalit so'zlar: turar joy infratuzilmasi, tuman rejalashtirishi, mintaqaviy iqtisodiyot, urbanizatsiya, demografiya, optimallashtirish.

Аннотация: В статье рассматривается системная взаимосвязь жилищной инфраструктуры, районной планировки и региональной экономики на примере города Ташкента. Жилищная инфраструктура представлена как исходное звено территориального развития, обеспечивающее формирование качества жизни населения и задающее направление планировочных решений. Показано, что районная планировка является механизмом интеграции жилищного строительства, инженерных коммуникаций и социальной инфраструктуры в пространственную структуру города. Проведен анализ влияния жилищной инфраструктуры на региональную экономику, выявлены прямые и косвенные эффекты. Обосновано применение демографических и экономико-математических моделей для прогнозирования жилищных потребностей и оптимизации планировочных решений. Приведены примеры из практики Ташкента (2010–2025 гг.), сопоставлены с зарубежным опытом (Германия, Турция, Южная Корея). Сделаны выводы о том, что комплексное развитие жилищной инфраструктуры в системе районной планировки является ключевым фактором устойчивого регионального развития.

Ключевые слова: жилищная инфраструктура, районная планировка, региональная экономика, урбанизация, демография, оптимизация.

INTRODUCTION

Housing infrastructure is not only a collection of residential buildings but also a complex of engineering, transport, and social systems that ensure the population's livelihood. In the context of active urbanization and structural changes in the economy, the role of housing infrastructure goes beyond "housing" policy: it becomes the starting point for shaping the spatial organization of the city and a factor determining the competitiveness and sustainability of the regional economy. The shift in focus from "planning → housing" to "housing → planning" reveals how the characteristics of the housing stock and the availability of related services determine the trajectories of territorial development.

Therefore, an important and relevant aspect of the research is to substantiate and quantitatively describe the role of housing infrastructure as an initial factor in district planning formation and its impact on the development of the regional economy.

Naturally, the main tasks include: a comprehensive definition and systematization of housing infrastructure components; description of the mechanisms integrating housing infrastructure into district planning processes; analysis of how changes in housing infrastructure transform into economic effects at the regional level; development and application of demographic and economic-mathematical methods for modeling and forecasting the influence of housing infrastructure on the regional economy; formulation of practical recommendations and model algorithms for use by khokimiyats and authorized bodies in decision-making.

For a systematic analysis and assessment of housing infrastructure, it is advisable to use a set of indicators – housing stock per 1,000 people (m^2/person); population density (people/ha); accessibility of social infrastructure facilities (time/distance to the nearest school/clinic); staffing ratio (doctors per 1,000 people, educators, etc.); percentage of housing in satisfactory technical condition; land-use mix index; transport accessibility index (average travel time to work); housing energy consumption ($\text{kWh}/\text{m}^2/\text{year}$), and others [1].

Between 2010 and 2025, the housing stock of Tashkent city increased significantly — from 45 million square meters to more than 70 million square meters, which indicates large-scale growth in housing construction and active urbanization. During this period, the average housing provision per capita increased by about 20%, reflecting an improvement in living conditions and greater housing accessibility for residents. In the city's new residential areas, more than 100 modern schools and kindergartens have been commissioned, contributing to the development of social infrastructure and the improvement of the urban environment's quality.

For example, the Chilanzar district has become one of the leaders in urban environment renewal: large-scale reconstruction of old quarters is underway, and modern multi-storey residential buildings are being actively constructed, including built-in kindergartens, clinics, and other social infrastructure facilities. In the Yunusabad district, the concept of "comprehensive microdistricts" is being implemented, including shopping centers, general education schools, sports grounds, and landscaped public areas, providing a high level of comfort for residents. The Sergeli district is characterized by the most intensive pace of housing construction: new residential areas — "Sergeli-5," "Sergeli-7," and others — are being created, equipped with transport infrastructure, including modern highways and metro lines. The Mirzo-Ulugbek district demonstrates a balanced approach to development: here, individual low-rise housing is combined with the construction of new residential complexes oriented toward young families and the creation of a comfortable living environment.

