Measuring Urban Competitiveness: An Application at the Urban Districts Level in the Galicia Cities of Vigo and Coruna (Spain)

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Abstract. Urban competitiveness, the study of which has broadened significantly in recent decades, is the ability of a specific urban territory to attract investment, people, and new activities. As highlighted from the previous studies, it depends on a multitude of closely interrelated factors that characterise urban areas. This work aims to develop a multidimensional methodology to quantitatively evaluate urban competitiveness at the district level and to support decision-making. The paper proposes a composite index structured into several dimensions that are useful for comparing the competitive performance of cities' districts relative to the city's social, economic, and physical characteristics, thereby providing a multidimensional ranking. The application phase focuses on the comparative analysis of the districts of the two main Galician cities, Vigo and Coruna, in Spain. The overall competitive performance of the city's districts is highlighted, and their strengths and shortcomings across different dimensions are considered. The results aim to emphasise the main components of the districts' competitiveness in two cities and to support decision-makers in improving competitiveness.

Keywords: urban competitiveness · Galician cities · multidimensional methodology

1 Introduction

Over the past 30 years, the concept of urban competitiveness has quietly changed. Initially limited to a macroeconomic perspective, it has gradually evolved into a multi-layered, systematic framework encompassing local capital, social dynamics, environmental sustainability, and the experience economy [1, 2]. Although the concept was originally based on national models such as the Global Competitiveness Index, it gradually changed as scientists and policymakers realised that competitiveness dynamics primarily operate at the urban and regional level and therefore localised analysis methods are required [3, 4]. Early definitions, such as Begg's pioneering research, focused on a city's ability to generate income and employment while competing with the outside world. Competitiveness itself was not regarded as an end, but rather as a means of increasing the well-being of their inhabitants [5].

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Later, insights from global urban theory and network analysis illuminated the strategic role of cities. It became clear that the positioning of cities within the cross-border flows of finance, services, and information shapes their competitiveness [6]. In addition, the rise of entrepreneurial urbanism has increased interest in growth strategies, public-private partnerships and local Marketing. At the same time, however, this process has raised concerns about social division, gentrification and the prioritization of competitiveness over equity and environmental goals. In response to these developments, contemporary urban planning, especially the concept of "local capital" developed by Camani and Capello, reassessed the source of competitiveness: it lies in the integrated use of tangible and intangible local resources such as infrastructure, human capital, relational capital, environmental and cultural assets, and institutional quality-all these factors together contribute to the true strength of a city [7].

A significant paradigm shift in the understanding of urban competitiveness was the World Economic Forum's Definition as "the collective force of policies, institutions, strategies, and processes that shape a city 's sustainable productivity" [1]. This formally incorporates economic, social, and environmental aspects into city valuation, consistent with the concept of the "Triple Bottom Line", and reinforces the recognition that competitiveness is inherently multifaceted. Modern research highlights several core areas, including economic structure, innovation capacity, human capital, accessibility, environmental sustainability, quality of life, cultural diversity, Governance, and international cooperation [2]. It is now argued that long-term competitiveness is equally closely linked to social cohesion, inclusion, environmental responsibility and resilience are linked to economic growth [8]. In recent years, social and environmental Competitiveness has become increasingly important. This shows how high levels of social capital, participatory governance, and demonstrable success in environmental protection increase urban Competitiveness. Sustainable tourism has also established itself as a new field that helps link cultural resources, environmental quality and service provision with competitive advantages [9, 10].

Large-scale comparative studies, like the Global Cities Competitiveness Report, have demonstrated a clear connection between urban performance and progress in reaching the Sustainable Development Goals (SDGs) [11]. However, critical research has also highlighted the contradictions, which are inherent in efforts to increase competitiveness. In particular, empirical links between competitive success and increasing inequality and urban polarization have been highlighted. In light of these criticisms, the concept of competitiveness is redefined. It is argued that inclusiveness, environmental health, resilience and Innovation should not be viewed as constraints on economic outcomes, but as frameworks that simultaneously promote them [12].

In this perspective, the transition to a circular economy can be framed as an important driver of sustainable urban competitiveness, as it aims to decouple economic performance from finite resource consumption through regenerative models. The circular economy is commonly articulated around three design-driven principles: eliminating waste and pollution, circulating products and materials at their highest value, and regenerating natural systems.

At the EU level, circular economy policy explicitly links circularity to a "cleaner and more competitive" economic model, reinforcing its relevance for competitiveness-oriented urban strategies.

