UDC: 711.434:502.131.1(574)
doi:10.5379/urbani-izziv-en-2022-33-01-01

Received: 13 January 2022
Accepted: 28 February 2022

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Sustainable urban development assessment: Large cities in Kazakhstan

Measuring the comparative level of urban sustainability is an important part of creating a sustainable urban future. This article assesses the sustainable development of the seventeen largest cities in Kazakhstan for 2007–2019 using a geodatabase on a GIS platform. The results show that none of the cities have reached a level of sustainability greater than or equal to a sustainable urban development index (SUDI) of 0.750, and no cities have an unsustainable level of development with a SUDI below 0.300. Therefore, all seventeen cities are classified as moderately sustainable. In future studies, the authors will look for ways to further improve the system for assessing the sustainability of cities in Kazakhstan.

Keywords: sustainable urban development, geodatabase, sustainable development indicators, sustainable urban development index, Kazakhstan

1 Introduction

Kazakhstan has committed itself to fulfilling the tasks set in Agenda 21 (United Nations, 1993) and the declarations of the Millennium Summit (New York, 2000) and the World Summit on Sustainable Development (Johannesburg, 2002). Kazakhstan has adopted a number of measures toward achieving sustainable development. It is a member of and active participant in the UN Commission on Sustainable Development, the Environment for Europe and Environment and Sustainable Development for Asia processes, and the regional Eurasian network of the World Business Council for Sustainable Development.

By adopting the Agenda for Sustainable Development for the period up to 2030, world leaders declared their determination to rid humanity of poverty, to preserve a prosperous planet for future generations, and to build a peaceful and open society for everyone, thereby ensuring decent living conditions for all people.

Kazakhstan also supported the Sustainable Development Goals (SDGs), guided by the fact that the guidelines of the UN document fully coincide with the country's priorities and objectives. These were identified in the strategy Kazakhstan-2050, the national plan 100 Concrete Steps to Implement Five Institutional Reforms, five social initiatives by Kazakhstan's head of state, and the program *Rukhani Zhangyru* (Spiritual Revival).

In 2016, the Committee on Construction, Housing, and Utilities of the Kazakh Ministry of National Economy published the *National Report of Kazakhstan on Housing and Sustainable Urban Development HABITAT III* (2016). The report considered issues related to the sustainable development of settlements, including demographic problems, urban planning, the environment and urbanization, legislation in territorial development management, and the urban economy. In addition, the main challenges, threats, and means for possible long-term sustainable development of settlements and housing were identified.

The total population of Kazakhstan as of 1 January 2022 was 19,125,600, of which 59.4% was urban. There are eighty-seven cities in Kazakhstan, and the share of urban population from 1991 to 2022 increased by 2.1%. This study analysed and evaluated sustainable development indicators for the seventeen largest cities in Kazakhstan. Three of these are cities of

