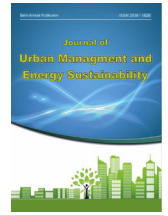


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A Participatory Framework for Land Re-Adjustment in Inefficient Urban Fabrics: A Fuzzy-Delphi Approach to Physical Development Modelling (Case Study: Eastern Zone of Zanjan City)**

Akbar Norouzi, Daryoush Ardalan*, Seyed Mohammadreza Khatibi

Department of Urban Planning, Qa.C., Islamic Azad University, Qazvin, Iran

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ABSTRACT

Inefficient urban fabrics, characterised by structural decay, fragmented land tenure, inadequate infrastructure, and socio-economic marginalisation, represent one of the most pressing urban governance challenges of the twenty-first century. In Iran, more than 166,000 hectares of urban land equivalent to 23 per cent of the national urban area are classified as Inefficient, rendering conventional, top-down redevelopment strategies both financially unsustainable and institutionally inadequate. This study proposes an operational model for land re-adjustment within Inefficient urban fabrics in eastern zone of Zanjan city, grounded in the principles of physical development and validated through a participatory Fuzzy Delphi Method. The research adopts an analytical-applied design; data were gathered through documentary and library methods and assessed qualitatively. Drawing on a systematic review of theoretical layers, twenty-one initial factors were extracted and subjected to four sequential Fuzzy Delphi rounds with a fifteen-member expert panel. Successive rounds applied escalating consensus thresholds (2.5, 3.0, 3.5, and 4.0 on a five-point Likert scale), reducing the factor set from 21 to 18, 15, 13, and finally confirming 13 indicators as the proposed model. Consensus was verified by Kendall's coefficient of concordance, which reached 0.792 in the final round. Findings indicate that spatial organisation, urban fabric connectivity, street permeability, and ownership rate exert the highest influence on the proposed LRA model. The study concludes that the integration of physical development principles with participatory land management instruments constitutes a strategically viable path toward sustainable urban regeneration in Iranian mid-size cities.

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*Corresponding Author:

Email: Daryoush.ardalan@iau.ac.ir

Phone: +982833665276

ORCID: <https://orcid.org/0000-0002-7705-0108>

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INTRODUCTION

The accelerating and uneven pace of urbanisation, particularly in developing countries, has become one of the defining characteristics of the twenty-first century. According to the latest United Nations projections, the global urban population share is expected to reach 68 per cent by 2050, with approximately 70 per cent of this growth concentrated in the developing regions of Asia and Africa (United Nations, 2022). While urbanisation can serve as an engine of economic development, its unmanaged expression in the absence of integrated land governance and anticipatory planning consistently produces expansive zones known as Inefficient urban fabrics. These zones, variously termed deteriorated, historical, peripheral, or informal settlements, are not only deprived of basic services and infrastructure but have become epicentres of vulnerability to natural and anthropogenic hazards, social instability, and resource misallocation (Tavakoli & Marzbali, 2021; World Bank, 2021). In Iran, this challenge has reached nationally critical dimensions. Official statistics indicate that over 166,000 hectares, equivalent to 23 per cent of total urban land in the country, are currently classified as Inefficient. This comprises approximately 70,000 hectares of mid-centre deteriorated fabric, 60,000 hectares of informal settlements, 32,686 hectares of historic fabric, and 500 hectares of former rural settlement fabric incorporated into urban boundaries (Urban Regeneration Company of Iran, 2022). These figures underscore the depth of a challenge that cannot be resolved through purely physical-engineering solutions. Recurring failures of past renewal interventions suggest that measures lacking a comprehensive perspective one that simultaneously addresses social, economic, and environmental dimensions tend to exacerbate existing problems rather than resolve them. A notable manifestation of this failure is the phenomenon of gentrification and involuntary displacement of original residents, which severs deep-rooted social ties and generates new

forms of marginalisation (Agahmanesh, 2019). Addressing this systemic challenge requires a rethinking of the instruments of urban intervention. The concept of physical development, understood not merely as spatial restructuring but as the coordinated improvement of physical indicators including street accessibility, density, land use mix, and infrastructure quality in alignment with social cohesion, economic viability, and environmental resilience, provides a comprehensive conceptual framework for intervention (Amiri, 2023; Khoshnodbakht et al., 2024). The instrument of land re-adjustment (LRA) emerges as a particularly well-suited operational mechanism for translating physical development objectives into actionable and equitable outcomes in the context of fragmented urban land ownership (Sorensen, 2000; Turk, 2008; Bai et al., 2020). By pooling small and irregularly shaped private parcels, redesigning street and public space networks, and redistributing the enhanced plots proportionally to original owners, LRA can simultaneously overcome the structural barriers of micro-ownership, generate public infrastructure without full state expenditure, and prevent the involuntary displacement associated with compulsory acquisition (Heidari, 2019; UN-Habitat, 2019).

Despite substantial theoretical attention to both physical development and LRA in the domestic and international literature, the operational linkage and contextual adaptation of these two concepts for the specific conditions of Iranian cities, particularly medium-sized cities, has been significantly neglected. Existing domestic studies have either focused narrowly on the technical feasibility of LRA in a specific area, such as Ansarimanesh, 2017 for Sanandaj or Delbar Azhdari, 2016 for Shiraz, or have confined themselves to analysing existing conditions with a sustainability focus, as in Sepahian et al., 2021 for Zahedan or Maroufnejad, 2021 for Ahvaz. International experiences, meanwhile, are not directly replicable due to fundamental differences in land tenure systems, municipal

fiscal capacity, and civic participation levels Wu et al., 2022. The present study therefore aims to address this research gap by developing a validated, participatory model for LRA in Inefficient urban fabrics from a physical development perspective, utilising the Fuzzy Delphi Method as a tool for expert consensus-building.

Theoretical Background and Literature Review

The concept of Inefficient urban fabric has been theorised across a range of disciplinary traditions. Urban geographers and planners have conceptualised such areas as the spatial product of intersecting market failures, governance deficits, and social inequalities (Lotfi & Ghazaie, 2019; Tavakoli & Marzbali, 2021). From a governance perspective, the World Bank, 2021 has emphasised that urban dysfunction is frequently the product of misaligned land allocation policies, weak value-capture taxation systems, and inadequate public service delivery. Couch, Sykes, and Borstinghaus, 2011 document three decades of divergent regeneration trajectories in Britain, Germany, and France, demonstrating the decisive role of contextual political economies and path dependencies in shaping outcomes. Roberts, Sykes, and Granger, 2017 provide a comprehensive framework for understanding urban regeneration as a process that must integrate physical, social, economic, and environmental renewal simultaneously, a principle reinforced by the extensive evidence base assembled in Ramezani et al. 2025 and Rasoolnazi et al. 2022.

