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Accessibility analysis in spatial planning: A case of special economic zones (SEZs) in Campania, Southern Italy

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ABSTRACT

The strategic role of Special Economic Zones (SEZ) at the Italian level has also been underlined by the Italian National Recovery and Resilience Plan, which has provided an important economic endowment to relaunch the national economy, in general, and the Campania region territorial economy, in particular. Literature and best practices clearly show that many factors determine the success of a SEZ, with transport accessibility being one of the key factors. This study performs a transport accessibility analysis both at national and first/last-leg levels, by comparing the accessibility of the Campania SEZ areas, the other SEZ areas in Italy and all the other Italian local labour systems. The study focuses on the Campania region, as it represents the first Italian pilot project of spatial planning through the establishment of SEZs. The Campania region exhibits, on average, good transport accessibility both at a national level (considering the multi-modal freight Italian transport network) and at a first/last-leg level (considering relevant nodes of the network, such as tollbooths, freight stations, ports, interports and airports). Also, the impact of SEZ implementation on land use planning has been discussed, to provide a useful tool for stakeholders that are interested in revitalizing the area, at different levels: i) land use policymakers, to plan interventions/planning concerning infrastructures and spatial planning; ii) national policymakers, to establish SEZs in other geographical areas; iii) investors, to assess the convenience of investments in this geographical area.

1. Introduction

Special Economic Zones (SEZs) are considered effective tools to stimulate industrialization and structural transformation (Abdusharipovich, 2018). The concept of SEZ has been defined in different ways over time, so it is not possible to give it a unique connotation at present (Zeng, 2015). However, based on the international experience with SEZs, the Italian Government, in launching the SEZs through the Legislative Decree No 91 of June 20, 2017, has implicitly assumed that SEZs are areas where fiscal and administrative advantages are provided for all those companies already operating or willing to establishing within them.

There are different forms of SEZs, characterised by different allowed activities, target markets, as well as administrative and fiscal advantages, with different regulations for business and trade flows depending on the country in which they are located. They have single management or administration enjoyed, they offer benefits for investors physically within the zone and have a separate customs area (duty-free benefits) and streamlined procedures (FIAS, 2008; Farole, 2011). Thus, SEZs are conceived as land uses and 'zones of advantage' for establishing new companies, attracting foreign investment and facilitating companies' export businesses, investment, economic growth and job creation. The geographic agglomeration of firms emerges also due to land use policy guidance (Li et al., 2021).

In recent decades, the scientific literature has defined SEZs as economic policy tools to attract productive activities to a limited geographical area, exploit local economies, and reduce transaction costs generating vertical and horizontal agglomeration (Hamada, 1974; Ge, 1999). An administrative committee generally coordinates activities in the area, for managing Foreign Direct Investment (FDI) and for infrastructure planning/design (Zeng, 2012).

Although implementation, management, administration and incentives depend from State to State, what is similar to other SEZs worldwide is the principle on which they were founded, which is to

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stimulate the country's economic growth by attracting foreign investment, thanks to tax and administrative concessions and their accessibility.

The interest and the reason for this in-depth study are linked to the fact that SEZ Campania represents the first national pilot project of SEZ in Italy, following the establishment of which other SEZs have been defined in Southern Italy (Apulia, Abruzzo, Calabria, Sardinia, Sicily), while other international (China, India, Africa, etc.) and European SEZs have been implemented since the 1970 s. Since it has been pointed out in the literature that one of the success factors of SEZs lies in their transport accessibility, the current paper aims at discussing the potential implications of transport accessibility for Campania SEZ areas, performing an analysis both at a national and a local (first/last-leg) levels. In the transport-related literature, little attention has been paid to providing insights on infrastructural accessibility as a key factor for the success of a SEZ, thus this paper aims to fill this gap in transportation research. Moreover, to the best of our knowledge, this is the first paper to perform a quantitative analysis of the accessibility to an economic evaluation of a SEZ. Therefore, this paper has a twofold research direction: i) to describe the Campania SEZ as a first Italian experience and ii) to provide a quantitative analysis, in terms of accessibility to/from all the areas involved in the established SEZ, considering the infrastructures programmed in the medium and long term in the region.

The analysis has been conducted at national and first/last-leg levels, the zoning of all local labour systems of the Italian Institute for Statistics (ISTAT) has been considered, and the analysis has been supported by the implementation of a multi-modal freight supply model and a freight demand model segmented in 8 different macro-commodity classes, each one with ad hoc estimated coefficients for generation/distribution models. The comparison in terms of transport accessibility has been performed between the Italian local labour systems which a) include SEZ areas of the Campania region, b) include other ZES areas in Italy, and c) do not include any SEZ areas. At a local level, a local accessibility analysis, referred to as first/last-mile accessibility analysis throughout the paper, has been performed with reference to relevant nodes of the network (tollbooths, stations, ports, interports and airports), with different granularity and a different modelling framework for both transport supply and demand models. The results of this study can be a useful tool for stakeholders at three different levels: i) regional public decision-makers, to plan further interventions/planning concerning infrastructures within the regional territory ii) national policymakers, to establish SEZs in other geographical areas iii) potential investors, to assess the convenience of investments in this specific geographical area.

