

Original Article

Architectural and Urban Planning Methods for Calculating Demographic Carrying Capacity in Astana

Ainur Muldagaliyeva¹, Seimur Mamedov²

¹Department of Architecture and Design, S. Seifullin Kazakh Agrotechnical Research University, Astana, Kazakhstan.

²Department of Architecture, 2Eurasian National University, Astana, Kazakhstan.

¹Corresponding Author : muldagaliyeva.ainur@gmail.com

Received: 14 August 2025

Revised: 16 September 2025

Accepted: 15 October 2025

Published: 31 October 2025

Abstract - In the context of rapid urban densification, there is a growing need to reassess the regulatory standards of urban planning. This study aims to identify the gap between current regulatory standards and actual living conditions, using residential complexes in Astana as a case study. The research encompasses a comprehensive analysis that incorporates architectural and urban planning calculations and the collection of statistical and sociological data. A significant excess in population density over the current standards is revealed, leading to overloading of social, engineering, and transport infrastructure, deterioration of the environmental situation, and a decline in urban living quality. To enhance the accuracy of calculations and the quality of design solutions, the study proposes adjusting the regulatory parameters and introducing a correction factor that accounts for the actual distribution of the population by housing types and comfort classes. The findings justify the need to revise existing regulatory standards to ensure sustainable urban development and enhance the effectiveness of urban planning policy.

Keywords - Population density, Regulatory indicators, Residential development, Urbanization, Urban planning.

1. Introduction

Urban planning is one of the fundamental foundations for the formation and development of settlements. Urbanization has become a global trend, gaining momentum every year [1]. Consequently, leads to greater economic and geographic density, the need for more efficient organization and use of resources, and compact land development [2].

Given the rapidly changing context, urban planning must organically adapt to new realities and challenges [3].

Thus, urbanization significantly affects territorial planning patterns, implying an increased role for comprehensive urban planning to ensure the sustainable development of both settlements and the country as an integrated system [4]. The population's quality of life and social well-being directly depend on holistic territorial planning [5].

In turn, established urban planning standards directly affect the quality and efficiency of the cities [6]. In this context, it is essential that the key urban development regulatory standard of a city, such as the master plan of Astana, be based on relevant, reliable, clearly defined, and scientifically justified standards, which will ensure the harmonious development and long-term sustainability of the urban environment [7].

Kazakhstan's urban planning regulatory framework is based on construction standards and normative documents (SP RK). These standards establish compulsory construction, design, density, and urban renovation requirements.

Furthermore, the development of the master plans is implemented by construction standards and norms. Likewise, in Kazakhstan, master plans define the directions of the spatial development of the cities.

Determining optimal regulatory parameters for residential space per person helps balance building density and the resulting development of infrastructure, including education, healthcare, transport, and green spaces. This enables the city's long-term growth within the framework of sustainable development [8].

The quality and efficiency of urban planning directly depend on established standards and practices of its application. Incorrect parameters in the standard inevitably lead to planning distortions and unbalanced development of the cities.

The main challenge lies in the need for the revision of applicable standards and the adaptation of international experience to local conditions in Astana. This need is due to Astana's current urban planning situation, along with the



degradation of problems such as overcrowded construction, traffic jams, lack of infrastructural facilities, and the growing need to implement «cities for people» approaches.

In the research conducted by Tong Li, Chunliang Xiu и Huisheng Yu, scholars emphasized the identification of spatial imbalances between the distribution of human activity and land use, applying the concept of the influence of habitat quality on population dynamics in combination with information and communication technology tools [9].

Kim Dovey и Elek Pafka introduced the integrative assessment model of city density, which considers the interrelation of building parameters, population, and structure of the open spaces [10].

A group of researchers led by Francisco Javier Abarca-Alvarez demonstrates the capability of artificial intelligence in the study of density metrics and morphological features of European cities [11].

E. Sherbina and I. Kuznetsov showed effectiveness in the application of GIS technologies for spatial analysis of building density in large cities [12].

The collection of these studies constitutes an extended methodological base for studying and modelling urban structure in the context of sustainable development.

The studies reviewed in the research showed tendencies toward a comprehensive assessment of the spatial characteristics of the urban environment through interdisciplinary approaches, without in-depth, detailed analysis of the regulatory framework. In contrast, the present study proposes a new method for examining building density. The research emphasizes a detailed comparison analysis of the regulatory framework.

As an example of the Astana case, inconsistencies between urban planning standards and the actual parameters applied to design projects were identified. Moreover, the regulatory prerequisites of urban deformations have been identified. As a result of the study, a new method for calculating the building density is proposed.

2. Materials and Methods

2.1. Document Analysis Method

The theoretical sources analyzed in this study were conventionally divided into two main categories: scientific-analytical and regulatory documents. The first category includes various research-based publications used to assess the degree of elaboration of current urban planning issues and to identify their root causes. The second category encompasses documents related to regulatory standards in the field of urban planning.