To align the competitiveness perspective with circular economy (CE) and urban resilience agendas, we interpret district competitiveness as the capacity to generate well-being while reducing resource throughput and environmental externalities. In this sense, CE-related urban assets, such as proximity to enabling reuse/repair services, access to shared mobility, and the presence of green/blue infrastructure, act as drivers of competitiveness by strengthening local value retention, reducing exposure to resource-price shocks, and improving liveability. Therefore, although our baseline index is built on social, economic, and urban-structure dimensions, the empirical framework is designed to be extensible toward CE-specific indicators when district-scale data become available.

This paper contributes by: (1) operationalising competitiveness at district scale using an integrated socio-economic and urban-structure indicator system; (2) enabling cross-city comparability through joint standardisation of all districts; (3) providing a reproducible GIS-based workflow for mapping intra-urban disparities and supporting policy design.

2 Competitiveness and Urban Development

The growing interest in integrating the concepts of competitiveness and urban development arises from the increasingly central role that cities play in contemporary societies [13]. Urban areas have become key reference points for global economic and social dynamics, and in recent years, they have entered into direct competition to offer favourable conditions for attracting investments, residents, and skilled human capital. Within this globalised context, the traditional approach, focused solely on the relationships between a city and its immediate surroundings, has become insufficient [14]. Advances in communication and transport technologies now enable cities to interact with distant territories, thereby allowing geographically separated urban systems to compete across diverse domains, including industrial production, specialised services, and environmental management [15].

Major metropolitan areas such as New York, London, and Tokyo now orient their development strategies towards competing with similarly sized international cities, often giving secondary importance to internal national competition. In the European context, the establishment of the single market and the free movement of goods and people have heightened cities' awareness of opportunities and risks associated with European integration [16]. Similarly, in Asia, cities such as Hong Kong compete with rapidly expanding urban centres, including Guangzhou and Shanghai, to strengthen their roles as continental economic and financial hubs [17].

A widely used definition describes urban competitiveness as a city's ability to maintain or enhance its position within a regional, national, or international context. Competition thus occurs between comparable urban systems pursuing similar objectives related to resource preservation and the improvement of residents' well-being, through the effective management of external and internal drivers of urban development [18].

Before becoming fully established in the urban planning literature, the concept of competitiveness was supported by early studies that focused primarily on economic

factors contributing to territorial attractiveness. Kresl & Singh (1999) proposed a two-component framework distinguishing between economic aspects, such as production, infrastructure, location, economic structure, and urban services, and strategic aspects, including government efficiency, development strategies, public–private cooperation, and institutional flexibility [19]. As a result, dimensions not directly linked to business performance were typically excluded.

The subsequent scientific debate expanded the scope of analysis. Martin and Simmie (2008) defined urban competitiveness as the capacity of cities to continually improve their business environment, human capital, and physical, social, and cultural infrastructures [20]. According to their view, a competitive city is capable of attracting and retaining innovative, high-growth firms and a skilled, entrepreneurial workforce, ultimately achieving high productivity, employment, and wages while reducing socio-economic disparities [21, 22].

Further contributions incorporated both tangible and intangible factors, such as environmental quality, cultural and technological resources, human capital, and aesthetic attributes, that directly or indirectly influence the locational choices of firms and individuals seeking to meet economic and personal needs [23, 24].

In urban contexts, circular economy principles translate into "value-retention" loops that reduce material throughput and waste while potentially supporting local economic dynamism and resilience.

Across scientific disciplines, increasing attention has been devoted to developing quantitative and qualitative methods for measuring urban competitiveness. This trend is driven by the need of public and private decision-makers for reliable information systems that support development strategies [25]. Nevertheless, assessing the competitiveness of territorial systems, whether regions, metropolitan areas, or cities, remains challenging due to the multidimensional nature of the phenomena involved, including well-being, quality of life, infrastructure, and service provision [26]. Consequently, analyses relying on single indicators are insufficient, underscoring the need for multidimensional indicator sets that capture a broader range of structural attributes [27].

Today, there is broad agreement that meeting the needs of individuals and groups for an improved quality of life is central to the competitiveness of cities. These new needs are leading to a shift in urban priorities: from production-oriented approaches such as infrastructure development and investment promotion to strategies that promote sustainable, people-centered development. Porter described this transition in four phases: production, investment, Innovation and ultimately quality of life.

3 Methodology

A concise and robust methodological framework is essential to comprehensively understand the competitiveness of urban districts. This study uses a composite indicator approach that integrates socio-economic and spatial variables to create a consistent evaluation model [9]. By applying clear procedures such as indicator selection, data normalization, category aggregation, and the creation of a comprehensive competitiveness index, it ensures comparability between different intervals and establishes an analysis method that is transferable to other urban environments [28, 29]. This well-structured approach

serves as a transparent analysis tool that supports evidence-based planning and helps highlight regional strengths and challenges.

