Decision Support for Urban Regeneration Through a Territorial Criticality Index

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Abstract. Contemporary urban regeneration processes are increasingly affected by the shortage of economic resources but also by the increasing complexity of territorial contexts; these factors lead to the need of decision-making support tools capable of guiding the definition of intervention priorities in a transparent and comparable way. Within this framework, this paper proposes the development of a composite multi-criteria indicator aimed at identifying urban critical issues in the preliminary planning stages. Moreover the indicator integrates economic, social, and environmental dimensions through a structured process of variable selection, data normalization, and result aggregation, based on the principles of Multi-Criteria Decision Analysis (MCDA).

The methodology is conceived as a flexible and replicable tool, applicable to different urban contexts by adapting the set of indicators without modifying its basic conceptual framework. The approach is tested along the Asse Prenestino of the city of Rome, an urban corridor characterized by marked morphological, functional, and socioeconomic diversity. The results show an uneven distribution of critical issues along the axis and allow for the clear identification of the most vulnerable macro-areas, validating the indicator's effectiveness as a preliminary screening tool. The proposed index does not provide an operational design guidance but suggests a concrete analytical basis for guiding public choices and sustaining informed, comparable, and transparent decision-making processes in complex urban contexts.

Keywords: Criticality Index · Multi-criteria Analysis · Vulnerable Areas

1 Introduction

The growing scarcity of economic, social and environmental resources represents one of the main challenges that characterise urban policies nowadays and, in particular, regeneration processes in large European cities. The intensification of demographic pressures, the reduction in the financial capacity of local authorities and the increase in territorial

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inequalities imply the adoption of decision-making tools capable of effectively and transparently guiding the distribution of public investments. The United Nations 2030 Agenda [1] and the most recent documents of the Organisation for Economic Co-operation and Development (OECD) [2] underline how urban regeneration can no longer be interpreted as a set of specific interventions; it must be directed by a systemic analysis of the territories capable of recognizing those areas greatly exposed to economic, social and environmental vulnerabilities. This uneasy scenario shows that the scarcity of resources translates into the need to strictly define intervention priorities. Public administrations should select the zones where investments can generate the most significant effects, maximizing social returns and avoiding waste of resources. This need is particularly strong in cities characterized by resilient territorial heterogeneity: here spatial inequalities manifest themselves as disparities in income levels, access to services, provision of urban greenery, or quality of the built environment [3]. In the absence of satisfactory analytical tools, the definition of priorities depends on fragmented or weak comparable estimations, with the risk of overlooking particularly vulnerable areas. To address this complexity, literature highlights the growing importance of decision support tools, capable of systematically and transparently guiding public choices based on experimental evidence [4]. Among these, urban indicators represent one of the main tools used to define and assess dissimilar territorial conditions. Economic, social and environmental indicators allow for a multidimensional representation of urban quality, making it possible a comparison among mixed portions of cities through measurable and replicable variables [5, 6]. When complex phenomena become readable information it is particularly useful to start the preliminary phases of urban planning and regeneration procedures. However, when the number of indicators grows and the variables belong to very different domains, there arises the need for tools capable of integrating them and providing a synthetic measure of territorial criticalities. In this context, multi-criteria evaluation approaches (MCDA – Multi-Criteria Decision Analysis) are now broadly recognized as operative methodologies for aggregating mixed information and comparing it according to transparent and reproducible processes [7, 8]. The use of MCDA allows for the combination of economic, social and environmental sides in a single index, so facilitating the identification of priority areas in complex urban contexts characterized by poor resources. In this respect, numerous studies show how these methods are particularly appropriate for the initial screening phases [9]. The Roman context, and in particular the Asse Prenestino, offers a substantial case study for testing the effectiveness of a multi-criteria approach to defining regeneration priorities. The axis, which connects the central hub of Rome Termini with the eastern areas up to the peri-urban sector towards Gabii, passes through a sequence of neighborhoods characterized by deep differences in terms of socioeconomic conditions, infrastructural facilities and environmental quality. Together with consolidated residential areas, there are also places marked by social fragility, reduced quality of public space, limited greenery, high percentages of impermeable soil and property values lower than the city average [10]. This mixture makes the axis particularly suitable for testing the ability of the multi-criteria indicator to integrate different information and provide a synthetic reading of the territorial criticalities, showing strengths and weaknesses. According to this concept, the case study does not represent the main object of the research, but a test bed to evaluate the applicability,

strength and potential of the proposed method. The construction of the multi-criteria indicator is therefore configured as a general methodological contribution, aimed at supporting the definition of intervention priorities in settings characterized by resource scarcity, through a clear and replicable procedure. Compared to existing MCDA applications in urban studies, the proposed approach emphasizes simplicity, transparency and replicability, making it particularly suitable for data-constrained contexts. In this sense, the model is conceived as a preliminary screening tool rather than a fully operational decision-support system.