The theoretical foundations of land re-adjustment trace their origins to nineteenth-century German land consolidation practice (Umliegung) and Japanese land readjustment legislation, which provided the institutional template for contemporary applications (Sorensen, 2000). Turk, 2008 provides a systematic examination of LRA applicability across diverse national contexts, identifying property rights regimes, administrative capacity, and stakeholder trust as the three critical enabling conditions. Bai et al. 2020 analyse the evolution of policy

frameworks governing inefficient urban land readjustment in China, demonstrating the importance of institutional learning and adaptive governance. UN-Habitat, 2019 operationalises the LRA concept within the global sustainable urbanisation agenda, providing a practical guide that has informed interventions in over forty countries. Ahad Nezhad Reveshty et al. 2024 adapt remote sensing-assisted identification of Inefficient fabric conditions to the Iranian urban context, providing the methodological basis for objective condition mapping prior to LRA intervention.

Physical development as an analytical and prescriptive concept for urban form has received renewed theoretical attention in the context of climate resilience and sustainable urbanism. Tian, Wang, and Hao, 2025 introduce a grid-based methodology for characterising and planning fractured urban textures, directly informing the spatial organisation indicators employed in this study. Yang et al. 2024 advance percolation theory as a tool for urban texture identification and connectivity analysis, offering quantitative support for the street permeability and fabric connectivity indicators that emerge as highest-weighted in this study's Delphi results. Naghibi, 2024 reconceptualises small vacant lands as critical nodes in urban resilience systems, reinforcing the theoretical case for green space access as a model indicator. Ghouchani et al. 2023 assess contextual element efficiency in reducing vulnerability of historic fabrics, providing validation for the structural compactness and building density indicators. The Fuzzy Delphi Method was selected as the consensus-building instrument in accordance with its established applicability in multi-stakeholder urban planning contexts where uncertainty and value plurality preclude purely technical optimisation. The FDM integrates fuzzy set theory with the iterative expert consultation structure of the conventional Delphi method, enabling more nuanced representation of expert judgement than binary scoring allows Hsu, Lee, & Kreng, 2010.

MATERIALS AND METHODS

Characteristics of inefficient urban fabric

The theoretical framework for factor extraction combined three conceptual layers: (1) the physical development model, with dimensions of urban form, infrastructure, transport, density, green space, housing, and urban services; (2) the LRA mechanism, with attention to spatial reorganisation, community participation, and

value redistribution; and (3) the specific contextual conditions of Iranian Inefficient urban fabrics. The convergence of these layers yielded twenty-one candidate factors distributed across seven criteria, as presented in Table 3. Tables 1 and 2 below summarise the theoretical characterisation of Inefficient urban fabrics and the applicable LRA principles respectively. (Tab. 1)

Table 1: Nature and characteristics of Inefficient urban fabrics (source: authors)

Analytical Dimension	Key Characteristics	Associated Consequences and Challenges	Sources
Physical-Spatial	Structural instability (low-resistance building materials); Micro-plot size (< 200 m ²); Street network impermeability (width < 6 m); Severe facade and infrastructure deterioration; High building density and compact blocks; Severe deficit of public, green, and parking space	Extremely high seismic and multi-hazard vulnerability; Blockage of renewal due to micro-ownership; Disruption of emergency access and service delivery; Visual and environmental quality degradation; Formation of urban heat islands; Inability to develop new infrastructure networks	Babaei-Aghdam et al., 2016; Sarvar, 2019; Ahad Nezhad Reveshty et al., 2024; Fathi et al., 2021; Ghouchani et al., 2023
Socio-Economic	Predominance of low-income and socially marginalised residents; Low social capital and institutional trust; High unemployment or informal-sector employment; Resistance to renewal schemes; High risk of gentrification and involuntary displacement; Weak local economy; Absence or weakness of local civil society	Perpetuation and intensification of local poverty cycles; Difficulty in mobilising genuine resident participation; Increase of spatial inequality and urban polarisation; Failure of single-dimensional renewal projects; Loss of social capital and place identity; Reduction of property values and private investment disincen-tive	Agahmanesh, 2019; Maroufnejad, 2021; Lotfi & Ghazaie, 2019; Rasoolnazi et al., 2022; Samimian et al., 2024; Salehi et al., 2019
Environmental	Location within high-hazard zones (fault lines, flood plains); Air, soil, and water contamination from inadequate waste and wastewater management; Deficiency of green cover and public green space; Energy inefficiency due to building deterioration; Noise pollution from density and narrow streets	Elevated risk of natural hazard escalation to human catastrophe; Threat to physical and mental health of residents; Reduction of urban resilience at the macro scale; Increase of healthcare costs; Higher greenhouse gas emissions and environmental unsustainability	Ghouchani et al., 2023; Fathi et al., 2021; Ramezani et al., 2025

Managerial-Legal	Complexity and multiplicity of ownership titles (inheritance-based); Absence or weakness of transparent legal framework for participatory interventions; Misalignment between responsible agencies; Weakness of taxation system and inability to capture development value; Risk of corruption and rent-seeking in acquisition and transfer processes	Prolonged legal and administrative processes; Increase in transaction costs and stakeholder distrust; Failure of integrated planning schemes; Loss of investment opportunities; Failure to deliver spatial justice and equitable benefit distribution	Ziaabadi & Afrouz, 2024; Heidari, 2019; World Bank, 2021; Ziyari & Saeidi Chakan, 2025
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The concept of land readjustment and its importance in urban intervention

The tool of “land readjustment and readjustment” as one of the key and participatory mechanisms in urban development management and renovation of inefficient textures has received a lot of attention in recent decades. This tool is an operational response to one of the biggest obstacles to renovation, namely “small, scattered and irregular land ownership”, and with a voluntary and cooperative approach, seeks to create a balance between public and private interests in the urban development process (Heidari, 2014; Bai et al., 2020). After implementing infrastructure plans and allocating a portion of the consolidated lands to roads, public spaces and urban services, the remaining lands, which have been optimized in terms of shape, size and accessibility, are redistributed among the origi-

nal owners, in proportion to their previous land value (Heidari, 2014; Mohammadi, Moradi and Ghadei Kalashmi, 2015). In the face of the complexities and obstacles to the renovation of dilapidated urban areas, the tool of land readjustment emerges not as an option but as a strategic necessity. The importance of this tool lies in its ability to provide an operational, equitable, and sustainable response to the most fundamental problems of these areas. On a national scale, given the 166,000 hectares of inefficient urban areas, methods that rely solely on compulsory acquisition and government capital are neither cost-effective nor scalable (Iranian Urban Regeneration Company, 1401; World Bank, 2021). Therefore, the characteristics of applying land readjustment principles in inefficient urban areas can be presented in the table below. (Tab. 2)

Table 2: Application of land re-adjustment principles in Inefficient urban fabric intervention (source: authors)