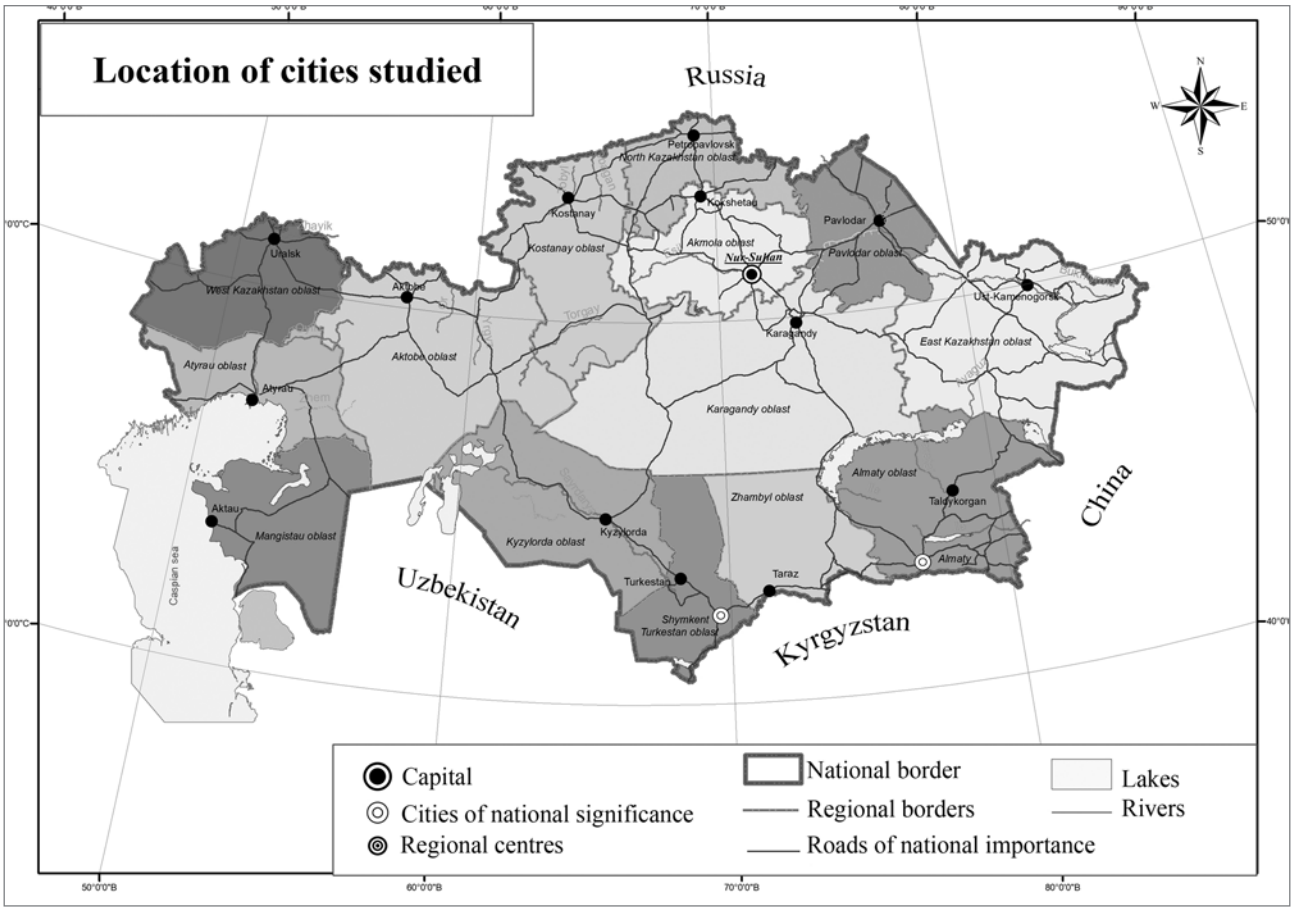

Figure 1: Location of cities studied (illustration: authors).

Table 1: Population of cities studied, 2019.

Up to 250,000	250,000 to 500,000	500,000 to 1 million	Over 1 million
Aktau	Aktobe	Shymkent	Almaty
Kokshetau	Atyrau	Karaganda	Nur Sultan
Kostanay	Kyzylorda		
Petropavl	Pavlodar		
Taldykorgan	Taraz		
	Oral		
	Oskemen		
	Turkistan		

Source: Bureau of National Statistics of Kazakhstan (2020).

national significance, and fourteen cities are regional administrative centres (Figure 1). In Kazakhstan, cities of national significance include settlements with special significance for the country or those with over one million people (see the law On the Administrative-Territorial Structure of Kazakhstan, as amended on 3 July 2017, Article 3). The official statistics in Kazakhstan provide the most complete data for the study period of 2007–2019, primarily for cities of national significance, as well as for regional administrative centres, which served as the basis for choosing only these seventeen cities. About 44.9% of the total population and 77.2% of the urban population of the country is concentrated in these seventeen cities (Table 1). From 1997 (when it became the capital) to 2022, the population of Nur-Sultan increased rapidly, by almost 950,000 people.

For the remaining seventy cities in Kazakhstan, the official statistics on the main socioeconomic, demographic, and environmental indicators of the cities do not make large-scale studies of sustainable development possible. There is growing interest in the sustainable development of Kazakhstan's leading cities among both city authorities and their residents, as well as in new approaches to urban planning, which focus not only on economic growth but also on improving the quality of life and social wellbeing. An important task in the development of cities is to increase their attractiveness not only for business, but also for residents' comfort and the economical use of the cities' resources.

This study was carried out by calculating integral indices based on twenty-seven indicators for economic, environmental, and social blocks. The authors examined how much sustainability was achieved in the largest cities in Kazakhstan from 2007 to 2019 through an economic and geographical analysis. The analysis is based on the hypothesis that implementing a national urban development policy in a country that supports the sustainability of cities should result in a positive trend in sustainable development indicators. The cities of Nur-Sultan (the capital) and Almaty (the financial and research centre of the country) are expected to rank as highly sustainable compared to the other cities surveyed.

2 Urban sustainability concepts

This study examines the sustainable development of the largest cities in Kazakhstan based on a spatial geodatabase generated with the use of GIS. Its main objectives are to form an information base for socioeconomic and environmental indicators of the cities, to identify ways to achieve sustainable development, and to determine future prospects for their development. The term *sustainable development* dates back to 1987 and to the report Our Common Future, produced by the World Commission on Environment and Development (WCED). The report defines sustainable development as human actions that maintain the balance between human needs and the environment, as well as between current and future human needs (WCED, 1987).

When researching cities, to better understand the term *sustainability*, the importance of sustainable urban development must be taken into consideration (Dizdaroglu & Yigitcanlar, 2016). This can be seen as a process of change in which the exploitation of resources, the direction of investment, technological development, and institutional change are consistent with current and future needs (WCED, 1987). The term *sustainable city* as a concept became popular in the 1990s (Roy, 2009), denoting the relationship between aspects of economic, social, and environmental sustainability with a combination of indicators for each of these components (Ahvenniemi et al., 2017; Medeiros & Van der Zwet, 2020, Sviržić Gotovac et al., 2021). Considering all these aspects, Hiremath et al. (2013) defined sustainable urban development as achieving a balance between urban development and environmental protection, taking into account equality in income, employment, housing, basic services, social infrastructure, and transport in urban areas.

Sustainability assessment can be used to better conceptualize and define urban sustainability. There are countless resources for assessing sustainability across sectors and scales, as well as growing research on sustainability assessment for the urban context. On an urban scale, sustainability assessment usually comes down to determining and measuring the indicators and publishing documents with sets of hundreds of indicators (Xing et al., 2009; Boyko et al., 2012; Zhou et al., 2012; Ameen et al., 2015; Mudau et al., 2020). There are a number of types of potential sustainability assessment systems (Olalla-Tarraga, 2006). The definition and measurement of indicators is often the basis for assessing sustainability, and the choice of indicators for assessing the sustainability of cities often lacks a theoretical basis. Sustainability assessments in the literature often focus on the national and global scales (Sumner, 2004; Davidson, 2011; Davidson et al., 2012; Chesson, 2013; Moyer & Hedden, 2020).