Additionally, the analysis included architectural standards (SP RK 3.02-101-2012, Multi-Apartment Residential Buildings) and urban planning standards (SP RK 3.01-101-2013, Urban Planning, Layout and Development of Urban and Rural Settlements; Comprehensive Urban Development Standard MD RK 3.01-01.4-2022).

2.2. Method for Collecting Statistical and Archival Data

This research collected statistical and archival data to obtain document-based information about existing urban developments and regulatory benchmarks. This method involved analyzing open statistical sources, demographic data, urban planning documents, and archival materials related to the design of residential areas. It proved effective in evaluating the applicability of current standards to contemporary conditions and provided empirical justification for new computational approaches.

2.3. Public Survey

A sociological survey assessed public opinion on urban planning decisions related to creating a comfortable urban environment. A total of 237 individuals from diverse socio-economic backgrounds participated. The questionnaire included 12 questions designed to determine public perceptions of urban planning activities in Astana. The survey was conducted through both individual and group interviews. Systematization of the responses revealed prevailing opinions for each question and a characteristic typology of living conditions, including factors such as living space per person, number of residents per dwelling, and accessibility of essential facilities.

2.4. Field Survey Method

The field survey method was employed to investigate architectural and urban planning solutions in various city areas. The examined sites included both under-construction and completed residential complexes. These urban planning objects varied in typological and classificatory characteristics, residential density, and construction stage. In addition to architectural structures, adjacent territories were also analyzed. The results were systematized and utilized in subsequent stages of the research.

2.5. Graph-Analytical Method

The graph-analytical method involved spatial analysis of the studied areas using cartographic materials and graph construction. The analysis was based on land plot extractions occupied by residential buildings, obtained from the Public Cadastral Map of the Unified State Real Estate Cadastre, ensuring accuracy in determining the physical parameters of the plots. Residential complexes with various development parameters were analyzed, allowing for a comparative assessment of regulatory and actual population densities. The resulting materials facilitated the visualization of spatial and quantitative discrepancies, identifying a persistent trend of exceeding the regulatory density in modern housing developments.

2.6. Mathematical Calculation Method

The study utilized a mathematical calculation method to quantitatively assess population density and actual occupancy of residential areas. Both architectural and urban planning analyses have been explored. This approach led to a mismatch between planned figures and actual living conditions, justifying the need to adjust existing population density calculation methods. The urban planning analysis utilized a coefficient calculated to indicate the deviation of the exact number of residents from the regulatory limit, taking into account the built-up area and building typology.

To implement the calculations, the following formula is introduced:

$$X = \frac{a*b}{c} \quad (1)$$

This made it possible to identify the extent to which development density exceeds the design standards. The architectural analysis evaluated housing provision based on building classifications by amenities and actual living space per person.

In this context, the following formula is used:

$$Saa = \frac{Sla}{n} \quad (2)$$

These actual occupancy parameters were compared with standards outlined in industry documents.

2.7. Comparative Analysis

A comparative analysis method was employed to identify differences and common scientific approaches to defining urban density and development within the comprehensive urban planning framework. This method, based on systematic comparison of methodological tools and findings, proved effective for substantiating theoretical foundations and assessing the relevance of scientific approaches to urban planning. At this phase, results from theoretical analysis, sociological surveys, and field studies were also systematized to identify consensus and divergent opinions on urban planning decisions.

2.8. Problem Cause Identification Method

This stage focuses on identifying the primary causes of planning distortions in developing populated areas and analyzing their impact on architectural and urban development.

2.9. Discussion Method

The discussion method was used to interpret the results and critically evaluate existing urban planning standards. Discussions were held in a dialogue format among architects, urban planners, professionals from related disciplines, and residents. This allowed the inclusion of stakeholder opinions with diverse experiences and perspectives on urban density

issues. Practical examples were reviewed, highlighting discrepancies between regulatory requirements and the actual residential development situation, and exploring potential ways to adjust the standards. This approach deepened understanding of the consequences of standard non-compliance and helped formulate substantiated proposals.

2.10. Proposals and Summary of Results

Analyzing the prerequisites and causes of the identified problems facilitated the development of proposals to improve the quality of living environments and planning practices in populated areas. At the final stage, the root causes of inadequate urban planning were systematized, and specific changes to urban planning practices were proposed.

3. Results

3.1. Analysis of Changes in Housing Standards (Soviet Context)

The norm for living space necessary to ensure a healthy life was first calculated in the 19th century by German hygienist Max Joseph von Pettenkofer. His research demonstrated that a minimum of 25 cubic meters of living space per person, equivalent to about 8.25 square meters, was required to maintain clean air – a key condition for comfortable housing [13].

During the Soviet period, urban development patterns, including prescribed housing space, were directly influenced by the political regime and the established model of the linear socialist city. In 1926, the USSR's average housing norm for urban residents was approximately 5.5–5.7 square meters per person. However, official data from the first Five-Year Plan indicated that 23 million square meters of housing were constructed, decreasing the national average housing norm to 4.7 square meters per person [13].

Moreover, this indicator was significantly lower in specific regions. For example, in 1932, the housing norm in the industrial cities of the Urals was 3.5 square meters per person, ranging from 4.2 square meters in Sverdlovsk to 1.6 square meters in Magnitogorsk [14].