Dimension of Impact	Key LRA Mechanism/Characteristic	Expected Benefits in Inefficient Fabric	Sources
Physical-Spatial	Consolidation of micro-parcels; Integrated design of street and public space networks; Allocation of land for urban services from all owners' shares	Removal of the primary barrier to renewal (micro-ownership); Creation of standard, safe access for emergency services; Equitable provision of green space and public services; Enabling of resilient, modern construction; Improvement of fabric permeability and connectivity	Babaei-Aghdam et al., 2016; Heidari, 2019; Ahad Nezhad Reveshty et al., 2024

Economic-Financial	Generation of added value for owners' remaining plots; Reduction of large-scale state budget requirements for acquisition; Option to sell a portion of public land to offset infrastructure cost	Stimulation of private investment in renewal; Reduction of financial burden on municipality and government; Increase of total area value and tax base; Creation of financial incentive for owner participation; More equitable distribution of value-added between city and owners	Agabedi, 2019; Bai et al., 2020; World Bank, 2021; Sorensen, 2000
Social	Voluntary and consent-based participation of owners; Prevention of involuntary displacement and preservation of local community; Transparency in land calculations and redistribution	Strengthening of social capital and institutional trust; Prevention of destructive gentrification and exclusion of low-income residents; Increase of place attachment and sense of ownership; Reduction of resistance and conflict in renewal process; Long-term social sustainability of the neighbourhood	Agahmanesh, 2019; Samimian et al., 2024; Rasoolnazi et al., 2022; Salehi et al., 2019
Environmental and Resilience	Possibility of creating sustainable infrastructure networks (water, wastewater, energy); Allocation of adequate space for urban flood management; Creation of continuous green space and urban heat island mitigation	Enhancement of physical resilience against earthquakes and other hazards; Improvement of air quality and local environment; Sustainable management of water and energy resources; Increase of green space per capita and improvement of public health	Fathi et al., 2021; Ghouchani et al., 2023; Ramezani et al., 2025
Institutional-Legal	Provision of a transparent and legal framework for participation; Reduction of legal complexities from compulsory acquisitions; Creation of a participatory management committee	Acceleration of executive processes and reduction of legal disputes; Strengthening of urban governance and institutional accountability; Increase of transparency and reduction of corruption risk; Creation of a replicable and localisable model for other areas	Ziaabadi & Afrouz, 2024; Ziyari & Saeidi Chakan, 2025; Moradi, 2021

Physical development in inefficient urban textures according to the open land adjustment model

Understanding the concept of “physical development” requires understanding the semantic evolution of the keyword “development”. In the classical and conventional view that prevailed until the middle decades of the twentieth century, development was mainly considered equivalent to “economic growth” measured by indicators such as gross domestic product. In this view, linear progress and increasing material wealth were considered the ultimate goal (Tian et al, 2025). Sustainable development in the face of inefficient urban fabric requires moving beyond purely physical and project-oriented

renovation approaches and moving towards “sustainable and integrated urban regeneration”. This approach pursues physical improvement alongside strengthening social capital (preserving local communities, participation), economic mobilization (creating job opportunities, supporting the local economy) and environmental restoration (improving water, air, soil quality, increasing resilience) as equivalent and simultaneous goals (Ziari and Saeedi-Chakan, 1404; Rasoolnazi et al., 2022). Here, the land readjustment tool acts as a key implementation mechanism for achieving sustainable development goals in inefficient contexts. This tool is aligned with sustainability in two ways: first, from a physical and environmental perspective,

by organizing smallholdings and creating the necessary space for passages, green spaces, and sustainable water and wastewater networks, it directly contributes to improving safety, accessibility, environmental health, and physical resilience (Heidari, 2014; Fathi et al., 2019). Second, from a socio-economic perspective, by designing a participatory mechanism based on land capital, it can prevent forced displacement of residents (social sustainability) and distribute

the added value created in a way that creates the motivation and financial capacity for renovation within the local community itself (economic sustainability) (Aghamanesh, 2019; Bai et al., 2020). Therefore, at a glance, this type of physical development can be presented in multiple criteria, according to the principles of land readjustment, and each criterion obviously includes factors affecting the concept: (Tab. 3)

Table 3: Criteria-factor matrix for physical development in Inefficient urban fabric with reference to land re-adjustment patterns (source: authors)

Concept	Criterion	Factor	Sources
Physical sustainability	Urban form	Spatial organisation	Khoshnodbakht et al., 2024; Izadi & Amiri, 2016; Ahmady et al., 2024
		Land use mix	
		Urban fabric connectivity	
		Street network quality	
		Population compactness	
Urban management	Urban infrastructure	Infrastructure services quality	Ministry of Roads and Urban Development; Fathi et al., 2021; Ramezani et al., 2025
		System efficiency	
		Street lighting quality (Round 1 only)	
Urban transport	Urban accessibility	Transport node access quality	Ahad Nezhad Reveshty et al., 2024; Babaei-Aghdam et al., 2016; Yang et al., 2024
		Street permeability	
Urban density	Density	Building density	Heidari, 2019; Bai et al., 2020
		Gross population density (Rounds 1-2 only)	
Urban environment	Green and public spaces	Green space per capita (Rounds 1-2 only)	Naghibi, 2024; Shammaei & Nazarpoor Dezki, 2022
		Green space access quality	
Urban habitation	Urban housing	Housing price (excluded pre-Round 1)	Agahmanesh, 2019; Salehi et al., 2019; World Bank, 2021
		Environmental comfort level (excluded pre-Round 1)	
		Ownership rate	
Urban services	Service functions	Service land use per capita (Round 1 only)	Samimian et al., 2024; Liu et al., 2022
		Pedestrian access	
		Urban services quality (Round 1 only)	

Methodology

The present study adopts an analytical-applied research design. Given the interpretive paradigm governing the research, the foundational inquiry into core concepts, including Inefficient urban fabric, physical development, and land re-adjustment, grounds the study in a developmental research orientation. Data collection was conducted through documentary and library methods; the epistemological framework is qualitative. Following a systematic review of theoretical foundations, twenty-one initial factors were extracted and subjected to evaluation through the Fuzzy Delphi Method, employing a participatory decision-making approach within a fifteen-member expert panel over four sequential rounds in the eastern zone of Zanzan city case study. (Fig. 1) In each round, the mean score, standard deviation, and Kendall's coefficient of concordance for the round were calculated, and factors failing to meet the escalating consensus threshold were eliminated. This iterative process concluded when Kendall's coefficient reached stability and all remaining

factors exceeded the final threshold of 4.0. The expert panel was composed of fifteen specialists selected to satisfy one or more of the following criteria: (i) faculty membership in urban planning or architecture with specialisation in Inefficient urban fabrics, urban renewal, or housing; (ii) senior management or technical staff in municipal administrations, housing authorities, or urban regeneration agencies with direct operational experience; and (iii) demonstrated research output in the topic domains of the study. Anonymity among panellists was maintained throughout the Delphi process to prevent social influence bias. Open-ended questions were incorporated in early rounds to capture dimensions not represented in the initial factor set. Consensus was assessed through Kendall's coefficient of concordance (W), with a panel size exceeding ten experts, values of $W > 0.7$ were considered statistically significant. Data from closed questions were analysed using descriptive statistics, while open-ended responses underwent thematic analysis.