While the composite-index approach is established in the literature, this study contributes by operationalising a district-level competitiveness assessment in a way that is (i) transferable across cities, (ii) comparable through joint standardisation of all districts from both case studies, and (iii) statistically streamlined by screening multicollinearity to limit double counting before aggregation. In addition, the workflow is designed to be reproducible and GIS-ready, enabling planners to visualise intra-urban disparities and relate them to policy-relevant dimensions (Human & Society, Economy, Urban Structure).

The set of 21 indicators used in this study derives from a broader initial pool of 35 indicators identified through an extensive review of the scientific literature on urban competitiveness and multidimensional territorial assessment. The original set was designed to capture the full spectrum of social, economic, and spatial dimensions typically considered in composite index methodologies. However, during the data collection phase, several indicators had to be excluded due to the lack of reliable, systematically available data at the suburban district scale used for the analysis. For some variables, data were either not collected by official statistical agencies at this level of detail, presented inconsistencies across the two case-study cities, or were available only at coarser administrative scales, preventing meaningful intra-urban comparison.

The normalisation of indicators was necessary to make characteristics comparable and amenable to aggregation. The methodology used the min-max method (1) because it is applicable to indicators with positive, negative or zero values and because it allows one to widen the variability of indicators lying within a small interval.

It proposes using min–max normalisation to place indicators on a common scale while preserving relative differences. However, min–max can be sensitive to extreme values. This study complements the baseline results with a robustness check using an alternative normalisation (e.g., z-scores or trimmed min–max) to verify that the main spatial patterns are not driven by outliers.

$$y_{SCi} = \frac{x_{SCi} - \min(x_{SCi})}{\max(x_{SCi}) - \min(x_{SCi})} \tag{1}$$

S indicates the statistical unit, C the category and i the indicator.

The distances obtained through normalisation represent the absolute measures of the gap between each statistical unit and the "ideal" one. The methodology considered indicators that negatively affect competitiveness.

For the finalisation of the dataset, a correlation analysis is also necessary to evaluate relationships among indicators and assess their impact on the overall structure of the indicator set (Table 1).

We proceeded with aggregating normalised indicators across the different categories. In the literature, there are numerous criteria for weighting and aggregating variables, ranging from ex ante systems of weights to criteria that infer the meaningfulness of indicators from data analysis (e.g., using multivariate statistical analysis). However, these aggregation methods sometimes implicitly involve a degree of subjectivity. We did not develop a system of weights, as this paper is a first approach to the research. Furthermore, we wanted to develop an innovative application at the district scale. Therefore,

Table 1. The set of indicators included in the methodology.

Category	ID	Indicator	Source
Human & Society	HS1	Population density	INE, 2023
	HS2	Population with Education superior/Total population	INE, 2023
	HS4	Average age of the population	IGE, 2023
	HS5	Number of pensioners/Total population	IGE, 2024
	HS7	Population under 15 years old/Total population	IGE, 2024
	HS8	Voters	IGE, 2023
	HS9	Asociationes/total population	IGE, 2023
Economy	E2	Persons affiliated to the Social Security/Active population	IGE, 2023
	E5	Business density	IGE, 2023
	E6	Beds per tourist dwelling	INE, 2025
	E8	People affiliated with Social Security/Active population	IGE, 2023
Urban structure	U1	Percentage of Buildings surface	IGE, 2023
	U4	Percentage of Green areas surface for each district	Uban Atalas, 2018
	U5	Percentage of Industrial buildings	IGE, 2023
	U6	Percentage of Commercial buildings	IGE, 2023
	U7	Number of Schools/Population 5–19	IGE, 2025
	U8	Health services density	Sergas, 2025
	U10	Land use mix	Uban Atalas, 2018
	U11	Roads density	OSM, 2025
	U12	Bus/train stops density	OSM, 2025
	U13	Cycling and footway density	OSM, 2025

we put forward the hypothesis of interchangeability between dimensions, giving equal importance to different indicators.

