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ACCESSIBILITY ACROSS ITALY: A GRID CELL APPROACH

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Accessibility across Italy: A grid cell approach[*]

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Abstract

This paper aims to address and discuss the measurement of within-country accessibility by computing travel times for Italy. Typically, domestic accessibility is measured at the municipal level, the smallest unit of analysis used in official national statistics; however, this territorial division may lack the granularity needed to capture specific variations within each unit. Conversely, supranational accessibility leverages finer information; however, if collected worldwide, global satellite and geocoded data may struggle with fine-grained accuracy within a country. To tackle these issues, we propose and analyze some measures of accessibility—defined by travel times to cities, transport infrastructure, and facilities at the sub-municipal level—using grid cells of five-by-five kilometers for the whole Italian territory and combining geocoded information with data from the national census and governmental offices. The measures computed in this paper offer a finer-grained quantification of accessibility, capturing differences within the same administrative level. Additionally, the grid cell approach—an analytical framework independent of political or administrative boundaries—allows for a more exogenous accessibility measurement. We use maps to visually present our findings.

Keywords: Accessibility; Travel times; Infrastructure; Italy; Grid cells.
Jel Classification: H54, O18, R41.

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1 Introduction

In the past decade, economic and transportation literature has shown a growing interest in understanding how easily individuals can access desired destinations and the time required to reach them. Accessibility is a multidimensional concept commonly quantified through various indices, reflecting the proximity of goods, services, and employment opportunities for individuals and firms. Travel times are the flip side of the coin: they provide essential information for discussing accessibility. Reduced travel times, driven by technological advancements, have led to increased flows of people, goods, and information, influencing urban mobility, the spatial distribution of activities, and location choices. However, assessing accessibility and travel times remains complex, as both involve a broad set of dimensions linked to numerous topics across different disciplines.

Accessibility and travel times are central to the discourse on first- and second-nature geography. First-nature factors, referring to natural features such as elevation and ruggedness, and second-nature factors, involving human-made infrastructure like roads and railways, have recently been discussed in the economic geography literature as key components for understanding accessibility dynamics and their critical role in driving regional development (Ketterer and Rodríguez-Pose, 2018).

The motivation for this study stems from the need to address the significant disparities in accessibility across various regions of Italy, which have broad implications for economic opportunities, quality of life, and social inclusion. We do it at a finer level of analysis with two aims. First, to construct novel information that can be matched with further territorial details, such as firm and individual locations. Second, to evaluate how accessibility may influence other outcomes, providing a picture of accessibility discrepancies within the areas of the same municipality.

In recent years, advancements in geospatial techniques, geocoded infrastructure data, and the availability of satellite information have improved our ability to assess accessibility as a critical component of socioeconomic development. Istat—the Italian National Institute of Statistics—released updated data on various accessibility measures for all 7,903 Italian municipalities (LAU).[1] Calculations based on these statistics provide an essential first step in understanding territorial differences. However, the level of the analysis may not capture significant variation within a unit. Conversely, the accessibility to cities computed by Weiss, Nelson, Gibson et al. (2018) at the grid cell level overcomes the municipal aggregation, offering consistent, high-resolution data worldwide, regardless of municipal or institutional boundaries. However, this global representation may obscure important national-level details. Figure 1 makes clear the argument. We map travel times to the nearest city with at least 50,000 inhabitants for the NUTS 2 region of Sardinia at both the grid cell and municipal level, comparing averages at the five-by-five kilometer grid cell using travel times by Weiss, Nelson, Gibson et al. (2018) (A), the cost surface by Weiss, Nelson, Vargas-Ruiz et al. (2020)[2] combined with endpoints from census data (B), and exploiting data by the Italian National Institute of Statistics (C). The grid cell-level analyses (A and B) reveal a more substantial internal variation within municipalities compared to municipal-level data (C). The municipal-level statistics (C) mask significant differences, not only in geographically diverse areas, where mountainous or rural regions usually face

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[1] Released data include both bilateral travel times between all Italian municipalities and data reflecting each municipality's accessibility to various key destinations.

[2] Weiss, Nelson, Vargas-Ruiz et al. (2020) make available both their precomputed travel times and the cost surface used to compute them. For our computations we use the latter.

considerably longer travel times compared to urban areas, but also within the same geographical locus. An example is the province of Oristano in western Sardinia. Despite a territory uniformly flat, some areas are more disadvantaged than others, a disparity that must be reconnected with the quality of the present infrastructure. Comparing the map generated from the raster file by Weiss, Nelson, Gibson et al. (2018) (A) with the map we created by combining the cost surface from Weiss, Nelson, Vargas-Ruiz et al. (2020) and endpoints constructed using census data (B), significant differences exist. For instance, Olbia, a municipality in northeastern Sardinia with over 60,000 inhabitants and a key reference city for neighboring municipalities is absent from map A. This suggests that while satellite data are well-suited for gaining a global perspective and allow for consistent cross-country comparisons, they may lack the granularity needed to capture specific regional variations within a country.

Our approach overcomes the limitations of supranational data and is based on the methodology we developed for map B. We decompose Italy into five-by-five kilometer grid cells[3] and combine the friction surface of land-based travel speeds constructed by Weiss, Nelson, Vargas-Ruiz et al. (2020)[4] with endpoints derived primarily from Italian national sources. This produces a highly detailed analysis of travel times and accessibility within Italy, providing a finer resolution for intra-country measurements.

We examine travel times to major urban centers, ports, airports, medium-to-large railway stations, and motorway access points. The detailed data offered by this work can be merged with other location measures to study the impact of accessibility on various outcomes at the firm or individual level. By highlighting territorial disparities, this study offers policymakers actionable insights to support balanced regional development and enhance social and economic inclusion nationwide. Our findings shed light on accessibility gaps that impede equitable development, especially in rural areas, southern Italy, and the islands of Sardinia and Sicily, where infrastructure investments have historically lagged. In this context, the study underscores the importance of transport justice in ensuring equitable access to essential services such as healthcare, education, and employment, and contributes to the broader field of accessibility research, aligning with studies by Ryan et al. (2023) and Kim and Chung (2018).

The paper is structured as follows. Section 2 provides a review of the relevant literature. Section 3 introduces the data and details the methodology. Section 4 presents and discusses the results, utilizing maps for visualization. Finally, Section 5 offers concluding remarks.

2 Literature review

Recent economic studies have paralleled a long-standing interest in transportation and land-use planning literature with a renewed emphasis on accessibility and travel times. Measuring and accounting for ease of access to locations at reduced travel times can be traced back to early works such as Harris (1954) and Hansen (1959), who demonstrated that areas with better accessibility tend to develop at higher densities and are more attractive than less accessible areas.

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[3] The choice of dividing Italy into 5x5 km grid cells is driven by computational considerations. Conducting the analyses presented in this paper on a standard computer using 1x1 km grid cells would make some calculations either infeasible or prohibitively time-consuming.

[4] In the works by Weiss, Nelson, Vargas-Ruiz et al. (2020) and by Weiss, Nelson, Gibson et al. (2018), the global friction surface is used to compute travel times worldwide to the nearest healthcare facility and nearest city, respectively. The difference between the friction surfaces used in the two papers is the accuracy of roads for developing countries: the former is more detailed.

Various perspectives have been used to analyze accessibility, such as the freedom of individuals to choose different activities (Burns, 1979), the role of transport systems in facilitating these choices (Dalvi and Martin, 1976), and the advantages offered by transportation and land-use systems (Ben-Akiva and Lerman, 1979). Geurs and van Wee (2004) provided a comprehensive review of accessibility measures based on various factors and components, highlighting the complexity of defining and quantifying accessibility. Muraco (1972) integrated both static and dynamic criteria into a comprehensive accessibility index. Ingram (1971) introduced the concept of relative accessibility, defined as the extent to which two locations are connected on the same surface. This concept led to other indices focusing on the number of opportunities accessible within a specific travel time or the cost of reaching a given number of opportunities (Wickstrom, 1971; Wachs and Kumagai, 1973), and numerous studies have continued to refine our understanding of accessibility, which remains a complex and evolving topic.

Urban economic literature has traditionally focused on accessibility and travel times at a regional level, examining how transportation systems optimize resources and achieve goals, such as increased mobility, reduced travel times, and improved connectivity. However, sub-regional analyses have become more prevalent recently. The first global map of travel times to major cities was released by the Joint Research Center in 2008, with data developed by Nelson (2008) in collaboration with the World Bank. This map accounted for factors such as geographical barriers, national borders, and the quality of transport infrastructure. Weiss et al. (2018) expanded Nelson's work by updating global travel times to cities for 2015, using a spatial resolution of one-by-one kilometer. In 2020, Weiss et al. (2020) created a global map of travel times to healthcare facilities, incorporating walking-only and motorized friction surfaces to assess geographical and infrastructural barriers. And in the same year, Christodoulou et al. (2020) constructed a dataset on urban accessibility and congestion in European cities with at least 250,000 people.