Sustainable development is based on three main components: social, economic, and environmental. Each country has its own set of social and economic characteristics, and each region has a specific set of environmental tasks. The "trinity of the concept of sustainable development" does not only mean that at the present stage it is important to collect more data on the negative impact of the environment on human health. First, it is necessary to conduct a comprehensive analysis of the cause-and-effect processes occurring in the relationship between people and their environment. At international research institutes, many countries and groups of researchers are developing sets of indicators for assessing and monitoring sustainable development (Dizdaroglu, 2017).

To measure the quality and sustainability of the urban environment, a special project of the United Nations Environment Program (UNEP) and GRID-Arendal has been implemented. To prepare reports on the environmental protection of cities (Cities Environment Reports on the Internet, CEROI), as part of this project, a system of state-of-the-environment indicators was introduced that makes it possible to analyse individual urban problems in detail. The initial set of indicators was developed in 1998. The Swiss scorecard for sustainable development monitoring, called MONET (*Monitoring Nachhaltiger Entwicklung*), includes eighty indicators, structured around the following twelve topics: living conditions, health, social cohesion, international cooperation, education and culture, research and technology, work, economic system, production and consumption, mobility and transport, energy and climate, and natural resources. The system evaluates and comments on the current situation and development of Switzerland, taking into account the social, economic, and environmental aspects of sustainable development (SFSO, 2019). The Urban Sustainability Index (USI) of China, developed by the Urban China Initiative (UCI) in 2010, consists of a set of indicators that provide a comprehensive assessment of urban sustainability in four categories: the economy, society, resources, and the environment. USI data not only provide a rich resource for academic research, but also serve as a guide for Chinese politicians as they evaluate the country's efforts in sustainable development and formulate urban development policies (UCI, 2019). The U.S. Cities SDG Index, compiled by a team of independent experts from the SDSN (Sustainable Development Solutions Network) Secretariat, is assessed by using forty-four indicators for fifteen of the seventeen sustainable development goals. The selected indicators are closely related to the indicators approved by the UN Statistical Commission (Espey et al., 2018).

The STAR (Sustainability Tools for Assessment and Rating) Community Index covers twenty-one indicators across eight target areas of the STAR rating system: natural systems; the built environment; climate and energy; the economy and jobs; education, arts, and community; equity and empowerment; innovation and process; and health and safety. The leading indicators are organized into an online platform in which US cities and districts can annually update the data on the key sustainability indicators (STAR Communities, 2019). The index, developed by Arcadis, a global design and consulting firm, and the Center for Economic and Business Research (CEBR), assesses cities' success based on social, environmental, and economic factors. CEBR rated the hundred leading cities in the world, using thirty-two different indicators to develop an indicative sustainability rating for each of them. The cities are rated for each of the three aspects of sustainability, and the total index for the city is equal to the average of the three sub-indices (Arcadis, 2018). Among the global international developments in building an integral index of sustainable development for cities, it is worth highlighting the UN Habitat City Prosperity Index (UN-Habitat, 2013). It aggregates five groups of indicators: productivity, quality of life, infrastructure development, environmental sustainability, and equality. In general, evaluating the constructiveness of the methodological approach, the well-known controversial nature of the results obtained, and the need for further development of the index should be noted (Cohen, 2017).

Because cities are complex systems embedded in and associated with unique ecological systems, and each city is determined by its own cultural and historical context, it is quite difficult to adequately select from numerous to apply a single assessment to all urban areas around the world (Gonzalez et al., 2011). Thus, it may be more useful to agree on a common assessment of the sustainability of cities with a common set of guidelines that determine the criteria and indicators that are unique to each city. The effectiveness of sustainability indicators can be

characterized by three features: reliability, legitimacy, and significance (Ciegis et al., 2009). Sustainable development is a multifaceted problem, which includes a large amount of complex information. There is some need to systematically reduce this information to a more concentrated form when building a pyramid of information aggregation, which is based on raw data and in which indices are at the top.

To analyse and assess the level of sustainable development of large cities, the rating experience of leading research groups and organizations such as PWC (Dolgikh, 2015), Ernst & Young, the Australian Conservation Foundation (ACF, 2010), Forum for the Future (2019), and the European Green Capital (European Commission, 2022) was considered.

Since 2012, the Sustainable Growth Management (SGM) Agency has annually held a rating of the sustainable development of Russian cities with more than 100,000 people. The agency uses its own integral index of urban sustainability, taking into account economic, social, and environmental factors (SGM Agency, 2016). The rating covers 185 cities in Russia with a total population of 78.4 million, or 78% of the total population of all 1,112 Russian cities. At the same time, an integral index is used: the cities' sustainable development index (SDI). It is calculated on the basis of forty-two statistical indicators characterizing the sustainable development of cities based on three main components: the economic, environmental, and social sphere. All components include indicators reflecting various aspects of urban development: the level and quality of the economic base of the city; the state of communal, engineering, and social infrastructure; the state of the population; the structure of labour resources; and the environmental situation.

Most of these sustainable development ratings cover only large cities, using the following indicators: meeting basic needs of the population, quality of life, environmental situation, environmental protection, efficient use of resources, infrastructure development, management efficiency, and potential for future sustainable development. In some of these ratings, along with statistics, the results of sociological studies and the results of other ratings are used.

