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Innovation in Urban and Regional Planning

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Preface

Following a history of more than 20 years, the 13th International Conference on Innovation in Urban and Regional Planning (INPUT 2025), entitled “Methods, models and technologies for future cities and regions,” focused on the advances in knowledge and on the technical perspectives that the evolution of planning systems might offer to scholars, professional planners, and practitioners.

The Conference was hosted by the Urban Project Laboratory (UPLab) at the University of Pavia, Department of Civil Engineering and Architecture (DICAr).

The INPUT legacy has grown over the years, and nowadays it is clearly recognizable, at the national and international scale, as an active group (with very promising young researchers) that is open-minded to technological revolutions and their effects on the analysis and management of cities, regions, and territories.

The tradition of INPUT was highlighted during the final ceremony with a round table in which some of the founders of the Conference, Prof. Dino Borri, Prof. Giuseppe Las Casas, Prof. Arnaldo Cecchini, discussed about the evolution of the ideas that carried to the creation of INPUT and about the realization (or failure) of forecasts made in the past basing on the trust in technological development possibilities.

INPUT 2025 was held from the 8th to the 10th of September, with an opening ceremony featuring distinguished hosts. The Conference was patronized by the Italian Society of Urbanists (SIU), the Province of Pavia, the Municipality of Pavia, the Lombardy Regional Council of Engineering Professional Associations (CROIL), the Engineering Professional Association of Pavia Province, Architects, Planners, Landscape Architects, and the Conservators Professional Association of the Province of Pavia.

This book gathers 47 papers submitted to the INPUT 2025 Conference. After undergoing a blind-review process, the accepted papers are arranged by the thematic sessions of the Conference:

- AI and Machine Learning for Urban and Territorial Analysis and Forecast.
- New Simulation Methods and Models.
- Transition’s Management: Ecological, Energetic, Economic.
- 3S City (Smart, Safe, Sustainable).
- Impact Assessment of Nature-Based Solutions in Cities: Theoretical, Methodological and Practical Perspectives.
- How Is the City Moving? Tracking Flows and Enhancing Planning Policies.

- Innovations in the 15-Minute-City Approaches: Conceptual, Data-Driven, and Practical Developments Towards a Sustainable Urban Planning.
- Circular Economy and Planning. Fostering Energy and Industrial Symbiosis in Cities and Ports.

November 2025

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Gaps in Access and Availability of Data for the Georeferenced Description of Mobility Flows and Network Geometry. An Overview of Open-Source Data Availability in Italy: Initial Evidence from the MAC4TI Project

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Abstract. In recent years, the digitalization of planning processes has accelerated, partly due to the substantial investments made available to EU countries to achieve the sustainability, equality, and territorial cohesion goals set for 2030 and 2050. While a positive relationship between regional and economic development and accessibility to the transport network has been demonstrated, numerous EU-funded projects also aim to identify further connections between the hard infrastructure framework and socio-economic and environmental conditions at the regional scale.

To achieve these objectives and to automate processes capable of generating indicators and digital models that can support mobility planning, the accessibility and availability of validatable and georeferenced data are essential.

This article, therefore, presents evidence of the structural limitations encountered during the initial phases of the MAC4TI project, which aims to develop a GIS environment capable of integrating infrastructure and transport data with information on accessibility and mobility across Italy.

In conclusion, the findings demonstrate that both the quantity and quality of data are fundamental conditions for the success of similar projects. However, to effectively support policymakers and activate participatory planning processes, interventions are needed in the digital infrastructure, which currently lacks consistency in data availability and spatial localization capabilities.

Keywords: Mobility plan · Data aviability · GIS model · Regional development

1 Introduction

In the era of digitalization, the availability and accessibility of data are fundamental elements for the implementation of socio-economic and green development strategies promoted by the European Union [1–3]. Indeed, financial, geopolitical, and economic crises, along with the effects of climate change, have highlighted the inequalities and barriers to community growth and to achieving equitable and resilient regional development [4–7].

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This article focuses on issues related to accessibility to the transport network and the relationship between infrastructure systems, regional competitiveness, and development. While the European Green Deal [2] outlines the overarching sustainability goals to be achieved at the EU level - including transport, accessibility, and territorial cohesion - it is the NextGenerationEU initiative and the individual National Recovery and Resilience Plans (NRRPs) that define the strategies and mechanisms through which these objectives are to be pursued [8, 9]. According to these instruments, part of the green transition involves greater digitalization of public sector processes and procedures [3].