Advances in geocoded data collection have further propelled sub-regional research. The proliferation of smartphones and mobile apps has introduced new data sources for empirical studies. González et al. (2008) used mobile phone data to analyze human mobility patterns, while more recent studies by Akbar et al. (2023) and Couture et al. (2018) used Google Maps data to estimate travel times in different countries at various times of the day. Miyauchi et al. (2021) and Kreindler (2024) also used smartphone GPS data to analyze urban traffic in Japan and Bangalore, respectively.

The ease of reaching strategic locations and accessing essential public services is a central theme in accessibility literature, aiming to address critical rights such as social equity and the inclusion of vulnerable populations. Within the framework of transport justice, key priorities include ensuring a fair distribution of access to essential activities, establishing minimum accessibility standards for key destinations, and evaluating how policies protect individual rights, prioritize disadvantaged groups, reduce inequalities in opportunity, and mitigate transport-related externalities (Pereira et al., 2017; Martens, 2017). Lee and Miller (2018) underline how low accessibility and unequal access can deepen socio-economic and health disadvantages and how improving residents' access through new public transit options could enhance their ability to reach jobs and healthcare services. Ryan et al. (2023) illustrate how variations in accessibility, shaped by socio-demographic factors and temporal dynamics, influence individuals' likelihood of choosing sustainable travel options, thereby affecting commuting patterns.

Commuting has been another key area of research, particularly concerning cost reduction and transport efficiency. For policymakers, understanding how people respond to increased travel times and potential modal shifts due to congestion is crucial for formulating effective strategies. Commuting also highlights equity issues, as disparities in accessibility exacerbate socio-economic inequalities. Jacob et al. (2019) showed that increased commuting times negatively affect female well-being, while Bunten et al. (2024) found substantial differences between Black and White workers' commute times. However, the gap has narrowed over the years. In Parks (2004), improved access to jobs is linked to lower female unemployment rates among specific demographic groups. Fuchs et al. (2024) explored the commuting burden across different demographic groups, using geocoded administrative data to analyze disparities.

In the context of inclusion, accessibility for vulnerable groups, sustainability, and resilience, the concept of 10-, 15-, and 20-minute cities or neighborhoods has garnered increasing interest among researchers. The benefits for social cohesion and people interactions of these urban models—which enable residents to access essential services within a short walk or bike ride from home—have been known since Jacobs (1961). Indeed, as remarked by Moreno et al. (2021), the quality of urban life is inversely proportional to the amount of time spent on transportation, mainly when using motor vehicles. However, the time needed to reach a specific destination varies by time and individual. Willberg et al. (2023) stress how diurnal, seasonal, and age-related factors affected walking accessibility, influencing more access for some groups of people, like the elderly. Capasso Da Silva et al. (2020) argue that urban planning should prioritize accessibility over transportation infrastructure, which has historically been the focus of city design. Weng et al. (2019) discuss the benefits and challenges of walkable neighborhoods, noting that in cities, amenities are often concentrated in central areas, leaving peripheral residential zones with limited access, which reduces walkability and creates unintentional social inequality.

Regarding Italy, accessibility is characterized by significant regional disparities. Alampi and Messina (2011) find that road connections bring northern and central Italian regions closer to the geographic center of Europe. Still, despite decades of gradual improvements in national road transport, regional disparities remain unchanged. While high-speed and long-distance rail connections have significantly improved links between major cities in central and northern Italy, connections between medium-sized and smaller neighboring towns have not seen similar advancements. Beria et al. (2017) use an exponential decay impedance function—including travel time, distance, fares, and the ease of interchanging between modes of transportation—as a measure of potential accessibility for Italy. Their results reveal significant disparities in accessibility within Italy: northern areas have higher accessibility than southern regions and remote territories. Cascetta et al. (2020) find that high-speed rail contributed to a notable increase in accessibility and per capita GDP in Italy's connected regions. Still, it has also exacerbated regional inequalities, creating a "two-speed" Italy.

Using high-resolution data, our study aligns with this evolving literature, addressing regional and sub-regional disparities, contributing to the understanding of accessibility within Italy.

3 Data and methodology

We compute travel times and accessibility measures using a cost distance analysis for grid cells. The least-cost path is conducted by combining grid cells as origins, the cost surface constructed by Weiss, Nelson, Vargas-Ruiz et al. (2020) as the cost of moving across the landscape, and geocoded locations from census, official national statistics, and governmental offices data as destinations. The method relies on the principle that people usually take the least resistant path, with travel mainly happening on roads.

Italy is divided into 13,544 grid cells of five-by-five kilometers,[5] using the dataset from Eurostat,[6] making our research comparable and compatible with other analyses.[7]

The cost surface developed by Weiss, Nelson, Vargas-Ruiz et al. (2020) is a geocoded raster file in GeoTIFF format (1x1 km, 30 arc-second cells).[8] It is a global friction surface that includes land-based travel speeds, estimating the time needed to cross each pixel of 1x1 km using motorized transport infrastructure: the cost of moving through each pixel on the Earth's surface refers, therefore, to the travel time rather than the financial cost. It accounts for geographical features (e.g., landscape characteristics, land cover, elevation, slope, waterways) and existing infrastructure like roads, railways, and navigable rivers. It also considers national borders and other relevant transport constraints as of 2019. Figure 2 shows the cost surface data for the entire globe by Weiss, Nelson, Vargas-Ruiz et al. (2020).[9] This motorized transport friction surface assumes that individuals travel using vehicles. Road data are sourced from OpenStreetMap (OSM) and Google Maps, and speeds based on road types (e.g., highways vs. smaller roads) are from OSM. We isolate the friction surface for the sole Italian territory and use it as our cost raster file.

To measure accessibility across Italy, we use five different sources and typologies of accessibility: cities, ports, airports, railway stations, and motorways. We generate ending points for each type, representing the range of potentially reachable least-cost path destinations starting from the grid cell origin points.

Accessibility to cities of at least 50,000 inhabitants is our first measure of accessibility under scrutiny. It serves as a baseline for evaluating accessibility to larger urban centers and their associated services and opportunities. Using Italian 2021 census data from Istat on municipalities population, we select those cities that meet or exceed the 50,000-resident threshold.[10]

Accessibility to ports is a crucial factor in transportation planning, logistics, and supply chain management, affecting the efficiency of trade, tourism, and the movement of goods and people. We use as endpoints data from the Italian Ministry of Infrastructure and Transport, which provides a dataset containing identification details for the 15 Port System Authorities (AdSP), overseeing 58 Italian ports in 56 municipalities.[11] We also use data from Assoporti[12] to identify passenger ports. Italy counts 34 passenger ports in 32 municipalities.[13]

To account for airport accessibility, we use data from ENAC (Italian Civil Aviation Authority), which

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[5] On the equator this is roughly equivalent to a grid resolution of 2.7 arc minutes (0.0450°).

[6] https://ec.europa.eu/eurostat/web/gisco/geodata/grids.

[7] While more detailed, using 306,929 1x1 km grid cell origin points becomes impractical when the number of destinations is large.

[8] We downloaded the raster file about the "Global Motorized Friction Surface" from the Malaria Atlas Project (MAP, https://data.malariaatlas.org/maps).

[9] Speeds are expressed as the time, in minutes, required to travel one meter.

[10] Italy has a total of 140 cities with populations of at least 50,000 residents. The list, which also applies to 2019, is provided in Appendix A.

[11] https://dati.mit.gov.it/catalog/dataset/autorita-di-sistema-portuale-adsp.

[12] https://www.assoporti.it/it/home/.

[13] The passenger ports of Arbatax (in the municipality of Tortolì, Sardinia) and Termoli are not included in the dataset from the Italian Ministry of Infrastructure and Transport (MIT). The list of ports and passenger ports used in our analysis is provided in Appendix B.

lists 39 airports of national interest in 37 municipalities in Italy.[14]

Accessibility to railway stations is measured using 164 Gold and Platinum railway stations in 125 municipalities as endpoints,[15] according to the data and classification provided by the RFI (Rete Ferroviaria Italiana), part of the Italian State Railways (Ferrovie dello Stato Italiane).[16] RFI categorizes Italian train stations into four categories: Platinum, Gold, Silver, and Bronze. The ranking is based on four parameters: facility size (the total area and spaces accessible and usable by travelers), footfall (the number of travelers who use the railway facility daily), interchange capacity (the ability of a railway facility to connect, interact, and operate in an integrated manner with other public transportation systems without restrictions or limitations), commercial service level (the quality of passenger services offered by the facility, assessed in terms of rail traffic). Platinum stations are major railway facilities with high footfall (over 25,000 average daily users) and high-quality passenger services for long-, medium-, and short-distance travel. This category generally ensures the availability of services for high-speed trains, specific city-related services, and services for non-traveling visitors. Gold stations are, instead, medium-to-large railway facilities with high footfall (over 10,000 average daily users) and high-quality passenger services for long, medium, and short-distance travel. Services for non-traveling visitors are generally guaranteed, with city-related services provided less frequently.

