NET4SAFE: Network for Emergency and Safety Management. A Platform for Emergency Management and Accessibility

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Abstract. The constant increase in the frequency and intensity of impactful climate events, combined with the Italian territory's complex morphology and extreme urban fragmentation, underscores the urgent need for tools that support more resilient and effective planning. This study introduces an innovative and scalable methodology for analyzing territorial accessibility. The model is based on an initial application of network theory, which, through geospatial data, represents urban settlements and their infrastructural connections. The aim is to identify areas most vulnerable due to limited accessibility to both services and key infrastructure networks. The study sets the foundation for the development of an operational tool to support emergency planning and response management. The proposed system serves as an efficient Decision Support System (DSS) for public authorities, adaptable to various territorial scales and integrable with demographic, building, and risk-related indicators. This approach addresses a gap in territorial knowledge and aims to provide an accurate representation of the infrastructural fabric. Such representation enables the definition of intervention priorities and risk mitigation strategies, ultimately promoting sustainable urban development.

Keywords: Network Planning · Emergency Management · Decision Support System

1 Introduction

The fragmentation of settlements currently observed across the Italian territory has made settlement systems highly energy-consuming and increasingly costly to manage for public administrations. This configuration lacks resilience and contributes to various environmental issues, as evidenced by the growing frequency of climate-related emergencies. These events increasingly expose the inherent vulnerabilities of a territory already heavily affected by multiple types of risk. Such dysfunctions concern the energy footprint of settlements, the fragmentation of natural habitats, access to social services, resilience to environmental hazards, and the decline of ecosystem functions. In Western industrialized countries, there has been an uncontrolled expansion of urbanized land, often

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O. Gervasi et al. (Eds.): ICCSA 2025 Workshops, LNCS 15889, pp. 117–128, 2026.
https://doi.org/10.1007/978-3-031-97603-2_8

unjustified by significant demographic changes. In Italy, this phenomenon—commonly referred to in the scientific literature as 'sprawl'—has long been regarded as a sign of effective governance, with regulations that have favored the development of new areas over the regeneration of existing ones. A scattered pattern of growth which, due to the specific characteristics of the national context, makes land recovery and management more complex. To describe the Italian case, the term 'sprinkling' has been proposed, as it more accurately captures the fragmented distribution of settlements across the territory—an aspect typical not only of Italy but also of other regions in Southern Europe [1]. Italy's high degree of administrative fragmentation—7,893 municipalities as of 2025—represents an emblematic case that highlights, about territory, environment, and social communities, the issues and dysfunctions that arise in the absence of spatial planning and a strategic interpretation of development goals. For these reasons, urban planning in Italy has been described as 'molecular', with serious consequences including excessive urbanization, the loss of coordinated planning, difficulties in infrastructure management, and poor efficiency in the rational organization of public services—ultimately resulting in unstructured growth and high energy consumption [2–5]. Moreover, in recent years, the urbanization process has accelerated on a global scale, transforming cities into the main hubs of human life, with both beneficial and problematic implications. The United Nations (UN) and the European Union (EU) urge the protection of soil, the environment, and the landscape—factors recognized as valuable components of natural capital—and promote the achievement of net-zero land take by 2050. This goal should be aligned with demographic growth and pursued without increasing the current rate of land degradation by 2030. It is in response to these objectives that new techniques and tools for spatial planning must be adopted, capable of providing timely and appropriate responses to territorial transformations. These should support the sustainable management of land and its proper uses through effective response actions embedded in urban policies [6–9].

In this context, the first essential aspect to address concerns the understanding of the geography of the country's settled areas, their demographic structure, their level of accessibility, and the risks to which they—together with the connecting infrastructures—are exposed. Such knowledge becomes a fundamental prerequisite both in the early stages of emergency management and for the implementation of appropriate actions aimed at mitigating vulnerability to various types of risk. In particular, the role of road connections will be analyzed, focusing on their distribution and typology, as well as their implications for urban and rural resilience.

