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City size, borrowed size and institutional educational supply: Evidence from the Fergana economic region, Uzbekistan

Madinabonu Nematova
Namangan State University
Shavkatjon Jumakhanov
Namangan State University
Yulduz Usmonova
Namangan State University
Zuhriddin Juraev
phd.zjuraev@gmail.com

Kokand University

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Abstract

Composite liveability indices summarise urban conditions in single city-level scores, concealing the structure of provision they aggregate. This study measures the relative institutional supply of education across the five major cities of the Fergana economic region, Uzbekistan, decomposed into preschool, general secondary, vocational, and higher education. Institutional counts per 10,000 residents were normalised within the five-city group and averaged using equal weights to construct a composite institutional supply-density index. Robustness was assessed under alternative weighting schemes and normalisation methods. Institutional supply proved only weakly related to city size, and inter-city disparity followed a U-shaped pattern, being lowest at the compulsory level and greatest at the discretionary ends of the educational ladder. No city exhibited a balanced provision profile, and one city's pattern of provision was consistent with an agglomeration shadow. Decomposition by educational level therefore reveals policy-relevant imbalances concealed by composite scores, illustrates the usefulness of the borrowed size and agglomeration shadow framework for interpreting service provision in a Central Asian urban system, and offers a transparent, data-light spatial analysis tool transferable to other service domains and other data-scarce policy settings.

Keywords: applied spatial analysis; institutional supply density; educational infrastructure; agglomeration shadow; borrowed size; urban and regional policy; Fergana Valley; Uzbekistan

1. Introduction

Cities concentrate the population, economy and public services of their regions, and how well they provide for daily life has become a central concern of territorial development policy worldwide. That concern has produced a measurement industry: composite liveability indices now rank cities globally and increasingly steer national urban policy, even as scholarship questions what a single city-level score can legitimately claim to represent (McArthur & Robin, 2019). Among the domains such indices summarise, education occupies a special position. Educational institutions shape human capital formation, anchor the daily routines of households and influence residential and migration decisions, yet in liveability frameworks education is typically folded into an aggregate social block, and the territorial organisation of its distinct levels, from preschool to university, is rarely examined in its own right.

The question is of practical urgency in Uzbekistan, where the national development strategy to 2030 assigns priority to expanding education services in major cities (Decree No. PF-21, 2026), a national adaptation of ISO 37120 codifies urban quality-of-life measurement (O'z DSt ISO 37120, 2023), and a thirty-city liveability rating has been published at the republican level (Institute for Macroeconomic and Regional Studies, 2023) amid accelerating urbanisation (Salimova, 2025). These instruments, however, report aggregate scores: none disaggregates educational provision by level of education or relates it to a city's position within its regional system of cities. The Fergana economic region concentrates the problem in its sharpest form. Five of the country's major cities, Namangan, Andijan, Fergana, Kokand and Margilan, lie within roughly a hundred kilometres of one another in a densely populated valley, jointly accommodating over two million residents at population densities several times the national average. In so compact a polycentric system, what each city provides cannot be

understood in isolation from its neighbours, which is why this study interprets provision through the borrowed size framework of contemporary urban systems research, in which cities may host more, or fewer, functions than their own size would support depending on their position in the regional system.

The aim of this study is to measure and interpret the relative institutional supply of education across the major cities of the Fergana economic region. The measure is deliberately modest in its claims: it is an index of institutional supply density, based on the number of educational institutions per 10,000 residents, that captures neither institutional capacity, educational quality, nor accessibility. Its scope and limitations are specified in Section 3. The study is conceived as applied spatial analysis in the evidence-for-policy tradition: a transparent, replicable quantitative measure is constructed from official statistics to inform territorial planning decisions in a setting where fine-grained spatial data remain scarce. Three objectives structure the study: (i) to construct a level-decomposed index of institutional educational supply density for the five cities; (ii) to measure inter-city disparity by level of education and identify each city's provision profile; and (iii) to test the robustness of the resulting ranking to alternative normalisation and weighting schemes. Section 2 positions the study within the literature and presents its conceptual framework. Section 3 describes the materials and methods. Section 4 reports the results, Section 5 discusses them, and Section 6 concludes.

2. Literature review and conceptual framework

2.1. Measuring urban liveability

Urban liveability has consolidated into a distinct field of measurement over the past two decades, propelled by global rankings such as the Global Liveability Index of the Economist Intelligence Unit and the City Prosperity Index of UN-Habitat, and codified in standards such as ISO 37120. The rankings established the multi-criteria composite as the field's dominant instrument, yet they have also drawn a sustained critique. McArthur and Robin (2019) argue that liveability discourse couples a vague normative rhetoric to expert-produced indicators, producing single scores that acquire policy authority while misrepresenting the differentiated realities they claim to summarise. The constructive response within the measurement literature has been disaggregation. Higgs et al. (2022) demonstrate how policy-relevant liveability indicators can be built spatially, from local to global scales, and Giles-Corti et al. (2022), examining Australia's twenty-one largest cities at the level of small territorial units, show that liveability varies as much within cities as between them and that city size alone does not determine outcomes.

Beyond the Anglophone core, the same measurement logic has been adapted to sharply different regional conditions, and the adaptations converge on a common lesson: the content of a liveability index is context-dependent. Studies of Russian cities have anchored comfort assessment in access to social infrastructure and services (Polyakova et al., 2021; Saenko et al., 2021; Sidorov, 2018; Sidorov et al., 2019), while East Asian work has developed remote-sensing and multi-criteria approaches in which ecological and climatic parameters carry the principal weight (Chen et al., 2023; Li et al., 2024; Xiao et al., 2022). Research on Central Asian and neighbouring territories has foregrounded environmental stress and green infrastructure (Momosheva et al., 2024; Turdimambetov et al., 2024), transport (Boboev & Davlatov, 2024) and the consequences of weakly governed urban growth (Hamidullah, 2025; Zhalehdoost & Taleai, 2025), and survey-based traditions have insisted that objective provision be confronted with residents' subjective satisfaction (Bahadir & Aktaş, 2023; D'Souza et al.,

2023; European Commission, 2023) and with the needs of groups that aggregate indices treat as homogeneous (Gonzalez et al., 2024).

Whatever their differences, these literatures agree that composite scores conceal more than they reveal unless they are opened up, and the axis along which they have been opened has been overwhelmingly spatial: variation within cities. Disaggregation along a second axis, by the level or order of the service itself, has received far less attention.

2.2. Education within liveability assessment

Education illustrates the cost of that neglect. In the major frameworks it enters as one component of a broad social block, typically as a single aggregate indicator, although its territorial organisation differs from that of any other liveability domain: educational systems are vertically differentiated into levels that serve distinct age cohorts, perform distinct functions and, crucially, operate over catchments of very different radii. A preschool serves a neighbourhood; a general secondary school a district; a vocational institution a city and its surroundings; a university an inter-regional and increasingly international field. Level-specific studies exist but are rare and single-tier, such as the assessment of school provision under demographic pressure in Sevastopol (Saenko et al., 2021).

