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Urban Fragmentation and Residential Segregation in Medium-Sized Cities: A Multidimensional Urban Territorial Index (UTI) Analysis from Spain

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Abstract

Medium-sized cities are increasingly affected by processes of urban fragmentation and residential segregation, despite having traditionally been perceived as more socially cohesive and territorially balanced than large metropolitan areas. Acting as functional connectors between metropolitan hubs and rural regions, these cities are particularly vulnerable to unplanned suburban growth, housing market polarization and uneven access to urban opportunities. This study develops and applies a multidimensional Urban Territorial Index (UTI) to diagnose socio-spatial inequality in medium-sized cities, using Ciudad Real (central Spain) and its functional urban area as a case study. The UTI integrates six indicators across three analytical dimensions—socioeconomic, sociodemographic and housing—through a PCA-informed weighting scheme and GIS-based spatial analysis. The index is calculated at census-tract and neighborhood scales and is validated through internal consistency checks, external comparison with a local Human Development Index ($r = 0.87$; $p < 0.001$), and qualitative robustness assessments. Results reveal a pronounced core–periphery polarization: central and strategically located neighborhoods associated with key infrastructures (university, high-speed rail station and hospital) concentrate higher income levels, educational attainment and land values, while peripheral municipalities and disadvantaged neighborhoods exhibit higher unemployment, lower housing values and greater social vulnerability. The analysis also identifies population–housing mismatches linked to suburban expansion without equivalent functional integration. Beyond the local case, the study provides a transparent and replicable methodological framework tailored to medium-sized cities, where metropolitan-scale indices often fail to capture fine-grained socio-spatial disparities. The UTI offers a practical tool for comparative analysis, temporal monitoring and evidence-based urban policy, supporting more inclusive and territorially balanced development strategies in diverse institutional and geographical contexts.



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1. Introduction

Urban fragmentation and residential segregation represent growing concerns for social sustainability in contemporary urban systems, particularly in medium-sized cities that act as strategic connectors between metropolitan hubs and rural hinterlands. Although these cities have traditionally been perceived as more socially cohesive and territorially

balanced than large metropolitan areas, recent research demonstrates that they are increasingly exposed to processes of spatial inequality, socio-demographic polarization and functional disconnection [1,2]. Their intermediate position within national urban hierarchies makes them especially vulnerable to unplanned suburban growth, selective migration and infrastructure-led development, often occurring without sufficient governance coordination or long-term territorial vision.

Medium-sized cities play a key role in regional cohesion by concentrating public services, educational institutions, healthcare facilities and administrative functions. However, their capacity to absorb growth and redistribute opportunities is frequently constrained by limited institutional resources and fragmented planning frameworks. In many European contexts—particularly in Southern Europe—these constraints have coincided with urban development models that prioritize land consumption and residential expansion over compact and integrated growth. As a result, dispersed urban forms, low-density peripheral developments and growing functional dependence on central cities have become increasingly common [1,3].

In Spain, expansive urban development since the 1990s has intensified peripheral residential growth, frequently disconnected from historical urban cores. Local planning instruments, speculative housing dynamics and expectations of sustained demographic growth facilitated the rapid urbanization of peripheral land, often decoupled from actual population demand. This process has led to pronounced disparities in access to services, infrastructure and urban opportunities, particularly evident in medium-sized cities such as Burgos and Ciudad Real [3,4]. At the same time, historic centers and consolidated neighborhoods have experienced processes of demographic aging, social selection and, in some cases, incipient gentrification, further accentuating intra-urban contrasts.

Within this broader context, the Spanish case—and particularly medium-sized cities such as Ciudad Real—provides a particularly illustrative example of how these processes materialize at fine territorial scales. Ciudad Real, located in the autonomous community of Castilla-La Mancha, exemplifies many of these challenges. Since the mid-1980s, its urban trajectory has been shaped by major structural transformations, notably the establishment of a university and the arrival of high-speed rail (HSR). These developments have enhanced the city's regional accessibility and attractiveness but have also fueled population growth in peripheral municipalities and contributed to a polarized spatial structure. Central and southern neighborhoods increasingly concentrate higher income levels, higher educational attainment and aging populations, while suburban and peripheral areas present lower rental values, higher unemployment rates and a greater presence of migrant populations [5–8]. This pattern reflects a broader process of socio-spatial sorting associated with housing market segmentation and uneven accessibility to urban amenities.

At the same time, strategic infrastructures and tertiary-sector facilities—such as the university campus, the AVE station and the new hospital—have acted as spatial anchors that concentrate high-value residential development in specific areas, intensifying socio-spatial differentiation within the urban fabric [4,8].

Despite the growing body of literature on urban inequality, segregation and vulnerability, most existing research and methodological tools have focused on large metropolitan areas. There remains a significant gap in the development of integrated, multidimensional indices specifically designed to assess urban vulnerability in medium-sized European cities [9,10]. Many available approaches rely on unidimensional indicators or composite measures tailored to metropolitan contexts, which often fail to capture the interdependent nature of social, economic and housing variables in smaller and more fragmented urban systems.

Addressing this gap is particularly relevant for medium-sized cities, where administrative averages tend to mask sharp neighborhood-level disparities and where planning decisions can have long-lasting impacts on territorial cohesion. Robust diagnostic tools capable of operating at fine spatial scales are therefore essential to inform evidence-based urban policy and to support strategies aimed at reducing segregation and promoting social sustainability.

Based on these objectives, the study addresses the following research questions:

- To what extent do patterns of urban fragmentation and residential segregation emerge in medium-sized cities beyond large metropolitan contexts?
- How do socioeconomic, housing and sociodemographic dimensions interact to structure socio-spatial inequalities at intra-urban and inter-municipal scales?
- Can a PCA-informed composite index provide a robust and transferable tool for diagnosing and monitoring urban vulnerability in medium-sized functional urban areas?

Purpose and Intended Uses of the Urban Territorial Index (UTI)

The Urban Territorial Index (UTI) is conceived as a multidimensional diagnostic and analytical tool designed to capture socio-spatial fragmentation and residential segregation in medium-sized cities and their functional urban areas. Its primary purpose is not limited to the description of local inequalities but extends to several complementary applications relevant for both research and urban policy.

First, the UTI serves as a diagnostic instrument to identify clusters of relative advantages and disadvantages at fine spatial scales (census tracts and neighborhoods), allowing the detection of socio-spatial disparities that are often obscured by municipal averages in medium-sized cities. Second, the index is conceived as a comparative framework that can be applied across cities with similar demographic size and functional characteristics, facilitating benchmarking exercises within national and international contexts.

Third, the UTI is designed as a monitoring tool, enabling the analysis of temporal change when updated with comparable data over time. This feature allows local and regional authorities to track the evolution of segregation patterns, assess the effects of planning decisions, and evaluate the impact of urban policies. Finally, the index is intended to support evidence-based policy design by identifying priority areas for intervention in fields such as housing, urban regeneration, service provision, and mobility planning.

Although the UTI is empirically tested in a medium-sized Spanish city, its conceptual structure and methodological design are transferable to other European and non-European contexts, provided that a minimum set of socio-economic, sociodemographic and housing data is available. This makes the index particularly suitable for medium-sized cities, where metropolitan-scale indicators often fail to capture the specific mechanisms of fragmentation and peripheralization.