For these reasons, the management and availability of large volumes of data represent an integral and essential part of the process. However, in the context of accessibility and infrastructure, the creation of complete and accurate georeferenced datasets is often hindered by a lack of sufficient or high-quality data [10, 11]. To address this issue, the European Union has launched several initiatives aimed at improving the interoperability, accessibility, and standardization of territorial data, such as the INSPIRE Directive and the Copernicus Programme [12, 13].

In this context, this contribution presents the preliminary findings of the MAC4TI project, which is part of the broader ecosystem 'Growing Resilient, Inclusive and Sustainable' (GRINS), developed through access to funding from the Italian National Recovery and Resilience Plan (NRRP) [9]. The goal of the project is the development of a platform capable of facilitating the consultation and analysis of territorial data across various disciplinary sectors, in order to provide decision-making support for strategies and policies at both local and broader scales.

As shown in the literature, there is generally a positive link between territorial development and both physical structures—such as infrastructure networks—and intangible factors like social cohesion, inclusion, mobility, and environmental quality [5, 14, 15]. This article offers an overview and analysis of open-source data used to map and describe regional contexts, focusing on accessibility to infrastructure networks.

The goal is to highlight the limitations and challenges of building a geodataset with open-source data for statistically describing and spatially mapping a country's infrastructure network, using Italy as a case study. This process aims to identify gaps between data availability and usability, and the ability to convert statistical data into georeferenced formats. It also explores the barriers to integrating such data into a platform that is both accessible and adaptable to the needs of different stakeholders.

2 Literature Review

The description of urban phenomena through quantitative methods - such as statistical analyses or indicators - has recently gained increasing attention as a means to provide effective support to policymakers in structuring sectoral plans and in identifying where to intervene with target-based solutions [16].

Initially, these methodologies were employed in planning processes related to real estate investment strategies [17] and land consumption, or for climate change adaptation and mitigation [18]; today, the increasing computational power and the capabilities offered by artificial intelligence and Big Data are enabling their application in other areas of urban planning [19, 20]. As a result, smart city planning is increasingly oriented toward the development of systems of indicators and data, perceived as tools to support functional and innovative policies [20, 21]. For these reasons, mobility too must undergo this evolutionary step [22].

However, it has been noted that in certain socio-political contexts, the formulation of sustainable mobility plans faces several challenges, including the lack of comprehensive traffic data and insufficient institutional support from decision-makers [23]. These findings are consistent with the challenges encountered in accurately forecasting traffic flows, which typically require the implementation and management of specialized sensor infrastructures. However, a more accessible alternative has been identified in the development of data fusion methodologies aimed at producing usable measurements [24]. As proposed by Comi and Polimeni [25], a data-driven approach can support the sustainable management of micromobility by directly applying population daily trip data to a georeferenced matrix. A similar approach was adopted for managing post-pandemic walkability in Sydney and other city or region [26–28], highlighting the need for greater data availability.

A Spatial Data Infrastructure (SDI), also referred to as a geospatial data infrastructure, is a data framework that integrates geographic data, metadata, users, and tools in an interactive system designed to enable the efficient and flexible use of spatial data [29] but, today, the term Geographic Information System (GIS) is commonly used to refer to digital geospatial environments.

Over the years, the literature has expanded with numerous case studies on the use of GIS technologies as essential tools for analyzing urban mobility and designing strategies aligned with emerging smart city models [30–34]. Several studies also address the central issue of human movement and vehicular flows, either for the development of future and participatory predictive mobility models [35] or for the definition of descriptive indicators of urban accessibility and mobility phenomena, as exemplified by the European project CITYkeys [34].

However, the changing and time-sensitive nature of the context described in digital environments highlights the key role of georeferenced data as a basis for analysis [36, 37] and for developing computational models [31, 38]. Several studies point out that one major limitation in using GIS-based models for urban and regional mobility lies in: inconsistencies in open-source data platforms [30], limited availability and frequency of reliable measurements [31], and the gap between user and planner needs versus available technological tools [32].

As a result, there is a risk that mobility planning may be shaped more by what data is available than by the actual planning needs [31]. Thus, the literature shows that data availability for mobility planning tends to focus primarily on the local scale, often relying on ad hoc technological tools tailored to specific contexts - such as mobile phones, GPS devices, or dedicated apps - that can provide immediate and precise data. However, large-scale studies that incorporate statistical and ministerial data remain limited.

3 Methodology

This section summarizes the methodological approach adopted for the preliminary formulation of a list of data useful for constructing a geodataset capable of describing mobility and accessibility phenomena by applying them directly to the infrastructure network. In this regard, it is therefore necessary to define a method for identifying data sources and a set of criteria through which to describe the collected data.