An index that aggregates across levels without first measuring each of them separately therefore discards precisely the structure that makes education geographically informative, and no defensible a priori weighting can restore it, since the levels are not substitutes for one another. This motivates the design choice, developed in Section 3, of measuring provision level by level before any aggregation and of treating the composite as a summary of relative position rather than a measure of educational access.

2.3. Borrowed size and Agglomeration shadows

To interpret inter-city differences in level-specific provision, the study draws on the borrowed size framework. The intuition that services of higher order concentrate in centres of higher rank descends from classical central place theory (Christaller, 1966), but the contemporary literature has replaced its proportional, static logic with a relational one built around deviations. Alonso (1973) observed that a city may host more urban functions than its own size would normally support, borrowing size from its neighbours; Burger, Meijers, Hoogerbrugge and Masip Tresserra (2015) formalised the complementary condition, the agglomeration shadow, in which a city hosts fewer functions than its size warrants because a nearby centre's service radius suppresses duplication, and Meijers and Burger (2017) extended the concept from population size to performance and function. The framework is explicitly relational: what a city provides depends not only on its own mass but on its position within the regional system of cities.

The empirical literature adds an essential qualification: shadows are contingent, not automatic. Partridge, Rickman, Ali and Olfert (2009) found that proximity to larger centres generally benefited United States places below roughly a quarter of a million residents, with shadows detectable mainly over medium-sized metropolitan areas; Tervo (2010) showed for Finland that shadow effects emerged only in particular historical periods of the urban system's development; and Chen, Wang, Hao, Yin and Chen (2024) report that among Chinese cities borrowing effects outweigh shadowing. Whether a given city stands in light or shadow is

therefore an empirical question about a specific urban system at a specific time, which is exactly the question an institutional supply density index is built to answer.

Three considerations justify this framework over its alternatives for the present case. First, it matches the object: the Fergana economic region is a dense polycentric system in which five major cities lie within roughly a hundred kilometres of one another, including one directly adjacent pair, so relations of proximity, borrowing and shadowing are the system's defining feature, whereas core-periphery models address polarisation at the macro-regional scale and classical central place theory, being proportional, offers no vocabulary for cities that deviate from what their size predicts, and it is precisely the deviations that the results of this study turn on. Second, it matches the measurement: an index built on functions per 10,000 residents, normalised within a peer group, is in effect a domain-specific operationalisation of the Alonso deviation, positioning each city by the gap between the functions it hosts and the functions its size would support. Third, it matches a declared research agenda: Meijers and Burger (2022) call for moving the study of borrowing and shadowing beyond its economic connotation towards broader measures of prosperity and human needs satisfaction; educational provision is such a measure, and applying the framework to it responds to that call directly.

The framework also yields expectations against which the results can be read. The catchment hierarchy implies that inter-city disparity in provision should increase with the order of the education level, peaking at the university tier, where shadowing by higher-order centres should be strongest. The institutional mandate of compulsory schooling implies the opposite force for the general secondary tier, whose universal enrolment obligations should compress provision towards evenness irrespective of a city's position in the urban system. The framework is agnostic about the preschool tier, where provision is discretionary but catchments are small. The study is designed as a conceptually framed measurement exercise rather than a formal test: with five cities, the framework's role is to generate these expectations and to interpret deviations, not to estimate its parameters.

2.4. Research gap and contribution

Together, these three strands of literature reveal a common research gap. First, the liveability literature has responded to criticisms of composite indices by increasing spatial disaggregation within cities. However, comparatively little attention has been paid to disaggregating educational provision by service level across cities. Second, research on borrowed size and agglomeration shadow has focused predominantly on economic performance in Western Europe, North America, and East Asia. Public service provision has received far less attention despite repeated calls to extend these concepts beyond economic outcomes. Third, Central Asia remains largely absent from the borrowed size literature. This omission is notable because the region has a dense polycentric urban structure and closely spaced cities that are well suited to examining proximity effects.

Against this background, the present study makes a deliberately bounded contribution. It develops a transparent, level-specific measure of relative institutional educational supply density for the five major cities of the Fergana economic region. It then uses the concepts of borrowed size and agglomeration shadow as an interpretive framework for understanding the observed spatial patterns. Rather than testing these theories directly, the study employs them as an analytical lens to interpret differences in the distribution of educational institutions across neighbouring cities. Accordingly, the study aims to compare level-specific institutional educational supply across the five principal cities of the Fergana economic region and assess whether the observed patterns are consistent with the spatial dynamics associated with

borrowed size and agglomeration shadow. Because the index requires only institutional counts and resident population, both routinely published in official statistics, the approach is transferable to other public service domains and to other data-scarce regional systems, contributing to the translation of spatial analysis techniques across policy contexts.

3. Materials and methods

3.1. Study area and research design

The study covered the five major cities of the Fergana economic region of Uzbekistan: Namangan, Andijan, Fergana, Kokand and Margilan. The five cities jointly accommodate 2,105.7 thousand permanent residents on 0.44 thousand square kilometres and account for roughly one fifth of the total population of the economic region; population densities in the host provinces exceed the national average several times over (Table 1). The full structure of the indicator framework is provided in the supplementary material (Table S1).

Table 1. Profile of the major cities of the Fergana economic region, 2025

No.	City	Area, thousand km²	Permanent population, thousand	Density, persons per km²	Share of the urban population of the respective province, %
1	Andijan	0.07	492.4	7,034.3	27.3
2	Fergana	0.11	328.4	2,985.5	13.7
3	Margilan	0.05	257.9	5,158.0	11.0
4	Namangan	0.15	713.4	4,756.0	35.0
5	Kokand	0.06	313.6	5,226.7	13.3
	Total	0.44	2,105.7	5,032.1	—

Source: National Statistics Committee of the Republic of Uzbekistan (2025). Province shares refer to each city's own province and do not sum to a regional total.

The assessment forms part of a broader liveability indicator framework developed by the authors, comprising five criteria, fifteen indicators, and forty subindicators. The full framework is presented in the Supplementary Material (Table S1). The present study serves as a methodological pilot by operationalising the education block of the social environment criterion. Education was selected because it offers the most complete city-level official statistics and represents a national policy priority (Decree No. PF-21, 2026). The broader framework itself is not evaluated in this study. Within the framework, criterion weights were assigned in proportion to the number of subindicators under each criterion and subsequently refined using expert judgement and international rating practices.

3.2. Indicators and data

Educational provision was measured using four subindicators: the number of preschool institutions; the number of general secondary institutions, including specialised schools and organisations providing supplementary education for children; the number of vocational institutions, comprising academic lyceums, colleges, vocational schools, and technical schools;

and the number of higher education institutions, including branches of foreign universities. The data refer to 2025 and were obtained from official statistics published by the National Statistics Committee of the Republic of Uzbekistan (2025). Both state and non-state institutions were included.