Against this background, the present study proposes and applies a weighted Urban Territorial Index (UTI) to assess socio-spatial inequality and urban fragmentation in Ciudad Real and its functional urban area. The index integrates six indicators across three analytical dimensions—socioeconomic, sociodemographic and housing—using a PCA-informed weighting scheme and GIS-based spatial analysis. Beyond the local case study, the research aims to contribute a replicable methodological framework for diagnosing, comparing and monitoring urban vulnerability in medium-sized cities facing similar challenges of suburbanization, housing market polarization and uneven access to urban opportunities.

2. Theoretical Framework: Urban Fragmentation, Residential Segregation and Medium-Sized Cities

Urban fragmentation and residential segregation have become central concepts in contemporary urban studies, particularly in the context of medium-sized cities undergoing accelerated but uneven transformation. While early urban theory focused predominantly on metropolitan agglomerations, recent scholarship highlights that medium-sized cities experience similar—yet distinct—processes of socio-spatial differentiation, often with fewer institutional and fiscal capacities to mitigate their effects [1–3].

2.1. Urban Fragmentation: From Morphology to Socio-Spatial Processes

Urban fragmentation was initially conceptualized as a morphological phenomenon, linked to the physical discontinuity of urban fabrics produced by sprawl, zoning practices and infrastructure-led development [4]. However, more recent approaches emphasize its multidimensional character, integrating functional, social, economic and symbolic dimensions [5,11,12]. Fragmentation thus refers not only to spatial discontinuity but also to the weakening of social cohesion, unequal access to urban services, and differentiated opportunities across neighborhoods.

In Southern European contexts, fragmentation has been strongly associated with the transition from compact urban forms to dispersed and low-density development patterns since the 1990s [6,7]. Liberalized land markets, speculative housing production and infrastructure investments—often disconnected from demographic demand—have generated peripheral growth areas characterized by functional dependence on the core and limited urban centrality [9,10]. This process has been particularly intense in medium-sized cities, where new residential enclaves coexist with aging historic centers, producing hybrid urban morphologies and reinforcing spatial inequalities [13].

2.2. Residential Segregation and Socio-Spatial Inequality

Residential segregation refers to the uneven spatial distribution of social groups within urban space, commonly structured along socioeconomic, demographic and ethnic lines [14]. Classical approaches, rooted in the Chicago School, interpreted segregation as an ecological outcome of market dynamics [15]. Contemporary perspectives, however, stress the role of institutional factors, housing policies, labor markets and planning decisions in shaping segregation patterns [16–18].

In European cities, segregation tends to be less extreme than in North American contexts, yet it has intensified in recent decades due to rising income inequality, migration flows and housing market polarization [19,20]. Studies on Spanish cities reveal growing contrasts between high-income, well-serviced neighborhoods and peripheral or inner-city areas with higher unemployment, lower educational attainment and greater concentrations of migrant populations [21–23]. Medium-sized cities exhibit a specific form of segregation, often characterized by a combination of suburban affluence and peripheral vulnerability rather than large-scale inner-city deprivation [8].

2.3. Medium-Sized Cities, Functional Urban Areas and Peripheralization

Medium-sized cities play a strategic role in territorial cohesion, acting as intermediaries between metropolitan regions and rural hinterlands [24]. Nevertheless, they are increasingly affected by processes of peripheralization, understood as the cumulative socio-economic disadvantages experienced by certain territories within broader urban systems [25]. Peripheralization in functional urban areas (FUAs) is often linked to commuting dependency, demographic stagnation, limited service provision and weak governance coordination [26].

The functional urban area approach has been widely adopted to capture these dynamics, emphasizing flows of mobility, labor and services beyond administrative boundaries [27]. In low-density regions, such as central Spain, FUAs tend to display monocentric structures, with strong core dominance and limited polycentric integration [28]. This configuration reinforces socio-spatial disparities, as surrounding municipalities absorb housing growth without corresponding employment or service functions, generating mismatches between residential expansion and urban vitality [29].

2.4. Measuring Urban Vulnerability: From Single Indicators to Composite Indices

The growing complexity of urban fragmentation and segregation has prompted the development of composite indices aimed at capturing multidimensional vulnerability [30]. While single indicators (e.g., income or unemployment) provide valuable insights, they often fail to reflect the interdependencies between social, economic and housing dimensions [31]. Composite indices, when transparently constructed, allow for a more integrated diagnosis of urban inequality and support spatially targeted policy interventions [32].

Recent contributions advocate for PCA-informed weighting schemes to reduce arbitrariness and enhance empirical robustness in synthetic indices [33]. Such approaches have been applied to urban vulnerability, peripheralization risk and social deprivation, particularly in European and Latin American contexts [34–36]. However, most existing indices are tailored to large metropolitan areas, limiting their applicability to medium-sized cities with different spatial scales, data availability and urban dynamics [37].

Within this framework, the Urban Territorial Index (UTI) proposed in this study responds to the need for a multidimensional, scalable and replicable tool specifically designed for medium-sized functional urban areas. By integrating socioeconomic, sociodemographic and housing dimensions and by validating the composite against independent development indicators, the UTI contributes to ongoing debates on spatial justice, urban governance and sustainable urban development in non-metropolitan contexts [38].

3. Materials and Methods

3.1. Study Area and Territorial Delimitation

Ciudad Real, a provincial capital in Castilla-La Mancha, Spain, has undergone significant transformation since the 1980s due to the establishment of a university (1985) and the arrival of high-speed rail (AVE, 1992). The urban expansion resulting from these catalysts has contributed to a fragmented and polarized spatial structure [4].

This study adopts a functional urban area (FUA) approach to delineate the spatial scope of analysis. The delimitation follows the Urban Transformation Index (UTI) methodology, incorporating criteria such as demographic density (>100 inhabitants/km²), urban continuity, and functional connectivity. The resulting FUA includes Ciudad Real and six surrounding municipalities: Miguelturra, Poblete, Carrión de Calatrava, Ballesteros de Calatrava, Pozuelo de Calatrava, and Torralba de Calatrava. The analysis is conducted at three spatial scales: the FUA, 73 census tracts [5], and intra-urban neighborhoods.

This spatial definition is informed by previous studies on Functional Urban Areas in low-density regions, which use criteria based on linked population (mobility, commuting, and service accessibility) to define urban influence zones [13]. This approach is aligned with the European Spatial Development Perspective (ESDP), emphasizing polycentricity and the role of secondary urban nodes in regional cohesion.

3.2. Data Sources and Variables

To enhance transparency, replicability and international applicability, Table 1 summarizes all variables included in the Urban Territorial Index (UTI), indicating their definitions,

units of measurement, data sources, reference years, and potential substitutes available in other national or institutional contexts. This explicit specification responds to the need for comparability across medium-sized cities operating under different statistical and housing-market systems.

Table 1. Variables used in the Urban Territorial Index (UTI).