2 Aim

The aim of this paper is to propose techniques to construct a multicriteria indicator to support decision-making processes, aimed at identifying urban emergencies within a wide urban territory where regeneration interventions may be necessary. The indicator mixes economic, social, and environmental dimensions, providing a concise measure of territorial criticality, useful for the definition of priorities. The tool does not aim to determine how to get involved, but rather to identify where priority should be focused, providing an objective, transparent, and comparable base for the first planning phases. The proposed methodology is designed to be applicable to any urban scenario, adapting the set of indicators to local specificities.

The following part of the paper is organized as described below. Section 3 describes the methodology. Section 4 is dedicated to the presentation of case study and the application of methodology. Finally, in Sect. 5 the conclusions are discussed. Therefore, the practical implications of the research and further insights are illustrated.

3 The Methodology

The methodological approach adopted for the construction of the multicriteria indicator is based on a series of steps and this procedure is divided into: identification of the dimensions of the indicators, definition of the variables to be included, data normalization, assignment of weights and final aggregation.

3.1 Types of Indicators

The construction of the indicator starts from the identification of three large conceptual dimensions, broadly recognized in the literature as fundamental in evaluating the quality and vulnerability of urban scenarios:

- Economic indicators, which describe the level of material well-being, the attractiveness of the area and the dynamics connected to the real estate market. They usually reflect the solidity of the productive fabric, the availability of resources and the economic flexibility of the territory [11, 12].
- Social indicators, which represent aspects linked to the demographic composition, the socio-economic condition of residents, social inclusion, the presence of marginalization or housing pressure. This dimension of indicators allows us to understand the frailty of a community and its ability to support urban renovations [13, 14].

- Environmental indicators, which refer to the ecological quality of the built environment, the availability of green spaces, the permeability of the soil and, more generally, the aspects that influence the sustainability of urban settlements [15, 16].

These three dimensions allow for a multidimensional interpretation of the area, offering an integrated knowledge of its vulnerabilities. The specific indicators selected within each dimension are shown in detail in Sect. 4, related to the case study.

3.2 Indicator Selection Process

The selection of indicators that make up the three economic, social and environmental dimensions was made according to consolidated methodological criteria, which include the following features:

- interpretative relevance, i.e. the indicator's ability to represent a key phenomenon for interpreting critical problems;
- robustness and reliability of data, with preference for indicators available for all areas and derived from institutional sources such as the National Institute of Statistics (ISTAT), the Statistical Portal of the Municipality of Rome, the Higher Institute for Environmental Protection and Research (ISPRA), the Revenue Agency's Geopoi platform, and geomarketing software such as UrbiStat;
- discriminating capacity, i.e. the indicator's ability to show real differences between the portions of territory analysed;
- replicability, so that the indicator can also be applied to urban contexts other than the case study.

The selection process was guided both by literature review and by data availability constraints, ensuring consistency and applicability across the analysed areas.

3.3 Normalization of Indicators

Since the data referring to the indicators have different scales, units of measurement and orders of magnitude, a normalization was carried out in order to report all the variables on a single scale between 0 and 1 [17].

A min–max normalization was adopted, defined by the following formula:

$$x_{\text{norm}} = \frac{x - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}}$$

The normalization was applied across all macro-areas simultaneously in order to preserve relative differences among territorial units.

This transformation allows for the comparison of mixed values without introducing interpretative distortions.

Two methods were applied according to the nature of the indicator:

- direct normalization, when higher values of the indicator relate to more critical conditions (e.g. unemployment, density, housing pressure);

- inverse normalization, when higher values specify better conditions and therefore must be inverted so that a high value equates to greater criticality (e.g. income, urban greenery, permeable soil).

The use of the combination of the two methods allows for all the indicators to be oriented in the same interpretative direction: higher values of the final index always correspond to more critical conditions.

3.4 Aggregation and Assignment of Weights

Once normalized, the indicator data was aggregated to obtain a synthetic criticality index. Aggregation occurs by combining:

1. the normalized values of the data referring to the individual indicators,
2. the weights associated with each dimension of indicators (economic, social, environmental).

The integration follows the logic of the following multi-criteria models:

$$\text{Criticality index} = \frac{\sum(x_{\text{norm}} \cdot w)}{\sum w}$$

where:

- x_{norm} = normalized value of the indicator,
- w = weight attributed to the category to which the indicator belongs.

The aggregation follows a linear additive model, widely adopted in MCDA applications for its simplicity and interpretability.

The assignment of weights responds to the necessity to balance the relative importance of the three dimensions, avoiding that only one controls the result [18].

The specific values of the weights used in the case study will be shown in the following section, while here it is emphasized that:

- weighting gives coherence to the index;
- the sum of the products normalized value × weight allows us to identify the overall criticality level of each macro-area;
- the index allows for immediate comparison.

The methodology used is part of the broader framework of Multi-Criteria Decision Analysis, which provides a set of flexible techniques for facing decision-making problems characterized by multiple dimensions and even non-homogeneous criteria.