Accessibility to motorways is our final measure of accessibility under scrutiny. We use 15,171 motorway links from OpenStreetMap as endpoints for the 2019 Italian motorway network. Links represent entries or exits to or from a motorway. We convert lines into points, representing the range of possible destinations for the least-cost path computation.

Due to the large number of observations, we present our computations using maps. Results are discussed in the following section.

4 Results and discussion

4.1 Accessibility within territories

An initial representation of accessibility in Italy can be obtained starting with the cost surface by Weiss, Nelson, Vargas-Ruiz et al. (2020) and calculating the average travel times using the motorized transport infrastructure within a grid cell. The left-hand side of Figure 3 shows the minutes required to travel 1 km of territory using roads and/or railways in 2019 within a grid cell of 1x1 km.

Italy consists of 306,929 one-by-one kilometer grid cells. Within this territorial breakdown, we find that, on average, in the country, the minutes required to cross one kilometer of territory using motorized means of transport is 3.7. Travel times range from a minimum of 0.46 minutes (approximately 27 seconds) to a maximum exceeding 10 minutes. About 5% of the territory (16,501 grid cells) falls into the first category, where less than one minute is needed to travel one kilometer. Similarly, nearly 6% of grid cells (18,314) experience travel times exceeding 10 minutes per kilometer. Among NUTS 1 macro-areas, Central Italy and the

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[14] https://www.enac.gov.it/aeroporti/infrastrutture-aeroportuali/aeroporti-in-italia/. The list of airports used in our analysis is provided in Appendix C.

[15] The list of all municipalities with a Gold or Platinum railway station can be found in Appendix D.

[16] https://www.rfi.it/it/stazioni.html.

Islands record the shortest average travel times at 2.2 minutes per kilometer. In contrast, the northwestern regions exhibit the longest travel times, averaging 6.5 minutes per kilometer. The Northeast and the South fall in between, with average travel times of 4.8 and 2.9 minutes per kilometer, respectively. This high national variability reflects geography, transportation network, and, in turn, population density differences across the areas.

In terms of geography, Italian topography is quite diverse. It ranges from towering mountains to vast plains and long coastlines. The Alps in the north divide Italy from France, Switzerland, Austria, and Slovenia. The Apennines, instead, running down the length of the peninsula, divide Italy into its western and eastern parts. 35% of the territory is mountainous, 42% hilly, and 23% flat. The coastline is more than 7,600 km, and two NUTS 2 regions are large islands in the Mediterranean Sea: Sicily and Sardinia. In these terms, Italian geography can be considered neither advantageous nor easy. Despite being traversed by the Apennines, Central Italy has the least rugged terrain on average, with a Terrain Ruggedness Index (TRI) of 187 meters and an average elevation of 391 meters. This aligns with its lowest average travel time using the motorized transport infrastructure. In contrast, the North-West, characterized by a higher TRI (326 meters) and an average elevation of 789 meters, stands out as the NUTS 1 area with the longest travel times. However, results change when restricting the focus to plain areas (elevation $<$ 300 meters) within each NUTS 1 region. Now the North-West exhibits the lowest average travel time per kilometer at 1.4 minutes, followed by the North-East and Central regions at 1.6 minutes; the South and the Islands show slightly higher values, averaging 1.8 minutes per kilometer. The fact suggests a different endowment in terms of transport infrastructure.

The Italian motorway system is extensive with over 6,700 km of highways, and a high-speed rail network. Regarding grid cells, 9,451 and 22,894 out of 306,929 cells are crossed by motorways and railways, representing 3% and 7.5% of the total number of cells, respectively. Grid cells crossed by a primary, secondary, or tertiary road represent 10.7%, 21.9%, and 30.7%, respectively, of all grid cells. Across Italy's NUTS 1 macro-areas, 4.5% of all grid cells in the North-West are crossed by a motorway, the highest share nationally. This percentage decreases to 3.4% in the North-East, 2.8% in both the Center and the South and reaches its lowest at 1.8% in the Islands. A more balanced distribution emerges across NUTS 1 regions when examining railway coverage. The North-West leads with 8.6% of its grid cells crossed by a railway. The North-East, Center, and South follow with 7%, 7.5%, and 8%, respectively. The Islands rank last, with only 5.7% of grid cells intersected by a railway.[17] Areas traversed by motorways require less than one minute (50 seconds) to cross one kilometer. However, travel times rise to one minute if a grid cell is crossed exclusively by motorways, with no railways or other road types (primary, secondary, or tertiary). This fact highlights the role of multi-modality in reducing travel times. The same applies to railways. Grid cells served exclusively by railways have an average travel time of 1.77 minutes (106 seconds). However, when motorways and/or other roads insist on these areas, travel times decrease to 1.3 minutes (78 seconds).

In terms of population density,[18] a grid of one-by-one kilometer in Italy hosts 192 people, on average. In high-density cells (population above 1,500 inhabitants per km^2), the average time to cross one kilometer is 1.1 minutes. It increases to 1.2 minutes in moderate-density areas (at least 300 inhabitants per km^2) and

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[17] In terms of primary road coverage, the North-East leads with 12.4% of its grid cells crossed by primary roads, followed by the North-West at 11.2%, the Center at 10.6%, and the Islands at 10.4%. The South ranks last, with 9.3% of grid cells intersected by primary roads.

[18] Data are from Istat and refer to the legal population from the 2021 census.

rises significantly to 4 minutes in rural areas (with a population density below 300 people per km^2).[19] This pattern suggests that transport infrastructure tends to be denser and more accessible in more populated areas. Data confirms this trend: motorways are more concentrated in densely populated regions. Additionally, people tend to settle in flatter areas, with average elevations of 153 meters in densely populated areas, 229 meters in moderately inhabited areas, and 573 meters in rural regions. These findings highlight the strong interconnection between geography, transport infrastructure, and population density—three critical factors shaping travel times and accessibility.

Expanding our perspective, the right-hand side of Figure 3 displays travel times for 13,544 five-by-five kilometer grid cells. Motorized travel times within these larger grid cells link this initial measure of accessibility to the indicators presented in the subsequent maps, where computational constraints necessitated using a coarser grid.

4.2 Accessibility to urban centers

Travel time data can provide a measure of accessibility to a specific destination, enlarging the perspective of this work. Within-territory calculations report how long it takes to move across different points, emphasizing internal connectivity and spatial efficiency. Instead, assessing accessibility to a specific destination reflects the ease of reaching a key location from various starting points.

Figure 4 measures travel times to cities with at least 50,000 inhabitants in 2021. Less influenced by geographical constraints, this indicator captures both accessibility and market potential. It provides valuable insights into access to essential services such as schools, universities, hospitals, public offices, financial institutions, and recreational facilities.

On average, it takes 46 minutes to reach a large urban center in Italy, with travel times peaking at 849 minutes (over 14 hours) in the most remote areas. This wide variability is illustrated in Figure 4. The lightest grid cells represent areas where travel times to the nearest city are just 5 minutes, covering only 253 out of 13,544 grid cells (less than 2% of Italy's territory).[20] The majority of areas fall into the third category: 24.6% of the territory (3,331 grid cells) have travel times ranging between 15 and 30 minutes. In 39% of the Italian peninsula (5,325 grid cells), travel times to the nearest city start at a minimum of 45 minutes. Among these, 24% of cells (3,203) experience travel times exceeding one hour. The darkest regions, where travel times to the nearest large urban center exceed one and a half hours, are the country's most remote territories. These areas account for 8% of all grid cells.

Regarding NUTS 1 macro-areas, the Islands have the highest average travel time to reach a large urban center of 54 minutes. The North-West follows with 47 minutes, while the North-East averages 43 minutes. The South registers over 39 minutes, while the Center has the shortest average travel time, just over 38 minutes. However, significant differences exist between Sicily and Sardinia. Darker areas, indicating longer travel times, are more prevalent in Sardinia, which has only four cities classified as significantly large according to the used benchmark. In contrast, Sicily hosts 15 large cities, resulting in generally shorter travel times and better accessibility across the island.

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[19] For more information on settlement types and the different classes of degree of urbanization, refer to the Global Human Settlement Layer.

[20] In Italy, 140 cities have populations of at least 50,000 inhabitants. As a result, the 253 grid cells with the shortest travel times correspond to areas closest to the centroids of these urban centers, representing the most accessible sections within these cities.