Dimension	Indicator	Definition	Unit	Data Source	Year	Possible International Substitutes
Sociodemographic	Tertiary education	Population aged 25 or over with tertiary education	%	National Statistical Office (INE)	2021	Population census; Labour Force Survey
Sociodemographic	Foreign-born population	Share of residents born outside the country	%	National Statistical Office (INE)	2021	Population register; census data
Socioeconomic	Household income	Average household income per consumption unit	€	National Statistical Office (INE)	2021	Tax records; income surveys
Socioeconomic	Unemployment rate	Unemployed population aged 16–64	%	National Statistical Office (INE)	2021	Labour Force Survey; employment registers
Housing	Cadastral value	Official cadastral reference value of residential properties	€/m ²	General Directorate for Cadastre	2023	Property tax values; transaction price databases
Housing	Rental price	Average residential rental price	€/m ²	Ministry of Housing	2022	Rental observatories; real estate market portals

Urban vulnerability is approached as a multidimensional construct, integrating sociodemographic, socioeconomic and housing-related dimensions, in line with previous work on composite indices and socio-spatial inequalities [9,11]. Two main methodological traditions converge here: the use of disaggregated indicators, which allows detailed diagnosis of specific vulnerability dimensions but often fails to capture interactions between them, and synthetic indices, which integrate multiple variables at the cost of reduced transparency in individual contributions [10,14].

To balance these perspectives, a weighted synthetic indicator is constructed from six indicators organized into three dimensions:

Sociodemographic: Percentage of population aged 25 or over with tertiary education; percentage of foreign-born population (considering the nine most frequent nationalities).

Socioeconomic: Average household income per consumption unit; unemployment rate of the working-age population.

Housing: Cadastral reference value of residential properties (€/m²); average rental price (€/m²), distinguishing between apartment blocks and single-family houses when possible.

All indicators were obtained from official Spanish sources for the most recent year with complete coverage [5–7]: INE Population and Housing Census 2021 [5], INE Experimental Statistics [5], the General Directorate for Cadastre [6] and the Ministry of Transport, Mobility and Urban Agenda for rental prices [7]. This ensures internal temporal consistency across the dataset.

Although some housing variables used in this study—such as cadastral reference values or official rental indices—are context-specific, functionally equivalent indicators are widely available in many countries through tax registers, housing observatories, real estate transaction databases or large-scale market platforms. As a result, the UTI can be adapted to different institutional contexts by preserving the conceptual meaning of each dimension while substituting locally appropriate indicators.

3.3. Construction of the Urban Territorial Index (UTI)

The Urban Territorial Index (UTI) summarizes the relative socio-spatial position of each census section in Ciudad Real's functional urban area. The construction process comprises four steps and was implemented using a geographic information system (Table 2).

Table 2. Methodological Steps for the Construction and Classification of the Urban Territorial Index (UTI).

Steps	Methods
Step 1: Natural Breaks	Natural Breaks (Jenks) classification into 4 classes per variable in QGIS 3.28 (20).
Step 2: Dimensional scores (0–8):	$S_{sd} = \text{Education} + \text{Foreign-born}$ $S_{se} = \text{Income} + \text{Unemployment}_{inv}$ $S_h = \text{Cadastral} + \text{Rental}$
Step 3: Weighted UTI	$UTI = 0.40 \cdot S_{se} + 0.30 \cdot S_h + 0.30 \cdot S_{sd}$ (Weights from PCA: PC1 eigenvalue = 6.2 explains 62%; socioeconomic dominates (22). Range: 0–8.)
Step 4: Final UTI classified	Very Low (0–2), Low (2.1–4), Medium (4.1–6), High (6.1–8).

Source: Own elaboration.

First, each indicator was mapped at the census-section level and classified into four categories using the Natural Breaks (Jenks) method, which groups values into internally homogeneous intervals and maximizes between-class differences, following previous applications of urban vulnerability indices in Spanish medium-sized cities [6]. An ordinal score from 1 to 4 was assigned to each class, with 4 representing the most favorable situation and 1 the least favorable; in the case of unemployment, the scale was inverted so that higher unemployment rates corresponded to lower scores.

The choice of the Jenks natural breaks classification responds to the highly heterogeneous distribution of socio-economic and housing variables in medium-sized cities, where extreme values and spatial clustering are particularly relevant. Unlike quantile or quartile classifications, which impose equal-sized classes regardless of data structure, the Jenks method minimizes intra-class variance while maximizing inter-class differences, thereby enhancing the identification of spatial clusters of relative advantage and disadvantage.

To assess the sensitivity of the results to the classification method, alternative classifications based on quantiles were tested for selected indicators. The comparison shows that, while general spatial patterns remain stable, quantile-based maps tend to dilute extreme situations and reduce the visibility of highly vulnerable or highly advantaged areas. For this reason, the Jenks method was retained as the most appropriate option for the diagnostic purpose of the UTI.

Second, partial scores were calculated for each dimension by summing the scores of their respective indicators. The sociodemographic score combines education and foreign-born population; the socioeconomic score combines income and (inverted) unemployment; and the housing score combines cadastral value and rental prices. Each partial score therefore ranges between 2 and 8, preserving direct interpretability while reducing dimensionality.

Third, the three partial scores were integrated into a single composite value using a weighted linear combination. The weighting scheme was informed by both the literature on synthetic indices and an exploratory principal component analysis, which showed a stronger contribution of the socioeconomic dimension to overall variance, followed by housing and sociodemographic [5,15]. The final formulation of the UTI is: $UTI = 0.40 \cdot S_{se} + 0.30 \cdot S_h + 0.30 \cdot S_{sd}$, where S_{se} is the socioeconomic score, S_h the housing score and S_{sd} the sociodemographic score. The index is then normalized to a 0–8 theoretical range, although empirical values concentrate in intermediate ranges.

3.4. Principal Component Analysis and Weighting Scheme

To inform the weighting scheme of the Urban Territorial Index (UTI), an exploratory Principal Component Analysis (PCA) was conducted on the standardized indicators included in the three analytical dimensions. PCA was selected as an empirical technique to reduce arbitrariness in weight assignment and to identify the relative contribution of each dimension to overall variance, following established practices in the construction of composite socio-spatial indices (Table 3).

Table 3. Principal Component Analysis (PCA) results and weighting scheme.

Principal Component	Eigenvalue	Explained Variance (%)	Main Contributing Indicators
PC1	6.20	62.0	Household income; unemployment rate; rental price
PC2	1.85	18.5	Tertiary education; foreign-born population
PC3	1.05	10.5	Cadastral value

Note: PCA was conducted on standardized indicators. The weighting scheme of the Urban Territorial Index was derived from the relative contribution of each component, resulting in weights of 0.40 for the socioeconomic dimension and 0.30 for both housing and sociodemographic dimensions.

The PCA results show that the first principal component (PC1), dominated by socioeconomic variables, explains 62% of the total variance, confirming the central role of income and employment conditions in structuring socio-spatial inequality in medium-sized cities. The second component (PC2) is mainly associated with sociodemographic characteristics, while the third component (PC3) reflects housing market dynamics.

Based on the relative contribution of each component and to preserve interpretability and balance between dimensions, a weighting scheme of 0.40 for the socioeconomic dimension and 0.30 for both the housing and sociodemographic dimensions was adopted. This configuration reflects empirical variance patterns while avoiding excessive dominance of a single dimension in the composite index.

UTI values were classified into four levels—very low, low, medium and high—using the Natural Breaks method again. These classes allow the identification of clusters of relative advantage and disadvantage and provide a basis for mapping patterns of fragmentation and segregation.