The methodology is grounded in the principles of network theory, identifying nodes while simultaneously analyzing the systems of connections. Numerous scientific studies [10–17] have addressed the concept of 'node theory' in the field of urban planning. The presence of nodes necessitates connectivity, which can be supported by various modes of transport and by the broader system of relationships between nodes and their connections. Road and transit connections are typically local in scope and often take the form of a grid, which characterizes the layout of many cities. In contrast, rail, maritime, and air links integrate the city into a broader context of distribution and trade, often on a global scale [18]. In this way, the analysis enables the identification of areas that are more vulnerable in terms of accessibility and isolation, where the quality of connections plays a key role. It considers not only the number of connections but also their specific

weight, thereby contributing to a more accurate representation of the infrastructural resilience of a municipality or individual settlement areas. The work presented outlines a methodology currently under development, aimed at identifying and assessing the degree of accessibility of territories at both municipal and urban/peri-urban scales. Areas with better connectivity are generally more integrated into economic and social networks, facilitating access to public services, promoting sustainable mobility, and ensuring their reachability in emergencies.

Conversely, poorly connected areas tend to remain isolated and vulnerable, with the risk of being excluded from timely interventions in the event of catastrophic events. This vulnerability is further exacerbated by an urban structure which, although diverse and historically stratified, presents significant weaknesses in terms of emergency resilience. In a context where physical spaces are constantly intertwined with their social constructions, the idea of place as a fixed, material entity is surpassed. Place instead becomes a 'space of flows', making the adoption of advanced technological tools crucial to support risk and emergency management. In this way, the concept of the city shifts from a spatially bounded, human-centered phenomenon to a dynamic and complex urban system, which, in its incompleteness and indeterminacy, becomes the stage where urban elements take shape and adapt. The city emerges as an evolving organism, where past, present, and future merge, reflecting social dynamics and the ongoing attempts to regulate their interactions and spatial organization, that is, the urban development process in terms of conservation, transformation, or change concerning its original state [19].

2 Material

The data comes from institutional and open-source sources, such as ISTAT [20] for municipal boundaries and census sections and OpenStreetMap (OSM) for the road network [21]. The geographic data about census sections are available in shape file format from the website of Istituto Nazionale di Statistica (Istat). The scale of data representation is not uniform across the national territory, varying from a scale of 1:5 000 (typically in urban areas) to a scale of 1:25 000 (primarily in low or very low population density areas). Different attributes are associated with this census section. The one that has been used to identify the urban areas is the typology of the location (TIPO_LOC).

The field can take the following values:

1. *Inhabited centre*: an aggregate of contiguous or neighbouring houses with interposed streets, squares and the like, or in any case brief solutions of continuity characterized by the existence of public services or establishments (school, public office, pharmacy, shop or similar) that constitute an autonomous form of social life and, generally, also a gathering place for the inhabitants of the neighbouring areas to manifest the existence of a form of social life coordinated by the centre itself. Tourist meeting places, groups of villas, hotels, and the like intended for holidays, inhabited seasonally, must be considered as temporary inhabited centers, provided that during the period of seasonal activity they present the requirements of the centre.
2. *Inhabited nucleus*: inhabited locality, without the gathering place that characterizes the inhabited centre, consisting of a group of at least fifteen contiguous and neighbouring buildings, with at least fifteen families, with interposed roads, paths, squares,

farmyards, small vegetable gardens, small uncultivated areas and the like, provided that the interval between house and house does not exceed thirty meters and is in any case less than that between the nucleus itself and the nearest of the manifestly scattered houses.
3. *Production location*: an area in an extra-urban area not included in inhabited centres or nuclei in which there are more than 10 local units, or whose total number of employees is greater than 200, contiguous or close with interposed streets, squares and the like, or in any case brief solutions of continuity not exceeding 200 m; the minimum area must correspond to 5 hectares.
4. *Scattered houses*: houses scattered in the municipal area at such a distance that they cannot even constitute an inhabited nucleus.