The proposed indicator thus fits within the wider structure of Multi-Criteria Decision Analysis (MCDA), adapting its rules to the peculiar needs of the case study [19].

4 Case Study

The Asse Prenestino is one of the main urban corridors of the city of Rome, extending from the central hub of Termini Railway Station to the eastern area in the direction of Gabii. It is a historical and strategic linear axis, corresponding largely to the ancient Via

Praenestina, one of the most important consular roads of the Roman era, which linked the city with the ancient Praeneste (today's Palestrina). For centuries it was a strategic route for economic exchanges, military movements and the settlement development of the eastern area of Rome [20]. Even today this historical legacy is visible in the urban structure: the Prenestina is still one of the most important crossing axes, capable of connecting the historic centre with the fringe areas and with the peri-urban territories beyond the Grande Raccordo Anulare (GRA).

From a morphological and functional perpective, the axis shows a deep inner heterogeneity. In the central portion, high-density, culturally stratified historical urban fabrics prevail; proceeding towards the east, areas of urban transformation appear: production voids, abandoned warehouses, large linear infrastructures and residential sectors that developed in different ages. Moving towards the GRA (ring road), the continuity of the built environment becomes weaker and leaves space for mixed or fragmented areas; finally, beyond the ring road, the landscape takes on peri-urban connotations, with large agricultural fields and remarkable archaeological sites, such as the Gabii district. This complexity in its structure, functions, and rhythm of transformation makes the Asse Prenestino a particularly significant case for testing using analytical tools aimed at identifying the most critical areas and intervention urgencies.

Figure 1 shows the extension of the Asse Prenestino.

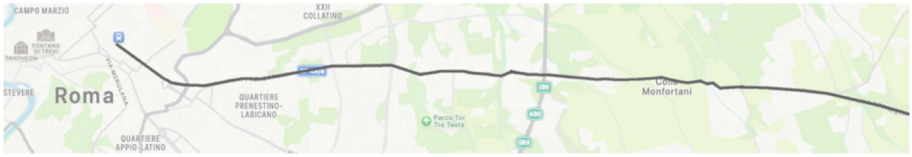

Fig. 1. Representation of the Prenestino Axis.

4.1 Subdivision of the Asse Prenestino

To analyze the territory in a uniform and comparable way, the axis was first divided into three main macro-areas, identified on the basis of territorial continuity, functional characteristics, presence of urban centers, and variations in the morphology of the built fabric. These macro-areas extend from the historic urban core to the Aurelian Walls, from the Aurelian Walls to the Grande Raccordo Anulare, and from the Grande Raccordo Anulare to Gabii, each characterized by a relatively homogeneous territorial identity.

Due to its considerable spatial extension and marked internal heterogeneity, the intermediate macro-area was further subdivided into three sections. This additional articulation allows for a more detailed interpretation of the transitional dynamics between the consolidated urban fabric and the peripheral areas.

As a result, the axis is partitioned into five segments. Although this classification does not rely on official statistical units, it provides a consistent analytical framework for examining the variations in urban structure along the axis.

The sub-macro-areas identified (Fig. 2) are the following:

1. Prenestina 1 – Inner City / Aurelian Walls
2. Prenestina 2.1 – From the Aurelian Walls to Portonaccio
3. Prenestina 2.2 – From Portonaccio to Palmiro Togliatti
4. Prenestina 2.3 – From Palmiro Togliatti to the Grande Raccordo Anulare
5. Prenestina 3 – From the Grande Raccordo Anulare to Gabii

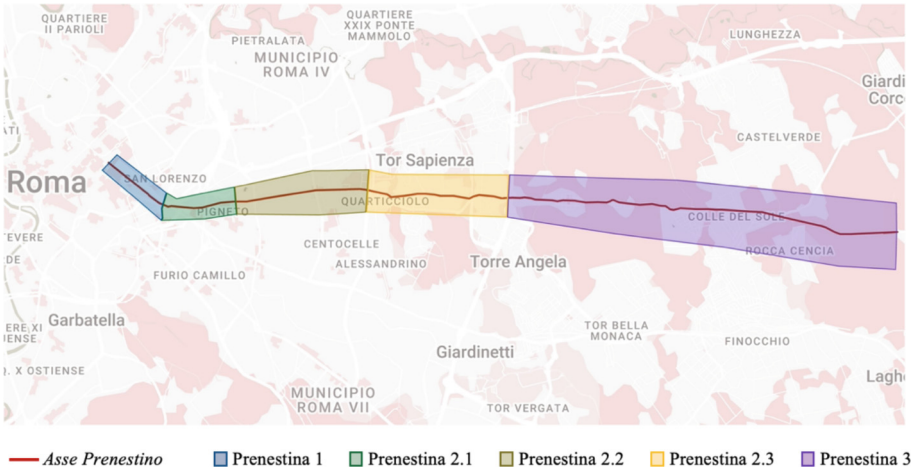

Fig. 2. Representation of the identified sub-macro-areas. Source: authors' elaboration based on Mymaps https://www.google.com/intl/it/maps/about/mymaps

Prenestina 1 – Inner City/Aurelian Walls

The first area identified lies between "Dente Cariato" *(= decayed tooth)*, a derelict structure, and Piazza dei Cinquecento. It is an extremely stratified urban space, featuring overlapping archaeological sites, office buildings, railway infrastructure, and historic buildings. The area is characterized by a solid urban development, intense traffic flows, and complex infrastructure that deeply touches its urban form. Porta Maggiore, the tomb of Minerva Medica, and the abandoned railway areas are key features that reveal both the site's historical value and its critical functional necessities. It is a high-density urban context, culturally significant but affected by congestion, low quality public space, and fragility related to the presence of huge empty areas and abandoned zones.