Each indicator was expressed per 10,000 permanent residents of the host city. This standardisation follows the per-capita provision approach adopted by UN-Habitat (2004) and removes the effect of differences in city size, which ranged from 257.9 thousand residents in Margilan to 713.4 thousand in Namangan.

The resulting measure represents an index of relative institutional supply density. Institutional counts per 10,000 residents do not capture the capacity, enrolment, or quality of educational institutions, nor do they account for accessibility in terms of travel distance or time. Consequently, one university branch and one large university, or one small and one large preschool, contribute equally to the index. Cities with similar institutional supply density may therefore differ substantially in class size, catchment congestion, and spatial coverage. The Education Provision Index (EPI) developed in this study should therefore be regarded as a first, data-feasible layer of educational assessment, providing a foundation for future incorporation of capacity-, quality-, and accessibility-based measures.

3.3. Construction of the education provision index

Because subindicators across the wider framework are expressed in heterogeneous units, all values were converted to a common scale of 0 to 100 by min–max normalisation. For subindicators with a positive direction of influence,

$$M_{ij} = \frac{X_{ij} - X_j^{\min}}{X_j^{\max} - X_j^{\min}} \times 100 \quad (1)$$

and for those with a negative direction,

$$M_{ij} = \frac{X_j^{\max} - X_{ij}}{X_j^{\max} - X_j^{\min}} \times 100 \quad (2)$$

where χ_{ij} denotes the observed value of subindicator j for city i, and $X_j^{\max}$ and $X_j^{\min}$ the highest and lowest values of that subindicator among the compared cities. All four education subindicators carry a positive direction, so Equation (2) was not invoked in this study.

The four normalised scores were aggregated with equal weights into the composite Education Provision Index (EPI) of city i:

$$EPI_i = \frac{1}{4}\sum_{j=1}^{4} M_{ij} \quad (3)$$

in which each level contributes a weight of 0.25, so the composite equals the arithmetic mean of the four normalised scores. Equal weighting was adopted because the four levels of education serve different age cohorts and functions, and no defensible a priori grounds existed for privileging one level within a supply-density index. Demand-side weighting by age cohort was considered and rejected: weighting levels by the size of their target cohorts would convert the measure from an index of supply density into a partial indicator of met demand, conflating two distinct constructs, and single-year age structures were in any case not published at the city level in Uzbekistan at the time of the study. The robustness of the results to the weighting choice was tested separately (Section 3.4).

Composite values were read against a five-band verbal scale (very low, low, medium, high, very high, in twenty-point intervals) constructed in the spirit of the Global Liveability Index. Because min–max normalisation applied to five cities assigns 100 points to the leading city and 0 points to the trailing city on each subindicator by construction, all scores express relative position within the compared group rather than absolute levels of provision, and the verbal labels were interpreted accordingly.

3.4. Disparity and robustness measures

Inter-city disparity within each level of education was quantified using the coefficient of variation (CV), calculated as ($CV = (\sigma/\mu) \times 100$), where ($\sigma$) is the standard deviation and (μ) is the mean of the per-10,000 population ratios across the five cities.

The robustness of the composite ranking was evaluated in three ways. First, Equation (3) was recalculated using three alternative weighting schemes (0.3, 0.3, 0.2, 0.2; 0.2, 0.2, 0.3, 0.3; and 0.4, 0.2, 0.2, 0.2). Second, the composite index was recomputed after omitting each subindicator in turn. Third, min–max normalisation was replaced with three alternative scoring methods: mean z-scores, each city's mean percentage of the regional mean calculated from the raw per-10,000 ratios, and mean ranks.

4. Results

4.1. Provision with educational institutions by level

Table 2 reports the number of institutions of each level, the ratios per 10,000 residents, and the coefficient of variation of each ratio across the five cities. Absolute and relative rankings did not coincide at any level. Namangan held the region’s largest preschool and general secondary networks in absolute terms yet led on neither once provision was expressed per 10,000 residents: Andijan ranked first in relative preschool provision and Fergana in general secondary provision. The divergence recurred in vocational education, where Namangan operated the second-largest network but recorded the lowest ratio in the group. In higher education, provision was concentrated in three cities, and Margilan hosted no higher education institution.

Table 2. Provision of the major cities with educational institutions per 10,000 residents, 2025

City	Population, thousand	Preschool *n*	per 10k	General secondary *n*	per 10k	Vocational *n*	per 10k	Higher *n*	per 10k
Namangan	713.4	395	5.54	128	1.79	15	0.21	8	0.11
Andijan	492.4	284	5.77	78	1.58	20	0.41	10	0.20
Fergana	328.4	115	3.50	68	2.07	12	0.37	9	0.27
Kokand	313.6	64	2.04	62	1.98	9	0.29	4	0.13

Margilan	257.9	52	2.02	38	1.47	9	0.35	0	0.00
CV, %			**48.2**		**14.2**		**23.6**		**71.8**

Note. n = number of institutions; CV = coefficient of variation across the five cities. Source: National Statistics Committee of the Republic of Uzbekistan (2025).

The magnitude of inter-city differences varied strongly by level. The ratio between the best- and worst-provided city was 2.9-fold for preschool education, 1.4-fold for general secondary education and 1.9-fold for vocational education, while for higher education the gap was unbounded, ranging from 0.27 institutions per 10,000 residents to complete absence. The coefficient of variation reproduced the same pattern in a U-shaped profile (Table 2, bottom row; Figure 1): disparity was lowest for general secondary education (14.2%), moderate for vocational education, and highest at the two ends of the educational ladder, reaching 71.8% for higher education. Disparity therefore did not rise monotonically from lower to higher levels of education.