In our case, urban areas are defined as the whole of inhabited center and nucleus (the sum of class 1, 2 and 3).

For the structural aggregate, it was referred to the Department of Civil Protection [22] created a dataset of structural aggregates across Italy to support post-earthquake damage assessment activities. This dataset, developed with the contribution of Regions, Autonomous Provinces, and the Revenue Agency, integrates data from regional geotopographic databases, cadastral maps, and Istat administrative boundaries (updated to 2021). The project harmonized heterogeneous data, ensuring uniformity at the national level. Released under an Open CC-BY 4.0 license, the dataset can be integrated with locally produced maps and has multiple applications. The cartographic data, divided by macro-regions, along with the related metadata, are available for free reuse through the GitHub platform, along with general information about the entire project. The data is available in shapefile format and requires specific software (GIS) for consultation. The polygonal layer of the built-up area is derived from the analysis of ortho-rectified images through the combined use of "feature extraction" techniques via deep learning methodologies and supervision for the control and correction of the algorithms [22–24].

Data on road infrastructure and points of interest come from OpenStreetMap. Data can be downloaded via the https://download.geofabrik.de/ portal. The OpenStreetMap Project based at OpenStreetMap.org, is a worldwide mapping effort that includes more than a million volunteers around the globe (https://osmfoundation.org/wiki/About) who contribute and maintain data on roads, trails, cafes, train stations and much more. OpenStreetMap emphasizes local knowledge. Contributors use aerial imagery, GPS devices, and low-tech field maps to verify that OSM is accurate and up-to-date. The data in question can be downloaded in.shp geographical format and, depending on the type of information to which they refer, can be point, linear or polygonal files.

Specifically, downloadable data, which are geographical data in.shp format, provide on different layers data relating to buildings, land uses, natural elements, places, points of interests, railways, and transportation lines. Table 1 shows the categories of OSM roads used in this study. The nomenclature and symbology adopted in methodological treatment are also reported.

Table 1. Classification of considered road network

OSM class	Istat classification	Adopted symbology
Motorway	Motorway	
Trunk		
Primary	State, Regional, and Provincial roads	
Secondary	Extra-Urban roads	
Tertiary	Urban roads	
Residential		
Unclassified		

3 Methodology

The proposed work aims to define a schematic methodology for characterizing urban areas based on accessibility. In this context, accessibility is understood as the number of connections between different urban areas and the type of infrastructure linking them. The underlying principle is as follows: the higher the number of connections a territorial entity has with others, the greater its level of accessibility. High accessibility is particularly crucial in emergency contexts. The principles underlying the methodology are based on network theory, identifying and characterizing nodes while simultaneously analyzing the systems of connection [25–28].

This methodology aims to provide a support tool for emergency management in two distinct contexts: ordinary conditions and emergencies. In the former, the goal is to identify the most underserved areas to improve accessibility by addressing infrastructural weaknesses. In emergencies, the use of this methodology makes it possible to provide essential geographical information, such as the location of the event triggering the emergency, the affected population, and the condition of the infrastructure.

The model is based on a graphical representation of the network of connections between major urban centres and smaller settlements, organized according to an infrastructural hierarchy.

Specifically, Figs. 1 and 2 illustrate two different territorial configurations, utilizing the same system of symbols to ensure consistency and comparability between the representations. In particular, the legend accompanying the figures distinguishes two primary groups of symbols: one pertaining to the road network and the other to the urbanized areas.

The road network is depicted through the use of lines, with the thickness of each line varying proportionally to the vehicular flow capacity that the corresponding infrastructure is able to support. More precisely, motorways are represented by the thickest lines, symbolizing their ability to accommodate the highest volume of vehicular traffic. Conversely, urban streets are illustrated with the thinnest lines, reflecting their function as routes characterized by a significantly lower traffic capacity and reduced vehicular flow. This differentiation in line thickness offers an immediate visual cue regarding the hierarchical importance of the various road types in the territorial framework. Regarding urban centers, these are represented using squares whose dimensions and shades