Prenestina 2.1 – From the Aurelian Walls to Portonaccio

This macro-area is a transitional stretch between the inner city and the easternmost part of the axis. Important legacies of the industrial city can be found here, such as the former SNIA industrial site, today partially redeveloped by the Energy Park and Lake Bullicante. Strong functional heterogeneity characterizes this area: abandoned industrial areas coexist with compressed residential areas, cultural facilities, university functions, small businesses, and large-scale linear infrastructure. This variety of functions and morphologies produce a fragmented urban landscape, with high potential but also critical

problems linked to degraded spaces, development pressures, and a lack of environmental value.

Prenestina 2.2 – From Portonaccio to Palmiro Togliatti
The identified macro-area shows elements of greater residential regularity and the positive existence of green spaces. This is where important historical and cultural landmarks of the area, such as Villa Gordiani and Forte Prenestino, are located. The urban fabric is predominantly residential, with medium-high density, and extensive commercial activities and local services. The presence of widespread green spaces and a consolidated built fabric gives the area a good urban quality, despite the presence of problems related to population pressure, traffic, and discontinuity between certain parts of the neighborhood. Generally, the area is relatively balanced, with reasonable criticalities if compared to the other macro-areas.

Prenestina 2.3 – From Palmiro Togliatti to the Grande Raccordo Anulare
The macro-area is one of the most complex segments of the axis, characterized by a remarkable presence of manufacturing activities, warehouses, logistics facilities, and large mobility infrastructures. The urban landscape is marked by some discontinuous features: manufacturing areas undergoing transformation, irregular lots, large commercial spaces distributed along the road, residual spaces, and a considerably reduced quantity of green space. The proximity to the GRA (ring road) emphasizes the morphological fragmentation, which provokes a weakening of the urban continuity and an increase in impermeable surfaces. This area points out both environmental and socioeconomical strongly critical conditions, as confirmed by the indicator analyses.

Prenestina 3 – From the Grande Raccordo Anulare to Gabii
The macro-area beyond the GRA (ring road), where the axis opens onto a peri-urban and semi-rural environment, is an alternation of scattered settlements, agricultural zones, land use facilities, and archaeological sites of great value, including the Gabii complex. The area also hosts hubs such as Rocca Cencia, currently being decommissioned, and large agricultural sectors along the Ponte di Nona corridor.Population density is remarkably lower than inland macro-areas, and the landscape features a greater presence of permeable soil and open spaces. Despite presenting challenges related to accessibility and the fragmented nature of the built environment, this area is generally less vulnerable than the other ones.

4.2 Indicators Selected for the Case Study

The indicators were selected to avoid redundancy, favoring different but non-overlapping variables in representing the same phenomena, while ensuring their transversal applicability to different territorial scenarios. Within this framework, Table 1 reports the non-normalized values of the indicators selected for each macro-area. All the data reported in the table were obtained from the Urbistat portal based on 2025, an official platform that provides urban statistical indicators derived from national databases. These values form the empirical basis of the analysis and allow us to observe the differences between the areas in economic terms (per capita income and OMI value (i.e. Real Estate

Market Observatory), social terms (population density, unemployment rate, residential buildings, commercial buildings, occupied dwellings, aging index, illiteracy rate), and environmental terms (permeable soil and green space).

Table 1. Unnormalized values of selected indicators.

Indicator	Prenestina 1	Prenestina 2.1	Prenestina 2.2	Prenestina 2.3	Prenestina 3
Per capita income (€)	24,646	24,598	24,586	24,574	24,566
OMI value (€/m^2)	3,429	3,095	2,738	2,416	1,564
Population density (inhabitants/km2)	14,408.80	14,374.50	15,795.90	2,566.90	1,283.10
Unemployment rate (%)	10.4	3.3	4.4	13.9	12.1
Residential buildings (%)	69.7	75.3	80.6	45.2	84
Commercial buildings (%)	30	19.1	18.7	51.7	13.9
Occupied dwellings (%)	80.5	89.7	95.4	91.1	71.2
Old age Index	163.3	189.2	218.3	156.3	96.67
Illiterate (%)	0.2	0.1	0.1	0.4	0.4
Permeable soil (%)	25	30	35	20	45
Green space (m^2/inhabitant)	5	8	12	10	25