Apart from Sardinia, the Alpine regions, and some grid cells in the Apennines, there appear to be no significant visual differences in accessibility between northern and southern Italy. The South has 43 cities with at least 50,000 inhabitants, compared to 49 in the North. However, city size matters considerably. Having a nearby town with 50,000 inhabitants differs substantially from living near a larger city, as larger urban centers typically offer a broader range of services, economic opportunities, and social infrastructure. This distinction underscores the qualitative difference in accessibility beyond mere travel times. Among Italy's 20 most populous cities, 11 are located in the North-West and North-East regions. The Center, South, and Sicily each host three large cities, highlighting a more balanced but less dense urban distribution in the central and southern parts of the country.

4.3 Accessibility to transport infrastructure

To evaluate accessibility to transport infrastructure, we focus on four main types of transport hubs: ports, airports, railway stations, and motorways.

Figure 5 shows travel times to the nearest major Italian port. According to the Ministry of Infrastructure and Transport, Italy counts 351 ports,[21] and 58 of these are nationally significant ports (*porti di rilevo nazionale* in Italian). These are strategic infrastructures essential for the entire economic and logistical system. They play a fundamental role in international trade, goods distribution, and maritime connectivity, acting as key hubs in the country's transport network and supporting both domestic and global commerce.

The average travel time to reach the nearest port in Italy is 77 minutes. Still, there is considerable variability, with travel times ranging from 0 minutes in coastal areas to a maximum of 857 minutes (over 14 hours) in rugged and elevated regions, particularly in the Alps. In 25% of the Italian territory (3,451 grid cells), travel times to ports range from one hour to one and a half hours. Additionally, 2,098 grid cells (16% of all cells) have travel times exceeding two hours, while 15% fall within the 90-minute to two-hour range. Overall, more than half of Italy's territory (56%) requires over 60 minutes to reach a major port.

Being a coastal area does not automatically imply short travel times. Many grid cells along the coast or on small islands in Sicily have travel times exceeding 2 hours. While these areas have access to ports, they are not connected to nationally significant ports, which limits their role in large-scale economic and logistical operations. This highlights the importance of distinguishing between general port access and accessibility to strategic maritime hubs.

Figure 6 shows travel times to the nearest Italian passenger port. Passenger ports are maritime facilities primarily designed for the embarkation, disembarkation, and transfer of passengers traveling by sea. These ports handle various passenger services, including cruises, ferries, and local maritime transport.

On average, it takes more than 88 minutes to reach one of the 34 passenger ports. In 66% of the Italian territory (8,987 grid cells), the travel time to the nearest passenger port exceeds one hour. Among these, 5,511 grid cells (41% of all cells) require more than 90 minutes, while 2,844 grid cells (21%) experience travel times exceeding two hours. As shown in Figure 6, being on the coast or an island does not necessarily guarantee shorter travel times to passenger ports. For instance, the western part of Sardinia experiences travel times exceeding two hours. Similarly, a vast area of the Calabria NUTS 2 region faces long travel times.

Regarding air transport infrastructure, Figure 7 shows travel times to the nearest airport. Italy has 39

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[21] For a directory of Italian ports, see https://dati.mit.gov.it/catalog/dataset/porti/resource/661bba97-829e-453e-8923-97023de9fced.

nationally significant airports. They are considered strategic for the national air transport system, ensuring territorial continuity, connecting major international destinations, and fostering regional economic development.

On average, it takes 63 minutes to reach the nearest airport. About 27% of all grid cells (3,645) have travel times between one hour and one hour and a half. 18% of the Italian territory (2,463 grid cells) experiences travel times of 30 to 45 minutes, while 19% (2,563 grid cells) falls within the 45-minute to one-hour range. Areas with travel times exceeding two hours, represented by yellow grid cells, are concentrated in the Alpine regions, central-eastern Sardinia, some Sicilian islands, and parts of Tuscany and Basilicata. These less accessible areas account for 7% (965 grid cells) of the total territory. Figure 7 reveals notable disparities in airport distribution across Italy. Northern Italy, particularly the Po Valley, hosts 14 airports, creating a dense and well-served transport network. In the Center, 6 airports are present, 2 of these are in Rome. However, despite a fair number of airports in the South and the Islands, several areas remain underserved due to geographical challenges and lower population density.

Figure 8 illustrates accessibility to Italy's railway infrastructure, focusing on travel times to at least Gold-level railway stations, which are medium-to-large facilities offering extensive services. The average travel time to reach a Gold station is 58 minutes. The largest share of grid cells (2,857 or 21% of the total) records travel times between 15 and 30 minutes. Nearly 19% of the territory (2,547 grid cells) registers times between 30 and 45 minutes, while 15% and 17% fall within the 45-60 and 60-90 minute ranges, respectively. The most striking feature is the extensive fuchsia area in Sardinia's NUTS 2 region, where nearly half of the territory faces travel times exceeding two hours. Similar patterns are observed in Calabria, parts of the Alpine regions, and on small islands. Overall, 9% of the territory experiences travel times of more than 120 minutes to reach a Gold railway station, underscoring significant regional disparities in rail accessibility.

The last map in Figure 9 highlights the times needed to reach the nearest motorway access. On average, it takes 101 minutes to get the closest motorway access. The yellow grid cells indicate areas with the shortest travel times, ranging from 0 to 5 minutes. These areas cover 12.6% of the territory (1,701 grid cells). The largest category includes 2,927 grid cells (21.6% of the total), where times vary between 15 and 30 minutes. Additionally, 20% of Italy's territory (2,716 grid cells) has travel times between 5 and 15 minutes. In terms of NUTS 1 macroareas, the North-East of Italy records the shortest average time, at 30.1 minutes, followed closely by the North-West at 30.8 minutes, the Center at 31.5 minutes, and the South at 35.5 minutes. The Islands show a significantly higher average travel time of 404 minutes, primarily due to the NUTS 2 region of Sardinia. Indeed, the most striking aspect of Figure 9 is the complete absence of motorways in Sardinia, therefore, the entirely dark-spotted grid cells of the region. This underscores a significant infrastructural gap, as the island lacks any motorway infrastructure.

5 Concluding remarks

This study provides novel insights into calculating and analyzing accessibility across Italy at a highly detailed territorial level. Travel times derived from the cost surface calculations in Weiss, Nelson, Vargas-Ruiz et al. (2020) have been integrated with endpoint data obtained from national sources to construct new accessibility indeces tailored to the Italian context.

Official statistics—such as population figures—reflect some territorial features with higher accuracy than geocoded data and provide information on the location and characteristics of transport infrastructure that are missing in the work by Weiss, Nelson, Vargas-Ruiz et al. (2018). By combining high-resolution geospatial methods with localized data, this research moves beyond traditional administrative boundaries. This approach enables the identification of significant disparities in accessibility both across and within municipalities, identifying localized accessibility gaps, even in seemingly uniform areas. As a first result, data underlying the visualization presented here can be merged with information on firm and individual locations to further evaluate the implications of accessibility on various outcomes.

The results presented in this study highlight considerable variance in accessibility across Italy. Northern Italy demonstrates the shortest travel times, supported by its extensive transport networks, particularly in the Po Valley of northwestern Italy, which connects major urban and industrial hubs. However, mountainous areas in the Alps face longer travel times due to challenging topography, reflecting persistent connectivity barriers. These findings highlight how developed transport networks contribute to reduced travel times, a pattern less evident in central and southern regions. Central Italy exhibits mixed results: while urban centers benefit from strong transport links, rural and mountainous areas—particularly in the Apennines—experience significant delays due to geographic constraints and limited infrastructure. In southern Italy, disparities become more pronounced. Regions such as Calabria, Basilicata, and parts of Campania show high travel times, reflecting sparse transport networks and rugged terrain. The islands of Sardinia and Sicily face some of the most severe accessibility challenges, with extensive areas exceeding 90 minutes of travel time to critical infrastructure or urban centers.

This research provides a robust foundation for future research and actionable recommendations to guide infrastructure planning and transport equity initiatives at a highly detailed territorial level. The findings underscore the urgent need for a comprehensive approach to addressing accessibility disparities across Italy. Investments in transport infrastructure must prioritize bridging the significant gaps existing in southern regions and the islands. Road and rail networks in these territories require substantial enhancement to reduce travel times and ensure connectivity for rural and under-served communities. Promoting transport justice remains central to these efforts, and equitable access to essential services, such as healthcare, education, and transport facilities, is vital for fostering economic efficiency and social equity. This study contributes to the discourse on transport geography, emphasizing the value of granular territorial data in addressing accessibility disparities and fostering equitable regional development.