Hence, we used simple averages to calculate a partial indicator of competitiveness for single categories (SC) (2). This operation is conceptually equivalent to putting all indicators on an equal footing.

$$M_{SCj} = \frac{x_{SC1} + x_{SC2} + \cdots + x_{SCn}}{n} = \frac{\sum_{I=1}^{n} x_{SCI}}{n} \tag{2}$$

Subsequently, in order to obtain a general measurement of competitiveness, we proceeded with the aggregation of the M_{scj} indexes, which represent the competitiveness of statistical units within single categories. We obtained a composite index of district

competitiveness based on their performance in sustainable development.

$$I_{UCSDG} = \frac{M_{S1} + M_{S1} + \cdots + M_{SM}}{m} = \frac{\sum_{C=1}^{m} M_{SC}}{m} \quad (3)$$

While Mscj indicates the level of competitiveness in the C category, IUCSDG shows the level of competitiveness of the S district, taking into account all the categories of the model. The results can be represented in GIS and in radar graphs.

Because min–max normalisation may amplify outliers, we implement a robust variant using a trimmed min-max approach (e.g., the 5th–95th percentiles) and verify whether district rankings and spatial clusters remain consistent. This check ensures that the observed centre–periphery gradients are not artefacts of extreme values.

4 The Case Studies

The cities of Vigo and A Coruña play central and complementary roles in Galicia, serving as key administrative, cultural, economic, and logistical hubs. Their differing spatial configurations are also reflected in their demographic and territorial profiles. Vigo, which covers 109.1 km^2 and has a population of over 293,000 inhabitants, is characterised by a diversified urban structure that combines a dense central area with extensive suburban districts. This structure forms the backbone of a vibrant city, supported in particular by a strong economy based on industry, logistics and shipping. Although the surrounding areas are more extensive, they are functionally connected to the city centre by a well-developed transport network, thus preserving the unity of the urban system.

A Coruña, on the other hand, has a remarkably high population density, despite its small area of 38.64 km^2, with over 249,000 inhabitants, making it the second largest city in Galicia after Vigo. Its urban structure is more extensive and multicentric, with a densely populated, economically vibrant centre bordered by peripheral areas characterised by port and industrial zones. This pronounced differentiation between centre and periphery adds complexity to the city while strengthening its role as the hub of the most significant metropolitan area in northern Galicia.

Due to their contrasting characteristics in terms of area and population structure, Vigo and La Coruña provide an excellent test field for the proposed multidimensional analysis method. By comparing the differences in size, population distribution and internal spatial structure of the two cities, competitiveness in different urban environments can be comprehensively evaluated and the reliability of the overall index developed in this study can be increased (Fig. 1).

When applying this method to the two target cities (9 constituencies in Vigo and 11 constituencies in La Coruña), the constituencies were chosen as the spatial analysis unit. This choice was made because socio-economic and spatial data are consistently available at the constituency level, these units have suburban characteristics and have an appropriate size to capture differences in internal competitiveness while ensuring the comparability of the analysis.

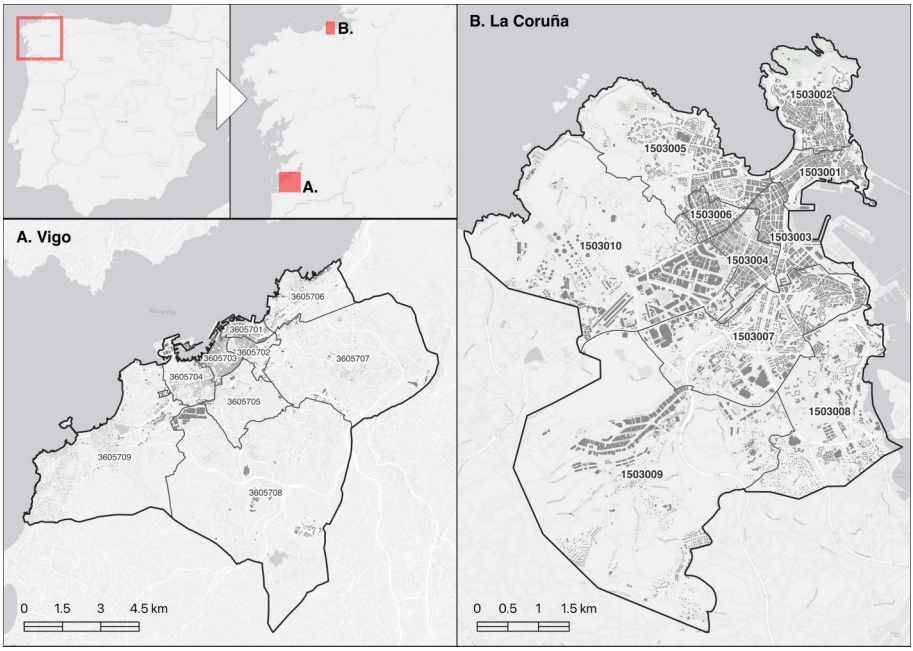

Fig. 1. The municipal electoral district subdivisions of Vigo and La Coruña in the Galicia region, Spain.