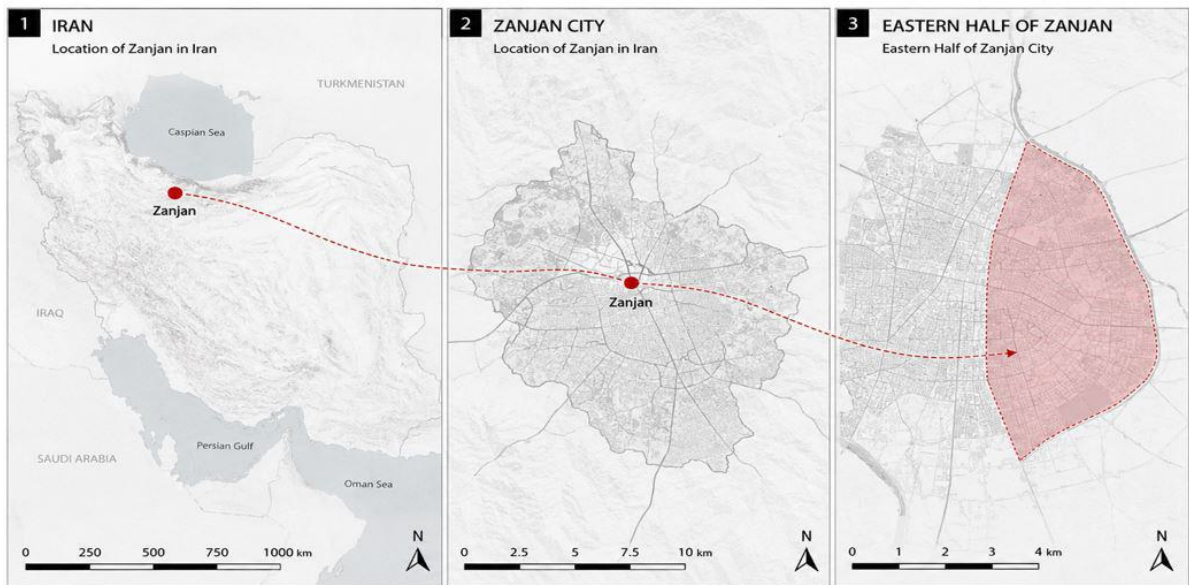


Figure 1: Location of Inefficient urban fabrics of Eastern Area (EH) in Zanzan City

DISCUSSION AND FINDINGS

The Fuzzy Delphi Method (FDM) is a structured, iterative expert consultation technique that integrates fuzzy set theory with the classic Delphi approach. The core advantage of FDM over conventional Delphi lies in its capacity to represent the inherent vagueness and subjectivity of expert judgements through triangular or trapezoidal fuzzy numbers, thereby producing more representative and statistically robust consensus outcomes. In this study, a five-point Likert scale was used for quantitative rating, and consensus was assessed through Kendall's coefficient of concordance (W) alongside standard deviation analysis across rounds. The expert panel comprised fifteen specialists with documented expertise in urban planning, urban regeneration, housing policy, and municipal management. Anonymity among panellists was maintained throughout to prevent conformity bias and group-think. The initial set of twenty-one factors, extracted from the theoretical framework in Table 3, was subjected to four sequential rounds of evaluation. In Round 1, three factors with mean scores below the threshold of

2.5 were excluded prior to formal circulation: environmental comfort level, housing price, and street network density. The remaining eighteen factors were distributed to the panel. Three further factors were removed at the end of Round 1 (mean < 2.5): service land use per capita, urban services quality, and street lighting quality, reducing the set to fifteen. In Round 2, two additional factors fell below the raised threshold of 3.0: gross population density and green space per capita, yielding thirteen factors. In Round 3, the threshold was raised to 3.5; all thirteen remaining factors exceeded this level, but two (gross population density and green space per capita, which had already been eliminated in Round 2) were confirmed absent; the thirteen factors were re-evaluated in Round 4 against a final threshold of 4.0. All thirteen achieved mean scores exceeding 4.0 in Round 4, with Kendall's W stabilising at 0.792. The expert panel unanimously accepted the thirteen factors as the validated proposed model.

Fuzzy Delphi Round 1: Initial Screening (21 to 18 Factors)

Table 4: Round 1 of the Fuzzy Delphi process: indicator scoring for the proposed LRA model in Inefficient urban fabric with physical development approach

	Factor	n	Mean	Std. Dev.	Min	Max
1	Spatial organisation	15	3.89	0.35	1	5
2	Land use mix	15	3.75	0.37	1	5
3	Urban fabric connectivity	15	3.56	0.37	1	5
4	Street network quality	15	3.45	0.45	1	5
5	Population compactness	15	3.69	0.37	1	5
6	Infrastructure services quality	15	3.02	0.40	1	5
7	System efficiency	15	2.95	0.35	1	5
8	Street lighting quality	15	2.61	0.37	1	5
9	Transport node access quality	15	3.31	0.52	1	5
10	Street permeability	15	3.52	0.67	1	5
11	Building density	15	3.36	0.52	1	5
12	Gross population density	15	3.40	0.57	1	5
13	Green space per capita	15	2.90	0.60	1	5

14	Green space access quality	15	2.96	0.58	1	5
15	Ownership rate	15	3.28	0.52	1	5
16	Service land use per capita	15	2.58	0.48	1	5
17	Pedestrian access	15	3.27	0.51	1	5
18	Urban services quality	15	2.63	0.43	1	5

Threshold for Round 1: mean > 2.5. Eliminated after Round 1: service land use per capita (2.58), urban services quality (2.63), street lighting quality (2.61).