Source: authors' elaboration based on data retrieved from the Urbistat portal https://www.urbistat.com/eng/

The preliminary analysis of the unnormalized data allows for an earliest interpretation of the differences between the five macro-areas of the Prenestino area, pointing out the magnitudes and original distribution of the variables examined. This phase is useful for understanding the nature of the observed phenomena and identifying any extreme values and imbalances. Direct observation of the raw values also allows for a grasp of the mixed framework of the Asse Prenestino: some areas are characterized by high population density, others show higher levels of greenery, and still others highlight socioeconomic frailties that are immediately apparent in the original data. Figure 3 shows the trend of the raw values of the economic, social, and environmental indicators. These representations support the first level of interpretation, allowing us to highlight the differences between

the five areas for each variable and predict some of the critical issues that will emerge in the next phase of the multicriteria analysis.

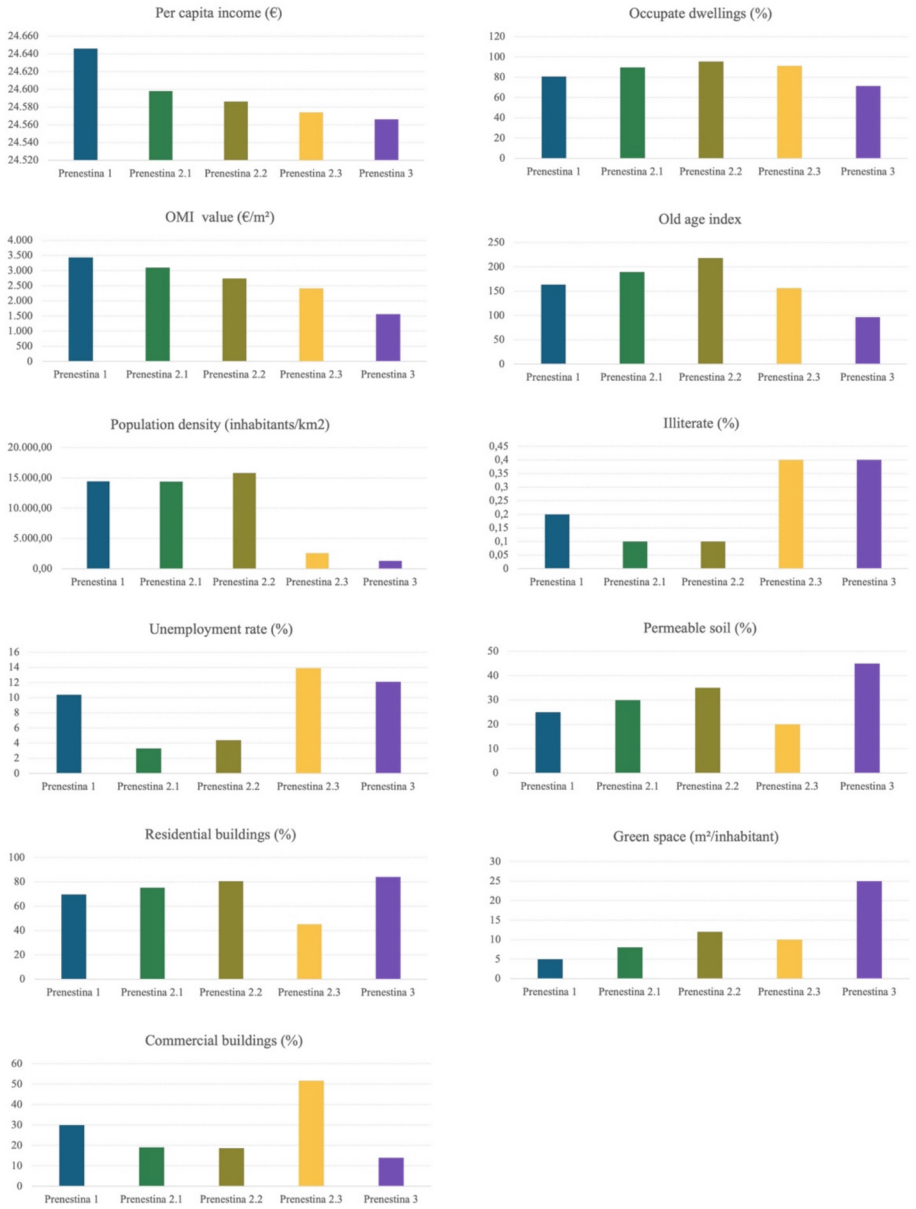

Fig. 3. Graph of the non-normalized indicators for each macro-area identified on the axis. Source: authors' elaboration.

4.3 Normalization of Indicator Values

Due to the different measurement scales and heterogeneous orders of magnitude, the values of the indicators considered are not directly comparable and require a normalization process through which all indicators are reported on a single common scale between 0 and 1 and then transformed into a set of homogeneous indicators. The normalization methods adopted for each indicator are described below, and the normalized data are shown in Table 2.