of grey vary according to the density of urbanization they exhibit. The differences in both size and coloration serve to convey the relative importance and functional role of each settlement within the overall territorial system. Larger squares shaded in dark grey correspond to densely urbanized centers, indicating areas with a high concentration of buildings and activities. In contrast, smaller squares with lighter grey tones are used to represent production sites or smaller inhabited nuclei, which are characterized by a lower degree of urbanization. This symbolic approach allows for a nuanced visualization of both the infrastructural and urban structure of the territory, enabling a more comprehensive understanding of the relationships between different nodes and the transport routes that connect them. By integrating variations in line thickness and square attributes, the graphical representation effectively communicates the complex interplay between urban density and infrastructural connectivity.

As previously mentioned, Fig. 1 and Fig. 2 show two different territorial configurations. Each configuration has significant implications not only for everyday mobility patterns and the efficiency of movement across the territory but also, and perhaps even more critically, for the management of emergency situations. The spatial organization of settlements and the structure of the road network profoundly influence how evacuate areas can be evacuated, how quickly emergency services can intervene, and how resilient a territory can be when subjected to natural disasters, accidents, or other crises.

In particular, the configuration of the territory affects factors such as the redundancy of routes, the accessibility of peripheral areas, and the potential isolation of certain settlements under emergency conditions. A fragmented or poorly interconnected territory may exacerbate response times and limit the effectiveness of rescue operations, while a more structured and hierarchical network can facilitate faster and more reliable interventions. Thus, analyzing and understanding these two territorial models is crucial for both the planning of mobility systems in ordinary circumstances and the preparation of effective emergency response strategies.

Figure 1 shows a territorial configuration characterized by a polycentric and scattered distribution of settlements, accompanied by a complex yet fragmented infrastructural network. The presence of main urban centers, minor settlements, and productive areas, distributed heterogeneously across the territory and connected through a multi-level road hierarchy (including highways, national/regional/provincial roads, and urban and extra-urban roads), suggests a reticular settlement model lacking a dominant central structure. However, the spatial distribution of settlements appears dispersed, and the road network is rather discontinuous, relying heavily on numerous secondary roads that are often inadequately structured. In such a context, functional connections between the different poles are fragile and vulnerable, particularly in emergencies (e.g., extreme weather events, natural disasters), where access to services and the timeliness of emergency response may be seriously compromised.

Figure 2, on the other hand, presents a more orderly and hierarchical configuration, with three main poles connected by a clear infrastructural axis. In this context, the management of connections becomes more efficient, with a denser road network that offers more effective alternative routes, reducing the risk of isolation of some areas and improving accessibility to essential services.

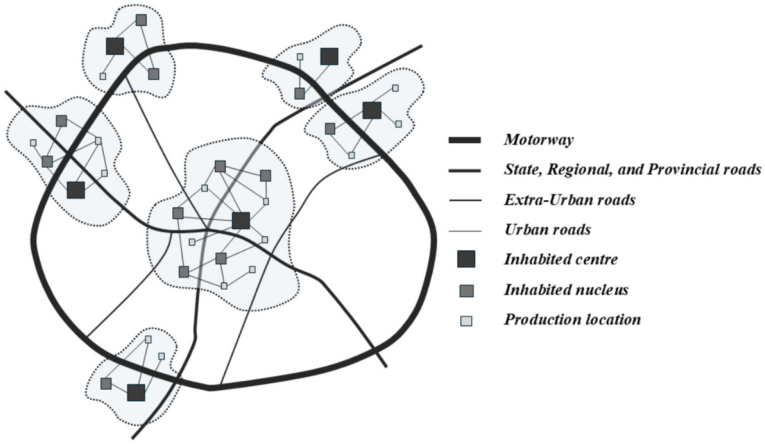


Fig. 1. Territorial configuration with fragmented connections (Authors' elaboration)