For replication purposes, the UTI can be conceptualized as a modular index. A core module includes the three dimensions used in this study—socioeconomic, housing and sociodemographic—based on indicators that are commonly available in official statistics. Optional modules may incorporate additional dimensions, such as environmental exposure, transport accessibility or service proximity, depending on data availability and research objectives. This modular structure enhances the adaptability of the index while preserving its conceptual coherence.

3.5. Validation and Analytical Strategy

The robustness of the UTI was assessed through internal and external validation. Internal consistency was evaluated using standard reliability statistics and correlations between the partial scores and the global index, confirming that each dimension contributes coherently to the composite measure. External validation was performed by comparing UTI values with independent indicators of social development and deprivation available at the municipal and neighborhood scale, including human development measures, and by contrasting the resulting spatial patterns with previous work on Castilla-La Mancha's urban systems [4,17,18].

In addition, the robustness of the Urban Territorial Index was examined through qualitative sensitivity checks aimed at assessing the stability of the results with respect to reasonable methodological alternatives. Specifically, the PCA-informed weighting scheme

was contrasted with an equal-weight configuration at an interpretative level, showing that the main spatial patterns and the identification of high- and low-UTI areas remain unchanged. This indicates that the index is primarily driven by the underlying spatial distribution of socioeconomic, housing and sociodemographic variables rather than by marginal variations in the weighting structure.

The analytical strategy combined cartographic visualization of UTI scores at census-section and neighborhood levels with descriptive statistics and bivariate correlations between the index and key demographic and housing variables (e.g., population growth 2001–2011 and 2011–2021, changes in housing stock, age structure). This made it possible to interpret patterns of urban fragmentation in relation to both long-term urbanization dynamics and current socio-economic conditions.

Accordingly, the robustness of the UTI is considered sufficient for its intended diagnostic and policy-support purposes in medium-sized cities.

4. Results

Ciudad Real has undergone significant transformations in recent decades, characterized by uneven growth between the capital and its urban area, a process of suburbanization, and the emergence of new socio-spatial dynamics. The data reveals more dynamic growth in peripheral municipalities compared to stabilization in the capital, alongside significant residential expansion in specific areas. Moreover, socioeconomic indicators highlight notable inequalities between neighborhoods, reflected in patterns of urban fragmentation and residential segregation. These processes underscore both the opportunities and the challenges the city faces in terms of urban planning and social cohesion.

4.1. Demographic Dynamics and Suburbanization (2001–2021)

Ciudad Real and its functional urban area (FUA) exhibit a two-phase demographic trajectory. During 2001–2011, the capital grew by +22.06% (61,280 → 74,798), while the urban area increased by +33.15% (19,847 → 26,427). In contrast, 2011–2021 shows a marked deceleration in the capital (+0.41%, to 75,104) and a more moderate expansion in the urban area (+8.00%, to 28,542). These figures confirm a redistribution of the population consistent with suburbanization patterns (Figure 1; Table 4).

Table 4. Weight Matrix of Ciudad Real and Its Urban Area.

Municipalities of Its Urban Area	Weight Matrix	Indicative Attributes
Ciudad Real	23	Highest cadastral values (€422–€1291/m ²) and income (€11,618–€27,813); high tertiary education
Miguelturra	17–22	Moderate rents (€351–€410); unemployment 10.3–27.7%; mid income (€11,618–€15,416)
Poblete	14–16	Low rents (€291–€351); unemployment 10.3–27.7%; low–mid income
Carrión de Calatrava	9–13	Low foreign-born (1.9–5.9%); unemployment 10.3–27.7%
Torralba de Calatrava	9–13	Similar to Carrión; moderate economic constraints
Ballesteros Calatrava	9–13	Low income; high unemployment; stock growth outpaces population
Pozuelo de Calatrava	8	Low rents (€291–€351); unemployment 10.3–27.7%; accessibility with labor-market constraints

Source: Own elaboration.

Within the ring of surrounding municipalities, Pozuelo de Calatrava and Ballesteros de Calatrava stand out for strong relative growth over the two decades (+116.39% and +106.34%, respectively), while Miguelturra consolidates its role as the main expansion pole in the FUA (Figure 1; Table 5).



Figure 1. Relative Growth of Population and Housing in Ciudad Real and Its Urban Area.

Table 5. Demographic change in Ciudad Real and the FUA.

Spatial Unit	2001–2011	2011–2021	Notes
Ciudad Real (capital)	+22.06%	+0.41%	61,280 → 74,798; then stabilization around 75,104
FUA (aggregate)	+33.15%	+8.00%	19,847 → 26,427; then 28,542
Pozuelo de Calatrava	—	+116.39% (cum.)	Strong suburban growth
Ballesteros de Calatrava	—	+106.34% (cum.)	Strong suburban growth
Miguelturra	+41.2% (2001–2011)	—	Main expansion pole
Selected satellites (Poblete, Torralba, Carrión)	—	+8.0% (aggregate)	Consolidation as residential extensions

Note: When a dash (—) appears in the table, it indicates that the data are not applicable. Source: Own elaboration.

4.2. Housing Stock Dynamics and Population–Housing Mismatch

Between 2000 and 2023, more than 20,000 new dwellings were added in the capital and its urban area, with peripheral municipalities (e.g., Miguelturra, Poblete, Pozuelo de Calatrava) absorbing a large share of the new supply. The 2008 financial crisis generated partially unoccupied developments (“ghost urbanizations”), especially in low-density expansions. From 2011 to 2021, the capital shows very low population growth (+0.4%), while housing construction accelerates in satellites (e.g., Pozuelo +116.4%, Ballesteros +106.3%, and Poblete +84.2% in stock growth terms reported), widening the population–housing gap typical of suburbanization cycles (Table 6).

Table 6. Housing development signals by municipality (2011–2021).

Municipality	Reported Housing Stock Growth	Salient Features
Pozuelo de Calatrava	+116.4%	High construction intensity; demand partly decoupled from population Stock growth with population decline (−20.3%) Strong expansion in low-density formats New large projects outside the Rondas; concentration near AVE, University, Hospital
Ballesteros de Calatrava	+106.3%	
Poblete	+84.2%	
Ciudad Real (capital)	—	

Note: When a dash (—) appears in the table, it indicates that the data are not applicable. Source: Own elaboration.

4.3. Morphological Change and Peripheral Expansion

Building age mapping (Figure 2) documents successive waves of outward growth: consolidation beyond the Rondas in 1940–1960; accelerated dispersion in 1960–2000; and from 2000 onwards, a shift to southern and peripheral sectors—*Nuevo Hospital*, *Larache*, *Las Vías*, *Estación de Autobuses*, *Vía Verde*—with Miguelturra and Poblete becoming functionally integrated extensions. The AVE station (1992), university campus (1985) and new General Hospital acted as spatial catalysts for second-ring development.