Examples from Tashkent's practice show that modern microdistricts are designed as integrated complexes that include residential buildings, social service facilities, educational and medical institutions, as well as a developed transport system. Housing infrastructure serves as the main framework for territorial development, determining the spatial organization of the city and setting the directions for the placement of social, engineering, and transport networks.

LITERATURE REVIEW

A significant contribution to the development and improvement of the scientific foundations of district planning methodology has been made by both domestic and foreign researchers. Their works cover a wide range of issues — from spatial-economic and social to engineering, algorithmic, and informational aspects of territorial structure formation. District planning, in this context, is regarded as a key instrument for managing the development of urban and suburban areas, determining the efficiency of the residential and social infrastructure of a region.

Among domestic scholars, particular attention should be given to the works of A.M. Sodikov, who elaborated the conceptual foundations of regional development strategies, forming a theoretical basis for new approaches to the spatial organization of residential development [2]. S.S. Zokirov, in his research, focused on the socio-economic aspects of densely populated urban districts and the management of urbanization processes, contributing to the development of modern principles of planning optimization [3]. A significant contribution

was also made by A.A. Urunov [6], who developed methodological foundations for the integrated development of regions, and Kh.R. Dzhumabaev, who proposed economic-mathematical models for planning residential infrastructure, supplemented by software tools for automating design processes [6]. S.Sh. Mirziyoyeva studied mechanisms for realizing competitive advantages within national development strategies, which directly relate to enhancing the effectiveness of planning decisions [1].

Foreign researchers have also made a fundamental contribution to the theory and practice of district planning. Rem Koolhaas (Netherlands) developed concepts of compact and multifunctional urban development, ensuring a balance between density and environmental comfort, while Jan Gehl (USA) focused on transforming inefficient urban spaces into livable districts. Russian scientists such as V.V. Vladimirov [8] and E.E. Leyzerovich [9] studied the regularities of service facility distribution, land-use issues within planning units, and the principles of fractional economic zoning in the context of regional and district planning.

Despite the high theoretical and practical significance of these studies, existing district planning models still have certain limitations. In most cases, they are focused on individual aspects — forecasting, functional zoning, or land-use optimization — without comprehensive consideration of demographic, infrastructural, and environmental factors. Meanwhile, ensuring the systemic interrelation of key planning parameters and developing tools for their integrated analysis remain pressing challenges of modern urban development.

The combination of these factors determines the necessity of forming new methodological foundations of district planning, aimed at the integrated development of territories, optimization of residential structures, rational distribution of functional zones, and enhancement of the sustainability of planning solutions under conditions of dynamically developing urbanization.

RESEARCH METHODOLOGY

The methodological framework of this research is based on the principles of a systems approach to managing the development of urban territories and residential infrastructure, on the theory of urbanization, and on the application of economic-mathematical modeling methods for drainage systems, which are considered an integral component of the residential environment.

The research methodology employs a comprehensive set of economic-mathematical analysis tools that enable the determination of optimal parameters of drainage systems, taking into account the objectives of rationalizing the housing stock and infrastructure of microdistricts. Within this framework, various types and methods of drainage system placement in urbanized territories are examined. Additionally, methods of systematization and classification, comparative and dynamic analysis, systems approach, as well as statistical data processing techniques, are applied.

ANALYSIS AND RESULTS

The lack of housing infrastructure development makes rational urban planning impossible and slows down sustainable socio-economic growth in the region, since the housing environment is the basis for developing the labor potential and quality of life of the population. Housing conditions directly affect demographic processes, including birth rates, migration inflows and outflows, and the duration of residence in one place. Housing availability serves as a key trigger for internal migration, shaping new settlement and population concentration patterns. In turn, such migration shifts change the employment structure, redistribute labor resources, and transform the demand for social, transport, and public services in urban and suburban areas.

It should be noted that district planning is a tool for linking housing to transport, engineering, and social networks. When housing infrastructure (new projects, modernization of existing stock) becomes the development driver, planning solutions are formed around it: the distribution of functions across the territory, the determination of attraction centers, and the formation of public space systems [2].