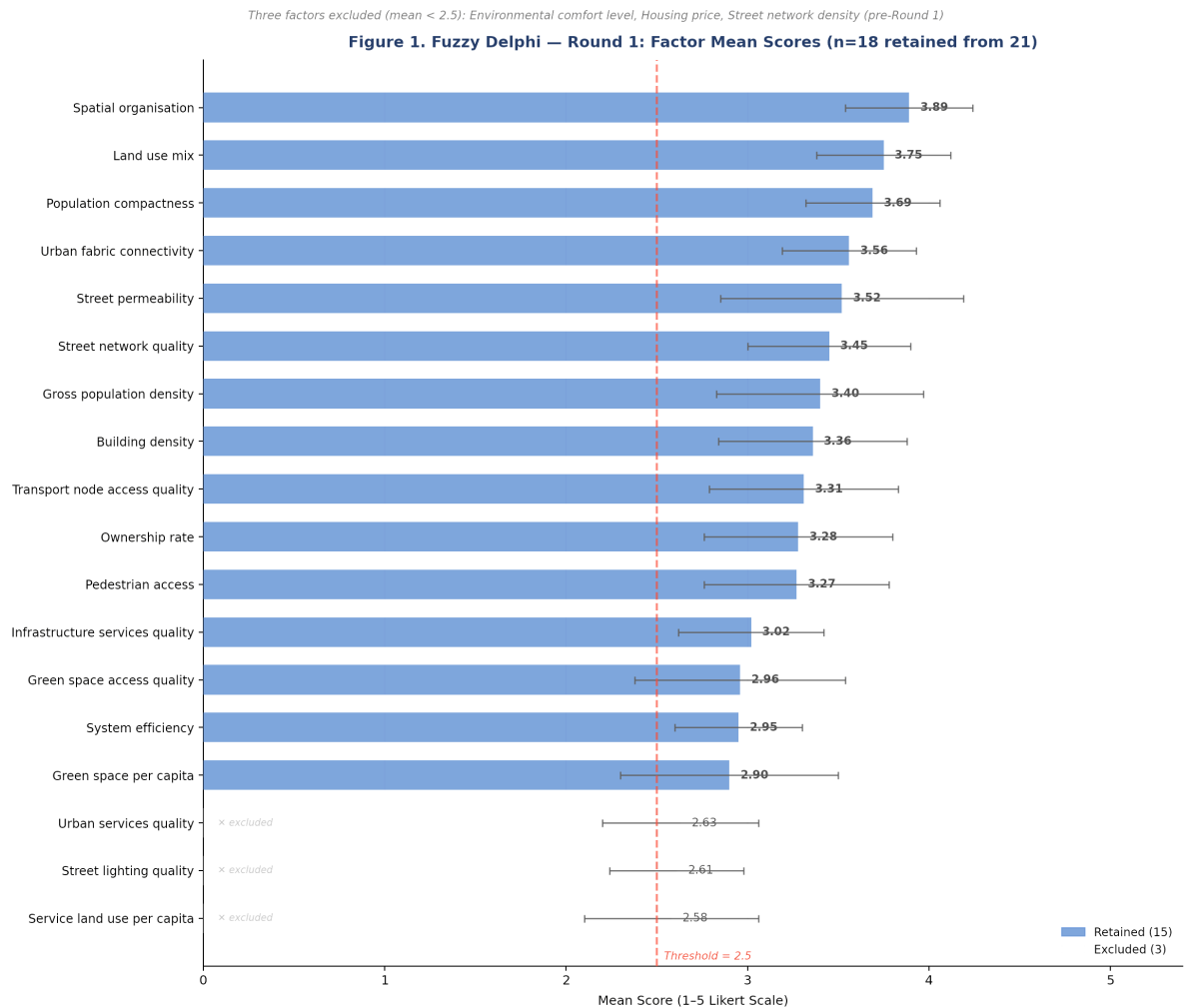


Figure 2: Fuzzy Delphi Round 1: Mean scores for 18 factors evaluated by the expert panel (n = 15). Factors falling below the Round 1 threshold (2.5) are shown as excluded. Threshold line shown in red.

Fuzzy Delphi Round 2: Second Screening (18 to 15 Factors)

Table 5: Round 2 of the Fuzzy Delphi process: indicator scoring for the proposed LRA model

	Factor	n	Mean	Std. Dev.	Min	Max
1	Spatial organisation	15	3.95	0.32	2	5
2	Land use mix	15	3.86	0.33	2	5
3	Urban fabric connectivity	15	3.66	0.35	2	5
4	Street network quality	15	3.52	0.41	2	5
5	Population compactness	15	3.70	0.29	2	5
6	Infrastructure services quality	15	3.55	0.36	2	5
7	System efficiency	15	3.12	0.37	2	5
8	Transport node access quality	15	3.89	0.44	2	5
9	Street permeability	15	3.70	0.52	2	5
10	Building density	15	3.59	0.50	2	5
11	Gross population density	15	3.20	0.42	2	5
12	Green space per capita	15	3.12	0.39	2	5
13	Green space access quality	15	3.36	0.57	2	5
14	Ownership rate	15	3.59	0.48	2	5
15	Pedestrian access	15	3.76	0.49	2	5

Kendall's W (Round 2) = 0.765. Threshold for Round 2: mean > 3.0. Eliminated after Round 2: gross population density (3.20) and green space per capita (3.12).

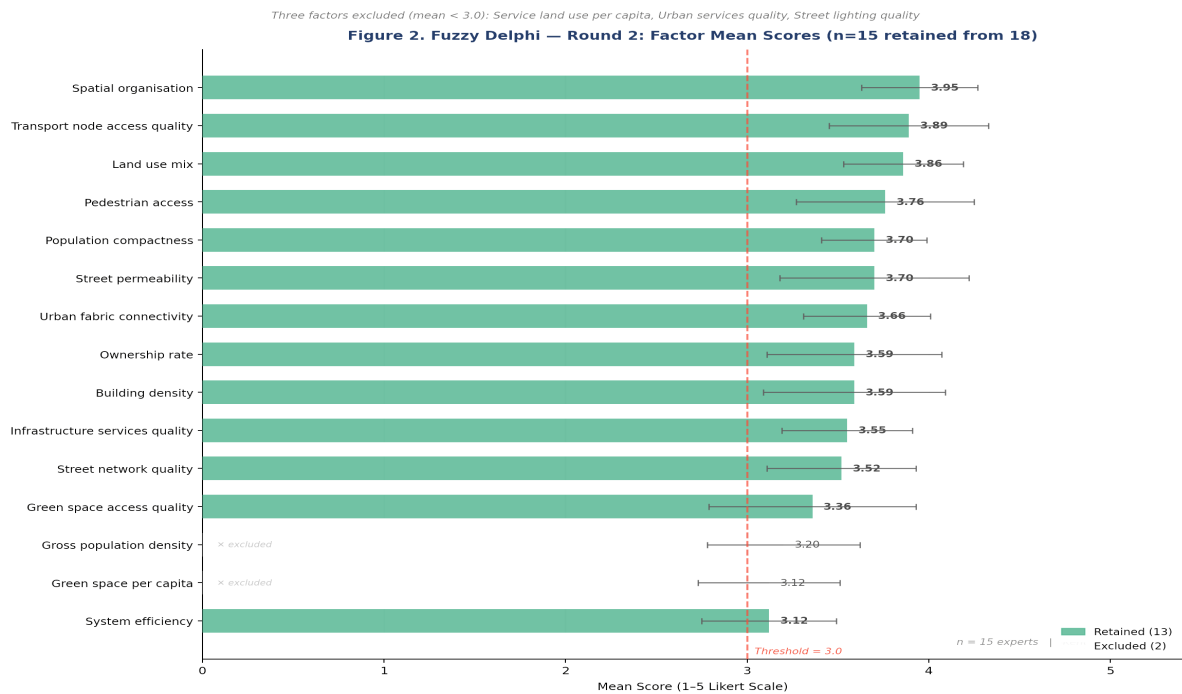


Figure 3: Fuzzy Delphi Round 2: Mean scores for 15 retained factors (n = 15 experts). Kendall's W = 0.765. Two factors eliminated (mean < 3.0) are shown in grey.