Table 2. Normalized values of the selected indicators.

Normalization	Prenestina 1	Prenestina 2.1	Prenestina 2.2	Prenestina 2.3	Prenestina 3
Per capita Income	0.000	0.600	0.750	0.900	1.000
OMIvalue	0.000	0.179	0.371	0.543	1.000
Population density	0.904	0.902	1.000	0.088	0.000
Unemployment Rate	0.670	0.000	0.104	1.000	0.830
Residential buildings	0.631	0.776	0.912	0.000	1.000
Commercial buildings	0.426	0.138	0.127	1.000	0.000
Occupied dwellings	0.384	0.764	1.000	0.822	0.000
Old age Index	0.548	0.761	1.000	0.490	0.000
Illiterate	0.333	0.000	0.000	1.000	1.000
Permeable soil	0.800	0.600	0.400	1.000	0.000
Green space	1.000	0.850	0.650	0.750	0.000

Per capita income (€)
Criterion: Inverse normalization

- 0 = area with higher income → less critical
- 1 = area with lowest income → more critical

Why: A lower income indicates lower spending power, social vulnerability, and less residential attractiveness.

OMI value (€/m^2)
Criterion: Inverse normalization

- 0 = area with higher real estate value → less critical
- 1 = area with lowest real estate value → more critical

Why: Low property values may reflect low demand, deteriorating buildings, or poorer urban quality.

Population density (inhabitants/km^2)
Criterion: Direct normalization

- 0 = area with lower density → less critical
- 1 = area with higher density → more critical

Why: Higher density means more urban planning pressure and less public space per inhabitant.

Unemployment rate (%)
Criterion: Direct normalization

- 0 = area with fewer unemployed → less critical
- 1 = area with more unemployed → more critical

Why: A high unemployment rate indicates socioeconomic fragility and potential social hardship.

Residential buildings (%)
Criterion: Direct normalization

- 0 = less residential area → less critical
- 1 = more residential area → more critical

Why: A very high residential share indicates monofunctionality and high housing pressure.

Commercial buildings (%)
Criterion: Direct normalization

- 0 = area with less commercial buildings → less critical
- 1 = area with greater presence of commercial buildings → more critical

Why: A very high percentage of commercial buildings may indicate a functional imbalance in the urban fabric, with a reduced presence of residential spaces and potential congestion, increased local traffic, and a decrease in livability. A high concentration of commercial activities can also put pressure on mobility services, a lack of public spaces, and increased exposure to noise and air pollution. In this sense, a higher percentage is interpreted as an indication of greater urban pressure and potential criticality.

Occupied dwellings (%)
Criterion: Direct normalization

- 0 = area with fewer occupied homes → less housing pressure
- 1 = area with more occupied homes → more critical

Why: More occupied housing means higher effective population density and greater burden on services.

Old age index
Criterion: Direct normalization

- 0 = area with lowest aging index → less critical
- 1 = area with higher aging index → more critical

Why: A high aging index indicates a significant demographic imbalance due to the high proportion of older people compared to younger people. This leads to greater pressure on social and health services, a lower capacity for socioeconomic innovation, and greater overall vulnerability of the region. At the urban level, a very elderly population may face greater difficulties in accessing services, in daily mobility, and in participating in urban transformation processes, contributing to a critical social situation.

Illiterate (%)

Criterion: Direct normalization

- 0 = area with lowest percentage → less critical
- 1 = area with higher percentage → more critical

Why: A high percentage of illiteracy is an indicator of social exclusion and cultural fragility.

Permeable soil (%)

Criterion: Inverse normalization

- 0 = area with more permeable soil → less critical
- 1 = area with less permeable soil → more critical

Why: Less permeability means greater risk of flooding, heat island effects, and less environmental sustainability.

Green space (m^2/ab)

Criterion: Inverse normalization

- 0 = area with more greenery available → less critical
- 1 = area with less greenery → more critical

Why: A low level of greenery reduces the quality of life, healthiness, and social opportunities.

The radar chart in Fig. 4 provides a direct visualization of the multidimensional profile of the five macro-areas, comparing the relative intensity of individual indicators after normalization. The radial representation highlights, through the width and shape of the different "footprints," the presence of heterogeneous configurations among the analyzed areas: some show marked peaks corresponding to specific critical factors, while others present more balanced or distributed profiles. A comparative reading of the trajectories allows for a quick understanding of which dimensions—economic, social, or environmental—contribute most to general vulnerability and to the identification of the zones where critical issues are most concentrated.