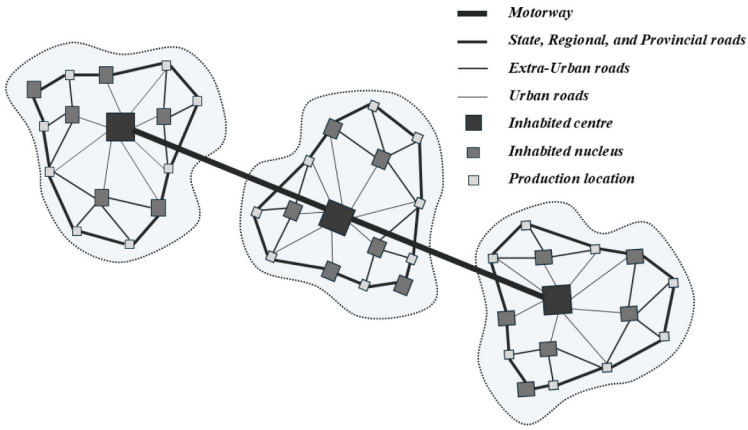


Fig. 2. Territorial configuration with more structured connections (Authors' elaboration)

Within this framework, three main nodes are identified, representing the primary urban centres, which are interconnected by a hierarchically structured transport network. This network includes motorways—as the primary axis of connection between urban centres—national, regional, and provincial roads that link the urban centres to the surrounding territory, and extra-urban and urban roads that provide local connectivity between smaller settlements. This organization makes it possible to assess the degree of accessibility of the various settlements and the role of urban centres in the distribution of territorial functions.

Settlements have been classified into three categories based on their size and level of connectivity, as previously outlined in the materials section:

- Inhabited centre
- Inhabited nucleus

- Production location.

This classification enables the analysis of the distribution of population and infrastructure, highlighting the degree of dependence of smaller settlements on the main urban centres. To make these dynamics more intuitive, the graphical representation employs varying sizes and line thicknesses to indicate the relative weight of each node, while connections are differentiated according to their function. This visual approach highlights the urban hierarchy and the relationships between different sectors, offering a clear overview of territorial organization and its underlying functional logic.

The developed model provides an immediate interpretation of the urban network, highlighting how nodes are distributed and interconnected. Each node assumes a specific role within the system, depending on the number of buildings, the extent of built-up areas, and its functional use—whether residential, commercial, administrative, or industrial. This distinction allows for an understanding not only of the network structure but also of the weight and significance of each node within the urban fabric.

4 Discussion and Conclusions

The methodology, although still under development and subject to further validation, represents a preliminary yet significant step forward in understanding the vulnerabilities and resilience of areas characterized by dispersed settlements [29, 30]. Its flexible structure allows the model to be adapted to different territorial contexts, providing an effective tool for analyzing road infrastructure connectivity and vulnerability. An effective representation of the applied methodology can be illustrated through an analogy with the human body: main roads function like arteries, ensuring the connection between central and peripheral areas, just as blood nourishes bodily tissues. However, in the territorial context, the situation is far more complex. There are no homogeneous tissues composed of cells, but rather a collection of scattered housing units which, although they have infrastructural and service needs, are not organized uniformly. This configuration results in high costs for ordinary management and, above all, for emergency response. Settlement dispersion thus represents a critical challenge for territorial planning, raising questions about its long-term sustainability and the system's capacity to cope with catastrophic events.

The real territorial system is not as rigidly structured as the model; in fact, the real-world scenario often features a high degree of settlement dispersion, resulting in very high emergency management costs. Figure 3 illustrates a typical configuration found in Italy, where a strong tendency towards dispersed urbanization can be observed. For this purpose, structural aggregates produced by the Civil Protection Department are also included.