The remainder of the paper is organized as follows: Section 2 provides a summary of the literature articulated on two main strands, the first describing the main experiences of SEZs worldwide and in the Italian context and the second recalling quantitative accessibility analysis methodologies; Section 3 describes the methodology used for the accessibility analysis of the current case study both at national and at first/last-leg level; Section 4 presents the case study and results of the analyses on the current scenario both at a national and at a first/last-leg level, with a related discussion of criticalities observed; Section 5 symmetrically describes the results of the analysis on a medium/long-term scenario, by simulating the effects of all the infrastructural interventions planned in the region (i.e. at a first/last-leg level); Section 6 opens the discussion on the main findings and Section 7 draws the main conclusions and suggests some future steps of analysis.

2. Literature review

This section proposes a literature review on the main topics that are relevant to the paper. Section 2.1 outlines previous experiences with SEZs worldwide, Section 2.2 describes the SEZ implementation in Italy and Campania region and, finally, Section 2.3 reports a summary of studies on transport accessibility methodologies.

2.1. *Special economic zones (SEZs): a worldwide overview*

The first example of a free-trade zone in Europe was registered at Shannon Airport in Ireland and dates to 1959. Since then, the demand for establishing SEZs has been growing in countries worldwide, especially those with emerging or transitional economies. These SEZs have been inspired by some virtuous examples, such as China's Shenzhen SEZ, established in the 1980 s near Hong Kong and referred to as the "Shenzen miracle" because 40% of its GDP is attributable to the economy coming from companies with foreign capital. The establishment of the Shenzhen SEZ had positive effects on the whole Chinese economy in terms of foreign direct investments (FDI), exports and employment, becoming a model to refer to (Zeng, 2010). The success of Shenzhen SEZ is due to the following factors: the high level of performance of the Chinese transport infrastructure chain (railways, roads, ports), the granting, from local authorities, of appropriate administrative, fiscal, customs and financial incentives and, finally, the significant investments in research and development (R&D), which have enabled the transport sector to use Electronic Data Interchange (EDI) and Information and Communications Technology (ICT) systems. Moreover, a further determining factor lies in the strategic position of the area, as it is crossed by the important traffic corridor between Hong Kong, Macao and Taiwan (Zeng, 2010).

The number of SEZs currently established has become significant compared to the past. Indeed, in 1997, there were 845 SEZs worldwide, while to date there are about 4300 SEZs established in 135 countries, mainly concentrated in Asia and the Pacific (43%), the Americas (24%), Central and Eastern Europe and Central Asia (19%), the Middle East and North Africa (9%) and Sub-Saharan Africa (5%) (SRM, 2017). Noteworthy, the United Arab Emirates has institutionalized SEZs in a large part of its national territory.

However, if many successful examples can be mentioned (Tanger Med, Poland, Latvia, Ireland, South Korea, just to name a few), many failures can also be found, most of them in Africa and India (60 in Maharashtra alone). The African failures were mainly due to the high price of water and electricity and the excessive distance to the main connection nodes. The success factors, on the other hand, were due to a good domestic economy and excellent infrastructure (Zeng, 2015). However, SEZs hide dangers and pitfalls, such as economic losses at the central level due to lost tax revenue or the possibility of money laundering through false export invoices. Five crucial steps can maximize the chances that SEZs will succeed (McKinseyandCompany, 2019): developing an integrated SEZ strategy, reducing the friction of doing business and creating incentives, attracting anchor investors and adjacent industries, developing infrastructure and fostering a thriving community.

More generally, there is little internationally comparable data on the actual performance of SEZs, making it difficult to provide a generalized assessment of their effectiveness. The World Bank study (2017), developed over the period 2007–2012 on a sample of 346 SEZs in 22 countries, revealed that the growth of SEZ areas is difficult to sustain over time. The economic dynamism of the most successful areas occurs in the early years and slows down over time, leading the economic performance of SEZs to become similar to that of surrounding areas. Additionally, tax relief for businesses, as well as the availability of national one-stop shops and regional regulatory untying, have had little impact on business growth. The national and regional economic environment, as well as industrial costs and proximity to developed markets, affect the performance of SEZs.

Based on a study by Zeng (2015), the following Table 1 summarises the potential drivers of a SEZ and the actions to be avoided for circumventing failures. The points developed based on analyses of Chinese and African SEZs, are useful in terms of success points and provide some common lessons. The success factors of SEZs are multiple and only if they act together and in a coordinated manner will they be able to return the expected fruits, and therefore only if all the actors, institutional and private, work in a coordinated manner towards the success of an

Table 1
Key success factors and failure of SEZs.