The housing structure, including the minimum area of rooms and apartments, was designed to maximize population involvement in the labour process. Thus, the concept of the socialist city extended beyond the physical planning structure, subordinated to the needs of city-forming enterprises. It encompassed the design of residential buildings, reflecting the prevailing political ideology of the time.

In the USSR, the housing norm per person was calculated based solely on the Apartment's living space, excluding bathrooms, kitchens, and balconies. According to 1975 statistical data, the per capita living space in the USSR was 7 square meters. At the 27th Congress of the Communist Party

in 1986, it was announced that this figure had reached 14.6 square meters per person. These statistics are undoubtedly contentious, particularly given the population increase of 27 million people during that time [14].

3.2. Housing Parameters in the Context of the City of Astana

The linear settlement system also had a significant historical impact on Astana's planning framework and urban development.

Tselinograd (now Astana) had a clearly defined structure based on linear settlement, proposed in the 1962 master plan. It featured three key zones: an industrial zone north of the railway, a residential zone in the centre, and a recreational zone with dacha areas to the south. This linear city model represented Soviet idealism rooted in a planned economy [15].

Since the 1990s, the socio-economic conditions of the city and the country have undergone drastic changes. Industrial enterprises ceased to be the primary factor shaping the city's planning structure. With its new status as the capital, Astana experienced rapid development in the service sector, resulting in the emergence of a new economic specialization centred on administrative and service functions [15].

Significant transformations took place, creating comfortable urban spaces that became a priority in the city's planning and development strategy. The need to improve the quality of the living environment and provide conditions that meet residents' needs for public spaces and comfortable, spacious housing led to new architectural and urban planning trends. The development of market relations and increased competition among developers shifted the focus toward residents' needs and expectations.

According to official statistical data, this trend is also reflected in the increase in the average housing area per person. However, these data typically consider the total housing area rather than the sum of individual living room areas.

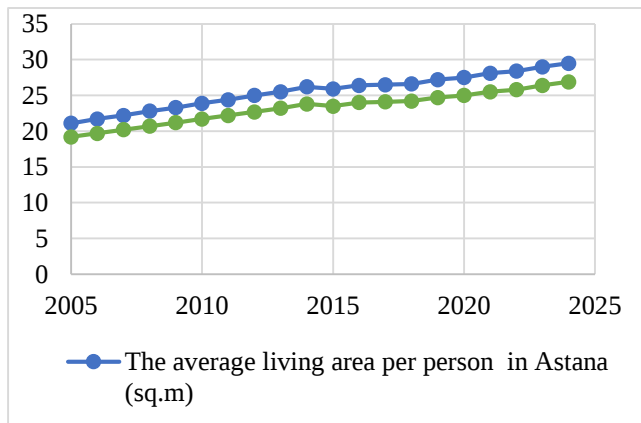


Fig. 1 The average living area per person, according to CEIC data

From 2005 to 2013, the national urban average living area per person increased by approximately 0.5 square meters annually, reflecting active construction and improvements in housing conditions. From 2014 to 2023, the growth rate slowed, with variations ranging from a decrease of 0.3 sq m in 2015 to an increase of 0.6 sq m in 2023, potentially due to economic factors or changes in data reporting methods. Between 2005 and 2024, the average urban living area per person nationwide increased by 40.1%, while in Astana, the growth was 39.8% [16].

Astana's growth trend has been more stable, influenced by its capital status and higher income levels compared to the national average.

At the same time, planning urban developments and specific construction projects directly depends on regulatory parameters applied by architectural designers for calculations. Current regulatory indicators for living area (living rooms) vary according to housing class (I, II, III, and IV), based on factors such as living space per person, ceiling height, number of rooms, minimum kitchen area, quality of finishes, and others (SP RK 3.02-101-2012, Table 1 - Classification of Residential Buildings) [17]. A study of newly commissioned housing was conducted to analyze current development parameters, accompanied by a sociological survey of Astana residents regarding their housing.

In calculating actual population density, it is essential to consider the typical family size, a statistical indicator of the average number of people per household. The most recent national censuses were conducted in 2009 and 2021. In the inter-census period, due to urbanization trends, the average family size decreased slightly from 3.5 to 3.2 people nationwide and from 3.1 to 3.0 in Astana. This metric is necessary to analyze the number of residents per dwelling in the ongoing study [18].

Current development patterns in cities, particularly in the capital region, reveal a discrepancy between regulatory standards and actual population density parameters, specifically the living area per person.

An adjustment coefficient, dependent on the housing class, is proposed based on the analysis conducted, utilizing architectural calculation methods and sociological surveys. This coefficient is essential for a more accurate picture of urban population density.

The living space per person varies across different housing classes. In Class I and II apartments, and to a certain extent in Class III housing, residents typically have corresponding income levels. In Class IV apartments, however, the designated living space per person is significantly lower and often not maintained, directly depending on the residents' financial capacity.

Therefore, an adjustment coefficient of 1.3, depending on the housing class, is proposed to analyze the actual residential population.