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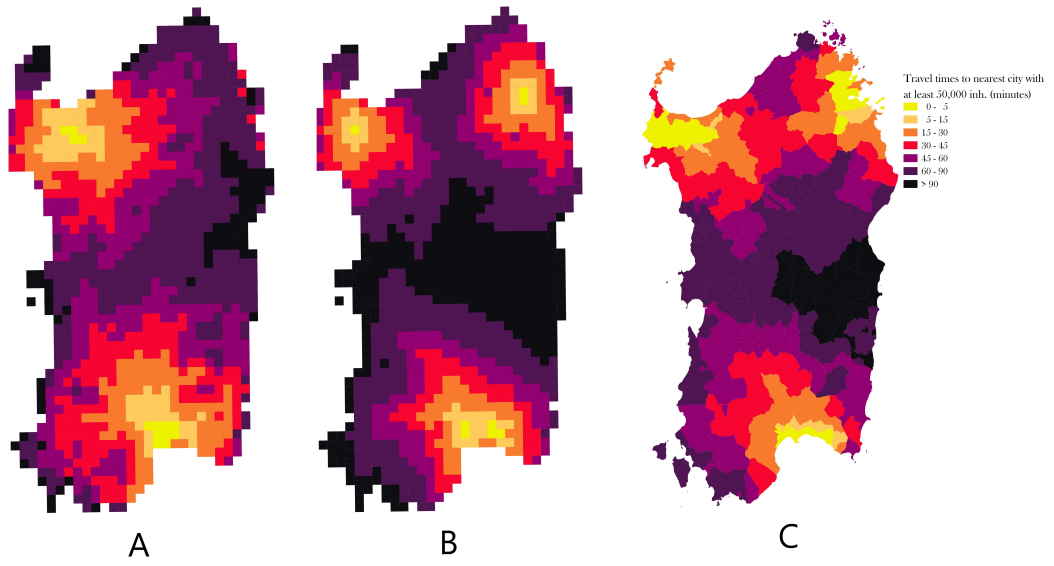
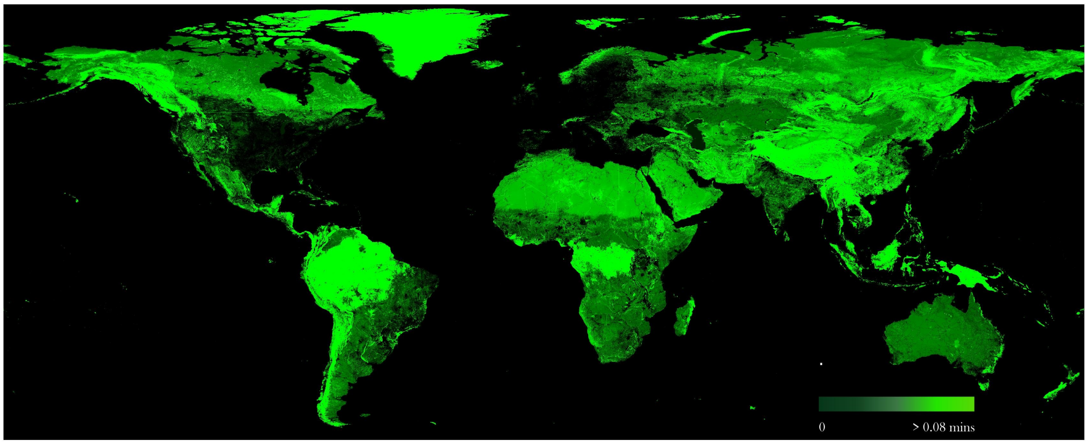
Figures and tables

Figure 1: Travel times to the nearest city of at least 50,000 inh. in 2019 (minutes): 5x5 km grid cell averages with Weiss, Nelson, Vargas-Ruiz et al. (2018) data (**A**), 5x5 km grid cell averages with Weiss, Nelson, Vargas-Ruiz et al. (2020) cost surface and our endpoints (**B**), municipalities with Istat data (**C**)



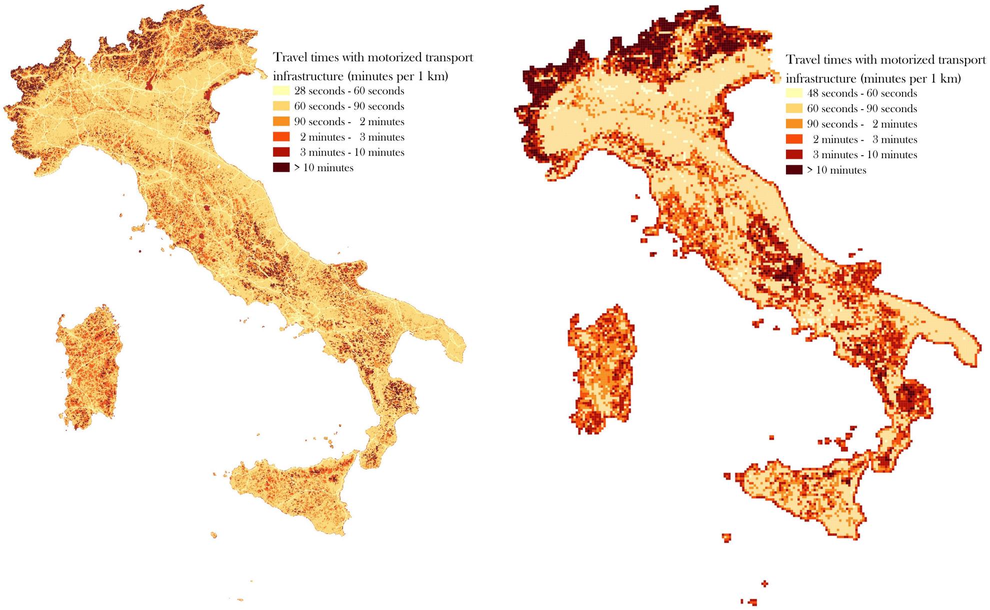
Source: Own elaborations from Weiss, Nelson, Vargas-Ruiz et al. (2018), Weiss, Nelson, Vargas-Ruiz et al. (2020), and Istat data

Figure 2: Global motorized friction surface 2019, 1x1 km



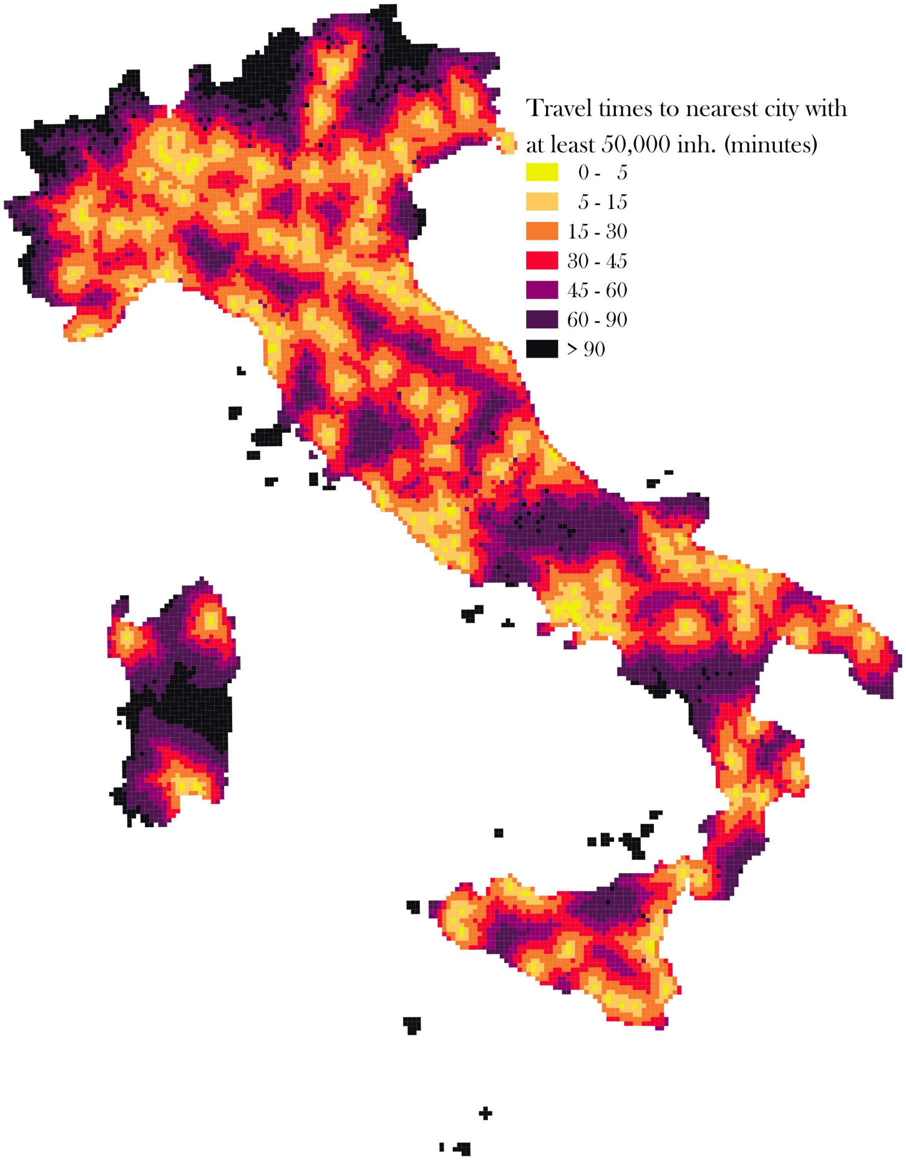
Source: Own representation based on Weiss, Nelson, Vargas-Ruiz et al. (2020) data