Accordingly, the first part outlines the methodology used to identify open-source data sources during the initial phase of the MAC4TI project, within the GRINS ecosystem. The second part lists the relevant and necessary criteria through which the available data were classified and deemed suitable for the subsequent construction of a consultable geodataset (Fig. 1).

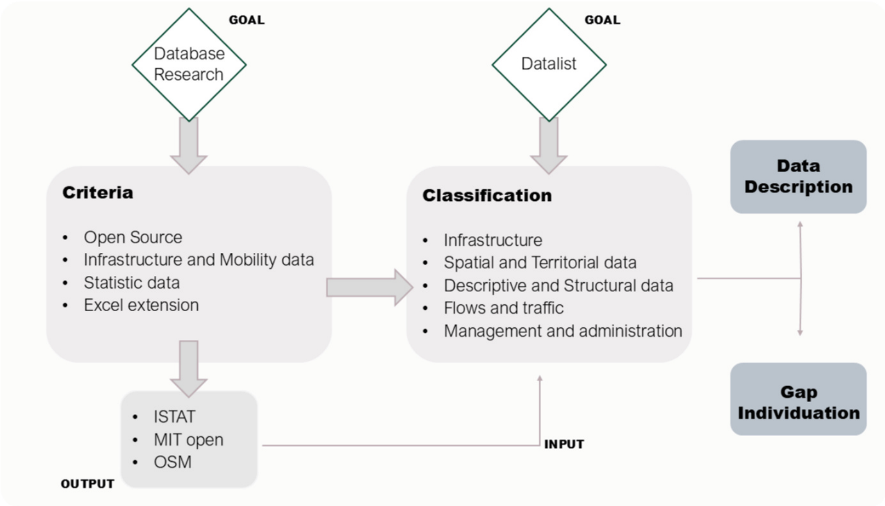

Fig. 1. Diagram summarizing the methodology applied for constructing the datalist containing georeferenced data used to build the GIS model.

3.1 Data Source Research

The first step in building the dataset involved identifying data sources. These were selected and classified according to three criteria: data accessibility, source reliability, and the possibility of manipulating the information. The latter factor is particularly crucial for the potential application of each data point within a GIS environment.

Based on these principles, three main sources were identified: the Italian National Statistical Institute (ISTAT) 'Atlante Statistico del Territorio – Territorial Statistical Atlas'; the OpenData database of the Italian Ministry of Infrastructure and Transport (MIT); and OpenStreetMap (OSM), a collaborative project aimed at creating freely accessible geographic maps.

Each of the three sources provides open-source data related to infrastructure, logistics, and mobility. However, it is important to note that the availability of data does not necessarily guarantee its intelligibility [17]. Indeed, ISTAT provides descriptive information about the population that is, in probabilistic terms, consistent with reality. The other two sources, however, share data provided by third parties - both public and private - and therefore require a verification process to assess their reliability.

3.2 Database Construction

The second step involves the classification of the data obtained from the aforementioned sources. For each dataset, specific characteristics were identified to describe them: data metadata, data scalability, and the type of information provided. At this stage of the methodology, a list of accessible data is compiled to produce a preliminary and consultable framework, with a view to the future development of a geodataset.

The data metadata includes information such as the reference year, file format and extension, and a brief description of the content. Scalability refers to how representative a dataset is of a given territory, based on two key aspects: whether the data is georeferenced—that is, whether it includes spatial location information—and its level of granularity. In this context, the Nomenclature of Territorial Units for Statistics (NUTS) is used as a reference framework [39]. NUTS is a geographic coding standard for referencing administrative regions of countries for statistical purposes, with levels ranging from 0 to 3 (State, Geographic Areas, Regions, and Provinces in the case of Italy).

Finally, the type of information is used to cluster the data based on the environment they describe - such as transport infrastructure or environmental and territorial features - or according to their functional or typological characteristics. This classification made it possible to build a database that compiles all available open-source data, forming the foundational structure for usability analyses and for identifying gaps and data deficiencies.

Indeed, in order to build a GIS environment capable of linking the geometric information of the transport infrastructure network with the statistical data describing mobility phenomena, it is essential that the latter can be transferred into a georeferenced environment. As highlighted in the following section of this article, this requirement represents one of the main challenges in the formulation of a geodataset.

Finally, in order for the data to be considered valid for subsequent implementation in a GIS file and for their sortable classification, only those available for download in tabular formats compatible with software such as Excel (i.e., .xls or.csv extensions) were selected.

4 Results and Discussion

In this section, the results from the survey of available open-source data—intended for the future development of the MAC4TI geodatabase—are presented. A total of 1,917 distinct samples were preliminarily compiled to form the dataset that will be analyzed in the following sections. This data list serves as the foundational structure for building a georeferenced dataset capable of linking geometric and spatial information with the statistical and quantitative data provided by ISTAT surveys. These data enable the description of the evolving regional socio-economic structure in relation to the transport network.