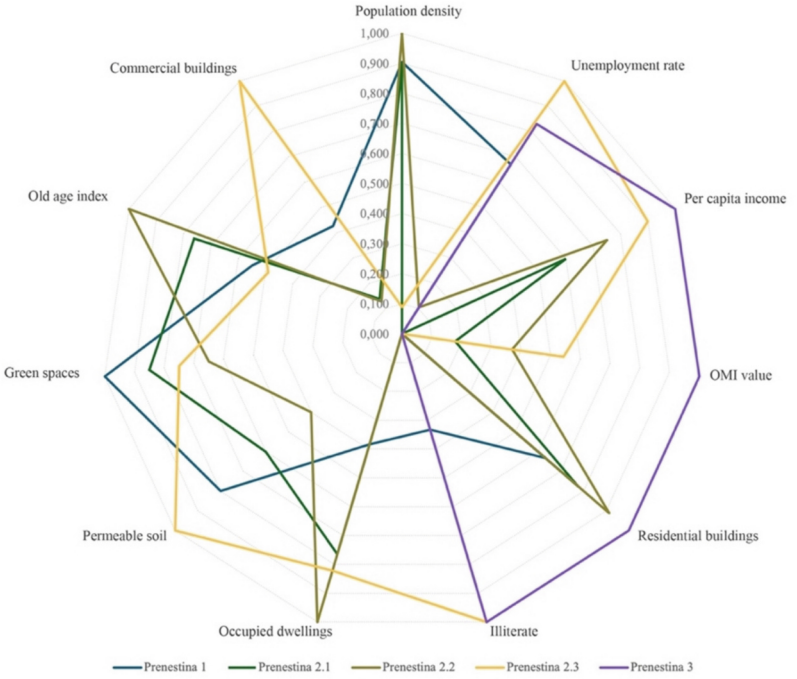

Fig. 4. Graphing of the 5 macro-areas. Source: authors' elaboration.

4.4 Synthetic Criticality Index

To define the synthetic criticality index, it was necessary to assign a weight to each indicator, reflecting the relative importance of the three dimensions considered—economic, social, and environmental—in the overall evaluation process. Consistent with the methodological approach adopted, the choice was made to assign equal overall weight to the three dimensions, thus evenly distributing the relevance of the dimensions comprising the multi-criteria assessment. The assignment of equal weights to the three dimensions reflects the idea that urban criticalities arise from the combined interaction of economic, social, and environmental factors and that no one of these components, in an initial analysis phase, should be considered a priori prevailing over the others. In this way, homogeneous weighting allows for an integrated interpretation of territorial vulnerability, limiting the risk of a single dimension excessively influencing the final result. Therefore each dimension contributes one-third to the final index but, within each dimension, the weight is distributed among the indicators that comprise it. The following structure results:

- Economic dimension → 2 indicators
  - o Overall size weight: 1/3
  - o Weight of each indicator: $1/3 \div 2 = 1/6 \approx 0.1667$
- Social dimension → 7 indicators

- Overall size weight: 1/3
- Weight of each indicator: $1/3 \div 7 = 1/21 \approx 0.047$

- Environmental dimension → 2 indicators
  - Overall size weight: 1/3
  - Weight of each indicator: $1/3 \div 2 = 1/6 \approx 0.1667$

In this way, each of the three dimensions—economic, social, and environmental—contributes 33.3% to the final indicator, preventing a single dimension from becoming dominant and ensuring an interpretative balance between the components of urban vulnerability.

The criticality index is calculated by combining the normalized values of the indicators with their respective weights according to the following formula:

$$\text{Criticality index} = \sum (x_{\text{norm}} \cdot w)$$

where:

- x_{norm} = normalized value of the indicator,
- w = weight assigned to the indicator.

Since the sum of the weights is equal to 1, a subsequent division by the total weights is not necessary. The result obtained (Table 3) represents a synthetic value, between 0 and 1, which expresses the relative level of criticality of each of the analyzed macro-areas, allowing for immediate comparison and the selection of the most vulnerable area.

Table 3. Criticality index values for each macro-area.

Area	Prenestina 1	Prenestina 2.1	Prenestina 2.2	Prenestina 2.3	Prenestina 3
Criticality index	0.483	0.529	0.557	0.739	0.466

4.5 Analysis of the Results

The application of the multicriteria indicator allowed us to obtain, for each macro-area of the Asse Prenestino, a synthetic criticality value derived from the combination of the normalized values and the weights assigned to the three indicator dimensions.The integrated interpretation of the index lets us immediately grasp the internal heterogeneity of the corridor and to outline a hierarchy of territorial vulnerabilities. The analysis of the results clearly shows that Prenestina 2.3 is the area with the highest widespread criticality level. Its value, significantly higher than the value of the other areas, is the result of the negative interaction between economic, social, and environmental dimensions. According to an economic vision, the combination of lower OMI values and a lower average income compared to the rest of the axis suggests the area's low attractiveness and the presence of real estate devaluation dynamics. Beyond that there is a complex social situation, characterized by higher unemployment rates and a less balanced population structure.