Figure 3: Travel times with motorized transport infrastructure in 2019 (minutes per km), 1x1 km (left) and 5x5 km (right) grid cells



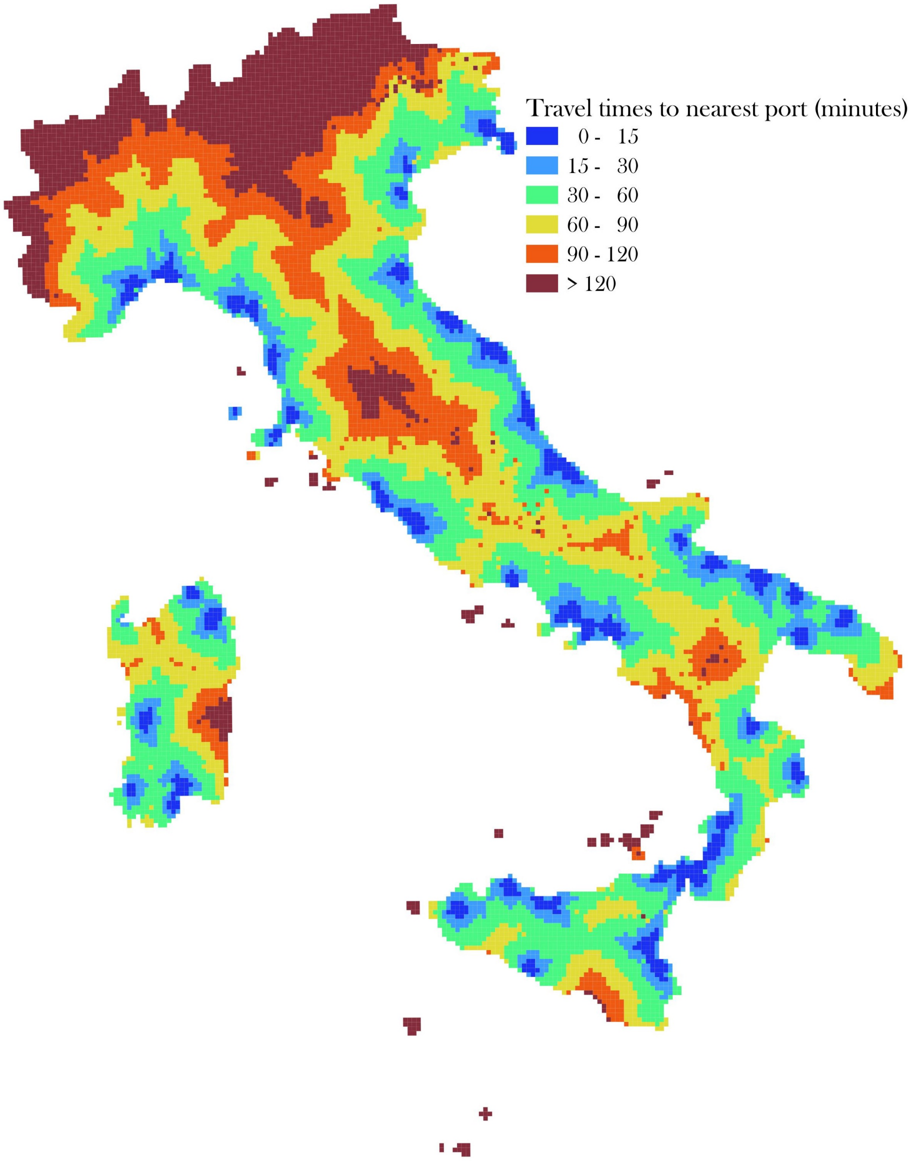
Source: Own elaborations from Weiss, Nelson, Vargas-Ruiz et al. (2020) data

Figure 4: Travel times to the nearest city of at least 50,000 inh. in 2019 (minutes), 5x5 km grid cells



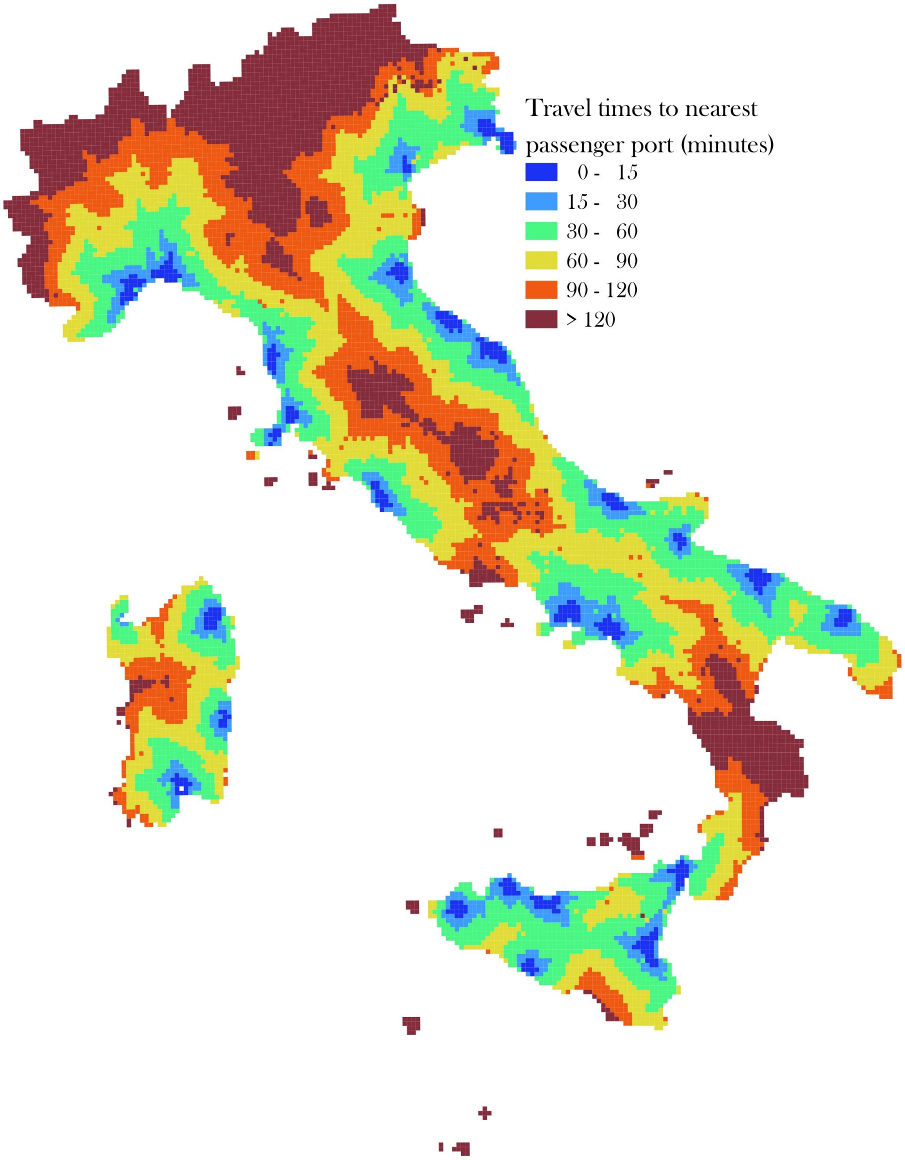
Source: Own elaborations from Weiss, Nelson, Vargas-Ruiz et al. (2020) and Istat data