Furthermore, according to SP RK 3.01-101-2013* “Urban Development. Planning and Development of Urban and Rural Settlements”, the average design indicator for housing provision depends on the ratio of residential buildings and apartments of varying comfort levels and is determined by calculation [19]. Nevertheless, normative indicators often distort the actual picture.

In practice, higher-class housing does not accommodate more people than lower-class housing with the same number of rooms. However, the norm states that for Class I housing with two living rooms, the expected number of residents is four, while for Class IV housing, it is only two. Hence, revising this regulatory indicator based on a family coefficient is also proposed (Table 1).

To ensure an objective representation, authors proceed with the urban planning calculation of population density within a given area.

According to SP RK 3.01-101-2013* “Urban Development. Planning and Development of Urban and Rural Settlements” [19] (clause 4.1.3), for preliminary determination of the total size of residential zones, generalized indicators per 1,000 inhabitants may be applied as follows:

In urban areas, hectares:

1. For districts predominantly composed of detached (estate-type) housing: 35–40;
2. For developments up to 3 stories:
 - a. without area land plots: 10–11;
 - b. with area land plots: 20–22;
3. For developments of 4 to 8 stories: 8 – 9;
4. For developments of 9 stories and higher: 7 – 8.

In rural settlements, hectares:

- predominantly estate-type development: 40–65.

A sample of land plots containing nine-story or higher residential complexes was used to analyze land use for residential development (Figure 2).

This represents the most characteristic typology of newly commissioned housing in cities nationwide, particularly in Astana. According to SP RK 3.01-101-2013* [19] indicators, this typology’s generalized land use standard is 7–8 hectares per 1,000 inhabitants.

To calculate the actual number of residents in residential zones based on the selected development typology, the following formula is proposed:

$$X = \frac{a \cdot b}{c} \quad (1)$$

Where:

x – correction factor for population density, accounting for the actual number of residents in a given area relative to normative indicators;

a – regulatory land area per 1,000 residents, depending on the development typology;

b – actual number of residents living in the analyzed residential complex;

c – land area of the analyzed residential complex.

According to SP RK 3.01-101-2013* [19], the generalized standard for developments of 9 stories and higher for preliminary determination of the total size of residential zones is 7–8 hectares per 1,000 inhabitants.

An average value of 7.5 hectares per 1,000 inhabitants is adopted for calculations.

Case studies:

1. Astana, residential complex «Korkem 2» comprises 854 apartments and a land area plot of 2.6 hectares. The analyzed residential complex includes 854 apartments. Assuming an average of 3 residents per Apartment, incorporating the family size coefficient, the estimated population of the complex is approximately 2,600 people residing in an area of 2.6 hectares.

Thus, the calculation for the residential complex “Korkem 2” is as follows:

$$\frac{7,5 \cdot 2,6}{2,6} = 7,5$$

Thus, the SP RK 3.01-101-2013* standard of 1,000 residents per 7–8 hectares is exceeded 7.5 times for this type of development. According to the normative guideline, no more than 350 people are permitted to reside on this site.

2. Astana residential complex «Sarmat 1» – 1,053 apartments, a land area plot of 4.3 hectares.

Using the same estimation method, the approximate number of residents is 3,200 people on 4.3 hectares. The normative indicator of 1,000 residents per 7–8 hectares is exceeded 5.6 times. According to the standard, the site is designed for approximately 570 people.

3. Astana, residential complex «Highvill», Block D – 422 apartments, land area plot of 2.3 hectares.

The estimated number of residents in the complex is 1,300 on 2.3 hectares. The standard of 1,000 residents per 7–8 hectares has been exceeded 4 times. Normatively, the site is designed to accommodate 300 residents.

4. Astana residential complex «Light House» – 197 apartments with a land area plot of 0.6 hectares.

The estimated population is approximately 600 people on 0.6 hectares.

Table 1. Analysis of the classification of residential buildings differentiated by comfort level in comparison with the indicators of SP RK 3.01 101-2013 “urban planning. Layout and development of urban and rural settlements”* [19]

Residential buildings classification	Standard residential floor area per person for a house or apartment, in square meters	Formula for occupancy of a Residential house or Apartment (calculated based on a 2-room layout)	Proposed calculation (based on three residents the average household size in Astana)	Amount of residential floor area, in square meters	Actual Occupancy area of a residential house or Apartment, in square meters $Saa = Sla/n$ (2)
Class I	> 25	$k = n + 2$;	$k = 3$	$30 * 2 = 60$	$60 \div 3 = 20$
Class II	19 to 25	$k = n + 2$	$k = 3$	$20 * 2 = 40$	$40 \div 3 = 13$
Class III	16 to 18	$k = n + 1$	$k = 3$	$17 * 2 = 34$	$34 \div 3 = 11$
Class IV	15	$k = n$	$k = 3$	$15 * 2 = 30$	$30 \div 3 = 10$
Notes 1 Total number of residential rooms in an apartment or house (k) and number of residents (n). 2 Saa – actual area; Sla – living area; n - number of people. 3 The specified regulatory indicators do not serve as a basis for determining the actual occupancy standard.					