In Kazakhstan, there is insufficient research on the sustainability of urbanized territories and cities. Studies by economists have been carried out for individual cities and regions of Kazakhstan. A scheme of sustainable development was developed for the city of Almaty (Zhumaeva, 2007), and the city's level of sustainability was investigated. Alibekova et al. (2018) determined that Almaty's sustainability index was increasing. In 2016, the development of Almaty became sustainable due to the high level of sustainability of the economic and social subsystems, but the environmental subsystem showed signs of unsustainability. Individual studies by economists have covered the industrial regions of Kazakhstan. Thus, the socioeconomic sustainability of the oil-producing regions of Kazakhstan was assessed using the Lorenz method of calculating the coefficient of concentration, and the contribution of each indicator to sustainability was taken into account. The calculations used nine socioeconomic and five environmental indicators (Yeleusizova, 2008). Ignatyeva (2010) developed a conceptual model of sustainable development of the East Kazakhstan region. Using her own methodology for assessing natural resources, production, and labour potential, she calculated the integral index of sustainable development for this region. Karimbergenova (2014) assessed the sustainable development of the Pavlodar region in the context of industrial regions of Kazakhstan (the East Kazakhstan and Karagandy regions) using ten social, seven economic, and three environmental indicators of the three regions. Conducting comprehensive economic and geographical studies using international theoretical and methodological developments in strategic planning and sustainable innovative development of cities is relevant for Kazakhstan.

Kazakhstan's cities, on their way to sustainable development, have implemented projects such as EXPO-2017: Energy of the Future, Industrialization 4.0, and Digital Kazakhstan. In Kazakhstan, four interrelated tasks have been determined to achieve sustainable urban development: ensuring the sustainable long-term economic development of cities; maintaining a supportive environment and sustainable infrastructure; developing the social sphere and the quality of life of the urban population; and improving the system of urban governance. In accordance with international experience in planning sustainable urban development, several indicators have been identified for the sustainable development of cities and their target values for three blocks: economic, social, and environmental (CSDC, 2019).

3 Materials and methods

The information base for the research was the official data of the Statistics Committee of the Kazakh Ministry of National Economy, the statistics departments of the cities of Almaty and Nur-Sultan, and regional statistics departments. For the spatial analysis of indicators, we considered the statistical data of large cities in Kazakhstan for 2007 to 2019. For processing the data, we used the Taldau information and analytical system and ArcGIS 10.2 software. This article uses an integrative methodology to assess the sustainability of cities, covering the most comprehensive range of integral urban development indicators.

Stages of assessing the sustainability of cities:

- Reviewing international developments in building integral sustainable urban development indices;
- Selecting applicable indicators;
- Combining the selected twenty-seven indicators into five groups and three blocks;
- Collecting primary statistics for the seventeen cities studied;
- Calculating standardized values for each of the twenty-seven indicators using a linear scaling method;
- Determining the integral indicator (subindex) for each of the five groups of indicators by calculating the average of standardized values for the relevant indicators;
- Determining sustainable urban development indices (SUDIs) based on subindices for each group of indicators, taking into account weighting factors; and
- Creating a typology of cities based on their level of sustainability using SUDIs for 2007 and 2019.

3.1 Indicator-based urban sustainability assessment

To analyse and evaluate the level of sustainable development of large cities, an integral index was calculated: the SUDI. This index was calculated based on twenty-seven statistical indicators processed in the spatial geodatabase of Kazakh cities for 2007–2019. The geodatabase is divided into three main blocks: the economic, environmental, and social. The blocks include five groups of indicators describing urban development: the level and quality of the economic base of the city; the state of communal, engineering, and social infrastructure; the state of the population; the structure of labour resources; and the environmental situation.

Most international sustainability ratings rank data for individual countries or regions, considering the specifics of their development and the characteristics of national information collection systems. The data of several statistical indicators used in foreign ratings are not provided by the Statistics Committee of the Kazakh Ministry of National Economy. Therefore, the