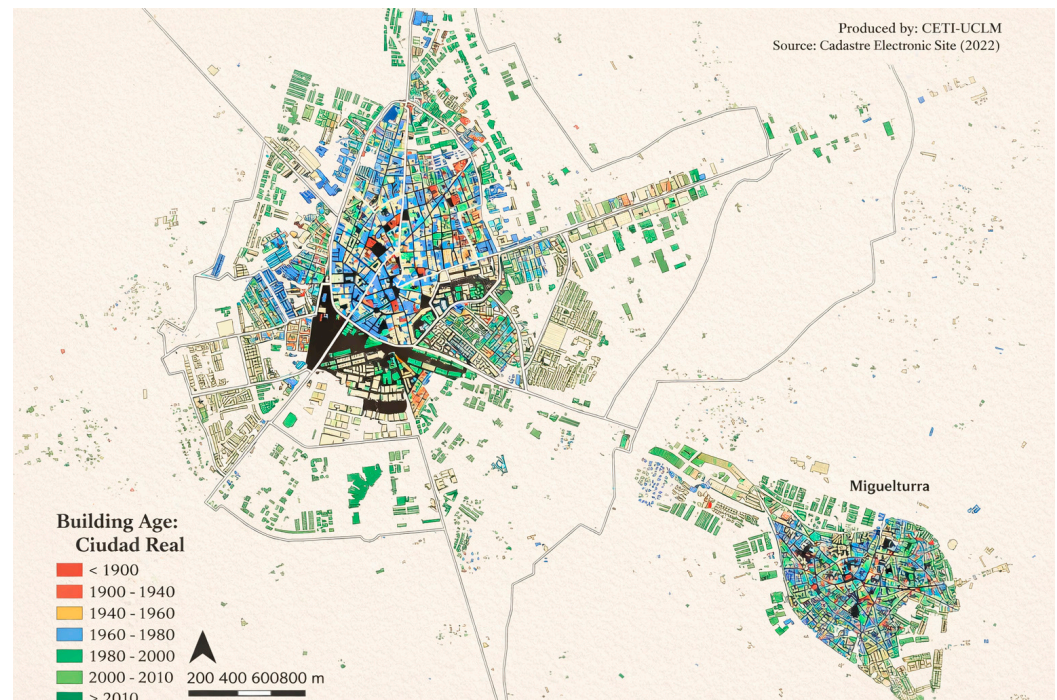


Figure 2. Evolution of Housing Construction in Ciudad Real (1900–2022).

This building age mapping (Figure 2) visually supports the narrative of progressive outward growth:

- Pre-1900: Historic compact city.
- 1940–1980: Expansion beyond the *Rondas*.
- 1980–2000: Dispersed suburbanization.
- 2000 onwards: Peripheral developments linked to AVE station, University, and Hospital, creating a dual morphology (compact core vs. low-density periphery).

The building age mapping (Figure 2) provides a diachronic visualization of Ciudad Real's urban growth, revealing distinct morphological phases and spatial logics. The historical core, characterized by pre-1900 structures (in red), forms a compact nucleus around which subsequent development radiates.

The first significant outward consolidation occurred between 1940 and 1960 (blue tones), extending beyond the *Rondas* and reinforcing a monocentric pattern. This stage corresponds to post-war urban densification and the stabilization of the primary road network.

From 1960 to 2000 (light green), the city experienced accelerated peripheral dispersion, particularly toward the northern and eastern sectors. This expansion coincides with the emergence of new residential enclaves and improved vehicular accessibility, marking a transition from compact growth to semi-dispersed suburbanization. The spatial footprint during this period evidences the fragmentation of the urban fabric, with isolated clusters progressively integrated through infrastructural corridors.

Post-2000 dynamics (dark green) indicate a pronounced shift toward southern and peripheral sectors, including Larache, Las Vías, the Bus Station area, and the Vía Verde corridor. Strategic facilities acted as catalysts for this second-ring development: the University Campus (1985), the AVE high-speed rail station (1992), and the new General Hospital. These nodes introduced functional polarity, fostering a polycentric tendency and redefining accessibility hierarchies. The integration of Miguelturra and, to a lesser extent, Poblete, reflects an incipient metropolitan configuration, where administrative boundaries become increasingly permeable due to continuous built-up areas and intermunicipal connectivity.

The morphological trajectory (Figure 2) encapsulates a structural transition: from a compact, monocentric city to a dispersed, multi-nodal system driven by infrastructural investments and tertiary-sector facilities. This evolution anticipates metropolitan dynamics within the framework of a medium-sized city, raising questions about sustainability, mobility, and governance in future urban planning.

4.4. Urban Territorial Index (UTI): Municipal-Level Patterns

The Urban Territorial Index (UTI) aggregates six standardized indicators across three analytical dimensions—socioeconomic, housing and sociodemographic—through a weighted linear combination. Specifically, the socioeconomic dimension includes average household income per consumption unit and the inverted unemployment rate; the housing dimension incorporates cadastral reference values (€/m²) and average rental prices (€/m²); and the sociodemographic dimension is represented by the share of the population with tertiary education and the proportion of foreign-born residents. The weighting scheme assigns greater importance to the socioeconomic dimension (0.40), followed by housing (0.30) and sociodemographic characteristics (0.30), reflecting both theoretical assumptions and the results of the principal component analysis, which identified socioeconomic variables as the main contributors to overall variance.

A Synthetic Indicator has been created, categorized according to a “weight matrix” for the neighborhoods of Ciudad Real and its urban area, following the methodology of [12].

UTI values were classified into four categories—very low, low, medium and high—using the Jenks natural breaks method. This classification maximizes intra-class homogeneity while enhancing inter-class differentiation, making it particularly suitable for identifying spatial clusters of relative advantage and disadvantage in heterogeneous urban contexts. The resulting spatial distribution of the index reveals a clear pattern of core–periphery polarization. Higher UTI values are concentrated in the central city and in specific southern sectors associated with recent high-value residential development, whereas low and very low values dominate in peripheral municipalities and disadvantaged intra-urban areas (Table 7).

Table 7. Municipal weight matrix and indicative attributes.

Municipality	Weight	Indicative Attributes (From Mapped Indicators)
Ciudad Real	23	Highest cadastral values (€422–€1291/m ²) and income (€11,618–€27,813); high tertiary education
Miguelturra	17–22	Moderate rents (€351–€410); unemployment 10.3–27.7%; mid income (€11,618–€15,416)
Poblete	14–16	Low rents (€291–€351); unemployment 10.3–27.7%; low–mid income
Carrión de Calatrava	9–13	Low foreign-born (1.9–5.9%); unemployment 10.3–27.7%
Torralba de Calatrava	9–13	Similar to Carrión; moderate economic constraints
Ballesteros Calatrava	9–13	Low income; high unemployment; stock growth outpaces population
Pozuelo de Calatrava	8	Low rents (€291–€351); unemployment 10.3–27.7%; accessibility with labor-market constraints

Source: Own elaboration.

At the municipal scale, Ciudad Real concentrates the highest overall UTI weight (23), reflecting its role as the economic, administrative and service core of the functional

urban area. As shown in Table 3, the capital combines the highest cadastral values (€422–€1291/m²), the highest income levels (€11,618–€27,813) and a greater proportion of residents with tertiary education. This profile contrasts sharply with that of surrounding municipalities, highlighting the asymmetric distribution of resources and opportunities within the functional urban area.