Through district planning, housing becomes a key factor in stimulating the regional economy – with direct impact: the construction industry makes a significant contribution to GDP formation (in Uzbekistan, the construction sector accounts for about 8–10% of GDP). This indicator reflects the importance of housing construction as a fundamental economic sector determining investment and employment dynamics; and indirect impact: the development of the housing sector creates a multiplier effect through increased employment, higher demand for building materials, services, and durable goods. In turn, this stimulates related industries — transport, energy, furniture, and household appliance production [3,4].

The formula for the multiplier effect is as follows: $\Delta B P \Gamma = k \cdot \Delta \Phi$, where $\Delta \Phi$ – housing stock growth, and k – multiplier coefficient (0.3–0.5). This relationship shows that the increase in housing construction volume is directly proportional to the growth of regional product.

For example, the implementation of the “Urban Renewal” program in Tashkent has led to the growth of the construction sector, infrastructure development, and the activation of related industries; in Turkey, large-scale housing construction serves as a driver of regional employment and small business development; in Germany, housing construction is considered part of the strategic Raumordnung (spatial planning) system aimed at balanced territorial development.

As a multidimensional assessment of this effect, the article considers the main optimization criteria — minimization of deviations from the target population size; minimization of deviations in apartment composition; minimization of deviations in the number of floors; and minimization of residential area. In general form, mathematical models of housing stock optimization (by number of floors, building and block-section typology, apartment composition, and building area) and infrastructure are formulated as problems of maximizing building density and minimizing the required area under a fixed population size (with or without considering surplus total area) [5,6,7].

To determine

$$|N_3 - N_p^j| \rightarrow \min$$

subject to constraints on:

– demography (apartment composition):

$$\begin{cases} (1 - \eta) \text{CTK}_1 < \text{ПС}_1 < (1 + \eta) \text{CTK}_1 \\ \dots \\ (1 - \eta) \text{CTK}_6 < \text{ПС}_6 < (1 + \eta) \text{CTK}_6 \end{cases} \quad (1)$$

– building height:

$$k_1^H \mathcal{J}_{\text{микр}} < \mathcal{J}_R < k_1^B \mathcal{J}_{\text{микр}}, \quad (2)$$

where N_3 - specified population size;

N_p^j - population calculated at the j -th iteration;

j - iteration number;

$\text{CTK}_1 \div \text{CTK}_6$ – required percentage ratios of one- to six-room apartments;

η - permissible deviation from the required apartment composition (as a fraction of one);

$$\text{ПС}_1 = \frac{Q_1}{Q_{\text{общ}}} 100, \dots, \text{ПС}_6 = \frac{Q_6}{Q_{\text{общ}}} 100$$

– obtained percentage ratios of apartments of various

types in the development;

k_1^H, k_1^B - respectively, lower and upper limits (in %) for R — building height;

$\mathcal{J}_{\text{микр}}$ - housing stock of the microdistrict.

To meet demographic constraints, the author used a penalty function of the following form:

$$\text{ШФ} = \sum_{i=1}^6 \text{ШФ}_i, \quad (3)$$

where:

$$\text{ШФ}_i = 100 |\pi \omega_i - 100 \eta|, \quad i = \overline{1,6};$$

$$\pi \omega_i = \frac{\omega_i}{\text{ПС}_i}, \quad i = \overline{1,6};$$

$$\omega_i = |\text{ПС}_i - \text{CTK}_i|, \quad i = \overline{1,6}.$$

Thus, the criterion of this mathematical model takes the form:

$$F = \sum_{i=1}^6 \text{ШФ}_i \rightarrow \min,$$

subject to the constraint on deviation from the specified population size:

$$k_2^H N_3 \leq N_p^j \leq k_2^B N_3, \quad (3)$$

where k_2^H, k_2^B – respectively, lower and upper boundaries of variation in the calculated population of the microdistrict (as fractions of one).

The function ensuring compliance with the ratio of different building heights is defined as:

$$Z_R = \frac{Ж_R}{k_i \cdot Ж_{\text{МИКР}}} 100$$

The deviation is determined as: $\omega_R^* = |Ж_R^* - Z_R|$.

In percentage terms:

$$\omega\pi_R = \frac{\omega_R^*}{Ж_R^*} 100$$

Penalty values are calculated using the formula:

$$\Pi_i = 100|\omega\pi_R - \varphi|$$

where φ – allowable deviation from the specified ratio of building heights (in %).