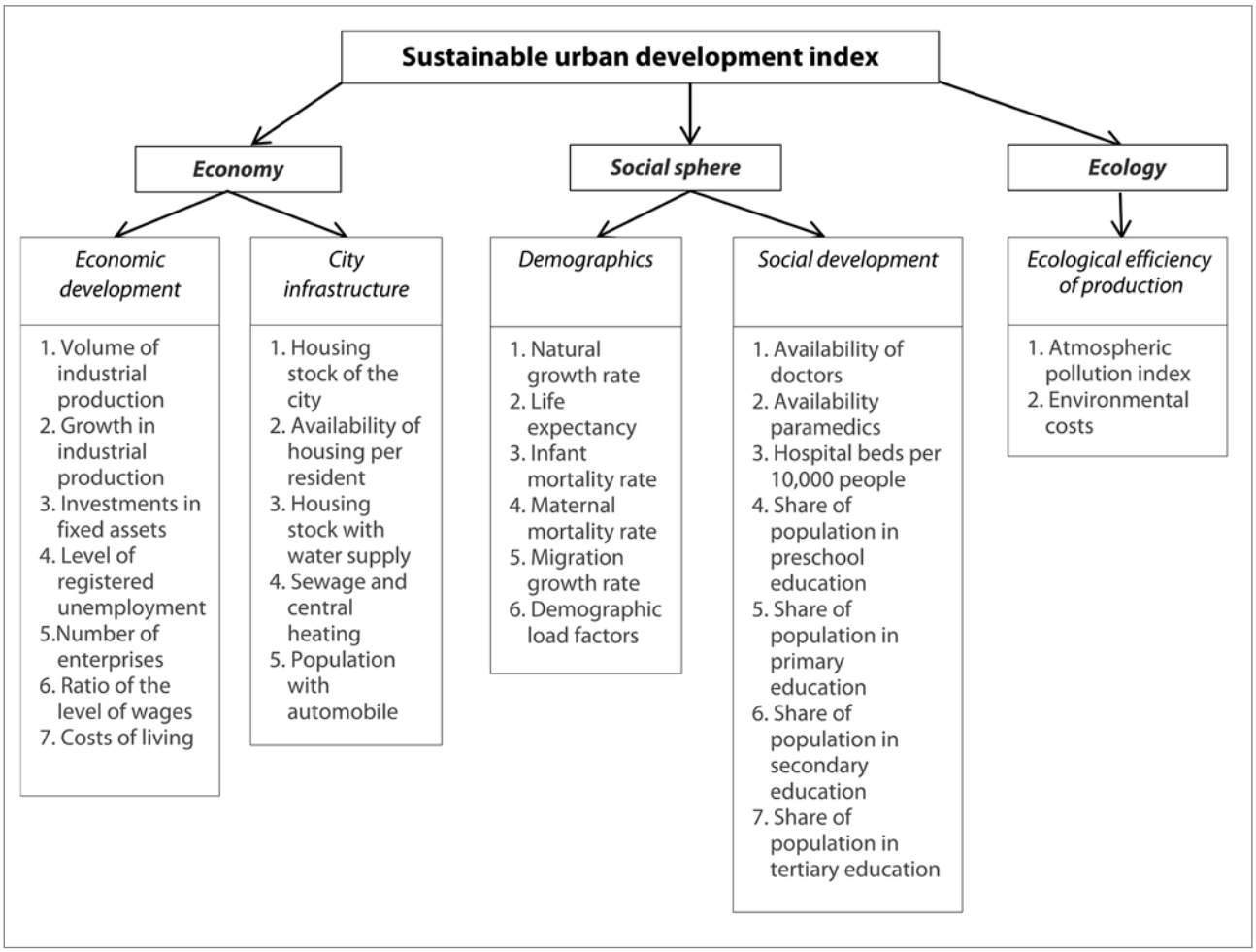

Figure 2: SUDI indicators (illustration: authors).

selection of indicators for assessing the sustainable development of cities was made by considering the existing system of statistical indicators of the country. The selection of indicators was carried out based on the list of SGM Agency indicators used to compile the sustainable development rating of cities in Russia. Due to the lack of statistical data on sustainability parameters for cities in Kazakhstan and the delay in their official publication, some indicators were excluded. The indicators are shown in Figure 2.

3.2 Index calculation

To calculate the integral index of each indicator, a linear scaling method was applied, as a result of which the indicators were measured on an *N*-point scale. The value of zero in this case corresponded to the lowest level of sustainable development, and the value of *N* corresponded to the highest one. In our case, $N = 1$.

The conversion was carried out using Equation 1 and Equation

$$I_j^i = \frac{x_j^i - x_{\min\ j}}{x_{maxj} - x_{minj}}, \quad (1)$$

$$I_j^i = 1 - \frac{x_j^i - x_{\min\ j}}{x_{maxj} - x_{minj}}, \quad (2)$$

where I_j^i is the standardized value of indicator j of city i,
x_j^i is indicator j of city i,
$x_{\min\ j}$ is the minimum value of indicator j, and
x_{maxj} is the maximum value of indicator j.

If the statistical indicator is associated with an integral indicator of increasing dependence, then the conversion is carried out using Equation 1; if on the contrary, the statistical indicator is associated with an integral indicator of decreasing dependence, the conversion is carried out using Equation 2. The sustainable development index of the city is determined by taking into account the weight of each group of indicators using Equation 3 (Denevizyuk, 2012):

$$I_{SUD} = w_1 I_1 + w_2 I_2 + w_3 I_3 + w_4 I_4 + w_5 I_5; \quad (3)$$

where I_n is an integral indicator of the corresponding group of indicators, and
w_n is the weight coefficient of the corresponding group of indicators satisfying the conditions $w_n \geq 0$, $\sum_{wn} = 1$.

In accordance with the comparative importance of indicators and the significance of each of the groups of indicators, they were assigned an appropriate weight: economic development = 0.3, urban infrastructure = 0.1, demographics = 0.1, social infrastructure = 0.3, and environmental situation = 0.2 (Denevizyuk, 2012). The final SUDI was obtained from five sub-indices for the groups of indicators, taking into account the corrective weights selected based on established methods. The weight coefficients were assigned for each group of indicators based on assessments by Russian and Kazakh geographers and economists specializing in sustainable development.

4 Results: typology and ranking

Based on the calculated sub-indices for five groups of indicators, typologies were created for the cities studied. The cities were categorized under three types (sustainable, moderately sustainable, and unsustainable), and these were divided into seven subtypes based on the level of sustainability (Table 2).

The block of economic indicators consists of two groups of indicators: economic development and urban infrastructure (Figure 2). The economic development typology of cities was created based on the sub-indices calculated from six indicators for each city for 2007–2019. In general, there is an improvement in the economic development indicators. Based on the level of economic development, all the cities were assigned to different subtypes of a moderately sustainable type. Thus, for 2007–2019 only the city of Aktau, despite the decrease in the indicator (0.642 in 2007 and 0.613 in 2019), had a level of economic development close to sustainable. The cities of Pavlodar (from 0.446 to 0.521), Kokshetau (from 0.420 to 0.464), Kostanay (from 0.415 to 0.475), Karaganda (from 0.390 to 0.485), and Petropavl (from 0.382 to 0.460) with their corresponding index indicators were moved from the signs of unsustainability subtype in 2007 to the sustainable subtype in 2019. In the other cities, there was a slight improvement in the economic development index indicators.