One of the most critical aspects to consider is the impact of the loss of an infrastructural node following an emergency event (such as a landslide, flood, or earthquake). If the node is highly connected, its disruption can trigger cascading effects throughout the network, compromising the system's capacity for intervention, and emergency response is therefore essential to assess how the territorial system can reorganize itself in the event of an emergency to ensure a rapid and effective response. This requires advanced tools capable of simulating crisis scenarios and optimizing the management

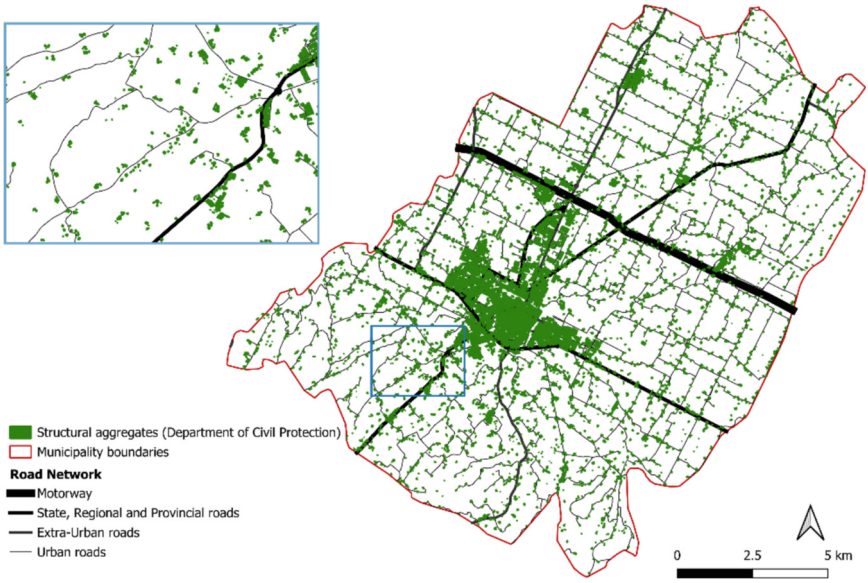


Fig. 3. Typical urban configuration in Italy with road network and structural aggregates (Authors' elaboration)

of available resources. The analysis is based on data from the Italian National Institute of Statistics (ISTAT), relating to census sections, which provide the number of inhabitants for each area. However, in zones characterized by dispersed settlements, such data are poorly representative as they are not directly associated with individual urban clusters. To improve the accuracy of the model, it would be beneficial to integrate data from the Civil Protection Department on structural aggregates, allowing for the estimation of the average number of inhabitants per dwelling and enabling a more realistic representation of population distribution. To provide a representative analysis, it is important to select a heterogeneous sample of Italian municipalities characterized by different levels of settlement dispersion, connectivity, and vulnerability to environmental risks. The selection of municipalities must consider the geographical and infrastructural diversity of the country, from poorly connected mountainous areas to medium-sized urban centres that serve as key nodes within the national road network [1, 31].

Further development of the research could involve the creation of an interactive platform that not only represents population distribution and the location of urban nodes but also highlights the main risks associated with each node. Such a platform could support the updating of emergency management plans and serve as a valuable tool for risk mitigation and territorial planning. A more detailed analysis should include:

- The classification of connections between nodes (national roads, motorways, secondary roads) to assess access capacity and vulnerabilities within the road network.
- The identification of open areas within nodes, including an analysis of the coverage ratio, the percentage of impervious surface relative to the total area—which affects the territory's resilience in the event of extreme weather events.

– The building and population density to better characterize the function of the nodes and to understand their weight within the settlement network.
– The identification of points of interest (POIs), such as essential services and strategic infrastructures, to estimate population flows and their concentration across different areas.

The use of data from OpenStreetMap could enhance the understanding of mobility dynamics, as areas with a high concentration of services tend to attract more people, increasing their criticality in emergencies.

Further development could involve the integration of artificial intelligence algorithms or optimization models to define the most efficient routes to reach affected areas, avoiding random interventions based solely on calls received by operational centres. Once the damaged and compromised infrastructures have been identified, the system could estimate the number of people affected, enabling more targeted and informed interventions.

A key point to highlight is that building density alone is not sufficient to characterize the urban fabric. For instance, an area with skyscrapers and one with low-rise buildings may have the same building density but differ entirely in terms of habitability and population accommodation capacity. For this reason, it is essential to integrate demographic data with information on the distribution of buildings. In abandoned historic centres, for example, there may be high building density but very few actual residents.