The value of the penalty function is defined as the sum of penalties by individual indicators:

$$\Pi\Phi^* = \sum_{i=1}^k \Pi_i$$

where k – number of building height types in the development; $Ж_R^*$ – required percentage ratio of R-story buildings..

The mathematical model under the specified population size takes the form:

$$F = N_p^d Ж_{\text{ТР}} \rightarrow \min$$

subject to constraints (1)- (3),

where $Ж_{\text{ТР}}$ – area of the microdistrict per inhabitant:

$$Ж_{\text{ТР}} = f(C_3, P^d, P^s, R_1).$$

To solve these optimization problems, the algorithms and application programs “Mahalla-4” and “Mahalla-4M” were developed and transferred to the State Fund of Algorithms and Programs.

Optimization of microdistrict residential development, taking into account housing infrastructure, represents a multicriteria problem requiring a balance between costs, area, comfort, and regulatory standards. The use of economic-mathematical models makes it possible to formalize these conditions and obtain consistent solutions.

When implementing multicriteria optimization models, in addition to the main indicators of residential development and housing infrastructure, one may also consider seismic constraints (e.g., no more than 9 stories in a seismic zone), insolation standards (amount of light and spacing between buildings), pedestrian accessibility of infrastructure (service radius for schools, kindergartens, etc.), and classification by housing types (taking into account differences in allowable building density) [6].

A multicriteria economic-mathematical model makes it possible to consider the complexity of urban planning tasks, analyze evaluation indicators, and make flexible, well-grounded decisions under limited resources.

Of particular interest in the practice of optimal microdistrict design is a class of problems in which the criterion has a vector nature:

$$Q(X) = [q_1(X), q_2(X), \dots, q_n(X)] ,$$

where the task consists in simultaneous extremization of n criteria:

$$q_i(X) \rightarrow \text{extr}, \quad (i = \overline{1, n}),$$

where S – the set of admissible states of vector X .

Assuming that all criteria are minimized (which can easily be achieved by changing the sign of those to be maximized), the multicriteria (vector) optimization problem can be written as:

$$q_i(X) \rightarrow \min, \quad (i = \overline{1, n}),$$

or in vector form:

$$Q(X) \rightarrow \min_{X \in S}$$

In the process of optimizing housing infrastructure, the criteria are subject to extremization through appropriate selection of the structure and parameters of the development, which are identified by vector X .

However, reducing a multicriteria problem to a single-criterion one is not always correct, since:

– it requires identifying one main optimization criterion, which leads to a simplification of the initial formulation and potential loss of information;

– transforming other criteria into constraints is also problematic, as it is necessary to define upper and/or lower bounds of variation Ax_i and Bx_i :

$$Ax_i \leq q_i(X) \leq Bx_i$$

Setting these bounds Ax_i and Bx_i is usually a serious challenge, since it involves limiting a criterion that, by nature, should attain an extreme value.

Defining such boundaries often presents considerable difficulty, as it constrains indicators that are inherently intended to reach extreme values.

Thus, reducing a multicriteria optimization problem to a single-criterion one is a forced and labor-intensive process.

In this study, the problem of optimizing residential infrastructure (by number of floors, building typology, and apartment-type ratio) and determining the required land area of a neighborhood for a fixed population size (with or without considering the surplus total area) is formulated as follows [7]:

$$\min Z = \frac{1}{\rho} \sum_{i=1}^p L_i D_i \quad ,$$

where L_i – indicator of inclusion of the i -th criterion in the composite criterion:

$$L_i = \begin{cases} 1, & \text{if the } i\text{-th criterion is included in the generalized criterion;} \\ 0, & \text{otherwise} \end{cases}$$

D_i – value of the i -th partial criterion.

Criterion D_1 corresponds to minimizing deviations from the specified population size of the neighborhood:

$$D_1 = \left(1 + \frac{W^j - W_2}{W_2} \right)^{g_1} \quad ,$$

where W_2 – given population size of the neighborhood;

W^j – calculated population size at iteration j ;

j – iteration number.