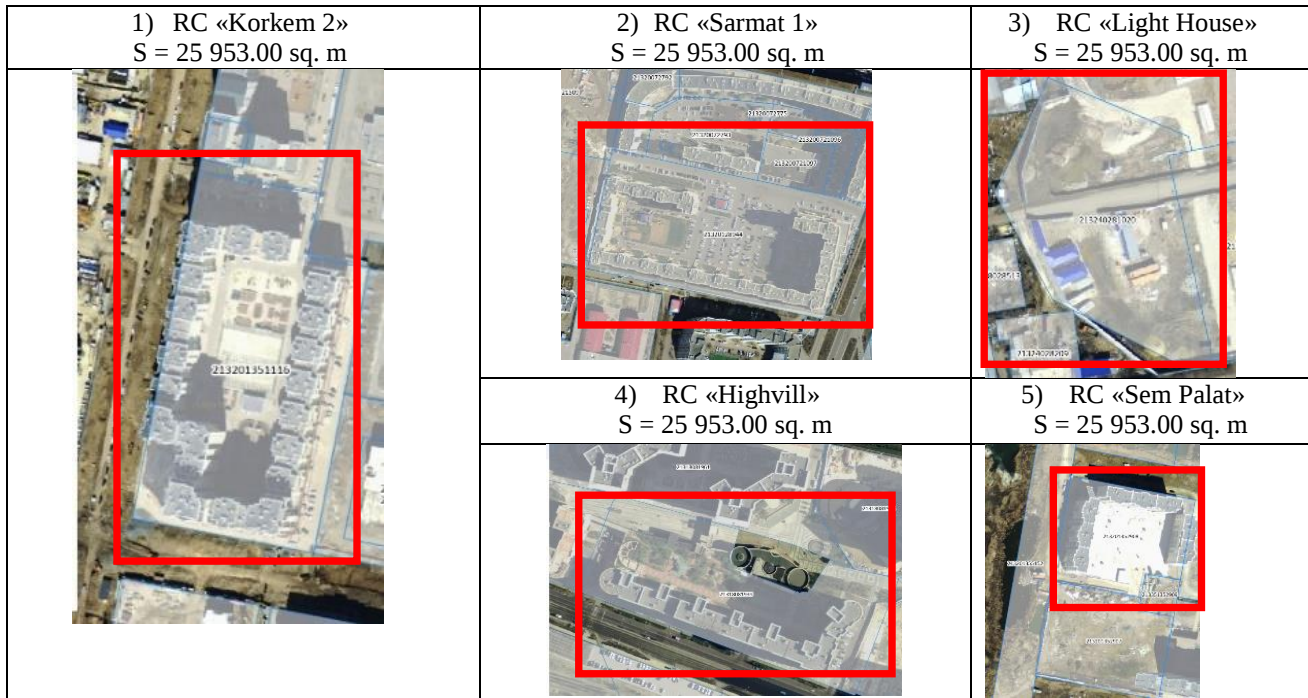


Fig. 2 Extracts of the analyzed land plots for residential complexes from the public cadastral map of the unified state real estate cadastre

Table 2. Analysis of population density in the specified residential complexes based on the actual number of residents within a given area in comparison to regulatory standards

No	Residential complex title	Number of apartments	Land area plots (ha)	Actual number of residents	Number of residents according to the standard	Correction factor for population density
1	RC «Korkem 2»	854	2,6	2562	347	7,5
2	RC «Sarmat 1»	1053	4,3	3159	573	5,6
3	RC «Highvill»	422	2,3	1266	307	4,2
4	RC «Light House»	197	0,6	591	80	7,5
5	RC «Sem Palat»	182	1,3	546	173	2,9

The normative indicator of 1,000 residents per 7–8 hectares is exceeded 7.5 times. The site is designed to accommodate only 80 people.

5. Astana residential complex «Sem Palat» – 182 apartments, land area plots of 1.3 hectares.

Approximately 500 people reside in this complex. The standard for this type of development is exceeded nearly 3 times. This land area is normatively designated for 173 people (162–185 residents).

The analysis revealed significant deviations in construction projects from the parameters established during the urban planning project design stage, with an average exceedance factor of 5 (Table 2). Considering that residential development is intended to include public and business infrastructure (approximately 30%, according to SP RK 3.01-101-2013 “Urban Development. Planning and Development of Urban and Rural Settlements” [19] and the Standards for Integrated Urban Development, MD RK 3.01-01.7-2022), the actual population density in core cities for residential buildings of 9 stories and above reaches 450–500 people per hectare [20].

Thus, the regulatory standards embedded in the design of urban development projects require substantial revision (Figure 3).

Such discrepancies at the planning level inevitably led to flawed territorial development, resulting in shortages of educational and healthcare facilities, insufficient engineering and transport infrastructure, traffic congestion, environmental degradation, and other critical urban challenges.

4. Discussion

As part of the research, relevant works by international colleagues concerning population density analysis in the context of urban planning were reviewed.