Success factors	Actions to be avoided
Strong commitment and support of the government to pilot market-oriented economic reforms: - making changes, through a gradualist approach; - creating an open and conducive legal and policy environment for the SEZs; - building a sound business environment; - putting in place a conducive regulatory environment for reforms, an efficient administrative system such as "one-stop-shops"; - having or implementing good infrastructures for the zones.	**Mushroom approach at the local level and high-level overlaps at the later stage:** - avoiding the imitative approach that has led to poor evaluation and planning.
Land Reforms: - contributing to the establishment of a modern land market.	**Environmental degradation:** - avoiding the use of low technology and labour- and resource-intensive production; - paying attention to the waste of resources, land consumption and environmental damage.
Investment incentives and institutional autonomy: - stimulating favourable policies to attract skilled; labour (provision of housing, research funding, education subsidies, etc.); - establishing a legislative authority to develop; municipal laws and regulations to govern these areas; - applying a simplified administrative process, sound infrastructure, rapid customs clearance, preferential tax rates and flexibility in hiring and firing workers, among others.	**Unbalance between industrial development and social dimensions:** - providing commensurate social and urban services, especially in remote areas or regions lagging.
Foreign Direct Investment and the Chinese diaspora: - providing cheap labour and good infrastructure in SEZs, as well as Open-Door policies coupled with various incentives.	
Technology learning, innovation, upgrading, and strong links with the domestic economy: - encouraging the concentration of highly qualified people, including many R&D personnel; - linking national companies to industrial clusters through supply chains or value chains.	
Innovative cultures: - training and informing a migrant community that is highly motivated to move to these areas because they tend to generate an innovative and entrepreneurial culture.	
Clear objectives, benchmarks, and competitions: - setting clear objectives and targets in terms of GDP growth, exports, employment, revenue, FDI generation and the like; - developing a high level of competition.	
Location advantages: - located in a coastal region or near major cities; - ensuring that there is good access to the main infrastructure.	

experiment that is of national interest.

In summary, despite many studies at the international level have described previous experiences with the establishment of SEZs in other countries around the world - e.g. China (Zeng, 2010, 2012, 2016), India (Aggarwal, 2005, 2006, 2007), Africa (Farole, 2011; Bernsein, 2012; Zeng, 2016) - only a few studies of the literature on SEZs focus on transport accessibility, while the latter represents one of the key factors for their success. The study by Frick et al. (2019) relates to transport accessibility concerning SEZs but it does not show any quantitative analysis that may emphasize the strategic role of zone location (Madani, 1999; Asian Economic Integration Report, 2015). Thus, the aim of the paper is that of describing the Italian case with the aid of a quantitative analysis of transport accessibility.

2.2. The SEZ in Italy and the Campania region

The Campania Region (Southern Italy) SEZ, as defined by the aforementioned Legislative Decree No 91 of June 20, 2017, was in 2018 the first SEZ to be established in Italy and is currently in the planning stage. In the latter, a definition of SEZ has been provided, as well as some constraints in their geographical definitions. For instance, a SEZ is defined as '*a geographically delimited and clearly identified area, also made of areas that are not territorially adjacent, provided they have an economic functional link, and which includes at least one port area, with the characteristics set out in Regulation (EU) No 1315 of December 11, 2013*'. Therefore, in the case of Italy and Campania, the detected SEZ areas need a good connection, as they are not territorially adjacent. In general, the above legislative order is not limited to supporting businesses from a financial, administrative, fiscal and customs perspective, but represents an effective tool to optimise the capacity of the Trans-European Networks - Transport (TEN-T) to connect all regions of the European Union (Berlinguer, A., 2016).

Despite several sector studies have been developed (Berlinguer, A., 2016; SRM, 2017; Aniello and De Santis, 2018; Regione Campania, 2018; Pwc, 2019), there are few bibliographical and scientific references related to SEZs at the Italian level and no one has considered infrastructural accessibility of SEZ as a crucial land use variable. Among the main advantages that companies have in investing in the Italian and Campania SEZs, is the exemption from current regulations, in terms of simplified environmental, landscape, building and port concession authorisations (source: Campania region website). The extent of the tax credit advantage generally depends on a zone by zone, the regulations being applied nationally and in the Italian case in the south of Italy, as opposed to the Simplified Logistic Zones located in the north of the country. As an example, for the SEZs in southern Italy, the tax credit on investments varies according to the size of the company (small, medium-large) and from region to region (the regions that were affected by the 2016 earthquake have greater tax benefits). Rather than indicating which category of subjects will be able to benefit from the tax and administrative advantages of the SEZ, it would be correct to list which sectors cannot have benefits, namely: steel, coal, shipbuilding, synthetic fibres, transport and related infrastructures, energy production and distribution, and energy infrastructure sectors, as well as the credit, financial, and insurance sectors. Moreover, the relief does not apply to companies in difficulty'. For tax credits, SEZs, Free Trade Zones (FTZ), and entities operating in the agriculture and fisheries and aquaculture sectors are also excluded from the benefit (Italian Revenue Agency Ministry of Economy and Finance). At the national level, the National Recovery and Resilience Plan (the Italian response to the Next Generation EU to overcome the pandemic crisis) has given a new impetus to the role of SEZs.

Following the start of work on the Campania SEZ, other areas of Italy have organised themselves to set up SEZs in their territories, namely: Abruzzo, Calabria, Ionian Interregional Apulia-Basilicata, Adriatic Interregional Apulia-Molise, Eastern and Western Sicily. The Campania SEZ, in particular, consists of 29 areas, not all adjacent to each other covering 37 of the 550 municipalities in the region and having a surface of 5154 ha. The areas have been identified based on distance from the port, ease of rail and road connections with the port areas, and availability of lands without urban and landscape constraints. The SRM study (2017), in addition to providing examples of best practises, defined the necessary tools for the success of the SEZs initiative, namely: an integrated set of companies, an efficient port, connected dryports and retro port areas, a smooth bureaucratic system, a good logistic system, the contribution of incentives and the concrete presence of institutions.