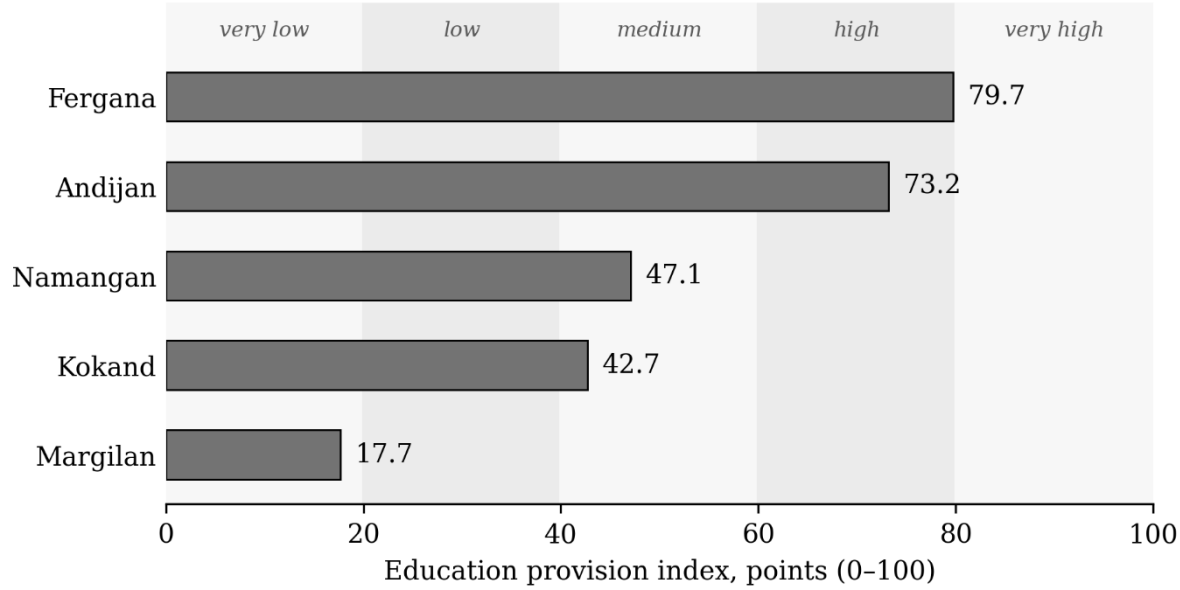


Figure 1. Inter-city disparity by education level, measured by the coefficient of variation of institutions per 10,000 residents (%).

4.2. Normalised scores and the composite index

Application of formulas (1) and (3) to the ratios of Table 2 produced the normalised scores and composite values reported in Table 3.

Table 3. Normalised scores and the education provision index (EPI) of the major cities

City	Preschool	General secondary	Vocational	Higher	EPI	Rank	Level

Fergana	39.6	100.0	79.2	100.0	**79.7**	1	high
Andijan	100.0	18.5	100.0	74.1	**73.2**	2	high
Namangan	93.8	53.7	0.0	40.9	**47.1**	3	medium
Kokand	0.7	84.3	39.2	46.5	**42.7**	4	medium
Margilan	0.0	0.0	70.8	0.0	**17.7**	5	very low
Mean	46.8	51.3	57.8	52.3	**52.1**		medium

Note. Computed from Table 2 using Equations (1) and (3). Scores of 0 and 100 mark the group minimum and maximum; verbal levels denote relative position within the group.

The composite EPI separated the five cities into three strata (Figure 2). Fergana (79.7) and Andijan (73.2) formed the upper stratum, both within the high band of the interpretation scale; each led the group on two of the four subindicators. Namangan and Kokand formed the middle stratum, within the medium band, and Margilan (17.7) occupied the bottom stratum alone, in the very low band, recording the group minimum on three of the four levels; its single strength was vocational provision.

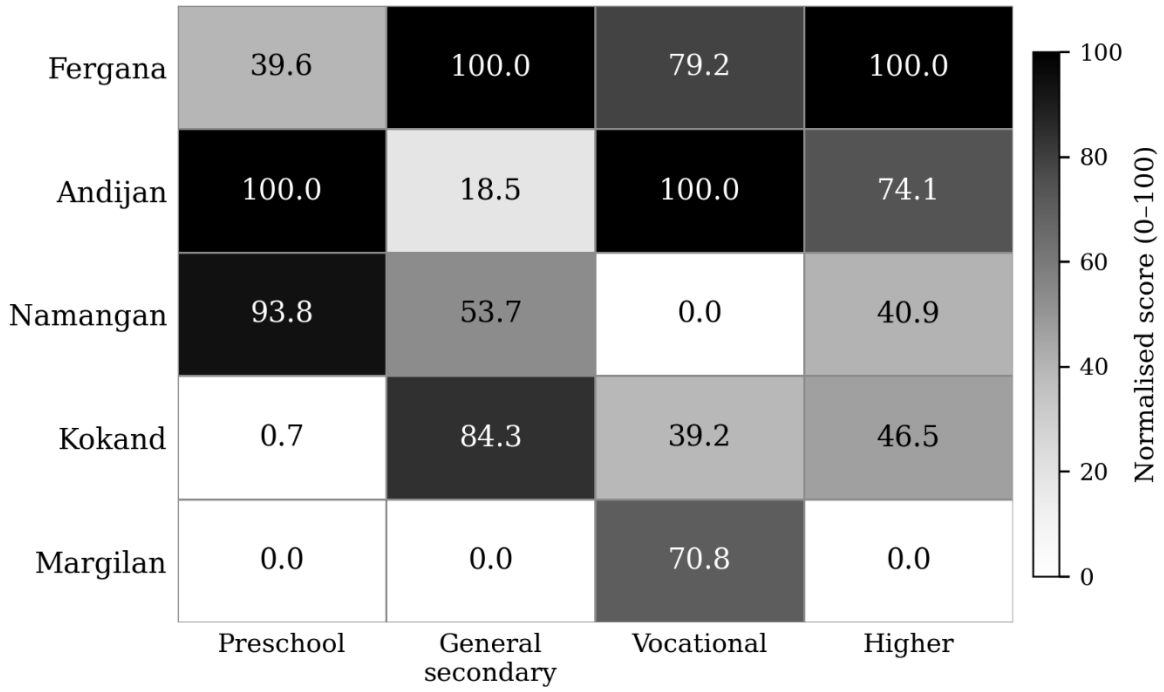


Figure 2. Education provision index of the five cities, 2025.

Note: Shaded bands denote relative position.

The stratification was visible in the gap structure of the ranking. The differences between consecutively ranked cities were 6.5, 26.1, 4.4 and 25.0 points: the two between-strata gaps exceeded the two within-strata gaps five- to six-fold, so the boundaries between strata were roughly an order sharper than the distinctions inside them.

Unbalanced provision profiles characterised the entire group, not only its lower strata (Figure 3). The amplitude between each city's highest and lowest normalised score ranged

from 60.4 points in Fergana to 93.8 points in Namangan, exceeding 60 points in every city. No city of the region combined consistently strong, or even consistently moderate, positions across all four levels of education; each paired near-leading provision on at least one level with a position at or near the group minimum, or well below the group mean, on another.