Miguelturra occupies an intermediate position in the UTI hierarchy (weights between 17 and 22), characterized by moderate rental prices (€351–€410), mid-range income levels (€11,618–€15,416) and unemployment rates ranging from 10.3% to 27.7%. Its position reflects a partial functional integration with the capital, combining residential growth with some degree of local employment and service provision. By contrast, municipalities such as Poblete and Ballesteros de Calatrava display lower UTI values (14–16 and 9–13, respectively), despite having experienced strong construction momentum. In these cases, low income levels and high unemployment persist alongside residential expansion, indicating a mismatch between housing supply and socioeconomic demand.

Carrión de Calatrava and Torralba de Calatrava also fall within the lower–middle range of the UTI distribution (weights between 9 and 13). Their profiles are marked by moderate economic constraints, relatively low shares of foreign-born population (1.9–5.9%) and limited housing market dynamism. While these municipalities do not exhibit extreme vulnerability, their position within the index suggests a fragile equilibrium that could be adversely affected by demographic stagnation or further labor-market polarization.

Pozuelo de Calatrava records the lowest UTI value (8), reflecting low rental prices (€291–€351), unemployment rates between 10.3% and 27.7%, and significant accessibility constraints linked to limited local labor-market opportunities. This situation exemplifies the risks of peripheralization within medium-sized functional urban areas, where residential expansion is not matched by sufficient economic diversification or service provision.

Overall, the municipal weight matrix presented in Table 3 confirms that urban fragmentation in Ciudad Real is not solely an intra-urban phenomenon but also operates at the inter-municipal scale. The UTI highlights how peripheral municipalities absorb residential growth under less favorable socioeconomic conditions, reinforcing a center–periphery structure typical of medium-sized cities in low-density regions. By integrating housing, labor-market and sociodemographic variables, the index provides a nuanced understanding of multi-scalar socio-spatial inequality and offers a robust basis for interpreting the patterns of fragmentation depicted in Table 3 and Figure 3.

4.5. Intra-Urban UTI Patterns by Neighborhood Groups

The intra-urban application of the Urban Territorial Index (UTI) reveals a pronounced socio-spatial hierarchy within Ciudad Real, structured into five neighborhood groups corresponding to distinct levels of relative advantage and vulnerability (Table 4 and Figure 3). This grouping highlights not only sharp contrasts between neighborhoods but also the existence of transitional zones that articulate the city's fragmented urban structure.

At the top of the hierarchy, Group G1 (high UTI) is represented exclusively by the Larache–Nuevo Hospital area, which concentrates the highest land values in the city (€927–€1291/m²) and the highest income levels (€22,362–€27,813), combined with very low unemployment rates. This neighborhood constitutes a consolidated enclave of affluence strongly linked to strategic infrastructures such as the new General Hospital, the AVE high-speed rail station and recent high-quality residential developments. Its spatial configuration and socioeconomic profile illustrate how infrastructure-led development can generate highly selective residential spaces, reinforcing socio-spatial polarization within medium-sized cities.

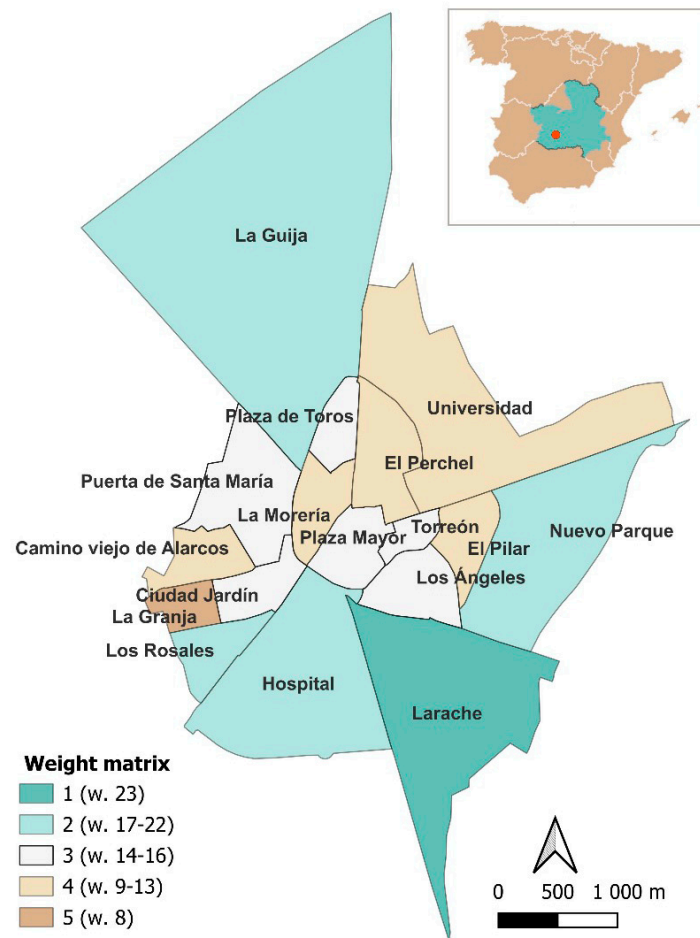


Figure 3. Urban Territorial Index (UTI) of Ciudad Real. Source: Own elaboration based on INE (Census 2021; demographic series 2001–2021), General Directorate for Cadastre (2023), and Ministry of Housing rental index (2022).

Group G2 (upper-middle UTI) includes the neighborhoods of *Los Rosales* and *Nuevo Parque*, which function as an intermediate belt between the most affluent southern sectors and more heterogeneous central and peripheral areas. These neighborhoods exhibit relatively stable rental markets, with prices ranging from €480–€580 in Hospital, €410–€480 in Los Rosales and €351–€410 in Nuevo Parque, alongside low to moderate unemployment levels. Their position within the UTI hierarchy reflects balanced socioeconomic conditions and relatively good access to services, making them attractive to middle-income households and contributing to their role as stabilizing areas within the urban system.

Group G3 (medium or mixed UTI) encompasses several central and semi-central districts, including Ciudad Jardín, Plaza Mayor, Torreón, Los Ángeles, Plaza de Toros and Puerta de Santa María. These neighborhoods display heterogeneous socioeconomic profiles, combining moderate income levels with varying degrees of social diversity. In particular, Plaza de Toros stands out for its higher proportion of foreign-born residents (12.2–17.8%), indicating a concentration of migrant populations within otherwise central urban spaces. This group illustrates the coexistence of social diversity and moderate vulnerability, characteristic of transitional areas where residential functions, commercial activity and historical urban fabric intersect.

In contrast, Group G4 (lower-middle UTI) comprises neighborhoods such as La Granja, La Morería, El Perchel, El Pilar and Puerta de Toledo–Atalaya. These areas are characterized by lower rental prices (€291–€351), reduced educational attainment and lower income levels, combined with higher levels of social vulnerability. Although they maintain relatively good

physical accessibility to the city center, their socioeconomic indicators reveal persistent disadvantages, reflecting long-term processes of residential sorting and limited upward mobility. These neighborhoods represent a critical target for urban policy interventions aimed at preventing further decline and reinforcing social cohesion.