Aniello and De Santis (2018) deepened the same issues by comparing the Simplified Logistics Zones (SLZ) and the SEZs, highlighting the relationship between the Northern Adriatic ports (characterized by the presence of a SLZ) and the project of the New Silk Road as a further development possibility. Moreover in 2018, the Campania Region developed a detailed study of the territorial, productive, infrastructural and socio-economic context of the region, through the Strategic Development Plan (Article 4 of Decree-Law No 91 of 20 June 2017 'Urgent Provisions for Economic Growth in the South of Italy') for establishing the SEZ in Campania. The Plan has framed the areas and sectors of development of the SEZ and defined the modalities and tools for governance. Furthermore, it provided a reference framework concerning bureaucratic and administrative simplifications introduced by the SEZ, as well as some references related to financial and fiscal facilitation. The study by Pwc (2019) mainly focused on the legal and regulatory aspects of Italian SEZs, emphasizing the limits imposed by European legislation within them. In a logic of enhancing the territories and their production several strategic sectors have also been identified, which, if put into a system, can give a particularly incisive boost to regional growth.

Concerning the Campania Region, the selection of areas is reported in detail in the Strategic Development Plan, Regional Council Resolution No. 175 of 28/03/2018. The document reports how the selection of areas has been made to include areas with special characteristics, such as ports, interports, airports, industrial and logistics areas. In particular, the information and data required for their identification were: urban planning framework, planimetric identification, legal nature of the areas, specifying any expropriation procedures, consistency of free areas and assigned areas, infrastructural endowment, infrastructure endowment for logistical connections with port areas, interports and freight villages and logistics platforms, number and type of localised enterprises, sectoral specialisation of productive activities and relative agglomeration.

Therefore, the choice was made focussing mainly on the importance of the links between the ports and the back-port areas as an economic-functional link with the main logistic and industrial hubs of the entire region rather than on spatial continuity. In this way, the selection has favoured strategic guidelines rather than homogeneous territorial expansion.

Among the other points considered it should be noted that:

- the industrial agglomerations are characterised by a long tradition in terms of location and adequate infrastructure and connections, as well as a natural vocation for attracting both greenfield and brownfield investments, also based on the use and control of the areas concerned;
- the industrial agglomerations located in inland areas, less connected to the port system, represent the territories most affected by the industrial crisis. Their inclusion in the SEZ area can represent an opportunity in terms of both strengthening the infrastructural connections with the Campania logistics system and relaunching the industrial fabric.

2.3. Literature review on quantitative analyses of transport accessibility

Accessibility is a key concept for describing and quantifying the interaction between activity and transport systems (Martìnez, 1995). Comprehensive reviews of the literature on transport accessibility or discussions on the topic can be found in Morris et al. (1979), Koenig (1980), Song (1996), Niemeier (1997), Kwan (1998), Handy and Niemeier (1997), Bhat et al. (2000), Geurs and van Wee, b) (2004a), Curl et al. (2011), Reggiani and Martín (2011), Páez et al. (2012), Silva et al. (2017).

Geurs et al. (2009) defined accessibility as "*the extent to which land use and the transport system enable (groups of) individuals to reach activities or destinations using a (combination of) modes of transport*". While Chan (2005) addressed the issue of spatial separation and the appropriate metrics for defining an accessibility function, multiple researchers and scholars have also written and discussed extensively accessibility measurement methods, such as Linneker and Spence (1992) and Reggiani (1998). Gutièrrez (2001) pointed out that changing transport infrastructure historically produces a progressive spatial contraction, which means that travel times and transport costs decrease (and overall competitiveness increases). Song (1996), Handy and Niemeier (1997) and Geurs and Van Wee (2004a) (2004b) widely discussed accessibility measurements for assessing the evaluation of land use and transport strategies.

Defining accessibility has been a major concern of geographers, transport researchers and planners since the early 1950 s. A seminal definition was provided by Hansen (1959), who described accessibility as the opportunity for an individual (or a group of homogeneous individuals) living in a certain zone to participate in a specific activity (or a set of activities) located in the territory.

Hack (1976) defines the accessibility of a point in a certain system as a function of its location in the space concerning the other points in the system, while De Lannoy and Van Oudheusden (1978) pointed out that the latter definition implies the use of a measure of relative distance, in terms of direct spatial connection or travel time / generalized cost. These definitions led to the introduction of mathematical measures of accessibility and the need to justify their theoretical and behavioural foundation (Morris et al., 1979; Koenig, 1980; Weibull, 1980). Many other definitions of transport accessibility can be found in the literature (see e. g. Morris et al., 1979; Vickerman, 1995; Bruinsma and Rietveld, 1998; Geurs and van Wee, 2004b). For the paper, i.e. the investigation of the interaction among SEZs areas and the concerned transport system, accessibility can be defined as the inherent characteristic of an area/-territory to be connected to (*active accessibility*) or to be reached by (*passive accessibility*) other areas /territories. On the one hand, mobility represents the easiness with which moving, while accessibility summarizes the easiness with which reaching a given destination from the other zones (passive accessibility of the destination) or moving from a given origin to the other zones (active accessibility of the origin).