Fuzzy Delphi Round 3: Third Screening (15 to 13 Factors)

Table 6: Round 3 of the Fuzzy Delphi process: indicator scoring for the proposed LRA model

#	Factor	n	Mean	Std. Dev.	Min	Max
1	Spatial organisation	15	4.15	0.30	3	5
2	Land use mix	15	4.10	0.31	3	5
3	Urban fabric connectivity	15	4.02	0.29	3	5
4	Street network quality	15	3.85	0.36	3	5
5	Population compactness	15	3.90	0.27	3	5
6	Infrastructure services quality	15	3.76	0.32	3	5
7	System efficiency	15	3.55	0.31	3	5
8	Transport node access quality	15	4.09	0.40	3	5
9	Street permeability	15	3.95	0.45	3	5
10	Building density	15	3.66	0.46	3	5
11	Green space access quality	15	3.52	0.51	3	5
12	Ownership rate	15	3.82	0.40	3	5
13	Pedestrian access	15	3.76	0.49	3	5

Kendall's W (Round 3) = 0.790. Threshold for Round 3: mean > 3.5. All 13 factors retained; Kendall's W increased only 0.025 over Round 2, indicating stabilisation of expert consensus.

Two factors excluded (mean < 3.5): Gross population density, Green space per capita — all 13 retained factors confirmed

Figure 3. Fuzzy Delphi — Round 3: Factor Mean Scores (n=13 retained from 15)

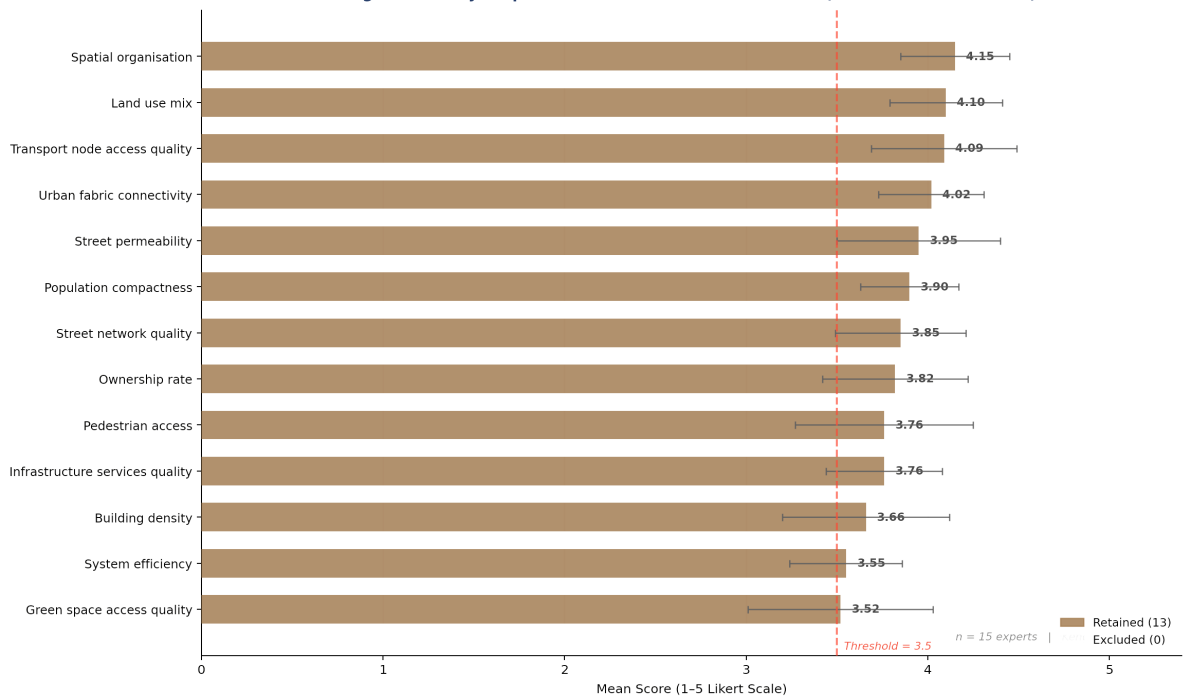


Figure 4: Fuzzy Delphi Round 3: Mean scores for 13 retained factors (n = 15 experts). Kendall's W = 0.790. All 13 factors exceeded the Round 3 threshold (3.5), confirming convergence.

Fuzzy Delphi Round 4: Final Confirmation (13 Indicators-Proposed Model)

Table 7: Round 4 of the Fuzzy Delphi process: final confirmation of 13 proposed model indicators

#	Factor	n	Mean	Std. Dev.	Min	Max
1	Spatial organisation	15	4.17	0.29	3	5
2	Land use mix	15	4.12	0.27	3	5
3	Urban fabric connectivity	15	4.15	0.19	3	5
4	Street network quality	15	4.03	0.30	3	5
5	Population compactness	15	4.09	0.22	3	5
6	Infrastructure services quality	15	4.02	0.29	3	5
7	System efficiency	15	4.16	0.23	3	5
8	Transport node access quality	15	4.12	0.35	3	5
9	Street permeability	15	4.25	0.36	3	5
10	Building density	15	4.08	0.37	3	5
11	Green space access quality	15	4.03	0.36	3	5
12	Ownership rate	15	4.25	0.26	3	5
13	Pedestrian access	15	4.17	0.32	3	5

Kendall's W (Round 4) = 0.792. All 13 factors confirmed (mean > 4.0). Incremental change in W from Round 3 to Round 4 = +0.002, confirming stable consensus. Expert consultation terminated.