Criterion D_2 corresponds to minimizing deviations from the specified ratio of different building heights:

$$D_2 = \left(1 - \frac{R}{R_1} \right)^{g_2} \quad ,$$

where $R_1 - const \geq 10^5$; $R = F_s(E)$;

$F_s(E)$ – penalty function value arising from violations of the prescribed ratio of different building heights.

Criterion D_3 corresponds to minimizing deviations from the specified ratio of different apartment types:

$$D_3 = \left(1 - \frac{V}{V_1} \right)^{g_3} \quad ,$$

where $V_1 - const \geq 10^5$; $V = F_s(k)$;

$F_s(k)$ – penalty function value arising from violations of the prescribed ratio of apartment types.

Criterion D_4 corresponds to maximizing building density:

$$D_4 = \left(1 - \frac{Q - Q_2}{Q_1 - Q_2}\right)^{g_4},$$

where Q_2 – density of high-rise development, m²/ha;

Q_1 – density of low-rise development, m²/ha;

Q – calculated density of neighborhood development:

$$Q = \sum_{i=1}^n F_i x_i / T$$

Criterion D_5 corresponds to the value of the fifth partial criterion, that is, the minimization of the required microdistrict area per resident:

$$D_5 = \left(1 - \frac{t - t_1}{t_2 - t_1}\right)^{g_5},$$

where (for example, $t_1 = 21,5$ m²/person for 9-story buildings and $t_2 = 32,2$ m²/person for 4-story buildings [13]);

t – area of the neighborhood per person:

$$t = \frac{T}{\sum_{i=1}^n F_i x_i / (\beta + k^0 V^0)}, \text{ without accounting for surplus area, } L = 0;$$

$$t = \frac{T}{\sum_{i=1}^n (F_i - Z_i^l) x_i / (\beta + k^0 V^0)} \text{ with accounting for surplus area, } L = 1;$$

g_i – importance exponent of the i -th partial criterion ($i=1, \dots, 5$);

ρ – number of partial criteria included in the composite criterion under constraints (1), (2), and (3).

The calculated population size is determined by:

$$\text{- if } L = 0: \quad W = \mathcal{K}_M / \beta + k^0 V^0$$

$$\text{- if } L = 1: \quad W = (\mathcal{K}_M - \sum_{j=1}^n Z_j^l x_j) / \beta + k^0 V^0$$

k^0 – number of dormitories, units;

V^0 – dormitory capacity, persons;

β – standard housing provision rate, m².

The required area of the neighborhood is calculated as:

$$T = \sum_{i=1}^7 P_i,$$

where P_i – area of the i -th infrastructure facility within the neighborhood.

These models have practical applications in developing national and regional development strategies; creating effective mechanisms for territorial management and support; as well as in designing and implementing socio-economic projects aimed at improving the population's quality of life and ensuring long-term well-being [4,5].

CONCLUSIONS AND RECOMMENDATIONS.

The development of neighborhood housing in urbanization conditions requires a systematic consideration of both technical and demographic changes, as well as forecast-based resettlement scenarios.

High-quality residential and social infrastructure promotes human capital growth by creating favorable conditions for health, education, and social activity [2,3,4].

The presence of modern utilities and transport facilities reduces external costs, including environmental pollution and transport emissions.

In the long term, such factors contribute to a sustainable urban environment, increase labor productivity, and ensure higher rates of socio-economic regional growth, taking into account:

the initiating effect of housing: improvement of housing conditions—through an increase in available housing stock and quality—acts as a catalyst for socio-economic processes. This triggers a sequential chain: migration flow shifts lead to population redistribution, which, in turn, generates new demand for services and redistributes economic activity within the city and region;

efficiency of district planning: rational district planning achieves maximum effect when investments in housing construction are synchronized with the development of social and engineering infrastructure. The overall efficiency multiplier (k) increases, since investments in housing enhance the returns from investments in education, transport, and utilities, forming a sustainable and integrated territorial growth;

spatial determinants of growth: neighborhood development with high density and mixed functional land use helps reduce transport costs, save travel time, and boost local business and consumer activity. Such spatial principles ensure more sustainable and balanced economic growth.

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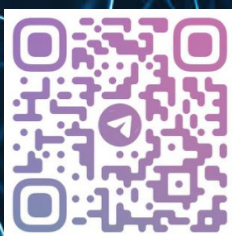
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