5 Measuring Urban Competitiveness

In this analysis, the Index was standardized using all constituency data from both cities to bring all values to a common scale. This method allows direct comparison and clearly highlights the relative differences in competitiveness between the two urban environments. Figure 2 shows the spatial distribution of the standardized competitiveness Index for each constituency in Vigo (a) and A Coruña (B). Based on the correlation analysis, variables with correlation coefficients above 0.7 were excluded. Specifically, the indices HS4, U6, U7, U11, and U13 exhibited strong multicollinearity, which could affect the significance of the overall Index. Therefore, they were removed from the final dataset.

In Vigo, competitiveness values show a clear centre-periphery gradient: the central districts display higher scores, reflecting stronger economic activity, better service provision, and a more consolidated urban fabric. Moving towards the outer suburban areas, the index decreases progressively, indicating more dispersed settlement patterns and comparatively lower concentrations of socioeconomic opportunities. This pattern highlights the role of the compact urban core as the main driver of the city's competitive performance.

In A Coruña, the spatial configuration is more heterogeneous. The central districts also exhibit higher levels of competitiveness, but the variation across peripheral areas is less uniform than in Vigo. Some outer districts maintain relatively positive scores, likely due to the presence of mixed-use environments, coastal accessibility, or consolidated neighbourhood services, while others show lower values associated with more

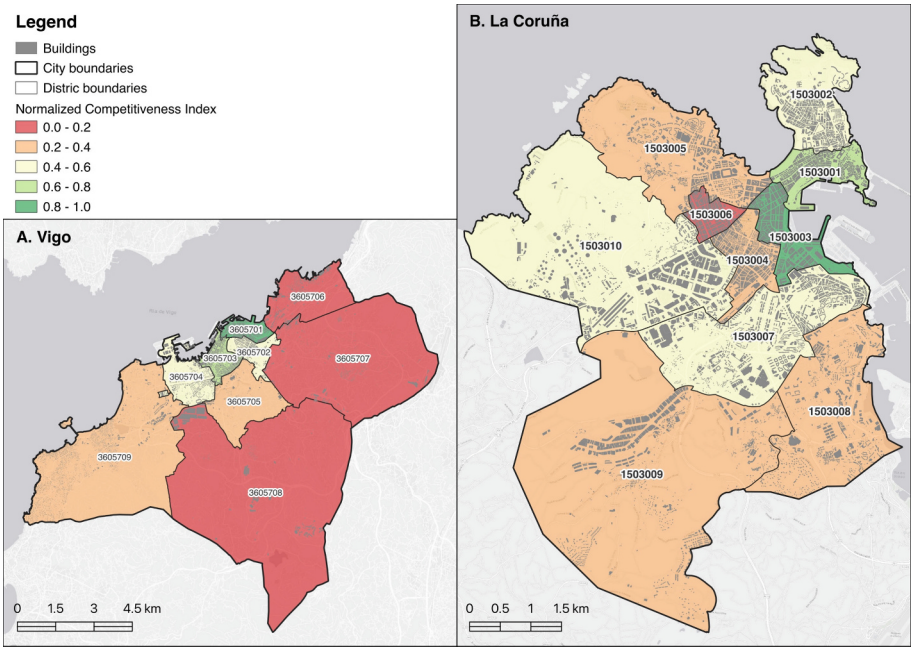

Fig. 2. The value of the synthetic competitiveness index for the municipal electoral districts of Vigo and La Coruña in the Galicia region, Spain.

fragmented urban morphologies. This internal diversity suggests a more polycentric structure, where multiple nodes contribute to the city's overall competitiveness.

Overall, the maps effectively show how the composite index captures intra-urban differences in competitiveness, emphasising how spatial structure, service distribution, and socio-economic conditions interact differently in the two cities.

The bar charts (Fig. 3) for Vigo and A Coruña highlight distinct patterns in the distribution of competitiveness indicators across the three analytical dimensions (Human & Society, Economy, and Urban Structure). Overall, the two cities display heterogeneous profiles, reflecting their different demographic structures, economic dynamics, and spatial configurations.