A more effective approach could involve the introduction of an index that relates building density to the resident population, such as the residential density at the census section level. Residential density provides information on the number of inhabitants per unit of area, while the average number of inhabitants per building helps estimate the actual human presence in each context. ISTAT data on vacant housing represent crucial information for understanding the real resident population.

An additional level of analysis could include mobility flow data, providing information on the centrality and relative importance of the nodes. Finally, to enhance the readability and interpretation of the results, the schematic representation could be enriched with satellite imagery and other geospatial data. “Since the research is based on the application of a specific methodology, the schematic representation becomes a key element for visualizing the structure of the analyzed urban system, enabling an immediate understanding of territorial and functional dynamics. This approach, by integrating both quantitative and qualitative data, provides more effective tools for territorial planning and management, intending to improve urban resilience and the capacity to respond to environmental risks.

Acknowledgments. This work is part of the project “Paride “*Piattaforma per la prevenzione delle emergenze ed il supporto alla sicurezza del territorio”*.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Felli, A., Di Pietro, G., Marziali, E., Zullo, F.: Il disperso italiano: un'emergenza nell'emergenza. Progettare Nel Disordine-Progettare IL Disordine (2024)
2. Calafati, A.G.: Economia della città dispersa, Università degli studi di Ancona, Dipartimento di economia (2003)
3. Romano, B., Ciabò, S.: Il futuro del paesaggio: tra urban sprawling e sviluppo sostenibile, Riconquistare il paesaggio. La Convenzione Europea del Paesaggio e la Conservazione della Biodiversità in Italia, pp. 257–267 (2008)
4. Romano, B., Zullo, F., Fiorini, L., Ciabò, S., Marucci, A.: Sprinkling: an approach to describe urbanization dynamics in Italy. Sustainability **9**, 97 (2017)
5. Romano, B., et al.: Sostenibilità, resilienza, adattamento per la tutela degli ecosistemi e la ricostruzione fisica in Italia Centrale (2020–2022). Rapporto tecnico finale – Progetto Sost.EN.&Re. Università degli Studi dell'Aquila (2022). ISBN 978-88-946095-1-614:41
6. Romano, B., Fiorini, L., Zullo, F., Marucci, A.: Una valutazione delle dinamiche di consumo di suolo in Italia: Gli esiti della ricerca DICEAA. In: Caring fo Our Soil: Aver Cura Della Natura dei Territori; WWF Italia Onlus, Rome, Italy, pp. 19–28 (2017)
7. Felli, A., Zullo, F.: Legislative foundations: exploring land take laws and urban regeneration policies in Italy and Europe. Land **13**(713) (2024)
8. Montaldi, C.: Consumo di suolo: Un complesso quadro di politiche, definizioni e soglie. Territorio **2023**(103), 147–156 (2024)
9. Tomei, V., Romano, B., Zullo, F.: Advanced planning tool mosaic (A-PTM) decision support tool towards the sustainable development goals. In: Marucci, A., Zullo, F., Fiorini, L., Saganeiti, L. (eds.) INPUT 2023. LNCE, vol. 463, pp. 717–727. Springer, Cham (2024). https://doi.org/10.1007/978-3-031-54096-7_62
10. Facchinetti, M.: Intorno al nodo: processi di densificazione urbana e territoriale nelle aree ad alta accessibilità infrastrutturale, Editore Pitagora (2007)
11. Claramunt, C., Winter, S.: Structural salience of elements of the city. Environ. Plan. B. Plan. Des. **34**(6), 1030–1050 (2007)
12. Cheng, J., Bertolini, L., le Clercq, F., Kapoen, L.: Understanding urban networks: comparing a node-, a density-and an accessibility-based view. Cities **31**, 165–176 (2013)
13. Schaub, M.T., Lehmann, J., Yaliraki, S.N., Barahona, M.: Structure of complex networks: quantifying edge-to-edge relations by failure-induced flow redistribution. Netw. Sci. **2**(1), 66–89 (2014)
14. Natapov, A., Czamanski, D., Fisher-Gewirtzman, D.: A network approach to link visibility and urban activity location. Netw. Spat. Econ. **18**, 555–575 (2018)
15. Ma, J., Shen, Z., Xie, Y., Liang, P., Yu, B., Chen, L.: Node-place model extended by system support: evaluation and classification of metro station areas in Tianfu new area of Chengdu. Front. Environ. Sci. **10**, 990416 (2022)
16. Antropia. https://www.antropia.it/la-teoria-dei-grafi-nella-citta-di-konigsberg/. Accessed 25 Jan 2025
17. The Geography of Transport Systems. https://transportgeography.org/contents/chapter8/transportation-urban-form/cities-connectivity/. Accessed 25 Jan 2025
18. Cvetinovic, M., Nedovic-Budic, Z., Bolay, J.C.: Decoding urban development dynamics through actor-network methodological approach. Geoforum **82**, 141–157 (2017)
19. Ewing, R., Pendall, R., Chen, D.: Measuring sprawl and its transportation impacts. In: Hanson, G.S. (ed.) Urban Sprawl: Causes, Consequences, and Policy Responses. Urban Land Institute, pp. 55–77 (2002)
20. Istituto Nazionale di Statistica (Istat). https://www.istat.it/. Accessed 13 Feb 2025
21. Open Street Map (OSM). https://www.openstreetmap.org/. Accessed 07 Feb 2025