The calculation of sub-indices based on the level of urban infrastructure development was carried out using five indicators of the cities studied for 2007–2019. The analysis of these indicators showed a significant improvement in the situation during the period analysed. Thus, from the subtype with the urban infrastructure development level close to sustainable in 2007, the cities of Pavlodar (from 0.704 to 0.762), Aktau (from 0.659 to 0.830), and Atyrau (from 0.602 to 0.766), moved to sustainable in 2019. The city of Oral moved from average sustainability to sustainable, with an increase of indicators from 0.582 in 2007 to 0.773 in 2019. There was a significant improvement in the situation in the city of Turkistan, which moved from signs of unsustainability to average sustainability, with an increase from 0.391 in 2007 to 0.531 in 2019.

The typology of the cities for the group of indicators "demographics" was compiled by using six indicators for 2007–2019. For the period considered, there was an improvement in the demographic development of the cities. Thus, the indicators of all the cities corresponded to the range of values of the average level of sustainability and the level of demographic development close to sustainable.

The typology of the cities based on the level of social development was created using the sub-indices calculated from seven indicators for 2007–2019. Thus, the indicators for the cities of Almaty (from 0.876 to 0.899) and Nur-Sultan (from 0.774 to 0.825) corresponded to the range of values of a sustainable level of social development. A significant improvement in indicators was observed in Taldykorgan, which moved from the subtype with signs of unsustainability to average sustainability with an increase from 0.358 in 2007 to 0.533 in 2019.

Based on the calculated sub-indices, an environmental situation typology was created using two indicators for the 2007–2019 dynamics. There was a significant deterioration in the environmental situation in Aktau, which moved from a sustainable environmental situation in 2007 with an index of 0.827 to signs of unsustainability in 2019 with an index of 0.411. The cities of Oral (from 0.506 to 0.443), Kokshetau (from 0.463 to 0.415), and Nur-Sultan (from 0.364 to 0.276) moved one level lower, with corresponding changes in the environmental indicators. Improvement was observed in Almaty, which moved from a crisis level for the environment in 2007 (0.086) to unsustainable development (0.247) in 2019. Based

Table 2: Classification by level of sustainability.

Types	Value range	Subtypes by sustainability level
Sustainable	≥ 0.900	High sustainability
	0.750–0.899	Sustainable
Moderately sustainable	0.600–0.759	Close to sustainable
	0.450–0.599	Average sustainability
	0.300–0.449	Signs of unsustainability
Unsustainable	0.150–0.299	Unsustainable
	< 0.150	Crisis level

Source: authors based on Gashu and Gebre-Egziabher (2019) and Golovanov (2015).

Table 3: Typology of large cities in Kazakhstan in terms of sustainability, 2007–2019.

Types	Subtypes	2007	2019
Sustainable	High sustainability		
	Sustainable		
Moderately sustainable	Close to sustainable	Aktau (0.672)	Atyrau (0.667)
		Atyrau (0.613)	Almaty (0.635)
		Nur Sultan (0.621)	
		Pavlodar (0.612)	
	Average sustainability	Nur Sultan (0.593)	Oskemen (0.594)
		Almaty (0.559)	Aktau (0.585)
		Kostanay (0.534)	Oral (0.565)
		Pavlodar (0.526)	Aktobe (0.556)
		Kyzylorda (0.516)	Kyzylorda (0.538)
		Oral (0.507)	Karaganda (0.533)
		Aktobe (0.505)	Petropavl (0.532)
		Kokshetau (0.503)	Kostanay (0.527)
		Karaganda (0.487)	Kokshetau (0.521)
		Taraz (0.472)	Taraz (0.506)
		Oskemen (0.458)	Shymkent (0.490)
		Petropavl (0.451)	Taldykorgan (0.486)
	Signs of unsustainability	Turkistan (0.413)	Turkistan (0.449)
		Taldykorgan (0.407)	
		Shymkent (0.397)	
Unsustainable	Unsustainable		
	Crisis level		

Source: authors.