At the bottom of the hierarchy, Group G5 (very low UTI) is represented by Camino de Alarcos, which concentrates the most severe socio-spatial disadvantages in the city. This neighborhood exhibits extremely high unemployment rates (ranging from 28.6% to 44.6%), a significant presence of foreign-born population (12.2–17.8%), and very low income and educational levels. The concentration of multiple vulnerability factors within a single urban space underscores the cumulative nature of socio-spatial disadvantage and highlights the risk of entrenched segregation in medium-sized cities when targeted policies are absent.

The stratification identified in Table 8 confirms the existence of a dual urban model in Ciudad Real, structured around affluent southern nodes and marginalized peripheral or semi-peripheral neighborhoods. This pattern is consistent with fragmentation dynamics documented in other medium-sized Spanish cities, where suburban expansion, infrastructure-led development and housing market segmentation interact to produce sharp intra-urban inequalities [1,12]. The UTI-based neighborhood grouping thus provides a clear and operational framework for identifying priority areas for intervention, underscoring the urgency of place-based strategies aimed at reducing segregation, improving access to opportunities and fostering territorial cohesion.

Table 8. Neighborhood groups by UTI class.

Group (UTI Class)	Neighborhoods	Key Mapped Indicators (Ranges)
G1-High	Larache-Hospital	Highest land prices (€927–€1291/m ²); income €22,362–€27,813; low unemployment
G2-Upper-middle	Los Rosales; Nuevo Parque	Rents: €480–€580 (Hospital), €410–€480 (Los Rosales), €351–€410 (Nuevo Parque); low–moderate unemployment
G3-Middle/mixed	Ciudad Jardín; Plaza Mayor; Torreón; Los Ángeles; Plaza de Toros; Puerta de Santa María	Higher foreign-born in Plaza de Toros (12.2–17.8%); otherwise, mixed socioeconomic profile
G4-Lower-middle	La Granja; La Morería; El Perchel; El Pilar; Puerta de Toledo–Atalaya	Low–moderate rents (€291–€351); higher diversity; lower income/education
G5-Very low	Camino de Alarcos	High unemployment (28.6–44.6%); high foreign-born (12.2–17.8%); low income/education

Source: Own elaboration.

4.6. Validation of the UTI

The UTI demonstrates strong external validity against a local Human Development Index proxy ($r = 0.87$; $p < 0.001$), confirming internal coherence across dimensions and the composite's ability to capture socio-spatial disparities at the census-section scale. Internal consistency checks (dimension–global correlations) indicate aligned contributions of socioeconomic, housing, and sociodemographic scores to overall variance (see Methods).

4.7. Synthetic Interpretation of Results

The spatial distribution of the UTI highlights the role of infrastructure-led development as a key driver of fragmentation. Facilities such as the university campus, the high-speed rail station and the new hospital act as spatial anchors that attract high-income households and high-value residential development, reinforcing selective accessibility and socio-economic sorting. Conversely, peripheral municipalities absorb housing growth without equivalent gains in employment, services or urban centrality, resulting in population–housing mismatches and increased functional dependence on the core city.

5. Discussion

5.1. Urban Fragmentation Patterns in Medium-Sized Cities: Transferable Insights

Although the empirical analysis focuses on Ciudad Real, the patterns identified through the Urban Territorial Index reflect dynamics that are increasingly common in medium-sized cities across Southern Europe and other low-density regions. In contrast to large metropolitan areas, where segregation often manifests through extensive inner-city deprivation or large-scale ethnic enclaves, medium-sized cities tend to display fragmented and discontinuous configurations, characterized by selective enclaves of advantage and dispersed pockets of vulnerability.

The results suggest that medium-sized cities with strong monocentric structures, limited polycentric integration and infrastructure-led growth are particularly prone to socio-spatial polarization. When residential expansion in surrounding municipalities is not matched by employment opportunities, service provision or effective inter-municipal governance, peripheralization processes intensify. These dynamics are likely to be observed in cities with similar demographic trajectories, housing market structures and institutional frameworks.

5.2. Comparative Perspectives: European and Latin American Medium-Sized Cities

Comparable patterns of urban fragmentation and residential segregation have been documented in medium-sized cities in both European and Latin American contexts. In Southern Europe, several studies show that suburban expansion driven by speculative housing cycles, infrastructure investment and permissive planning frameworks has contributed to socio-spatial differentiation, particularly in non-metropolitan and low-density regions [1,20]. In these settings, medium-sized cities often exhibit fragmented urban structures where new residential developments coexist with disadvantaged neighborhoods and weak functional integration.

Similarly, research on European cities highlights that socio-economic segregation has intensified not only in metropolitan areas but also in secondary and medium-sized cities as a result of housing market polarization, labor market restructuring and uneven accessibility to urban opportunities [27,31]. These processes tend to produce discontinuous spatial patterns, characterized by selective enclaves of advantage and dispersed pockets of vulnerability.

In Latin American medium-sized cities, urban fragmentation has been widely associated with peripheral residential expansion, unequal access to services and the coexistence of formal and informal urbanization processes [24]. Although institutional and socio-economic contexts differ, a shared feature across European and Latin American cases is the decoupling of residential growth from functional integration and social cohesion. This reinforces the relevance of multidimensional diagnostic tools such as the Urban Territorial Index (UTI), capable of capturing fine-grained socio-spatial inequalities beyond administrative boundaries and metropolitan biases.

5.3. Urban Fragmentation and Segregation in Medium-Sized Cities: Beyond the Metropolitan Bias

The results obtained for Ciudad Real confirm that urban fragmentation and residential segregation are no longer processes exclusive to large metropolitan regions but are increasingly structuring medium-sized cities and their functional urban areas. The UTI reveals a clear core-periphery polarization, where high-income, highly educated populations concentrate in central and strategically located southern sectors, while peripheral neighborhoods and surrounding municipalities accumulate socioeconomic and housing disadvantages. This finding aligns with recent international literature emphasizing that

medium-sized cities experience accelerated differentiation despite their smaller scale and traditionally higher levels of social cohesion.

Unlike metropolitan contexts, where segregation often manifests through extensive inner-city deprivation or large ethnic enclaves, medium-sized cities tend to display more fragmented and discontinuous patterns. In Ciudad Real, fragmentation is expressed through the juxtaposition of affluent enclaves linked to strategic facilities (hospital, university, AVE station) and vulnerable peripheral neighborhoods characterized by unemployment, lower educational attainment, and lower housing values. Similar configurations have been identified in other Spanish and Southern European medium-sized cities, where suburban expansion has not been accompanied by equivalent functional integration or social mixing.

5.4. The Role of Housing Markets and Infrastructural

One of the key mechanisms underpinning fragmentation in Ciudad Real is the mismatch between housing production and demographic demand. The analysis shows that peripheral municipalities absorbed substantial residential growth despite modest or even negative population dynamics, producing partially occupied developments and inefficient land use. This pattern reflects a broader post-2008 trajectory in Southern Europe, where speculative housing cycles and planning permissiveness generated excess supply in suburban locations.

Strategic infrastructures and tertiary-sector anchors—such as the university, the AVE station and the new hospital—have acted as powerful drivers of spatial restructuring. While these facilities enhance accessibility and urban attractiveness, their impacts are unevenly distributed. In Ciudad Real, they have reinforced the socio-spatial hierarchy by concentrating high-value residential development in their vicinity, without generating equivalent spillovers toward disadvantaged neighborhoods or surrounding municipalities. This confirms that infrastructure-led development, in the absence of redistributive planning instruments, may intensify rather than reduce segregation.