Figure 5: Travel times to the nearest port in 2019 (minutes), 5x5 km grid cells



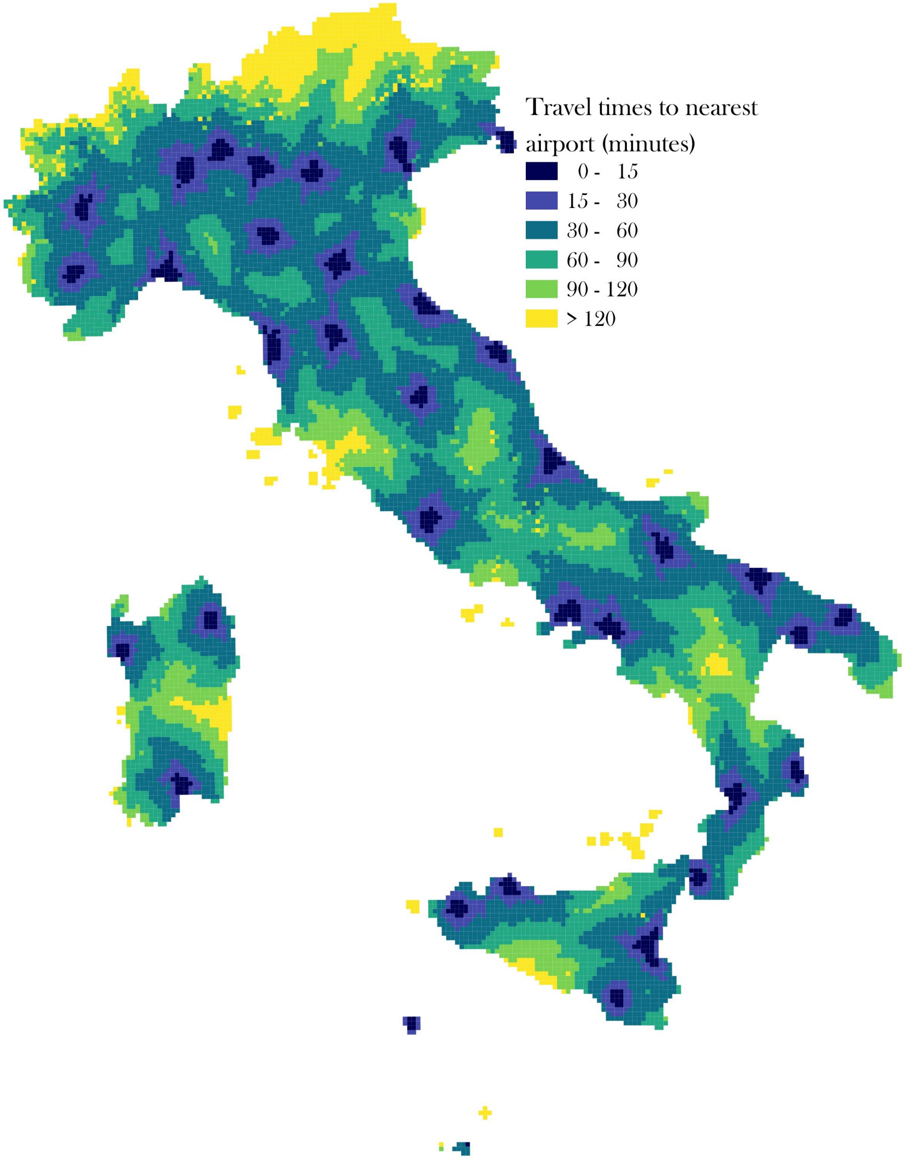
Source: Own elaborations from Weiss, Nelson, Vargas-Ruiz et al. (2020), Italian Ministry of Infrastructure and Transport, and Assoporti data

Figure 6: Travel times to the nearest passenger port in 2019 (minutes), 5x5 km grid cells



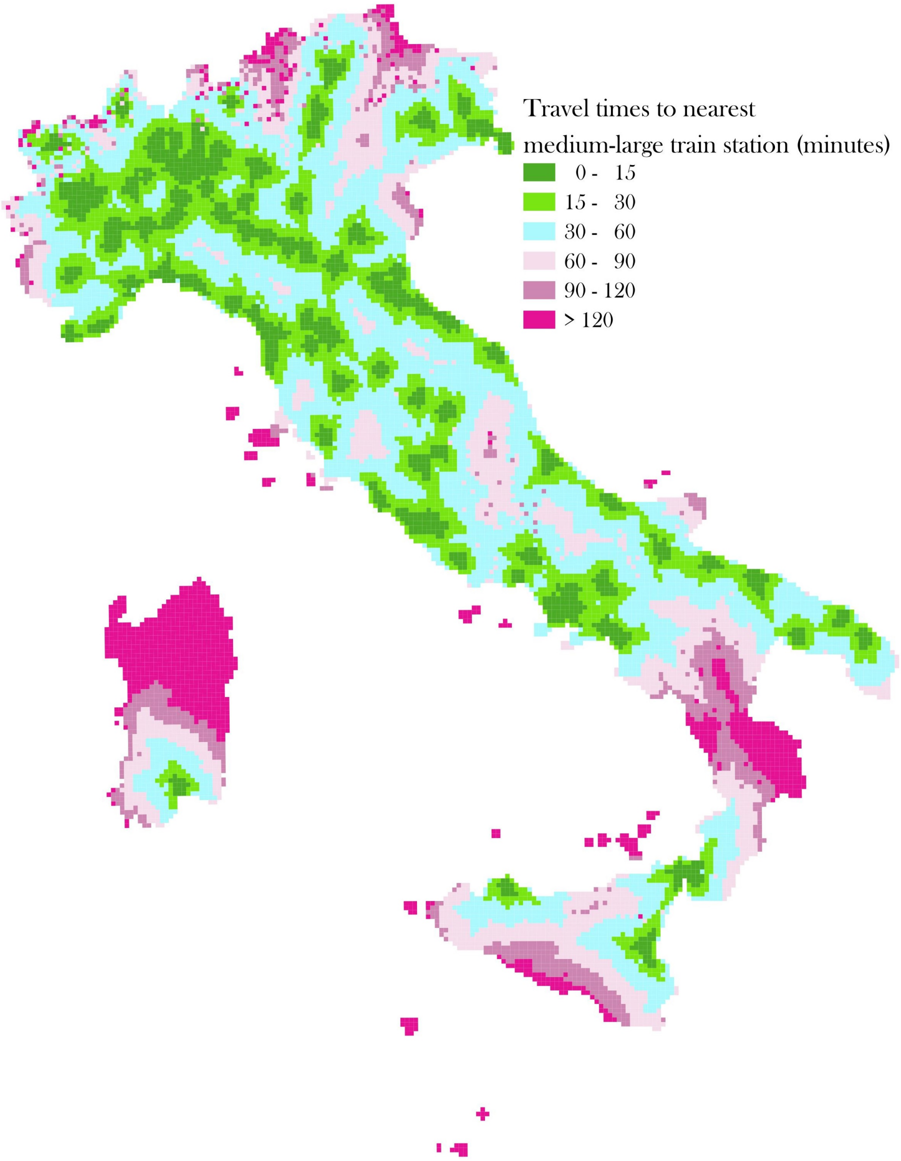
Source: Own elaborations from Weiss, Nelson, Vargas-Ruiz et al. (2020), Italian Ministry of Infrastructure and Transport, and Assoporti data

Figure 7: Travel times to the nearest airport in 2019 (minutes), 5x5 km grid cells



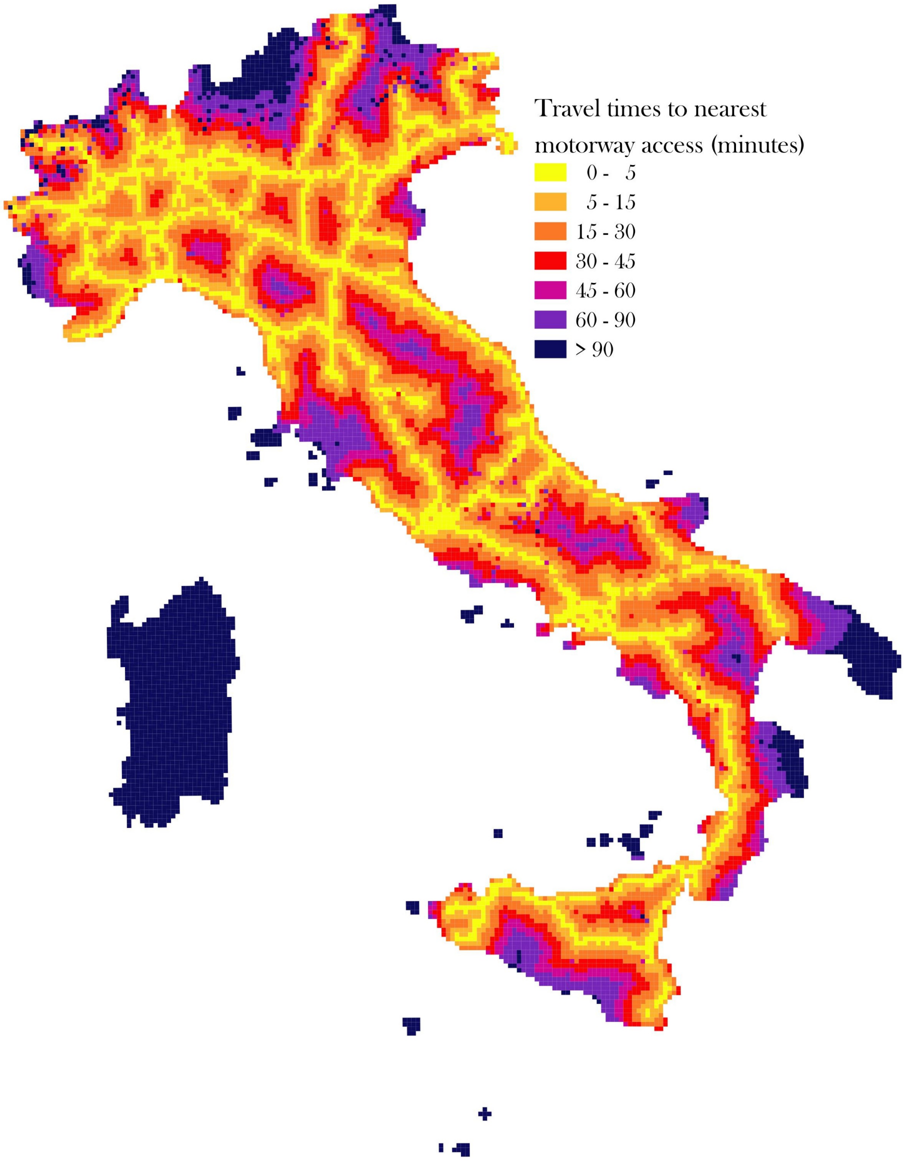
Source: Own elaborations from Weiss, Nelson, Vargas-Ruiz et al. (2020) and ENAC data