The quantitative analysis of active and passive transport accessibility is a prominent topic for planners and transport researchers, with well-established literature. Since the literature on land use-transport interaction, in general, and on transport accessibility, in particular, is extensive, several studies have proposed classifications for accessibility measures (see Handy and Niemeier, 1997 for a classification and Bhat et al., 2000 and Halden et al., 2000 for a comprehensive overview of the topic from a quantitative perspective). Several authors have clustered the accessibility measures in two macro-categories, the former being more macro-oriented and inspired by the gravitational analogy in physics, the latter being more linked to the micro-economic theory and the notions of satisfaction/consumer surplus at a single transport user level (see Weibull, 1980). According to Cascetta et al. (2013), the two macro-approaches to quantify accessibility can be referred to as:

- *Non-behavioural approach*: In the domain of this first macro-approach, in turn, two well-known methodologies can be mentioned: isochrones and gravity-based models. The former method has a long-standing history and is well-known in many disciplines, especially geography since the earliest isochrone maps were drawn in the 19th century (e.g. Galton, 1881). The rationale of the isochronic model is simply to express accessibility as the number of opportunities – activities or users in the context of active or passive accessibility, respectively - that are reachable with a travel time below a specific threshold. They give the possibility to draw simple maps showing the impedance in reaching different zones of a certain territory from important transport nodes such as airports, ports or stations (O'Sullivan et al., 2000; Gamper et al., 2011; Kolcsár and Szilassi, 2018; Xi et al., 2018). Gravity models can be considered as a generalization of the previous models, in that they allow to consider an impedance function that embeds information about distances/travel time/generalized costs among two zones (Gordon, 1976; Knox, 1981; Geertman and Ritsema Van Eck, 1995; Bertolini et al., 2005; Gallo et al., 2012; Papa and Coppola, 2012; Vale and Pereira, 2017; Piovani et al., 2018; Xia et al., 2018), without considering any thresholds. Their rationale resembles that of the gravity models for trade, which are well-known in the context of economics and transport demand, as they incorporate the evidence that trade flows (goods, passengers) among two countries increase with relevant masses (residents, freight volumes, activities) and decrease with distance (Isard, 1954; Hansen, 1959; Martin and Pham, 2020). However, the theoretical justification for gravity models has always been a matter of debate in the scientific community (see Deardorff, 2011). Other clusters that can be embedded into the behavioural approach group and are reported in Curl et al. (2011), with particular reference to infrastructural measures (Church et al., 2015) and cumulative measures (Casas, 2007; Escalona-Orcao and Cornago, 2007; Nettleton et al., 2007).

- *Behavioural approach*: in this second macro-approach, it is worth mentioning two distinct clusters namely the utility-based and opportunity-based measures.[1] Primarily, behavioural formulations draw on the theoretical background of random utility theory. Undoubtedly, the most used and well-known measure of accessibility is represented by the logsum (Ben-Akiva and Lerman; , 1985; Niemeier, 1997; de Jong et al., 2007; Bohnet and Gertz, 2009; Hasnine et al., 2019). The logsum measure is closely related to the notion of consumer surplus, which represents the net utility that a consumer (decision-maker in general) has in a certain choice situation, depending on the whole set of available alternatives (see Train, 2009; more details in Section 3). It is natural to express an accessibility measure by embedding information about relevant masses (population, freights volumes, number of travellers, number of activities) and impedances (distances, travel times, generalized costs) characterizing the analysed zones/areas. Measures based on the number of actual opportunities (Guy, 1983; Cervero et al., 1999; Dong et al., 2006; Cascetta et al., 2016; Kelobonye et al., 2020), perceived opportunities (Cascetta et al., 2016) and activities (Buliung and Kanaroglou, 2006; Casas, 2007; Farber and Páez, 2009) also exploit a theoretical framework based on the underlying assumptions of random utility models.

Out of this classification, other measures can be mentioned, such as behavioural measures based on alternative paradigms to that of random utility theory (e.g. Chorus, 2012 for a measure based on random regret minimization theory that is analogous to the logsum measure). Inturri et al. (2017) investigated accessibility as a measure of social, economic and environmental sustainability and found that accessibility is a key determinant in achieving environmental sustainability as well. Järv et al. (2018) extended the theoretical framework of accessibility modelling to the temporal dimension. Other accessibility measures using data envelopment analysis (DEA) and Principal Component Analysis (PCA) have also been used to assess the accessibility impacts of new high-speed rail infrastructure investments (Martín et al., 2004; Martín and Reggiani, 2007).

Although accessibility is a key concept for land use-transport interaction, many transportation plans ignore or at least place little emphasis on it. For instance, Boisjoly and El-Geneidy (2017) reports a review of 32 transport plans from several countries in Europe, Asia, North America and Australia, showing that, although accessibility is theoretically considered the main goal for planning, most plans did not incorporate quantitative measures of accessibility to support decisions. Sheepers et al. (2016) underlined its importance in the context of the AVENUE project, while Silva et al. (2017) investigated the causes of the implementation gap of accessibility measures among practitioners and outlined future challenges for accessibility studies.

To the best of the authors' knowledge, this paper is the first to provide an accessibility analysis to study the interaction between SEZs and a transport network of the same territory. In particular, given its behavioural foundation and the quality of the available data, the analysis has been conducted by resorting to behavioural utility-based accessibility measures. The next section illustrates the methodological steps of the analysis, details the specification of the accessibility model and recalls some aspects of the inherent theoretical background of the method employed.