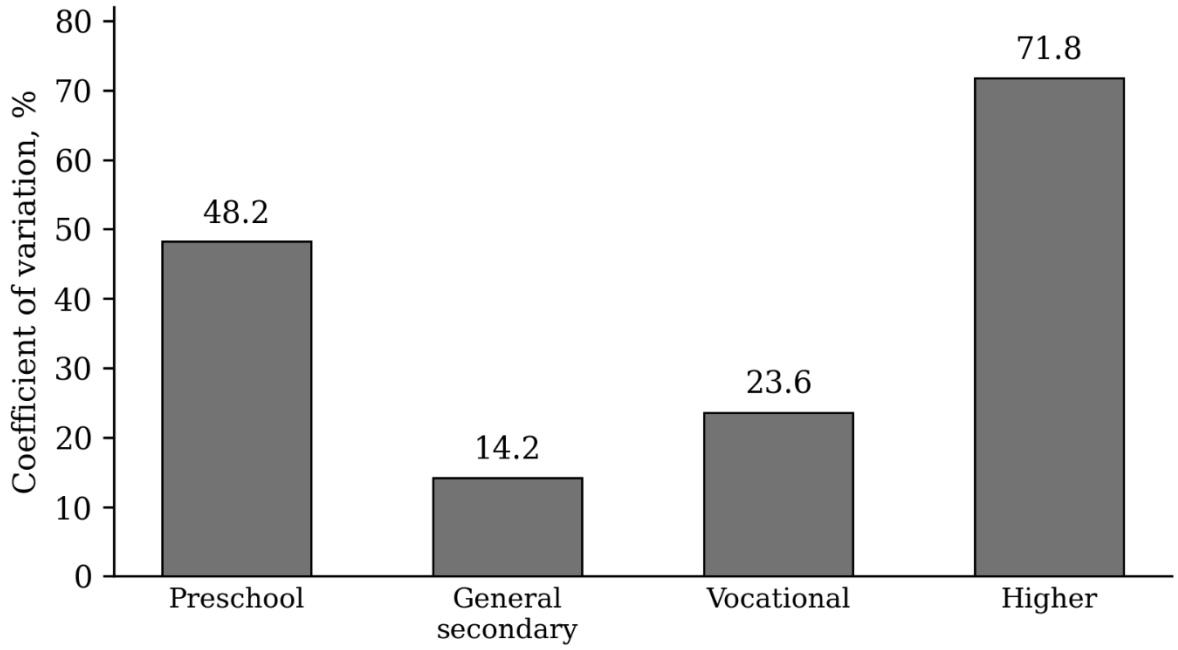


Figure 3. Normalised institutional supply scores by education level, 2025.

Note. Scores were normalised within the five-city group using min–max scaling; 0 and 100 represent the group minimum and maximum, respectively.

4.3. Robustness of the ranking

The robustness of the Education Provision Index (EPI) was assessed under three alternative weighting schemes in addition to the equal-weight baseline. The alternative schemes placed greater emphasis on (i) preschool and general secondary education (0.3, 0.3, 0.2, 0.2), (ii) vocational and higher education (0.2, 0.2, 0.3, 0.3), and (iii) preschool education alone (0.4, 0.2, 0.2, 0.2). The resulting EPI values are presented in Table 4.

Table 4. Sensitivity of EPI values to alternative weighting schemes

City	Equal	Mass levels	Advanced levels	Preschool emphasis
Fergana	**79.7 (1)**	**77.7 (1)**	**81.7 (1)**	71.7 (2)
Andijan	73.2 (2)	70.4 (2)	75.9 (2)	**78.5 (1)**
Namangan	47.1 (3)	52.5 (3)	41.8 (4)	56.5 (3)
Kokand	42.7 (4)	42.6 (4)	42.7 (3)	34.3 (4)
Margilan	17.7 (5)	14.2 (5)	21.2 (5)	14.2 (5)

The ranking proved highly stable under all alternative weighting schemes. Margilan remained last in every specification, with EPI values ranging from 14.2 to 21.2. Likewise, the composition of the upper and middle groups did not change. Only the internal ordering within each group reversed under the weighting schemes that placed greater emphasis on particular educational levels, reflecting the relatively small differences in EPI values between Fergana and Andijan and between Namangan and Kokand.

The leave-one-out analysis produced the same pattern, with the top pair and Margilan's bottom position remaining unchanged after the omission of each subindicator in turn.

Table 5. Sensitivity of the city ranking to alternative normalisation methods

Method	Resulting order
Min–max normalisation (baseline)	Fergana > Andijan > Namangan > Kokand > Margilan
Mean z-score	Fergana > Andijan > Namangan > Kokand > Margilan
Percentage of regional mean	Fergana > Andijan > Namangan > Kokand > Margilan
Mean rank	Fergana > Andijan > Kokand > Namangan > Margilan

Note. Computed from the per-10,000 population ratios reported in Table 2.

The ranking was equally insensitive to the choice of normalisation method (Table 5). Mean z-scores and mean percentage of the regional mean reproduced the baseline ranking exactly. Mean-rank scoring altered only the internal ordering of the middle pair, with Kokand moving ahead of Namangan, while preserving the overall three-group structure. Taken together, these findings indicate that the overall ranking is robust to alternative weighting, indicator omission, and normalisation procedures.

5. Discussion

5.1. City size and educational provision

The first question the results answer is whether the demographic weight of a city translates into educational provision. In the Fergana economic region it does so only loosely: the rank correlation between population and the composite index was positive but moderate, and the region's most populous city ranked third. The systematic divergence between absolute and relative rankings points to the mechanism. A large institutional network signals accumulated supply, but the demographic load carried by that network is a separate property, and in rapidly growing cities the denominator can outpace the numerator. Namangan's position is plausibly of this kind: its per-capita deficits at the vocational and higher levels may reflect population growth outrunning institutional expansion rather than institutional decline.

This reading extends, in a different institutional setting and at the inter-city rather than intra-city scale, the conclusion of Giles-Corti et al. (2022) that city size alone does not decide liveability outcomes; what the education case adds is that provision at discretionary levels appears to respond to a city's function and history more than to its demographic mass.

5.2. Margilan and the agglomeration shadow

The most theoretically instructive result is Margilan's position. In the vocabulary introduced by Alonso (1973) and developed by Burger, Meijers, Hoogerbrugge and Masip Tresserra (2015), a city experiences an agglomeration shadow when it hosts fewer urban functions than its size would normally support. Margilan, a city of a quarter of a million residents with no higher education institution and the group minimum on two further levels, presents a pattern consistent with an agglomeration shadow, and its location within the functional territory of the adjacent provincial capital supplies the standard explanation: higher-order services concentrate in the neighbouring centre, whose service area encompasses Margilan, reducing the incentive for duplicate higher-order functions to develop. A within-group contrast reinforces, though it cannot prove, this reading: Kokand, of comparable population but situated outside the immediate orbit of a provincial capital, hosts four higher education institutions, whereas Margilan, adjacent to one, hosts none. Establishing shadowing conclusively would require evidence on travel times, enrolment flows by city of residence, or the historical siting of institutions, none of which the present data contain; the interpretation is therefore offered as a hypothesis that the accessibility layer proposed below is designed to test.

The international evidence, however, warns against treating the shadow as automatic, and the warning is productive here. Partridge, Rickman, Ali and Olfert (2009) found that in the United States proximity to larger centres generally *benefited* places below roughly 250,000 residents, with growth shadows appearing mainly over medium-sized metropolitan areas; Chen, Wang, Hao, Yin and Chen (2024) likewise report that among Chinese cities borrowed size effects outweigh shadow effects. Margilan lies close to the population threshold identified by Partridge et al. (2009), suggesting that its current position cannot be attributed to spatial configuration alone. Tervo's (2010) long-run Finnish evidence points the same way: shadows are historically contingent, emerging in particular periods of the urban system's development rather than existing as timeless features. Margilan's provisioning deficit is therefore better read as the product of a specific institutional and planning trajectory within the Fergana–Margilan pair than as an inevitable consequence of proximity, and, importantly, as potentially reversible.