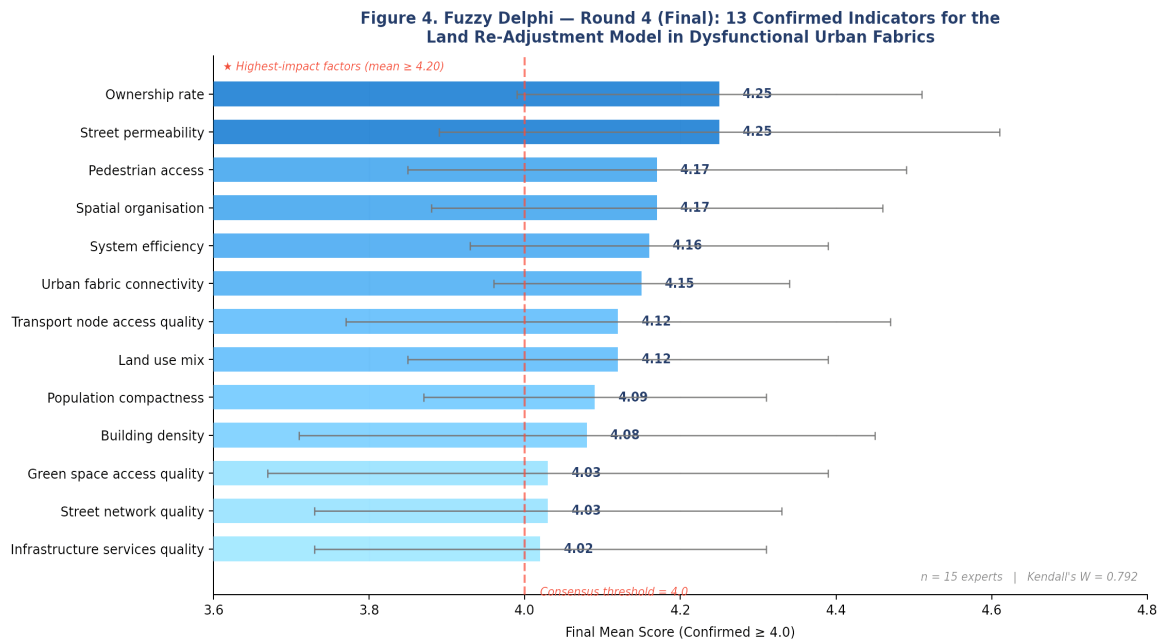


Figure 5: Fuzzy Delphi Round 4 (Final): Confirmed mean scores for the 13 proposed model indicators. Factors with mean ≥ 4.20 are marked with a star. The red dashed line indicates the final consensus threshold (4.0). Gradient shading reflects relative score magnitude.

The cessation of expert consultation after the fourth round was justified by four converging conditions. First, in Round 2, more than fifty per cent of panellists selected the retained factors as having high or very high importance, satisfying the standard FDM majority criterion. Second, the standard deviation of factor importance scores decreased substantially from Round 2 to Round 3, and again from Round 3 to Round 4, indicating progressive convergence of expert judgements. Third, Kendall's *W* increased from 0.765 in Round 2 to 0.790 in Round 3 and 0.792 in Round 4; given that the panel exceeded ten members, these values are statistically highly significant. Fourth, the marginal increase in *W* between Round 3 and Round 4 was only 0.002, indicating that further rounds would yield diminishing informational returns. The four conditions together confirm theoretical saturation and stable expert consensus.

Post-Delphi Analytical Synthesis

The convergence of the four-round Fuzzy Delphi process around thirteen confirmed indicators represents a significant methodological and substantive achievement. The reduction from twenty-one candidate factors to thirteen final indicators through iterative expert consensus embodies a progressive distillation of theoretical breadth into operational precision. Kendall's *W* progressing from 0.765 in Round 2 to 0.792 in Round 4 demonstrates that the expert community possesses a coherent and stable shared understanding of the factors most critical to land re-adjustment in Inefficient urban contexts, an outcome that carries considerable weight for policy formulation given the demonstrated track record of contested and inconsistent urban regeneration interventions in Iran Ziaabadi & Afrouz, 2024; World Bank, 2021.

Street permeability and ownership rate, both achieving the highest mean score of 4.25 in the final round, constitute the twin pillars of the proposed LRA model. This result is theoretically consistent and empirically grounded: the inability

of emergency vehicles to penetrate narrow, obstructed street networks is the primary risk amplifier in seismically active Inefficient fabrics Ahad Nezhad Reveshty et al., 2024; Ghouchani et al., 2023, while the fragmented, inheritance-derived ownership structure of these areas is the principal barrier to any coordinated spatial intervention Turk, 2008; Bai et al., 2020. The co-primacy of these two factors signals that effective LRA must be designed as a simultaneous solution to both spatial inaccessibility and ownership fragmentation a conclusion that reinforces the fundamental logic of the LRA instrument itself.

Spatial organisation (4.17) and urban fabric connectivity (4.15), both ranked among the four highest-scoring factors, reflect the centrality of morphological coherence as a prerequisite for sustainable urban regeneration. Drawing on Yang et al. 2024, who apply percolation theory to quantify the connectivity threshold beyond which a fabric becomes functionally integrated with its urban context, the present findings suggest that the design of LRA schemes must explicitly target connectivity restoration as a primary outcome rather than treating it as a secondary benefit. This is particularly salient for the eastern zone of Zanjan, where fragmented plot patterns and irregular street alignments produce a spatial structure that falls below functional connectivity thresholds.

System efficiency (4.16), ranking closely behind the top four indicators, captures the capacity of the post-intervention urban fabric to operate as an integrated service delivery system. This indicator encompasses not only the technical performance of infrastructure networks but also the operational coherence of land use patterns, service catchments, and transport connections. The expert consensus around this factor reflects the recognition that piecemeal physical improvements, addressing individual plots or street segments in isolation invariably fail to deliver the systemic improvements required for neighbourhood-scale regeneration. The LRA

mechanism, by operating at the parcel-aggregation scale, provides the minimum spatial unit necessary to achieve systemic efficiency gains Roberts, Sykes, & Granger, 2017.

Transport node access quality (4.12) and land use mix (4.12) achieved identical mean scores in the final round, together representing the interface between the renewed fabric and the wider urban system. The experts' emphasis on transport access reflects the documented pattern in Iranian Inefficient fabrics whereby disconnection from public transport networks perpetuates socio-economic marginalisation and prevents the economic revitalisation that is a necessary condition for sustainable community stabilisation Rasoolnazi et al., 2022; Wu et al., 2022. Land use mix, meanwhile, is theoretically foundational to walkable, vibrant, and economically self-sufficient neighbourhoods; its inclusion as a high-priority indicator is consistent with Jane Jacobs' foundational argument about the generative role of diversity in urban vitality, as operationalised in contemporary form by Tian et al. 2025. Population compactness (4.09) and building density (4.08) were retained as significant but secondary indicators in the final model. Their lower relative weighting compared to spatial organisation and permeability indicators suggests that the expert panel recognises density as a necessary condition for urban viability but not, in isolation, a sufficient one. This nuanced judgement is aligned with the contemporary planning literature, which consistently distinguishes between mere density (number of units per unit area) and quality density (the combination of density with accessibility, mix, and permeability that produces genuinely liveable urban environments). In the LRA model, density is therefore best understood as an outcome variable that must be optimised jointly with the higher-ranked spatial organisation and permeability indicators.