3. Accessibility analysis: methodology

This section illustrates the methodology for the transport accessibility analyses carried out in Sections 4–5. As remarked in Section 2.3, in this paper, the transport accessibility is defined as the inherent characteristic of an area/territory to be connected to (active accessibility) or to be reached by (passive accessibility) other areas /territories. The transport accessibility analysis performed in this paper concerns the SEZ areas of the Campania region. The active accessibility is important for those vehicles departing from SEZ areas to reach other zones/nodes of the study area analyses, while passive accessibility is important for those vehicles that have to reach SEZ areas from other zones/nodes of the study area.

In general, the analyses on the test site have been conducted by following the steps below:

1. identification of the study area and extraction of relevant infrastructure;
2. zoning of the study area;
3. identification of the elements/areas of interest within the analyzed study area;
4. implementation of a supply model for the simulation of the transport performance of the network;
5. implementation of a demand model for the simulation of (freight or passengers) the volumes of trips within the analyzed study area;
6. computation of the accessibility measures and representation of the results;

In particular, the accessibility analysis has been conducted at national and first/last leg levels of vehicle trips from/to SEZ areas in the Campania region. Thus, the analyses have been conducted with two different degrees of granularity, both in terms of the topological model and in terms of the analytical model, to better represent all the different features characterizing long-haul and first/last leg trips. Points 1–6 above have been particularised differently as a function of the scale of the problem. Section 3.2 shows the detail of the accessibility analysis plan at a national level, while Section 3.3 describes the analysis plan for the first/last-leg accessibility analysis.

3.1. Accessibility measures

The accessibility analyses at both the first/last leg and the national levels have been performed by resorting to the random utility theory (*RUT*), i.e. interpreting the accessibility measure as a utility measure associated with a set of different areas/zones, e.g. the set of toll stations in the previous example. According to the RUT, a decision-maker q associates a utility U_j^q to each alternative j and then chooses the alternative

[1] Cascetta et al. (2013) also classified isochrone and gravity models under the labels of opportunity and utility-based measures, respectively. However, this paper does not apply this classification, as gravity-based models do not necessarily require the definition of the concept of utility, being rather based on the gravity analogy, that embeds the effect of distance decay.

with maximum utility (rational decision-maker), i.e. $\max_{j\in C_q}\left\{U_j^q\right\}$, where C_q represents the choice set considered by the decision-maker q.[2] However, since the values of the utilities are unknown to the analyst, these can be treated as random variables, for which some distributional assumptions must be made. In particular, the average value of the maximum utility is generally referred to as *satisfaction* (Cascetta, 2009):

$$S_{C_q}^q = E\left[\max_{j\in C_q}\left\{U_j^q\right\}\right] \tag{1}$$

Random utilities are generally expressed as a sum of a deterministic term V_j^q, called systematic utility, and a random term ε_j^q. When assuming identically and independently distributed (i.i.d.) Gumbel (Extreme Value type 1) random terms, the variable $\max_{j\in C_q}\left\{U_j^q\right\}$ is still a Gumbel variable, with an expected value that can be computed with a closed-form expression as follows:

$$if \quad \varepsilon_j^q \sim i.i.d.Gumbel \rightarrow S_{C_n}^q = E\left[\max_{j\in C_n}\left\{U_j^q\right\}\right] = \theta \ln \sum_{j\in C_q} \exp\left(\frac{V_j^q}{\theta}\right) \tag{2}$$

θ being the Gumbel variance parameter. The term multiplying the variance parameter θ is generally referred to as the *logsum*.

Eq. (2) has some interesting properties. For instance, the satisfaction associated with a choice is always greater than or equal to each of the V_j^q (see Cascetta, 2009; §3.4):

$$S_{C_q}^q = E\left[\max_{j\in C_q}\left\{U_j^q\right\}\right] \geq \max_{j\in C_q}\left\{V_j^q\right\} \tag{3}$$

Moreover, since the log-transformation is strictly increasing and the exp-transformation is strictly positive definite, the satisfaction (2) increases when adding an $(n+1)^{\text{th}}$ alternative to C_q:

$$S_{C_{q,n+1}}^n = \theta \ln \sum_{j\in C_{q,n+1}} \exp\left(\frac{V_j^q}{\theta}\right) \geq S_{C_{q,n}}^q = \theta \ln \sum_{j\in C_{q,n}} \exp\left(\frac{V_j^q}{\theta}\right) \tag{4}$$

$C_{q,n+1}$ being the union among the set $C_{q,n}$ and the $(n+1)^{\text{th}}$ alternative.

Eq. (2) can be applied concerning the above-mentioned example concerning motorway toll booths in the Campania SEZ, considering that a generic decision-maker q in a SEZ i associates to each tollgate j a utility $U_{j/i}^q$.

More generally, Eq. (2) can be applied as a measure of both active and passive accessibility from/to the generic node i to/from a set of nodes j as follows:

$$A_i^{act} = \theta \ln \sum_{j\in C} \exp\left(\frac{V_{j/i}}{\theta}\right) \quad A_i^{pas} = \theta \ln \sum_{j\in C} \exp\left(\frac{V_{i/j}}{\theta}\right) \tag{5}$$

where C is the set of all zones of interest. Note that Eq. (5) implicitly assumes that, on average, decision-makers q perceive the same utilities, thus the further apex q can be suppressed.