The research conducted by the group of Chinese scholars Tong Li, Chunliang Xiu, and Huisheng Yu titled “Urban Human-Land Spatial Mismatch Analysis from a Source-Sink Perspective with ICT Support” [9] examines spatial mismatches between human activity and land use in cities.

The authors propose measures to optimize land use, control urban sprawl, and allocate resources more effectively, including limiting urban expansion, promoting mixed-use development, and ensuring the rational distribution of essential facilities. This study highlights the spatial disparity between land use and human activity in urban areas and proposes strategies for managing sprawl and enhancing resource allocation.

Density indicators are closely linked to the quality of urban development, influencing health, safety, livability, and sustainability. Various types of density, including residential, population, employment, and land use, are regulated through tools such as floor area ratio, site coverage, and open space coefficients.

An integrative approach to urban density conceptualization is proposed in the article “Urban Density Assemblage: Modelling Multiple Measures” [10] by Kim Dovey and Elek Pafka. It includes three key dimensions – buildings, population, and open space – interconnected with scale and urban intensity. The authors present conceptual and methodological strategies to improve the understanding and management of urban density:

Rethinking density as a multidimensional phenomenon (using models that account for population density, built-up density, employment density, perceived density, street network, and accessibility);

Utilizing a system of interrelated components by analyzing urban density through relationships between building forms, transport networks, functions, and users;

Adapting density considerations to local contexts (tailoring planning solutions to specific urban districts, their morphology, and socio-cultural features);

Integrating multiple scales of analysis (from neighborhood to metropolitan);

Combining quantitative and qualitative analysis (considering physical parameters and human perception, behavior, and experience). This approach advocates a shift in urban planning from rigid templates to a more complex, flexible, and accurate model of understanding density in its various forms and dimensions.

The article “Urban Shape and Built Density Metrics through the Analysis of European Urban Fabrics Using Artificial Intelligence” (2019) [11] by Francisco Javier Abarca-Alvarez, Francisco Sergio Campos-Sánchez, and Fernando Osuna-Pérez focuses on applying AI methods to analyze urban density and built form in European cities. The authors propose a methodology enabling a more precise and comprehensive evaluation of urban structures, utilizing 13 distinct density metrics. The study concludes:

A broad range of density indicators provides a fuller characterization of urban fabric. Using self-organizing maps ensures more accurate and reliable clustering compared to traditional methods. Results can inform more effective urban planning and city management strategies.

In their study, E.V. Shcherbina and I.V. Kuznetsov (“Analysis of Building Density in Large and Major Cities of the Volga Region Using Geographic Information Systems”) propose a methodology utilizing GIS tools to assess the distribution of building density in cities of the Volga region.

The results are presented as mosaic maps of density distribution. Comparison with previously published findings confirms the accuracy and reliability of the proposed methodology [12]. This collective body of research points to several key aspects of building density studies:

Building density is a complex parameter dependent on various interconnected indicators. Density must vary according to specific local context and territorial characteristics. Promoting mixed land use and ensuring walkable access to education, healthcare, and other essential services directly enhances land use efficiency; Tools such as artificial intelligence and GIS analytics can effectively support density analysis. Overall, these studies illustrate that the science of urban development is evolving toward a more holistic and accurate understanding of urbanization processes.

This study contributes to the existing body of literature on urban planning by addressing the issue of building density

through a critical examination of current practices and their regulatory foundations. In contrast to previous studies that have primarily applied broad or generalized methods, this research focuses on analyzing the present situation and identifying the underlying causes of deficiencies in urban planning.

The analysis reveals a pronounced mismatch between existing regulatory frameworks and actual construction practices, particularly the significant disparity between prescribed population density norms and real demographic patterns. To mitigate these inconsistencies, the study proposes specific solutions, including introducing a correction factor into architectural calculations and revising standards governing the determination of residential zone sizes based on projected population figures. The findings underscore the necessity of revising current standards to ensure sustainable urban development and enhance urban policy's overall effectiveness.