From an environmental perspective, the situation appears further intricate by limited soil permeability and a modest supply of urban greenery, factors that contribute to general worse environmental conditions compared to more central or external macro-areas. The Prenestina 2.1 and Prenestina 2.2 areas fall into an intermediate criticality range, presenting values that reflect a heterogeneous territorial condition. In Prenestina 2.1, the indicators show a coexistence of elements of fragility—such as the presence of high-density residential neighborhoods or abandoned industrial places—with more favorable elements, such as proximity to quality green spaces and the presence of emerging cultural functions. Prenestina 2.2, however, shows a slightly better balance: the supply of greenery and the presence of consolidated residential fabrics help mitigate some issues of social and infrastructural nature, even if they do not completely eliminate vulnerabilities related to population density and demographic structure. The corridor's outermost areas, Prenestina 1 and Prenestina 3, present lower levels of criticality. Prenestina 1, despite being located within the inner city, takes advantage of the presence of office buildings, greater accessibility to central infrastructure, and higher property values than other areas. However, heavy urban development and saturation of urban spaces produce a rigid balance between strengths and weaknesses. Prenestina 3, characterized by peri-urban conditions and a lower population density, presents more favorable environmental indicators—such as greater soil permeability and a greater availability of green spaces—which offset the presence of socioeconomic vulnerabilities and distance from major infrastructure and services.

The overall graph in Fig. 5 provides a visual summary of the distribution of critical issues along the Prenestina corridor, facilitating comparative analysis across macro-areas. The clear distinction between the Prenestina 2.3 value and the single one of the other zones highlights the usefulness and efficacy of the multicriteria indicator as a preliminary screening tool.

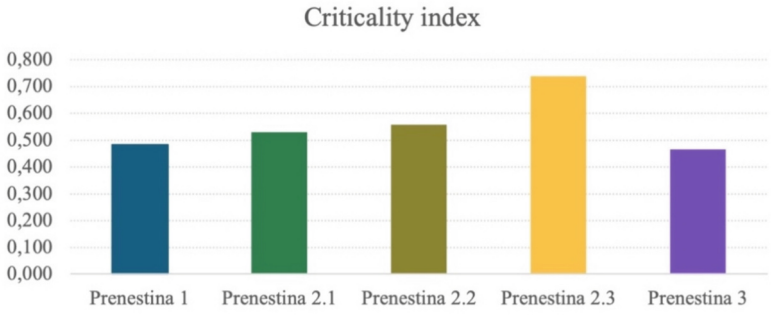

Fig. 5. Graph of the criticality index for each identified macro-area. Source: authors' elaboration.

The confirmation of Prenestina 2.3 as the most problematic area is a fully consistent evidence referring to the observed territorial conditions, and constitutes a basic step towards defining targeted project scenarios, where it is useful to concentrate resources, tools, and urban regeneration policies. This result strengthens the validity of the approach

adopted and gives a significant contribution to the construction of a decision-making process based on comparative analyses and transparent criteria.

5 Conclusions

This analysis demonstrates how the construction of a multicriteria indicator can be a significant tool to support decision-making processes in urban regeneration, especially in contexts characterized by really complex territorial structures and limited resources.

The methodological transparency and replicability of this method represent one of the its strengths: the indicator's structure, based on selected indicators, normalized, and aggregated according to explicit criteria, allows the approach to be adapted to diverse urban scenarios, appropriately modifying the set of indicators without modifying its conceptual structure. Therefore the index operates as a preliminary screening tool, useful for focusing attention on the most vulnerable conditions and sustaining the definition of intervention priorities in the earliest planning phases. At the same time, the approach possesses some core limitations due to its synthetic nature. The index is not planned to describe socio-spatial dynamics in detail or to provide operational design control, but rather to provide an initial understanding for more in-depth analyses. From this point of view, the criticality index does not substitute other assessment tools, but rather suggest a complementary element within a wider decision-making process. A significant side involves the assignment of weights to the various dimensions and indicators [21]. This aspect highlights the sensitivity of the model to weighting assumptions, reinforcing the need for future research aimed at testing alternative weighting schemes and evaluating their impact on the results. This paper aims at the choice of a uniform weighting between the economic, social and environmental dimensions, and responds to the necessity to guarantee interpretative balance and simplicity of application. Yet, this choice opens up possible future developments: the involvement of institutional, technical and local stakeholders in the processes of defining and calibrating the weights could allow for the attribution of a differential significance to the various dimensions based on particular objectives, political priorities or the features of the context analysed, strengthening the participatory and decision-oriented nature of the tool. Further developments refer to the extension of the approach to subcategories, i.e. mobility, accessibility to services, environmental quality or energy efficiency, as well as the integration with more advanced spatial analysis techniques. In this perspective, recent studies highlight how the integration of Artificial Intelligence within decision-support systems can enhance the capacity to interpret and intecetive complex urban dynamics and support faster and more adaptive planning responses [22]. Moreover, the particular attention is referred to identification of shared sustainability indicators and the development of Minimum Indicator Sets can further strengthen the comparability and effectiveness of evaluation frameworks, supporting more coherent and aligned urban policy strategies [23]. Generally, the paper underlines how multi-criteria approaches can offer a flexible basis for addressing complex decision-making problems, and they propose useful tools to guide public choices in a coherent, comparable and informed way.Finally, they can be adaptated and improved over time.

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