In this study, systematic utilities have been specified in two different ways, depending on the scale of accessibility analysis. Further details will be shown in Section 3.2 and Section 3.3.

[2] It is worth remarking that the assumption of a rational decision-maker can deviate significantly from reality in certain choice contexts, such as mode and route choices. A wide body of literature embeds latent variables in mode choice (see e.g. Atasoy et al., 2013; Paulssen et al., 2014) and route choice (see Prato et al., 2012) models, thus departing from the assumption of perfect rationality. Kahneman and Tversky (1979) explored choice behaviour within a bounded rationality setting. However, models departing from the assumption of perfect rationality are generally more burdensome. Therefore, the current paper resorts to RUT, representing a well-established framework in discrete choice analysis (see Haghani et al., 2021 for scientometric analysis) and accessibility analysis (see Cascetta, 2009).

3.2. National-level accessibility / Analysis plan and modelling framework

This section reports the detail of the transport accessibility analysis of the Campania SEZ at a national level. This analysis aims to compute the transport accessibility of all the zones within the Italian territory, to contrast the accessibility of SEZ areas in Campania both with the other SEZ areas programmed in Italy and the other zones within the national context. Each modelling framework component will be described in the following.

Study area and zoning) The whole national context has been considered as the study area in this preliminary analysis. The latter has been discretised consistent with the zoning provided by the Italian Institute for Statistics (ISTAT) concerning the so-termed *local labour systems*, leading to a total of 605 traffic analysis zones (TAZs) considered in the analysis. This can be considered a coarse-grained zoning, as the objective is to simulate the transport accessibility of each local labour system by introducing a very detailed specification of all cost rates (see below).

Identification of the elements of interest) The analysis aims to compute the transport accessibility of SEZ areas in the Campania Region within the whole national territory. Conceptually, this can be interpreted as transport accessibility to/from the SEZ areas concerning all the possible national destinations/origins in Italy, namely a measure of the easiness of each zone in exchanging flows within the national territory. In particular, the analysis compares the transport accessibility of the local labour systems which a) include at least a SEZ area in the Campania region, b) include at least a SEZ area within one of the other Italian regions, and c) do not include any SEZ areas.

Supply model for freight) A multi-modal supply modal has been implemented to support the transport accessibility analysis at a national level. In particular, the model simulates the performance of the service for the following modes: road, rail, maritime transport, and their multi-modal integration. For a very detailed description of the model, the reader is referred to the work by Marzano et al. (2022). The key components of the supply model for each modal network have been recalled below.

Road) The topological model has been built based on the OpenStreetMaps project graph. The final topological model for the road includes about 465.000 links and 324.000 nodes. For each link of the road network, several characteristics have been considered, namely: physical characteristics (geometry), functional characteristics (road classification) and operational characteristics (e.g. maximum speed for heavy trucks). The cost rates for the road transport supply model and concerned analytical assumptions on each of the cost rates are reported in Table 2.

Rail) The supply model for rail freight has been used in the study by Marzano et al. (2018). The topological model includes 17′929 km of rail network open to freight traffic and 122 rail terminals. The cost rates included in the analytical model have been indicated in Table 3.

Maritime transport) The supply model for maritime transport concerns Ro-Ro/Ro-Pax services. The model is the same as that used by

Table 2
Road transport supply model – cost rates and analytical assumptions (source: Marzano et al., 2022).

cost component	unit	value/function
driver cost (driving, thus calculated on t_{driv})	€/h	24.48
driver cost (resting, thus calculated on t_{rest})	€/h	0
tractor+trailer (truck) holding cost (calculated on t_{driv}+ t_{rest})	€/h	7.03 + 1.64 = 8.67
fuel consumption on a link l with speed v_l [km/h] and slope p_l [%]	l/km	$k_l = \frac{(v_l-70)^2}{5700} + 0.28(1+0.58p_l)$
fuel cost (not including discounts/subsidies)	€/l	1.115
motorway tolls (per kilometre or per stretch)	€	2021 official figures
other expenditures (insurance, taxes, maintenance)	€/km	0.18

Table 3
Rail transport supply model – cost rates and analytical assumptions (source: Marzano et al., 2022).

cost component	unit	value/ function
drivers (2 drivers onboard)	€/h	57.29
locomotive holding cost (incl. maintenance)	€/h	296.88
rolling stock holding cost (incl. maintenance)	€/h	83.33
energy and network toll	€/train·km	3.00
total (origin and destination) shunting costs and other terminal-related costs (e.g., train control)	€/train	1300
general expenditures (insurance included)	€/train	475

Marzano et al. (2020). The analytical supply model includes the cost rates indicated in Table 4.

Multi-modal freight supply model) The supply model for multi-modal freight transport considers the following combinations: road-sea-road accompanied, road-sea-road unaccompanied and road-rail-road. For the sake of brevity, the reader is referred to the work by Marzano et al. (2022); § 3.2.5 and Table 5) for a detailed explanation of the model and all its analytical assumptions. In general, the analytical multi-modal supply model includes the following cost rates:

1. Monetary costs for handling a trailer load at the terminal;
2. Waiting time at the terminal for each transfer node;
3. Maximum length of the road legs (catchment area thresholds) for port/stations terminals;
4. Other specific cost rates for each multi-modal combination (see Marzano et al., 2022).