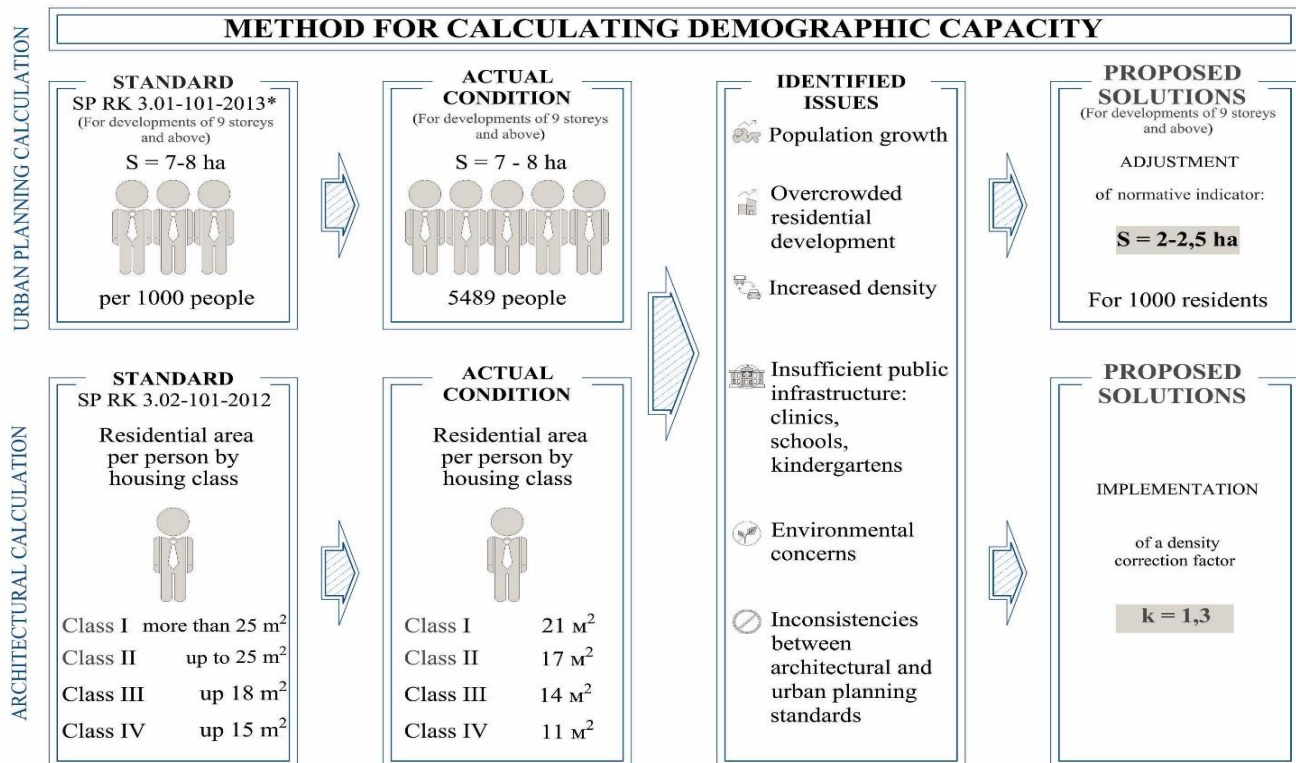


Fig. 3 Models of architectural and urban planning regulation for calculating demographic capacity (compiled by the authors)

Practical orientation: unlike more theoretical approaches, this study is directly aimed at changing urban planning practices; Identification of systemic errors: The study quantitatively demonstrates discrepancies between planned and actual population densities, which are crucial for preventing infrastructure crises, such as shortages in social, engineering, and transport infrastructure, as well as environmental degradation. Thus, the article emphasizes the urgent need to revise the regulatory framework as a

foundational element influencing urban planning decisions and proposes practical changes to address the identified issues.

5. Conclusion

The analysis demonstrated that existing standards and applied parameters do not reflect the actual situation. Key sources of high population density issues have been identified, specifically:

1. The review of international studies on the subject revealed the topic's relevance, the complexity of factors influencing building and population density, and the inconsistency between current urban planning regulatory standards and architectural parameters. This discrepancy leads to inconsistencies in the practical implementation of urban development.
2. A public survey revealed a mismatch between normative and actual living space per capita.
3. Field research has shown that current regulatory urban planning parameters for population density are significantly underestimated, resulting in inadequate infrastructure planning.
4. A comparative analysis confirmed that indicators used during the development of urban planning documentation are significantly understated and do not correspond to actual construction parameters. This results in over-densified development, traffic congestion, insufficient engineering capacities, and a lack of social infrastructure.
5. Specific regulatory documents identified incorrect normative parameters for calculating living space per capita. These determine the initial housing parameters, which in turn influence the planning of necessary social and engineering facilities and transport infrastructure. Underestimated regulatory values, in the context of actual overpopulation, contribute to the shortage of essential urban services and decrease the quality of the urban environment.
6. The architectural and urban analyses conducted suggest that a correction factor should be introduced to calculate the living area in construction projects, thereby obtaining a more accurate picture. Additionally, urban planning regulatory standards must be revised to accommodate prospective development's needs.

Adjusting the population density calculation standards during the development of urban planning projects, alongside the use of a proposed correction factor in construction planning, will lead to a more precise and objective representation of actual population distribution patterns and related development needs. This will enhance the reliability of urban planning calculations, optimize design solutions, and ensure more effective planning of urban infrastructure in response to actual demographic pressures.