Two further nuances follow. First, the shadow is function-specific. Margilan's single strong position, vocational provision, is consistent with its industrial specialisation in silk and textile production, which sustains training functions that proximity cannot substitute. This differentiation across functions within one city supports the argument of Meijers and Burger (2022) that borrowing and shadowing manifest in many varieties rather than as a uniform condition. Second, and central to the interpretation of the index itself, a shadow in provision may coexist with borrowed access. Margilan's residents plausibly use the universities of the adjacent provincial capital, in which case part of the measured deficit is compensated through the functional region. A supply-density index captures the institutional expression of agglomeration shadow but cannot observe the functional borrowing that may compensate for it. Rather than representing a weakness discovered after the fact, this defines the boundary of what the present layer of measurement can claim and identifies the accessibility layer as its necessary complement. Measuring both therefore requires combining supply-based and accessibility-based indicators.

The findings respond directly to the research agenda of Meijers and Burger (2022), who call for extending the study of borrowing and shadowing beyond economic performance to broader measures of human needs satisfaction. Educational provision represents one such dimension. The findings suggest that patterns consistent with agglomeration shadow can be observed in this domain even where previous evidence from China and the United States indicates that economic shadow effects may be weak or absent.

5.3. What composite indices reveal and conceal

The third dialogue concerns measurement. Critics of the liveability industry have argued that city-level rankings connect a vague normative rhetoric to expert-produced indicators whose single scores misrepresent the differentiated realities they claim to summarise (McArthur & Robin, 2019), and methodological work has answered by disaggregating indices spatially, within cities (Higgs et al., 2022). The present results support the critique from a different direction and suggest a complementary answer: disaggregation by service level. Had the analysis reported only composite values, the region would appear as a simple gradient from Fergana to Margilan.

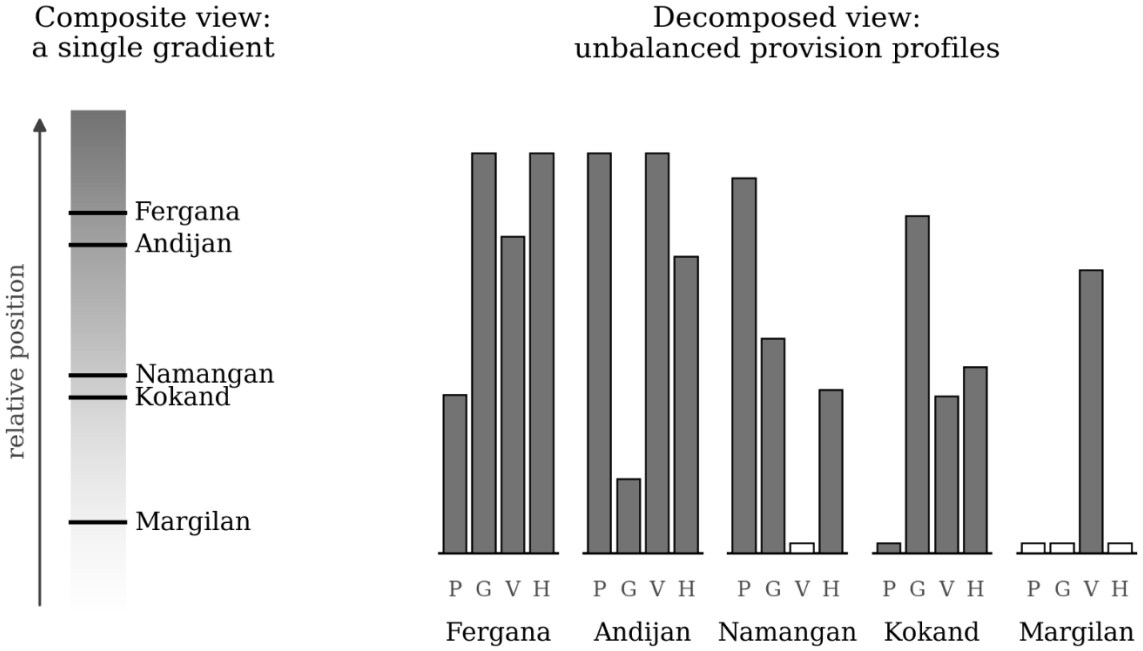


Figure 4. Composite versus decomposed representation of educational provision.

Note. P = preschool; G = general secondary; V = vocational; H = higher. Schematic based on Tables 2 and 3; vertical scales omitted.

The decomposed picture is qualitatively different: whereas the composite orders the cities along a single gradient, decomposition by education level reveals unbalanced provision profiles in every city (v.a. Fig. 4). Disparity is U-shaped across education levels (Figure 1), concentrated where provision is discretionary and nearly absent in the compulsory tier, whose evenness plausibly reflects mandated universal enrolment; and no city in the region, including the leaders, holds a balanced profile (v.a. Fig. 3), each pairing near-leading provision on one level with a position at or near the group minimum on another. A single score conceals precisely the imbalances that matter for policy. In this respect the decomposition is not descriptive detail but the analytical point, and it qualifies the verbal bands attached to composite values as, at best, summaries of relative position.

5.4. Implications

Three implications follow for regional policy. First, priorities should be differentiated by city and educational level rather than allocated by population size or composite rank: the binding constraints are Namangan's vocational and higher tiers, Kokand's preschool tier, and nearly all tiers in Margilan. Second, because every city's profile exhibits pronounced internal imbalance, targeted correction of specific weak levels is relevant to leaders and laggards alike. Third, for Margilan the policy choice is now explicit: either build internal capacity to counter the shadow effect, or deliberately organise borrowing within the Fergana–Margilan functional region, for instance through improved accessibility and cross-jurisdictional enrolment arrangements. While the feasibility of these instruments requires further analysis, the necessity of planning at the scale of the functional region rather than the municipal boundary follows directly from the supply-density results read through the borrowed size framework.

5.5. Limitations and future research

This study's limitations define the agenda for future research. First, the index measures relative institutional supply density within a five-city peer group. The resulting scores therefore represent relative positions rather than absolute levels, and the small number of observations makes the scale sensitive to individual values. Although the weighting, leave-one-out, and alternative-normalisation analyses demonstrate that the ranking is robust, they cannot eliminate this limitation. Second, institutional counts do not capture capacity, enrolment, educational quality, or accessibility in terms of travel time. Consequently, the borrowing hypothesis advanced in the discussion cannot be tested with the present data. Third, the analysis is cross-sectional, whereas evidence from Finland suggests that agglomeration shadow dynamics evolve over decades.