In Vigo, the standardized values for Human and social indicators (especially HS2 and other indicators on population structure and social participation) are relatively high, indicating excellent results in terms of education level and population distribution. Social indicators such as HS5 and HS9, on the other hand, remain at a medium level, indicating internal disparities between neighborhoods. Economic indicators show a complex picture: employment-related variables (such as E2) are relatively good, while indicators on industrial density and tourism potential are lower, indicating differences in economic power between neighborhoods. Significant internal differences can also be observed in the urban structure. Indicators such as the building area ratio (U1), green spaces (U4), industrial buildings (U5), use diversity (U10) and the number of public transport stops

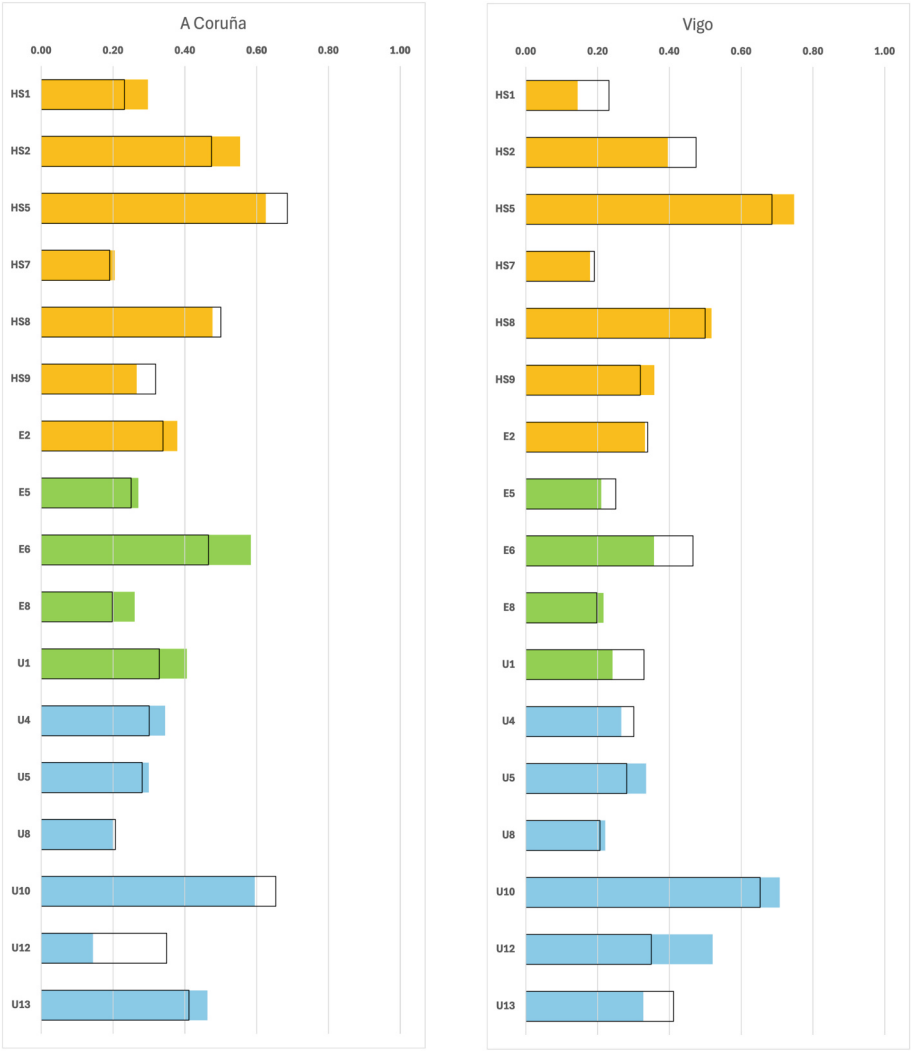

Fig. 3. The values of the competitiveness indicators and their comparison with the weight values for the municipal electoral districts of Vigo and La Coruña in the Galicia region, Spain.

(U12) show, that the centre is more integrated, while the urban structure is more fragmented in the periphery By excluding indicators on road network density and cycling infrastructure Correlation analysis has enabled a more concise but informative structural profile to be drawn up In A Coruña, the balance between human and social aspects is better, but the overall values are slightly lower than in Vigo, especially in terms of education level (HS2). Indicators such as the proportion of the population under 15 (HS7) and the number of eligible voters (HS8), on the other hand, show good values in several districts, indicating active civic participation and a healthy age structure of the urban population.

Economic indicators are more diverse than in Vigo, with a relatively high industrial density and tourism indicators in some districts, which reflects a compact urban structure and the concentration of economic activities Regarding the urban structure, A Coruña has a higher internal consistency than Vigo. Indicators such as U1, U4, U5 and U10 are relatively stable across the city districts, indicating a multi-core and evenly developed cityscape. The smaller difference between the center and the peripheral area seen in A Coruña 's indices could be partly due to the spatial arrangement in connection with the port. in addition to the historic central port, a second large port forms just outside the city limits (created to address the access problems caused by an oil refinery). A functionally dual center structure, which influences urban development. This dynamic must be seen in the broader institutional context of the Spanish metropolitan region. In the absence of a formal regulatory or administrative framework, each municipality acts independently despite its function as an integrated metropolitan system. As the examples of Vigo and A Coruña show, this administrative division makes it difficult to coordinate services and infrastructure between municipalities.