Pedestrian access (4.17) ties with spatial organisation as the third-highest-scoring factor, underscoring the expert panel's strong consen-

sus that walking connectivity is a fundamental determinant of both the social life and the economic vitality of regenerated neighbourhoods. In contexts where automobile ownership is low and public transport connectivity is inadequate, pedestrian access constitutes the primary modality of daily mobility for low-income residents. The LRA mechanism, by reconfiguring plot boundaries and reallocating land for pedestrian pathways, has a demonstrated capacity to transform previously impermeable fabric structures into walkable environments, as documented in several of the case studies reviewed by UN-Habitat 2019 and Bai et al. 2020.

Infrastructure services quality (4.02) and green space access quality (4.03), while retained as model indicators, scored marginally below the median of the final factor set. This relative positioning likely reflects the panel's recognition that infrastructure and green space, while essential components of liveable urban environments, are in Iranian Inefficient fabrics more directly constrained by fiscal capacity and right-of-way availability than by knowledge or planning intent. In other words, these outcomes are contingent on the successful resolution of the higher-priority spatial, ownership, and connectivity challenges that dominate the top of the factor hierarchy. The LRA model can directly facilitate infrastructure provision by creating the consolidated land parcels and rights-of-way that network installation requires, but its contribution to green space is more indirect, depending on the quantum of land secured through the pooling and redistribution process. The elimination of housing price, environmental comfort level, and street network density before the formal Delphi rounds reveals an important epistemological dimension of the expert consensus: the panel collectively judged these factors as either too market-contingent or too derivatively dependent on other retained factors to merit independent inclusion in an operational planning model. Housing price, in particular, is better understood as an outcome of successful LRA imple-

mentation rising as a result of improved spatial organisation, permeability, and infrastructure quality than as an input indicator. This interpretive conclusion suggests that the proposed thirteen-factor model is structured around process-enabling and design-specifying variables rather than outcome-measuring or market-signalling ones, a distinction that has important implications for how the model should be operationalised in practice. Taken as a whole, the proposed model establishes a coherent, empirically validated, and theoretically grounded instrument for guiding LRA processes in Iranian Inefficient urban fabrics. The four-cluster structure that emerges from the confirmed indicators comprising spatial form and connectivity, mobility and accessibility, density and services, and environmental quality maps directly onto the physical development framework advanced in the theoretical literature Tian et al., 2025; Yang et al., 2024; Naghibi, 2024. Future applications of the model in specific urban contexts should weight these indicators using multi-criteria decision analysis tools such as FAHP or FTOPSIS, allowing the relative priority of factors to reflect the distinctive physical and governance conditions of each target area. The case study of Eastern Zanzan, where the initial factor extraction was grounded, presents a particularly apt testing ground for this application given the availability of spatial data generated by Ahad Nezhad Reveshty et al., 2024 and the institutional engagement of the Zanzan Provincial Roads and Urban Development Authority 2022.

RESULTS AND CONCLUSION

This study set out to develop a validated, participatory model for land re-adjustment in Inefficient urban fabrics from a physical development perspective, employing the Fuzzy Delphi Method for systematic expert consensus-building. The research yields five principal results. First, the four-round FDM process, applied to a panel of fifteen domain experts with Kendall's W stabilising at 0.792, produced a final set of

thirteen validated indicators that form the proposed operational model. The progressive reduction from twenty-one initial factors through three successive elimination rounds demonstrates the discriminatory power of the FDM in identifying the core determinants of LRA effectiveness in this context. Second, street permeability (4.25) and ownership rate (4.25) emerged as the co-highest-priority indicators, confirming the dual structural diagnosis of Inefficient urban fabric: spatial inaccessibility and tenure fragmentation are the two most fundamental barriers to integrated regeneration, and any viable LRA scheme must be explicitly designed to address both simultaneously Turk, 2008; Bai et al., 2020; Heidari, 2019. Third, spatial organisation (4.17) and urban fabric connectivity (4.15) ranked among the top four factors, establishing morphological coherence and connectivity restoration as primary design objectives for LRA in the Iranian context. This finding is directly applicable to the spatial planning of the Eastern Zanzan zone, where connectivity deficits are among the most severely documented conditions Ahad Nezhad Reveshty et al., 2024.

Fourth, the decreasing standard deviations across rounds and the stability of Kendall's W between Rounds 3 and 4 (change of +0.002) confirm theoretical saturation, validating the methodological rigour of the FDM application and the reliability of the resulting model. This level of consensus is particularly significant given the acknowledged complexity and multi-stakeholder nature of urban regeneration decision-making in the Iranian institutional context Ziaabadi & Afrouz, 2024; Ziyari & Saeidi Chakan, 2025. Fifth, the analytical synthesis of post-Delphi findings reveals a structured hierarchy within the thirteen-factor model: the highest-priority cluster encompasses spatial, ownership, and connectivity variables that directly govern the feasibility of LRA implementation; the mid-priority cluster contains mobility, density, and systemic efficiency variables that determine the quality of the post-intervention urban environ-

ment; and the lower-priority cluster comprises infrastructure and green space variables whose achievement is contingent on the successful resolution of the higher-priority conditions.

The theoretical contribution of this study lies in its operationalisation of the intersection between physical development principles and LRA practice within the Iranian institutional context, filling a documented gap in both domestic urban planning scholarship and practitioner guidance. The methodological contribution lies in the systematic application of four-round FDM with statistical convergence validation to a multi-dimensional urban planning model, demonstrating the instrument's suitability for problems characterised by high stakeholder plurality and value uncertainty. The practical contribution lies in the production of a thirteen-indicator model that is directly applicable by urban planners, municipal decision-makers, and regeneration agencies to the prioritisation and design of LRA interventions in inefficient urban zones across Iranian cities.

The study is subject to certain limitations. The expert panel of fifteen members, while meeting the standard threshold for statistical significance of Kendall's W, may not capture the full diversity of expert opinion across all regional and institutional contexts in Iran. The model's validation through FDM establishes consensus but does not constitute empirical testing in a specific project context; such testing remains necessary before widespread application. Future research should apply the proposed model to multiple Iranian case studies using FAHP or FTOPSIS weighting approaches, enabling context-specific calibration of indicator priorities. Longitudinal studies monitoring the outcomes of LRA projects guided by the model would further validate its predictive utility. Comparative research examining the application of the model in different city-size categories would advance understanding of scale-dependent modifications required for effective deployment across the diverse urban landscape of Iran.

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