Future research should therefore extend the framework in several directions. The first priority is to incorporate measures of institutional capacity and enrolment. This should be followed by an accessibility layer based on travel-time measurement within the functional region, allowing direct assessment of whether Margilan's supply deficit is compensated by borrowed access. Additional extensions include a subjective satisfaction layer derived from resident surveys, a longitudinal analysis to determine whether the observed disparities are widening or narrowing over time, and application of the framework to its remaining criteria and to other economic regions of Uzbekistan.

6. Conclusion

This study set out to construct a level-decomposed index of institutional educational supply density for the five major cities of the Fergana economic region, measure inter-city disparity by level of education, and test the robustness of the resulting ranking. All three objectives were achieved.

The contribution is deliberately bounded. Methodologically, the study develops a transparent and replicable supply-density index that separates institutional provision from city size and demonstrates that composite scores should be decomposed by service level before they can effectively inform policy. Substantively, it shows that territorial disparity is concentrated at the discretionary ends of the educational ladder and that the borrowed size framework, originally developed to explain the economic performance of Western urban systems, provides a productive interpretive lens for educational provision in a Central Asian urban system.

For regional policy, the findings replace a single overall ranking with a differentiated picture of level-specific deficits and frame the choice facing shadowed cities as one between expanding local capacity and improving access within the functional region. The next step is to incorporate an accessibility layer based on travel-time measurement to test directly whether proximity compensates for the supply deficits identified by the index. More broadly, because it relies only on institutional counts and population data, the approach offers a readily transferable template for evidence-based assessment of public service provision in other domains and other data-scarce urban systems, where the demand for policy-relevant spatial measurement currently outruns the supply of fine-grained data.

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Research involving Human Participants and/or Animals

This research did not involve human participants and/or animals.

Informed consent

Informed consent was not required for this study. Therefore, this section is not applicable.

Data availability statements

The author(s) confirm(s) that all data generated or analyzed during this study are included in this manuscript.

References

Alonso, W. (1973). Urban zero population growth. *Daedalus, 102*(4), 191–206.

Bahadir, B., & Aktaş, N. (2023). Evaluating the urban quality of life: A study in an urban residential environment in Istanbul, Türkiye. *Forestist, 73*(3), 285–296. https://doi.org/10.5152/forestist.2023.22056

Boboev, O., & Davlatov, B. Sh. (2024). Ways of solving the transport problems of Dushanbe city. *Financial and Economic Bulletin, 4*(43), 53–62. (In Russian)

Burger, M. J., Meijers, E. J., Hoogerbrugge, M. M., & Masip Tresserra, J. (2015). Borrowed size, agglomeration shadows and cultural amenities in North-West Europe. *European Planning Studies, 23*(6), 1090–1109. https://doi.org/10.1080/09654313.2014.905002

Chen, L., Wang, X., Hao, Y., Yin, J., & Chen, D. (2024). Population agglomeration, borrowed size and urban economic growth in China. *Cities, 155*, Article 105491. https://doi.org/10.1016/j.cities.2024.105491

Chen, W., Yi, L., Wan, J., Zhang, J., & Jiang, Y. (2023). Evaluation of the livability of arid urban environments under global warming: A multi-parameter approach. *Sustainable Cities and Society, 99*, Article 104931. https://doi.org/10.1016/j.scs.2023.104931

Christaller, W. (1966). *Central places in southern Germany* (C. W. Baskin, Trans.). Prentice-Hall. (Original work published 1933)

D'Souza, N., Carroll-Scott, A., Bilal, U., Headen, I. E., Reis, R., & Martinez-Donate, A. (2023). Investigating the measurement properties of livability: A scoping review. *Cities & Health, 7*(5), 839–853. https://doi.org/10.1080/23748834.2023.2202894

European Commission. (2023). *Report on the quality of life in European cities, 2023*. Publications Office of the European Union. https://doi.org/10.2776/830208

Giles-Corti, B., Lowe, M., Saghapour, T., Rozek, J., Turrell, G., Roberts, R., Gunn, L., Hooper, P., Both, A., Butt, A., & Higgs, C. (2022). Spatial and socioeconomic inequities in liveability in Australia's 21 largest cities: Does city size matter? *Health & Place, 78*, Article 102899. https://doi.org/10.1016/j.healthplace.2022.102899

Gonzalez, N., Stafford, L., McPhail, S. M., Mohammed Selim, S., Kularatna, S., & Malatzky, C. (2024). Disability, equity, and measurements of livability: A scoping review. *Disability and Health Journal, 17*, Article 101521. https://doi.org/10.1016/j.dhjo.2023.101521

Hamidullah, N. (2025). Political instability and the treadmill of production: Sustainable urban processes in Kabul city. *Sustainable Processes Connect*. https://doi.org/10.69709/SusProc.2025.149300

Higgs, C., Alderton, A., Rozek, J., Adlakha, D., Badland, H., Boeing, G., Both, A., Cerin, E., Chandrabose, M., De Gruyter, C., De Livera, A., Gunn, L., Hinckson, E., Liu, S., Mavoa, S., Sallis, J. F., Simons, K., & Giles-Corti, B. (2022). Policy-relevant spatial indicators of urban liveability and sustainability: Scaling from local to global. *Urban Policy and Research, 40*(4), 321–334. https://doi.org/10.1080/08111146.2022.2076215

Institute for Macroeconomic and Regional Studies. (2023). *Key performance indicators*. IMRS. (In Uzbek)

Li, Z., Zhao, Z., & Zhang, T. (2024). Livability evaluation of urban environment based on Google Earth Engine and multi-source data: A case study of Kunming, China. *Ecological Indicators, 169*, Article 112968. https://doi.org/10.1016/j.ecolind.2024.112968

McArthur, J., & Robin, E. (2019). Victims of their own (definition of) success: Urban discourse and expert knowledge production in the Liveable City. *Urban Studies, 56*(9), 1711–1728. https://doi.org/10.1177/0042098018804759

Meijers, E. J., & Burger, M. J. (2017). Stretching the concept of 'borrowed size'. *Urban Studies, 54*(1), 269–291. https://doi.org/10.1177/0042098015597642

Meijers, E., & Burger, M. (2022). Small and medium-sized towns: Out of the dark agglomeration shadows and into the bright city lights? In H. Mayer & M. Lazzeroni (Eds.), *A research agenda for small and medium-sized towns* (pp. 23–38). Edward Elgar Publishing. https://doi.org/10.4337/9781800887121.00007

Momosheva, G., Nizamiev, A., Artykbaeva, S., & Daovlatova, F. (2024). Greening development prospects of urban settlements in Kyrgyzstan. *E3S Web of Conferences, 537*, Article 06002. https://doi.org/10.1051/e3sconf/202453706002

National Statistics Committee of the Republic of Uzbekistan. (2025). *Statistical collection: Socio-economic development of the Republic of Uzbekistan in 2025*. https://stat.uz.