22. Dipartimento della Protezione Civile. https://rischi.protezionecivile.gov.it/it/approfondimento/dataset-nazionale-degli-aggregati-strutturali-italiani/. Accessed 15 Feb 2025
23. Regione Emilia-Romagna – Geoportale: Edificato 2018 ottenuto con tecniche di feature extraction tramite machine learning (2018). https://geoportale.regione.emilia-romagna.it/notizie/servizi-e-applicazioni/edificato2018-ottenuto-con-tecniche-di-feature-extraction-tramitemachine-learning
24. Olivucci, S., Nerieri, M., Ruggieri, G., Romani, M., Ceresini, S., Gentili, G.: Il nuovo strato edificato da tecniche "deep learning" come fonte per l'aggiornamento del database topografico e per il monitoraggio del consumo di suolo. In: Atti della Conferenza ASITA 2019, Trieste, Italia, 2019, pp. 811–818 (2019). ISBN: 978-88-941232-5-8
25. Ding, R., et al.: Application of complex networks theory in urban traffic network researches. Netw. Spat. Econ. **19**, 1281–1317 (2019)
26. Milanović, J.V., Zhu, W.: Modeling of interconnected critical infrastructure systems using complex network theory. IEEE Trans. Smart Grid **9**(5), 4637–4648 (2017)
27. Faramondi, L., Setola, R., Panzieri, S., Pascucci, F., Oliva, G.: Finding critical nodes in infrastructure networks. Int. J. Crit. Infrastruct. Prot. **20**, 3–15 (2018)
28. LaRocca, S., Guikema, S.: A survey of network theoretic approaches for risk analysis of complex infrastructure systems. In: Vulnerability, Uncertainty, and Risk: Analysis, Modeling, and Management, pp. 155–162 (2011)
29. Khan, M.T.I., Anwar, S., Sarkodie, S.A., et al.: Natural disasters, resilience-building, and risk: achieving sustainable cities and human settlements. Nat. Hazards **118**, 611–640 (2023)
30. Baffoe, G., Zhou, X., Moinuddin, M., et al.: Urban–rural linkages: effective solutions for achieving sustainable development in Ghana from an SDG interlinkage perspective. Sustain. Sci. **16**, 1341–1362 (2021)
31. La Rosa, D.: Metodologie per le sintesi del piano. In: Mancuso, C., Martinico, F., Nigrelli, F.C. (eds.) I Piani Territoriali Paesaggistici nella Provincia di Enna. INU (2008)