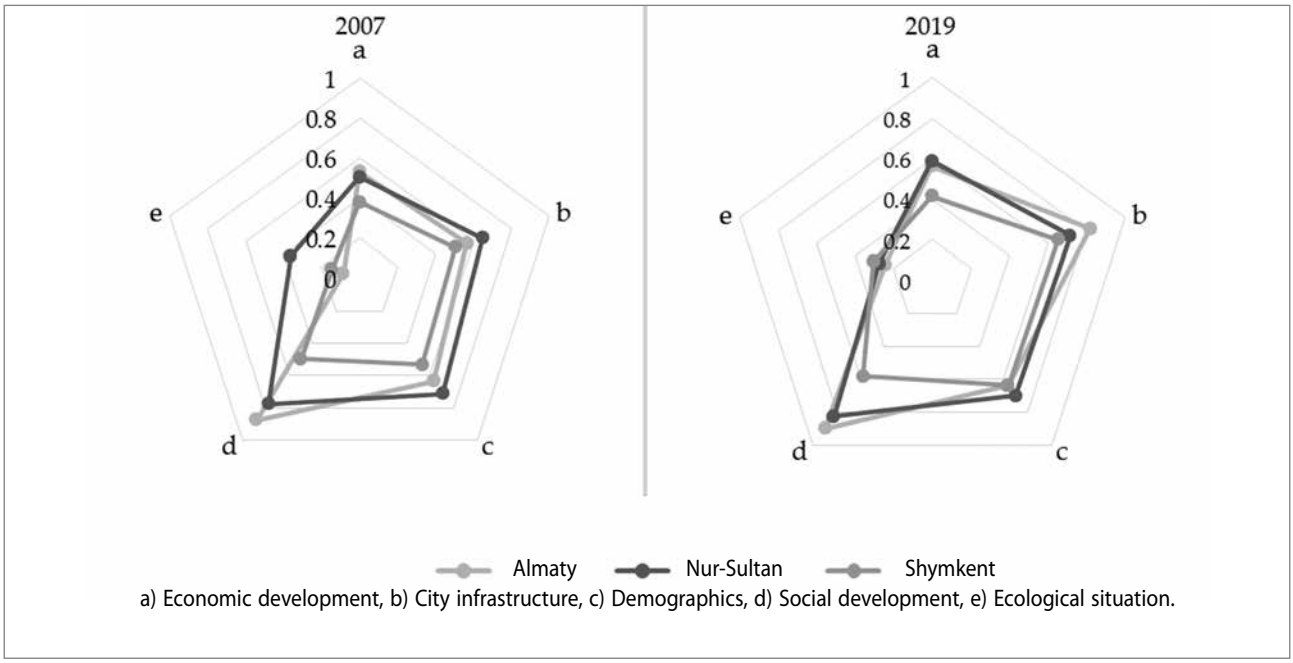

Figure 3: Changes in the groups of sustainable development indicators of cities of national significance (illustration: authors).

on the calculated SUDIs, an integral typology of the cities studied was created based on the level of sustainability for 2007–2019. The cities were classified as having sustainable, moderately sustainable, and unsustainable development (Table 3).

In general, there was an improvement in the sustainable development indicators in cities in Kazakhstan for the period analysed. Thus, the cities of Nur-Sultan (from 0.593 to 0.621), Almaty (from 0.559 to 0.635), and Pavlodar (from 0.526 to 0.612) moved from average sustainability to close to sustainable. It should be noted that the integral indices of all the cities studied for 2007–2019 were moderately sustainable.

5 Discussion

The transition to a new stage in the socioeconomic development of Kazakhstan involves the arrangement of all territories and the development of their infrastructure. In creating the prerequisites and foundations for innovative development, cities play an important role as the main centres for the reproduction of resources, including human potential. Cities are characterized by constant changes and development. Holistic economic, social, and demographic development and providing a favourable environment are the main prerequisites for sustainable development. This study helped identify weaknesses and strengths in the development of cities for five groups of sustainable development indicators. The results showed that all the cities analysed were moderately sustainable (Table 3). At the same time, there is a difference in the level of sustainability among the cities; the cities are divided into three subtypes: signs of unsustainability, average sustainability, and close to sustainable.

There is an improvement in the sustainable development indicators in 2019 compared to 2007. In 2007, only two cities (Aktau and Atyrau) were close to sustainable, twelve had average sustainability, and three (Turkistan, Taldykorgan, and Shymkent) had signs of unsustainability. Most cities have seen an increase in sustainability over twelve years. Thus, in 2019, four cities (Atyrau, Nur-Sultan, Almaty, and Pavlodar) were close to sustainable, and the remaining cities had average sustainability. In Nur-Sultan, Almaty, and Pavlodar there was an increase in the level of sustainability due to significant improvement in urban infrastructure and social development. Nevertheless, the low environmental indicators in Nur-Sultan, Aktau, and Almaty, the relatively low social development indicators in Atyrau, and the low demographic development in Pavlodar do not allow them to be classified as cities with sustainable development.

Taldykorgan and Shymkent, which had signs of unsustainability in 2007, reached average sustainability by 2019 due to improvements in demography, social development, and urban infrastructure. However, in terms of economics and the environment, no significant improvements were observed in these cities. Turkistan, despite the increase in sustainable development indicators for the study period, remained in the subgroup with signs of unsustainability in 2019. Figure 3 shows the