O'z DSt ISO 37120:2023. (2023). *Sustainable development of communities: Method for determining the liveability index of the urban environment*. Research Institute for Technical Rationing and Standardisation in Construction. (In Uzbek)

Partridge, M. D., Rickman, D. S., Ali, K., & Olfert, M. R. (2009). Do New Economic Geography agglomeration shadows underlie current population dynamics across the urban hierarchy? *Papers in Regional Science, 88*(2), 445–467. https://doi.org/10.1111/j.1435-5957.2008.00211.x

Polyakova, E. Yu., Lyakhova, N. I., & Novikova, O. A. (2021). Methodology for assessing the quality and comfort of the urban environment. *Bulletin of the Altai Academy of Economics and Law, 11*, 303–308. (In Russian)

President of the Republic of Uzbekistan. (2026). *Decree No. PF-21 on additional measures for the consistent continuation of reforms within the priority directions of the country's development until 2030*. https://lex.uz/ru/docs/-8050769 (In Uzbek)

Saenko, I. A., Dmitrieva, N. O., & Korotkova, S. A. (2021). Justification of the need to improve the system of indicators for assessing the quality of the urban environment with regard to the provision of the population with general education facilities: The example of Sevastopol. *Moscow Economic Journal, 6*, 74–82. https://doi.org/10.24412/2413-046X-2021-10361 (In Russian)

Salimova, Y. I. (2025). *Activation of urbanisation processes in Uzbekistan* Doctoral dissertation. Tashkent. (In Uzbek)

Sidorov, V. P. (2018). Features of assessing the comfort of the urban environment. In *Spatial organisation of society: Theory, methodology, practice* (pp. 82–86). Perm State National Research University. (In Russian)

Sidorov, V. P., Sitnikov, P. Yu., & Rubtsov, V. A. (2019). Assessment of the comfort of the urban environment: The example of Izhevsk. *Bulletin of Udmurt University: Series Biology, Earth Sciences, 30*(2), 244–254. (In Russian)

Tervo, H. (2010). Cities, hinterlands and agglomeration shadows: Spatial developments in Finland during 1880–2004. *Explorations in Economic History, 47*(4), 476–486. https://doi.org/10.1016/j.eeh.2010.05.002

Turdimambetov, I., Murgaš, F., Fedorko, V., Oteuliev, M., Madreimov, A., Shamuratova, G., Atabayev, S., & Reymov, A. (2024). Measurement of environmental indicators of the quality of life in a region with extreme climatic conditions: Evidence from around the Aral Sea. *GeoJournal of Tourism and Geosites, 57*(4spl), 1941–1951. https://doi.org/10.30892/gtg.574spl08-1361

UN-Habitat. (2004). *Urban indicators guidelines: Monitoring the Habitat Agenda and the Millennium Development Goals*. United Nations Human Settlements Programme.

Xiao, Y., Chai, J., Wang, R., & Huang, H. (2022). Assessment and key factors of urban liveability in underdeveloped regions: A case study of the Loess Plateau, China. *Sustainable Cities and Society, 79*, Article 103674. https://doi.org/10.1016/j.scs.2022.103674

Zhalehdoost, A., & Taleai, M. (2025). Enhancing urban quality of life evaluation using spatial multi criteria analysis. *Scientific Reports, 15*, Article 22048. https://doi.org/10.1038/s41598-025-05468-1

Table S1. Structure of the liveability indicator framework: criteria, indicators and subindicators

Criterion	Indicator	No.	Subindicator	Unit	Reference standard	Data source
I. Social environment	**I.1 Education**	1	Number of preschool education institutions	count	UN-Habitat	Statistics
		2	Number of general secondary institutions, including specialised schools and organisations providing supplementary education for children	count	UN-Habitat	Statistics
		3	Number of vocational education institutions	count	OECD	Statistics
		4	Number of higher education institutions, including branches of foreign universities	count	EIU	Statistics
		5	Travel time to educational institutions	h:min	UN-Habitat	Online mapping services
	I.2 Healthcare	6	Number of physicians	per 10,000 residents	UN-Habitat	Statistics
		7	Hospital beds	per 10,000 residents	OECD	Statistics
		8	Travel time to medical institutions	h:min	WHO	Online mapping services
		9	Emergency medical response time	h:min	WHO	Online mapping services
		10	Share of pharmacies operating 24 hours	%	WHO	GIS
		11	Share of inclusive social infrastructure facilities	%	WHO	Statistics
		12	Life expectancy	years	UN-Habitat	Statistics
II. Economic activity	**II.1 Employment**	13	Formal employment share	%	ILO	Statistics
		14	Informal employment share	%	ILO	Statistics
		15	Employment in the service sector	%	OECD	Statistics
		16	Commuting time to work	h:min	EIU	GIS
	II.2 Migration	17	Migration balance relative to population	‰	EIU	Statistics
	II.3 Business activity	18	Business entities	per 10,000 residents	UN-Habitat	Statistics

		19	Share of the service sector in the urban economy	%	World Bank	Statistics
	II.4 Investment	20	Investment per capita	USD	World Bank	Statistics
	II.5 Income	21	Average monthly income per capita	UZS	World Bank	Statistics
		22	Ratio of monthly income to expenditure	ratio	World Bank	Statistics
III. Stability and safety	**III.1 Housing**	23	Housing floor area	m²/person	DOM.RF	Statistics
	III.2 Utility networks	24	Population with continuous access to drinking water	%	DOM.RF	Statistics
		25	Population connected to gas supply	%	World Bank	Statistics
		26	Average duration of electricity interruptions	h:min	DOM.RF	Statistics
	III.3 Transport	27	Paved roads in the urban street network	%	DOM.RF	Survey
		28	Population using public transport	%	EIU	Statistics
		29	Traffic congestion duration	h:min	DOM.RF	GIS
		30	Road traffic accidents	per 10,000 residents	DOM.RF	Statistics
	III.4 Safety	31	Recorded crimes	per 10,000 residents	National statistics	Statistics
IV. Cultural and ecological environment	**IV.1 Ecology**	32	$PM_{2.5}$ concentration	µg/m³	ISO 37120	GIS
		33	Green space per capita	m²/person	ISO 37120	GIS
		34	Environmental noise level	dBA	ISO 1996-2	Survey
	IV.2 Culture	35	Population using cultural facilities	%	OECD	Survey
		36	Number of cultural institutions	count	UN-Habitat	Statistics
V. Digital governance and services	**V.1 Digital infrastructure**	37	Internet coverage	%	ISO 37120	Statistics
		38	Use of digital public services	%	UN-Habitat	Statistics
	V.2 Governance	39	Citizen participation in local governance	%	UN-Habitat	Survey
		40	Satisfaction with public services	%	UN-Habitat	Survey

Note: Compiled by the author(s). The complete framework comprises five criteria, fifteen indicators, and forty subindicators. Criterion weights in the broader framework are proportional to the number of subindicators under each criterion but are not applied in the present study. Only Subindicators 1–4

(Education) are operationalised in this study; the remaining indicators define the broader liveability framework and are presented for completeness.