The next section discusses the initial findings from the analysis of the data list, focusing on data type and scalability, in order to highlight the first critical issues related to the composition of the dataset.

The second part presents a classification of the data included in the list, based on their content. This section thus provides an overview of the semantics of the available data. Finally, the third section offers a commentary on the gaps and limitations identified in data availability and manipulability, with a view to their implementation within a GIS environment.

4.1 Datalist Analysis and Data Usability

As previously stated, access to the three data sources identified in the first phase of the methodology - ISTAT, MIT, and OSM - yielded 1,917 relevant entries. These can be typologically grouped into two main categories: transport infrastructure data (98.1%) and territorial data (1.9%).

The former describe the infrastructure network across various modes of transport - road, rail, air, maritime, and local public transport - as well as the phenomena associated with them, such as traffic volumes, number of terminals, or network length. The latter, instead, are territorial descriptive data and include information related to morphological and urban structure, land use, land consumption, and demographics.

However, a detailed review of these documents revealed the presence of empty.xls or.csv files that is, datasets made available for download by the identified portals but containing no actual information. This issue affected 56% of the datasets, which were therefore deemed invalid.

Moreover, it is useful to identify which source provides the majority of data: ISTAT (78.6%), MIT (7%), and OSM (14.4%). This imbalance among sources is mainly attributable to two specific factors related to the ISTAT atlas. First, the temporal granularity of the surveys conducted by the national statistical institute, which makes data available on an annual basis covering multiple factors since 1996. Second, the horizontal scope of the institute itself, which provides statistical insights across various sectors, unlike MIT and OSM, which are more sector-specific and focused solely on infrastructure and transport aspects.

4.2 Data Classification

The previous analysis allows for the classification of data into five reference clusters based on their content: infrastructure; spatial and territorial data; descriptive and structural data; flows and traffic; and management and administration (Table 1).

Within the infrastructure group are included all data capable of describing the Italian infrastructure network across various transport modes. This also includes data related to terminals, their quantity, and distribution. Part of these data enables the creation of a geolocated infrastructure network schema, which thus serves as the structural basis—pending validation—for the GIS model (see Fig. 2). In the development of this preliminary model, it is also noted that the primary source for constructing the infrastructure network, for each transport mode, is OSM.

Figure 2, taken as an example, highlights a potential gap in the availability of open source data for the construction of an infrastructure map. In fact, there is a clear lack of information on the railway network in southern Italy. This is due to a lack of transparency and data transmission and not to the physical condition of the network in these regions. In fact, this argument can be replicated for each mode of transport and for each associated

Table 1. Table identifying the five data classifications, both in total and valid entries.

Data group	Total	Valid
Infrastructure	913	237
Spatial and territorial data	21	21
Descriptive and structural data	424	245
Flows and traffic	427	290
Management and administration	132	49

network. Furthermore, as can be seen from Fig. 2 itself, the interpretation of tabular data is complex, as it does not always correspond to the Italian network classification nomenclature.

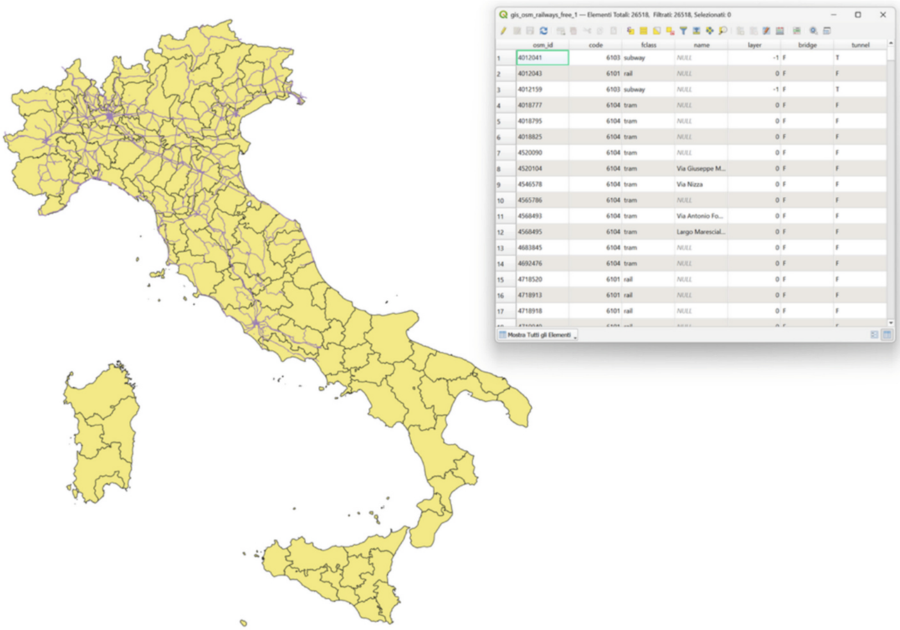

Fig. 2. A Figure showing a preliminary attempt to implement the Italian infrastructure network in a GIS environment. The railway network is represented: highlighting the lack of geometric data in the southern regions.