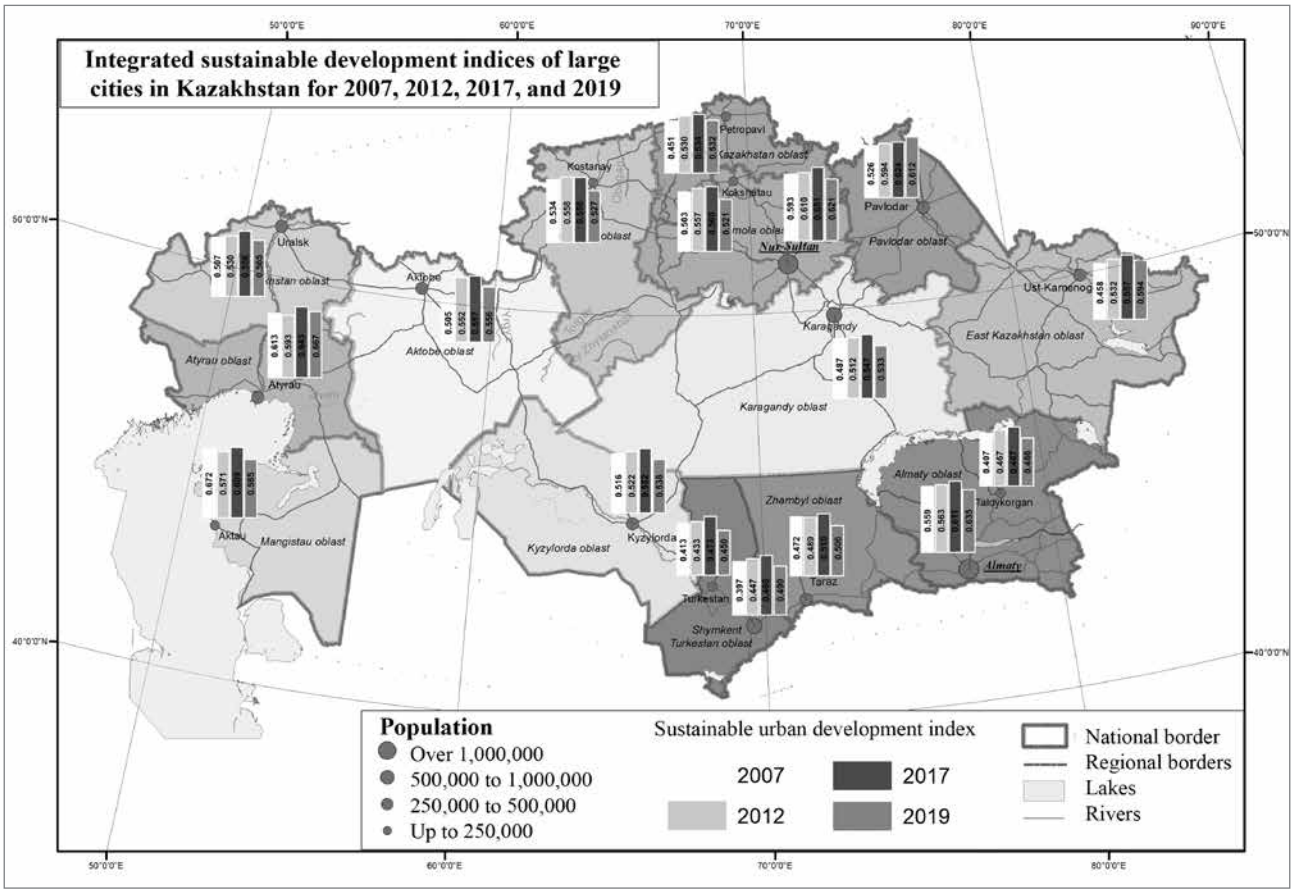

Figure 4: Integrated sustainable development indices of large cities in Kazakhstan for 2007, 2012, 2017, and 2019 (illustration: authors).

changes in the groups of sustainable development indicators of cities of national significance for the twelve years studied.

The relatively high indices in Nur-Sultan and Almaty are due to the high level of investment in developing urban infrastructure and the social sphere, a positive demographic situation, and steady economic development of cities of national significance. Köppen (2013) studied the project of building the new capital of Kazakhstan, Astana (Nur-Sultan); in his opinion, the city was not sufficiently different from the classic Soviet provincial city and was not sustainable. Based on our research, in 2007 Nur-Sultan had average sustainability, with a SUDI of 0.593. During the period studied, many sustainable development indicators for the city had positive dynamics (Figure 2) due to programs to improve socioeconomic development. In 2019, Nur Sultan was close to sustainable, with a SUDI of 0.621. The growth of the integral sustainability index was mainly due to improvement in the economic development indicators and city infrastructure groups. Shymkent attained the status of a city of national significance in 2018, reaching a population of more than one million, mainly through the gradual expansion of the city's borders by joining nearby rural settlements. Based on the study, a digital map of the level of sustainable development of large cities in Kazakhstan was developed, drawing from the spatial geodatabase created for sustainable development indicators (Figure 4).

Figure 4 shows that in all seventeen cities studied there is a positive trend in the SUDI for 2007–2019. The map presents additional information on the population of the cities studied, the population density of the regions (first-level administrative units), the major lakes and rivers in the country, and so on.

Although the study considered a wide range of factors, there are still some limitations and insufficient statistical data when choosing a set of sustainable urban development indicators. Therefore, in future studies, the authors will look for ways to further improve this system for assessing the sustainability of cities in Kazakhstan. The number of indicators for calculating the SUDI will be expanded by applying subjective assessment methods. The authors conclude that assessing sustainability using only objective indicators is not sufficient to show the full picture. By regularly updating the statistical information in the geodatabase, it is also possible to regularly monitor the sustainable development indicators of settlements in Kazakhstan.

6 Conclusion

This study examined the sustainability of seventeen large cities in Kazakhstan. The review of the literature and available methods from abroad for assessing sustainable development revealed the difficulties of their application for assessing the sustainability of cities in developing countries due to the limited available statistical information by city. The methodology for assessing urban sustainability proposed by SGM was studied to select key indicators for this study.

The calculated indices of sustainable urban development by groups of indicators make it possible to better assess the development trends for each indicator. The typology of the cities in terms of sustainability is based on the SUDIs of the cities studied. The study found that none of the cities attained a sustainability level exceeding or equal to a SUDI of 0.750, and there were no unsustainable cities with a SUDI below 0.300. Consequently, all seventeen cities are classified as moderately sustainable. Nevertheless, the cities leading in terms of sustainable development were identified, as well as cities with low rates of sustainable development. With SUDI indicators from 0.612 to 0.667 in 2019, the cities of Nur-Sultan, Atyrau, Pavlodar, and Almaty were the leaders, classified as close to sustainable. The remaining thirteen cities, with SUDI indicators from 0.449 to 0.594, had an average level of sustainability.

Based on this study, a spatial geodatabase was created for economic, socio-demographic, and environmental indicators for the seventeen cities for 2007–2019. This geodatabase was used to produce a digital sustainable development map for large cities in Kazakhstan (Fig. 4). The sustainability indicators of the cities studied can be used as a basis and guide for representatives of state and local government to achieve higher sustainable development for these cities, as well as for other cities and towns.

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