5.5. Methodological Contribution of the Urban Territorial Index

From a methodological perspective, the Urban Territorial Index represents a significant contribution to the study of urban inequality in medium-sized cities. By integrating socio-economic, sociodemographic and housing dimensions through a PCA-informed weighting scheme, the UTI overcomes the limitations of unidimensional indicators and equal-weight composites. The strong external validation against a local Human Development Index proxy ($r = 0.87$) confirms its robustness and internal coherence.

Importantly, the index is sensitive to intra-urban variation at the census-section level, enabling the identification of micro-spatial patterns of vulnerability that would remain invisible at the municipal scale. This is particularly relevant for medium-sized cities, where administrative averages tend to mask sharp neighborhood contrasts. The transparency and replicability of the UTI also make it suitable for comparative applications across similar urban contexts in Southern Europe and beyond.

5.6. Implications for Urban Policy and Governance

The findings have direct implications for urban policy in medium-sized cities. First, they highlight the need to move beyond growth-oriented planning strategies and toward integrated approaches that explicitly address socio-spatial inequality. Targeted densification and mixed-income infill in low-UTI neighborhoods could mitigate segregation while making more efficient use of existing infrastructure.

Second, improving functional integration within the functional urban area is crucial. Enhanced public transport, cycling infrastructure and inter-municipal coordination could

reduce dependency on private vehicles and improve access to employment and services for residents of peripheral municipalities. Third, housing policy instruments—such as inclusionary zoning, affordable rental housing and vacancy management—are essential to counteract market-driven polarization.

The UTI can serve as a decision-support tool for place-based policies, enabling local governments to prioritize interventions, monitor outcomes and align urban planning with the objectives of social cohesion and spatial justice.

5.7. Contribution and Interpretative Considerations and Cautions

This section highlights interpretative considerations that should be taken into account when applying composite indices such as the UTI across different urban systems. Methodologically, the paper shows how university–hospital–transport anchors can reshape intra-urban hierarchies and fragmentation if not accompanied by integration policies [1,12].

The interpretation of composite indices such as the UTI requires attention to several methodological and contextual considerations. Results may be sensitive to classification choices, temporal windows and institutional differences in housing and labor markets. While the Jenks classification enhances the identification of spatial clusters, alternative classification methods may smooth extreme situations. Likewise, differences in data availability across countries may require the use of proxy indicators that affect cross-city comparability.

These considerations do not undermine the validity of the UTI but rather highlight the importance of transparent methodological choices and context-aware interpretation when applying the index in different urban systems.

6. Policy Implications

The Urban Territorial Index (UTI) provides a flexible and operational tool for translating socio-spatial diagnoses into targeted urban policy interventions in medium-sized cities. Its multidimensional structure allows policymakers to identify priority areas, design place-based strategies and monitor the evolution of socio-spatial inequalities over time. While the empirical application focuses on Ciudad Real, the policy implications derived from the UTI are transferable to other medium-sized cities facing similar challenges of suburbanization, housing market polarization and uneven access to urban opportunities (Table 9).

Table 9. UTI classes and recommended policy actions.

UTI Class	Main Characteristics	Recommended Policy Actions
Very Low	High unemployment, low income and education levels, weak housing market	Amenity equalization; social infrastructure investment; inclusionary zoning; targeted urban regeneration
Low	Socioeconomic vulnerability, low rents, limited access to opportunities	Vacancy management; affordable rental housing; local employment programs; service accessibility improvements
Medium	Mixed socioeconomic profiles; transitional neighborhoods	Mixed-income infill development; housing rehabilitation; public space upgrading; mobility enhancement
High	High income, high land and rental values; strong market pressure	Land-value capture; affordable housing quotas; transit-oriented development; containment of speculative growth

For policy implementation, the UTI can be used as a monitoring and evaluation instrument. A baseline UTI can be established using the most recent available data, with updates conducted at regular intervals depending on data availability (e.g., every 3–5 years in line with census or administrative data cycles). Changes in UTI values over time can be used to assess the effectiveness of urban policies, identify emerging vulnerabilities and adjust interventions accordingly.

Moreover, the index supports coordination across policy domains, linking housing policy, transport planning and social infrastructure provision. By integrating socioeconomic, housing and sociodemographic dimensions, the UTI helps avoid sectoral approaches and promotes more coherent strategies aimed at territorial cohesion and spatial justice.

7. Limitations and Future Research

Several limitations should be acknowledged when interpreting the results of this study. First, although the UTI integrates the most recent available data, the indicators originate from slightly different reference years due to constraints in official data availability. While this temporal asynchrony is common in composite indices, it may affect the interpretation of short-term dynamics.

Second, methodological choices such as the use of the Jenks natural breaks classification and the selection of indicators may influence the spatial configuration of results. Although sensitivity checks suggest stable patterns, alternative classification methods or additional variables could lead to nuanced differences.

Third, the UTI does not currently incorporate environmental exposure, transport accessibility or daily mobility patterns, which are increasingly recognized as key dimensions of urban vulnerability. The absence of these factors reflects data limitations rather than conceptual constraints.

Future research should extend the UTI framework by integrating environmental and mobility indicators, constructing longitudinal panels to analyze temporal change, and applying quasi-experimental designs to assess the causal effects of specific urban policies. Comparative applications across different national and institutional contexts would further enhance the robustness and generalizability of the index.

8. Conclusions

This study demonstrates the usefulness of a multidimensional, PCA-informed Urban Territorial Index (UTI) for diagnosing socio-spatial fragmentation and residential segregation in medium-sized cities and their functional urban areas. By integrating socioeconomic, housing and sociodemographic dimensions, the UTI captures fine-grained spatial inequalities that are often overlooked by metropolitan-scale indices or municipal averages.

The empirical application to Ciudad Real reveals a clear core–periphery structure, in which higher-income, better-educated populations and higher land and rental values are concentrated in central and strategically located neighborhoods, while peripheral municipalities and disadvantaged intra-urban areas accumulate unemployment, lower income levels and greater social vulnerability. The results also highlight a population–housing mismatch associated with suburban expansion, where residential growth in surrounding municipalities has not been accompanied by equivalent functional integration or service provision.

Beyond the specific case study, the research contributes a transparent and replicable methodological framework tailored to medium-sized cities. The PCA-informed weighting scheme, combined with internal and external validation and qualitative robustness checks, enhances the empirical credibility and transferability of the index. The UTI is therefore well-suited for comparative analysis, temporal monitoring and policy support in urban systems characterized by intermediate scale, monocentric structures and limited metropolitan governance.

From a substantive perspective, the findings underscore that infrastructure-led development—particularly around transport, health and knowledge anchors—can intensify socio-spatial polarization when not accompanied by integrative planning strategies. Medium-sized cities facing similar development trajectories may thus experience increas-

ing fragmentation unless housing, mobility and social policies are coordinated within a functional urban area framework.

Overall, the Urban Territorial Index offers both an analytical contribution to the study of urban inequality and a practical instrument for evidence-based urban policy. Its application can support more inclusive, sustainable and territorially balanced development strategies in medium-sized cities across different geographical and institutional contexts.

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