'Spatial and territorial data' refers to datasets capable of describing the territory at a large scale through land use classifications, the delineation of protected or restricted areas, sites of cultural and social interest, and the distinction between public, private, and productive-use spaces. However, as highlighted in the previous table (see Table 1), these represent the smallest portion of the validated and usable data.

'Descriptive and structural data' and 'Flows and traffic', which represent the majority of the classified datasets, contribute to describing the movement of goods and people and, indirectly, accessibility to economic and labor markets. Additionally, they contain information related to the configuration of the infrastructure network, including its technical specifications and service capacity.

Finally, the 'Management and administration' category includes data related to the management of spaces for infrastructure terminals, such as concession agreements, as well as public expenditure incurred for the operation of the transport network.

4.3 Gaps and Structural Limitations for a Geodataset

To conclude this section, the identified gaps in the methodology for acquiring open-source data are outlined, with observations categorized according to whether the limitations are attributable to the type of data or to the source providing it.

An initial finding concerns the primary source used to provide information on the structure of the network, identified as OpenStreetMap (OSM). As a collaborative project that provides georeferenced data at the regional scale, OSM requires two levels of validation to ensure data quality. First, there is a risk of missing or unmapped areas - as evident in the southern regions shown in Fig. 2 - or of outdated data, which therefore requires manual modelling within the GIS environment. An additional manual intervention is needed for the border points, that is, the boundary areas between regions where it is necessary to ensure infrastructural continuity to enable effective computational models for mobility analysis.

In the case of the MIT database, data sharing involves both public and private companies, and therefore the approach is substantially different from that of a public institution such as ISTAT. In fact, this requires a top-down action and intervention by the Ministry—as the higher administrative authority—to ensure the continuous updating of data by third-party entities and companies operating in the transport sector.

Another structural limitation, common to all sources, concerns data that can be geolocated without any computational processing or subsequent modelling. Of the 842 valid samples, only 9.8% contain georeferenced or georeferenceable information. This highlights the already demonstrated difficulty in integrating statistical and quantitative data into a geometric network framework such as that of transport systems. This highlights how the collection and transmission of Open Source data using the NUTS classification system complicates the interpretation of territorial dimensions when compared to a hub-and-spoke framework such as that of infrastructure networks.

In conclusion, as evidenced by the high incidence of missing data, the concentration of available information in a limited number of sectors increases the risk that policymakers - and, consequently, public participation in planning processes, however innovative and digitalized - may focus on aspects that do not reflect the primary mobility needs. This leads to the risk - already highlighted in the literature - that data may drive planning decisions, rather than planning objectives guiding data collection.

5 Conclusion

In conclusion, based on direct experience from the initial applied studies conducted within the MAC4TI project, this article has confirmed findings already reported in the literature regarding the collection of mobility data for georeferenced digital applications. However, in the attempt to model a GIS environment capable of integrating statistical and quali-quantitative data - whether environmental or socio-economic - for the identification of regional economic correlations applicable to the Italian infrastructure network, additional shortcomings have emerged.

Specifically, the clustering of data into five categories initially allows for the identification of potential gaps and deficiencies in data availability. Further classifications, however, have revealed structural weaknesses in the data collection methodology, particularly in terms of its applicability to a spatial network such as that of transportation.

As previously mentioned, the infrastructure level of an area is traditionally assessed in terms of physical resources. Nevertheless, this study proposes the inclusion of complementary aspects, such as human, functional, and instrumental resources. In doing so, infrastructure endowment is understood not only as the physical presence of infrastructure but also as the associated service provision. This integrated approach aims to achieve a horizontal understanding of the phenomenon linking infrastructure and regional economics, based on a diverse and multifaceted set of indicators.

The next steps of this study will focus on the development of a geodatabase capable of integrating socio-economic variables at the regional scale with transport and mobility models. This tool will serve multiple purposes: to develop complex accessibility indices and assess their relationship with the local economic structure, and to generate thematic maps that visually represent the outcomes of the various analyses.

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