The higher demographic dynamism observed in the city of A Coruña is likely associated with recent immigration flows. Given the city's ageing native population and persistently low fertility rates, population renewal increasingly depends on international migrants. In northern Spain, where immigration tends to correlate with local economic vitality, this dynamic is captured indirectly by indicators of the youth population included in the Human & Society dimension.

When comparing the two cities, the charts clearly illustrate that Vigo shows more pronounced contrasts between central and peripheral districts across several indicators, while A Coruña exhibits a more uniform but less polarised structure. These differences align with the broader spatial organisation of the two cities and confirm the value of the composite index in capturing intra-urban disparities arising from demographic, economic, and morphological characteristics (Fig. 4).

An analysis of the top-performing constituencies in Vigo and A Coruña shows different but comparable patterns in the urban competitiveness of both cities. In both cities, the top-performing constituencies consistently show high values on key indicators such as economic strength, accessibility, and quality of urban services, indicating a balanced and robust regional structure. The top performing constituency in A Coruña is characterized in particular by socio-economic indicators (HS series) and urban services (U series), indicating a mature urban structure with efficient infrastructure and favorable demographic development. The top performing constituency in Vigo, on the other hand, shows a stronger concentration of high values in indicators of mobility, economic activity and urban environment, which reflects the dynamic economic structure of the city and the strategic importance of its city center. These constituencies largely meet the criteria for evaluating urban competitiveness, demonstrating that their strengths are closely linked to the dimensions of the composite indicators. Overall, this analysis confirms the effectiveness of the indicators in capturing differences within cities and shows that certain population groups in both cities emerge as clear centers of competitiveness within the urban system.