References

- [1] The Way We Live Now: Design for a Prosperous and Just Urban Life, United Nations Development Programme, 2020. [Online]. Available: <https://featured.undp.org/the-way-we-live-now/#>
- [2] Violetta Vasilievna Toskina, "Evolution of the Architectural Planning Structure of Settlements in Northern Kazakhstan in the 19th-20th Centuries: Using the Example of the Akmola Region," Ph.D. Dissertation, Candidate of Architecture, Higher Attestation Commission of the Russian Federation 18.00.01, 2009. [Publisher Link]
- [3] O.M. Roy, Fundamentals of Urban Planning and Territorial Planning, 3rd ed., Moscow, 2024. [Online]. Available: https://www.litres.ru/get_pdf_trial/70405564.pdf
- [4] Andre Luiz Przybysz et al., "Integrating City Master Plans with Sustainable and Smart Urban Development: A Systematic Literature Review," *Sustainability*, vol. 16, no. 17, pp. 1-18, 2024. [CrossRef] [Google Scholar] [Publisher Link]
- [5] Ebba Högstöm, Lina Berglund-Snodgrass, and Maria Fjellfeldt, "The Challenges of Social Infrastructure for Urban Planning," *Urban Planning*, vol. 7, no. 4, pp. 377-380, 2022. [CrossRef] [Google Scholar] [Publisher Link]
- [6] Susan S. Fainstein, "Planning Theory and the City," *Journal of Planning Education and Research*, vol. 25, no. 2, pp. 121-130, 2005. [CrossRef] [Google Scholar] [Publisher Link]
- [7] Zauresh Atakhanova, and Marzhan Baigaliyeva, "Kazakhstan's Infrastructure Programs and Urban Sustainability Analysis of Astana," *Urban Science*, vol. 9, no. 4, pp. 1-23, 2025. [CrossRef] [Google Scholar] [Publisher Link]
- [8] Yu.P. Bocharov, and S.O. Khan-Magomedov, NICOLAI Milutin, Moscow, Architecture-S, 2007. [Online]. Available: <https://science.totalarch.com/book/4682.rar>
- [9] Tong Li, Chunliang Xiu, and Huisheng Yu, "Urban Human-Land Spatial Mismatch Analysis from a Source-Sink Perspective with ICT Support," *ISPRS International Journal of Geo-Information*, vol. 11, no. 11, pp. 1-20, 2022. [CrossRef] [Google Scholar] [Publisher Link]
- [10] Kim Dovey, and Elek Pafka, "Urban Density Assemblage: Modelling Multiple Measures," *Urban Design International*, vol. 19, pp. 66-76, 2014. [CrossRef] [Google Scholar] [Publisher Link]
- [11] Francisco Javier Abarca-Alvarez, Francisco Sergio Campos-Sánchez, and Fernando Osuna-Pérez, "Urban Shape and Built Density Metrics through the Analysis of European Urban Fabrics Using Artificial Intelligence," *Sustainability*, vol. 11, no. 23, pp. 1-23, 2019. [CrossRef] [Google Scholar] [Publisher Link]
- [12] Shcherbina, and Kuznetsov, "Gis-Based Analysis of Building Density in the Territories of Large Cities and Megapolises of the Volga Region," *Urban Construction and Architecture*, vol. 14, no. 2, pp. 143-148, 2024. [CrossRef] [Google Scholar] [Publisher Link]
- [13] V. Evgeniya Konyševa, and Mark Grigorevič Meerovič, *Major Planning and Design of Urban Areas in the First Half of the 20th Century: (Based on Magnitogorska)*, 2012. [Google Scholar]
- [14] Dmitry Khmelnskiy, *The Architect Nikolai Milyutin*, New Literary Review, pp. 1-504, 2013. [Publisher Link]

- [15] Amanzhol Sh. Chikanaev, Astana Master Plan: What Went Wrong and Why, Nur-Sultan, 2020. [Online]. Available: https://www.maca.ru/attach/catalog/v_1978_202.pdf
- [16] Bureau of National Statistics, Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, The Main Socio-Economic Indicators for the Region: Socio-Economic Development of the Astana City in 1991-2022, Astana City Collections, 2023. [Online]. Available: <https://stat.gov.kz/en/region/astana/collections/?year=1991&period=year&name=36293>
- [17] Code of Rules of the Republic of Kazakhstan, Residential apartment buildings SP RK 3.02-101-2012, 2012. [Online]. Available: <https://kbexpert.kz/wp-content/uploads/2020/10/CH-ПК-3.02-101-2012-Здания-жилые-многоквартирные.pdf>
- [18] Many Patterly Turgin Statues Buildings Residential Multiple, State Standards in the Field of Architecture, Urban Planning and Construction, Collection of Regulations of the Republic of Kazakhstan, Agency of the Republic of Kazakhstan for Construction and Housing and Communal Services, Astana, 2012. [Online]. Available: https://ru.kipd.kz/pdf-viewer?pdf=https://api.kipd.kz/storage/uploads/images/2025/01/09/Аналитический%20обзор%20семейно-демографической%20политики%20рус_1736409249.pdf
- [19] Code of Rules of the Republic of Kazakhstan, SP RK 3.01-101-2013, Urban, Planning and Development of Urban and Rural Settlements, 2013. [Online]. Available: https://online.zakon.kz/Document/?doc_id=39214714&pos=1;-16#pos=1;-16
- [20] Methodological Document of the Republic of Kazakhstan, Integrated Urban Development Standard, MD RK 3.01-01.7-2022, Committee on Construction, Housing and Public Utilities, Ministry of Industry and Infrastructure Development of the Republic of Kazakhstan, 2022. [Online]. Available: https://online.zakon.kz/Document/?doc_id=32798343