Figure 8: Travel times to the nearest (at least) Gold-level railway station in 2019 (minutes), 5x5 km grid cells



Source: Own elaborations from Weiss, Nelson, Vargas-Ruiz et al. (2020) and Rete Ferroviaria Italiana data

Figure 9: Travel times to the nearest motorway access in 2019 (minutes), 5x5 km grid cells



Source: Own elaborations from Weiss, Nelson, Vargas-Ruiz et al. (2020) and OpenStreetMap data

Appendices

A List of cities of at least 50,000 inhabitants

North-West: Alessandria, Asti, Bergamo, Brescia, Busto Arsizio, Cinisello Balsamo, Como, Cremona, Cuneo, Gallarate, Genova, La Spezia, Legnano, Milano, Moncalieri, Monza, Novara, Pavia, Rho, Sanremo, Savona, Sesto San Giovanni, Torino, Varese, Vigevano.
North-East: Bologna, Bolzano, Carpi, Cesena, Faenza, Ferrara, Forlì, Imola, Modena, Padova, Parma, Piacenza, Pordenone, Ravenna, Reggio nell'Emilia, Rimini, Rovigo, Trento, Treviso, Trieste, Udine, Venezia, Verona, Vicenza.
Center: Ancona, Anzio, Aprilia, Arezzo, Carrara, Civitavecchia, Fano, Firenze, Fiumicino, Foligno, Grosseto, Guidonia Montecelio, Latina, Livorno, Lucca, Massa, Perugia, Pesaro, Pisa, Pistoia, Pomezia, Prato, Roma, Siena, Terni, Tivoli, Velletri, Viareggio, Viterbo.
South: Acerra, Afragola, Altamura, Andria, Avellino, Aversa, Bari, Barletta, Benevento, Bisceglie, Bitonto, Brindisi, Caserta, Casoria, Castellammare di Stabia, Catanzaro, Cava de' Tirreni, Cerignola, Corigliano-Rossano, Cosenza, Crotone, Ercolano, Foggia, Giugliano in Campania, L'Aquila, Lamezia Terme, Lecce, Manfredonia, Marano di Napoli, Matera, Molfetta, Montesilvano, Napoli, Pescara, Portici, Potenza, Pozzuoli, Reggio di Calabria, Salerno, Taranto, Teramo, Torre del Greco, Trani.
Islands (Sicily and Sardinia): Acireale, Agrigento, Bagheria, Cagliari, Caltanissetta, Catania, Gela, Marsala, Mazara del Vallo, Messina, Modica, Olbia, Palermo, Quartu S. Elena, Ragusa, Sassari, Siracusa, Trapani, Vittoria.

B List of ports and passenger ports

B.1 Ports

North-West: Genova, La Spezia, Savona, Vado Ligure (Savona).
North-East: Chioggia, Monfalcone, Ravenna, Trieste, Venezia.
Center: Ancona, Capraia Isola, Carrara, Cavo (Rio Marina), Civitavecchia, Falconara Marittima, Fiumicino, Gaeta, Livorno, Pesaro, Piombino, Portoferraio, Rio (Rio Marina), San Benedetto del Tronto.
South: Bari, Barletta, Brindisi, Castellammare di Stabia, Corigliano-Rossano, Crotone, Gioia Tauro, Manfredonia, Monopoli, Napoli, Ortona, Palmi, Pescara, Reggio di Calabria, Salerno, Taranto, Vibo Valentia, Villa San Giovanni.
Islands (Sicily and Sardinia): Augusta, Cagliari, Catania, Golfo Aranci, Messina, Milazzo, Olbia, Oristano, Palermo, Porto Empedocle, Porto Torres, Portoscuso, Santa Teresa Gallura, Sarroch, Termini Imerese, Trapani, Tremestieri (Messina).

B.2 Passenger ports

North-West: Genova, Savona, Vado Ligure (Savona).
North-East: Monfalcone, Ravenna, Trieste, Venezia.
Center: Ancona, Cavo (Rio Marina), Civitavecchia, Falconara Marittima, Livorno, Pesaro, Piombino, Portoferraio, Rio (Rio Marina).
South: Bari, Brindisi, Manfredonia, Napoli, Salerno, Termoli.
Islands (Sicily and Sardinia): Arbatax (Tortolì), Cagliari, Catania, Golfo Aranci, Messina, Olbia, Palermo, Porto Empedocle, Porto Torres, Termini Imerese, Trapani, Tremestieri (Messina).

C List of airports

North-West: Bergamo, Brescia, Cuneo, Genova, Milano Linate, Milano Malpensa, Torino.
North-East: Bologna, Parma, Rimini, Treviso, Trieste, Venezia, Verona.
Center: Ancona, Firenze, Perugia, Pisa, Roma Ciampino, Roma Fiumicino.
South: Bari, Brindisi, Crotone, Foggia, Lamezia Terme, Napoli, Pescara, Reggio di Calabria, Salerno, Taranto.
Islands (Sicily and Sardinia): Alghero, Cagliari, Catania, Comiso, Lampedusa, Olbia, Palermo, Pantelleria, Trapani.

D List of railway stations

North-West: Alessandria, Aosta, Asti, Balangero, Bergamo, Borgaro Torinese, Bosconero, Brescia, Carnate, Caselle Torinese, Castagnole Delle Lanze, Chiavari, Chivasso, Ciriè, Como, Costigliole D'Asti, Cremona, Cuneo, Domodossola, Feletto, Gallarate, Genova, Germagnano, Imperia, Isola D'Asti, La Spezia, Lanzo Torinese, Lecco, Lodi, Mantova, Mathi, Milano, Monza, Neive, Nole, Novara, Pavia, Pioltello, Rapallo, Rho, Rivarolo Canavese, San Benigno Canavese, San Maurizio Canavese, Savona, Sesto San Giovanni, Sondrio, Torino, Treviglio, Varese, Venaria Reale, Ventimiglia, Vercelli, Villanova Canavese, Voghera, Volpiano.
North-East: Bologna, Bolzano, Cervignano Del Friuli, Cesena, Faenza, Ferrara, Fidenza, Forlì, Modena, Monfalcone, Parma, Piacenza, Pordenone, Ravenna, Reggio nell'Emilia, Rimini, Rovereto, Trento, Trieste, Udine.
Center: Ancona, Arezzo, Cassino, Ciampino, Civitavecchia, Empoli, Firenze, Fiumicino, Foligno, Formia, Grosseto, Latina, Livorno, Lucca, Massa, Orte, Perugia, Pesaro, Pisa, Pistoia, Prato, Roma, Sesto Fiorentino, Siena, Terni, Viareggio.
South: Afragola, Aversa, Bari, Barletta, Battipaglia, Benevento, Bitritto, Brindisi, Caserta, Foggia, Lecce, Napoli, Pescara, Pozzuoli, Reggio di Calabria, Salerno, Taranto, Termoli, Villa Literno, Villa San Giovanni.
Islands (Sicily and Sardinia): Cagliari, Catania, Messina, Palermo.

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