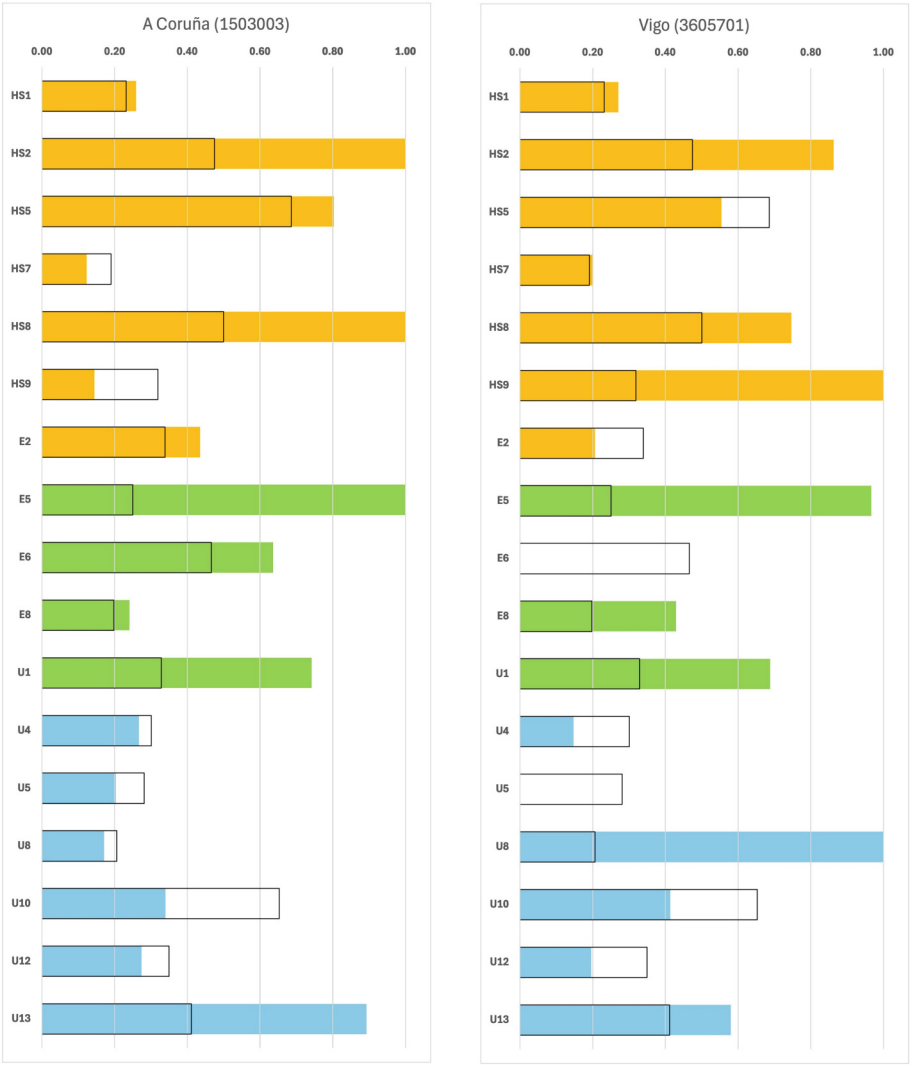

Fig. 4. The values of the competitiveness indicators and their comparison with the corresponding weights for the two best municipal electoral districts in Vigo and La Coruña in the Galicia region, Spain.

6 Conclusions

This study develops and applies a multi-layered conceptual framework to measure urban competitiveness at the neighbourhood level in the Spanish cities of Vigo and A Coruña. It shows how a composite index approach can effectively capture the structural, socio-economic and spatial diversity that characterizes the competitiveness of modern urban systems. The methodology, which integrates 21 indicators in three dimensions-human capital/social, economic and urban structure-provides a transparent and reproducible

analytical tool that highlights both the diversity within each city and the differences due to their respective location conditions. The results show clear Trends in both cities. their more established urban structure and stronger socio-economic base However, while Vigo exhibited a significant discrepancy between the centre and the periphery, A Coruña exhibited a multicore and internally more balanced structure in which several surrounding neighbourhoods achieved comparable competitiveness scores as the central neighbourhoods. These results demonstrate the power of neighbourhood-level analyses to uncover urban asymmetries that were not apparent in more comprehensive regional analyses. in addition to its empirical contributions, this study provides methodological added value by showing how composite indicators at the district level can support the development of more differentiated and evidence-based urban development policies by identifying local strengths and weaknesses. By identifying local strengths and weaknesses, planners and decision-makers can focus their efforts on areas where demographic weaknesses, Supply bottlenecks or low economic activity affect competitiveness. At the same time, the results highlight the importance of incorporating spatial structure into competitiveness analysis, as the diversity of building forms, use mix, accessibility and distribution of public services significantly affect local performance. In this sense, these composite indicators support a more comprehensive and sustainability-oriented Interpretation of competitiveness and are in line with the evolving multidimensional perspective in contemporary urban research.

Although this study makes an important contribution, it also has some limitations. First, the analytical framework is based on the availability of county-level data, which necessitated the exclusion of some of the original indicator sets. This may have limited the thematic coverage of the analysis, especially in areas where there were no consistent county-level data sets, such as indicators on Innovation, environmental performance and digital infrastructure. Second, the decision to assign equal weights to all indicators, while understandable given the first exploratory application, leads to a simplification that may not fully reflect the relative importance of each competitive component. Third, while Minimum-Maximum normalization is a common method, susceptible to extremes and can amplify differences caused by outliers. These limitations open up different approaches for future research. Firstly, expanding the indicator set (especially by adding variables from the environment, digitalization and Innovation) could increase the complexity of the Index. Secondly, future applications could explore alternative weighting methods, such as expert weighting, data-driven approaches such as principal component analysis and factor analysis, and hybrid models that reconcile statistical robustness with policy relevance. Thirdly, longitudinal analyses should be developed to identify Trends, Fourthly, the extension of this methodology to other urban contexts inside and outside Spain allows for more comprehensive comparative analyses and strengthens the external validity of the Index Finally, the Integration of competitiveness results with spatial analyses in a GIS environment (such as cluster analysis and spatial autocorrelation) provides deeper insights into the regional logic that shapes competitiveness and contributes to more spatially precise planning. Overall, this study lays the foundation for a scalable and adaptable analytical framework and deepens our understanding of competitiveness in cities by highlighting the structural, socio-economic and spatial factors that contribute to differences in regional performance.

Indicator availability at the district level may bias the index toward dimensions that are better measured (e.g., accessibility and built form) while under-representing innovation and environmental performance. Similarly, joint standardisation improves cross-city comparability but may compress within-city variance when one city exhibits more extreme values. Finally, indicator screening reduces multicollinearity but can remove conceptually meaningful variables; therefore, we report excluded indicators and correlations in an appendix and provide sensitivity checks to confirm that substantive interpretations are stable.

This study contributes to both academic discussion and practical policymaking and provides a tool to support more equitable, sustainable and contextual urban development strategies.

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