A shortest path algorithm considering all the routes on each modal network has been applied to compute the minimum cost on each *od* pair, as it is realistic to assume that trucks and heavy vehicles move on the minimum paths on long-haul trips.

Demand model for freight flows) The freight origin-destination (*od*) flows in the study area have been estimated by resorting to the model underlying the Italian National Freight Model, described in Marzano and Papola (2004) and Cascetta et al. (2008). In particular, the 8 macro-commodity classes listed in Table 5 have been considered for the analysis, according to the segmentation provided by ISTAT. The freight demand model provides a tool for interpreting the results in terms of marginal rates of substitution between relevant attributes.

Accessibility analysis) The accessibility analysis has been based on two types of indicators. The first type of indicator used is represented by Eq. (5). For this purpose, ad hoc systematic utility specifications have been used. In particular, both a distribution model, i.e. the model simulating the percentage of demand generated at an origin that is attracted by each destination between all the TAZs considered in the analysis, and the provenance model, i.e. the model simulating the percentage of demand at a destination that is generated by each origin between all the TAZs considered in the analysis, have been estimated. The systematic utilities within (5) have been expressed as:

National level)

$$V^k_{j/i} = \beta^k_c(\omega^k_M M^k_j + C_{ij}) V^k_{i/j} = \beta^k_c(\omega^k_M M^k_i + C_{ji}) \tag{6}$$

Table 4
Maritime transport supply model – cost rates and analytical assumptions (source: Marzano et al., 2022).

cost component	unit	value/function
tractor holding cost	€/h	7.03 (accompanied), 0 (unaccompanied)
trailer holding cost	€/h	1.64
maritime fare (accompanied)	€/km	0.85 up to 300 nm, 1.1 more than 300 nm
maritime fare (unaccompanied)	€/km	0.68 up to 300 nm, 0.88 more than 300 nm

Table 5
National-level accessibility analysis / Macro-commodity classes for the demand model segmentation.

Macro-commodity class *k*	Description
1	mechanical machinery and apparatus, electrical machinery and apparatus, television sets, communication equipment, means of transport.
2	chemical products, rubber and plastic articles.
3	products of the textile and clothing industry, leather products, wood and wood products, paper and paper products, furniture, and other manufactured goods.
4	coal, coke, crude oil, refined petroleum products, natural gas.
5	secondary raw materials, municipal and other wastes, other commodities.
6	metal ores, other mining products, fabricated metal products, building materials, ceramic products.
7	mail, parcels, containers, pallets, swap bodies, goods transported in the course of removals, grouped goods, goods contained in containers or unidentifiable swap bodies.
8	agricultural products from hunting and fishing, foodstuffs, beverages, and tobacco.

where M^k_j, M^k_i are the masses associated with the node *j*, *i* for the macro-commodity class *k*, and C_{ij} (C_{ji}) represents the minimum monetary cost across all the considered modes in the multi-modal supply model for going from zone *i* (or *j*) to *j* (or *i*), β^k_c is the monetary cost coefficient for *k*, i.e. the marginal utility of transport costs (which are expressed in [€/ton]), and ω^k_M is the marginal rate of substitution between transport monetary cost and attracted/generated masses.

In particular, the mass M^k_j is an estimated volume of goods of the commodity class *k* aimed at reproducing the capability of generating/attracting freight flows of *j*. Note that systematic utility in Eq. (6) has been expressed in the evaluation space, where the expression $(\omega_M M^k_j + C_{ij})$ indicates an equivalent monetary cost embedding also the effect of the mass at the node *j*. The computation of transport costs C_{ij} has been performed through the multi-modal supply model described above, while the M^k_j has been obtained by ISTAT.

The estimation of the coefficients in (6) has been conducted with the aid of a non-linear least squares estimator (*NLS*), exploiting observations on the observed freight traffic volumes at a national level. Indeed, from the latter values, the observed shares $\widehat{P}_{i|j,k}$for the pair *i,j* and macro-commodity class *k* have been computed, allowing to estimate coefficients

$$(\beta^k_c, \omega^k_M)_{NLS} = argmin(\sum_{i,j}[\widehat{P}_{i|j,k} - P_{i|j}(\beta^k_c, \omega^k_M)])^2 \tag{7}$$

where $P_{i|j}\left(\beta^k_c, \omega^k_M\right)$ is the modelled multinomial logit probability for the zone *i* (destination for active accessibility, origin for active accessibility), given the zone *j* (origin for active accessibility, destination for passive accessibility) and macro-commodity class *k*, which is a function of the vector of coefficients β^k_c, ω^k_M. The summation is extended across all the pairs (*i,j*).

The second type of indicator for the national-level accessibility analysis is the average transport monetary cost, computed as follows for each macro-commodity class and the two cases of active and passive accessibility:

$$\overline{C}^{act,k}_i = \frac{\sum_{j'} C_{ij'} M^k_{j'}}{\sum_{j'} M^k_{j'}} \quad \overline{C}^{pas,k}_j = \frac{\sum_{i'} C_{i'j} M^k_{i'}}{\sum_{i'} M^k_{i'}} \tag{8}$$

where $\overline{C}^{act,k}_i$ and $\overline{C}^{pas,k}_i$ the average monetary cost values for the active and passive accessibility measures, respectively. In Eq. (8), average transport monetary costs are weighted on all the masses at the destinations (active accessibility) and origins (passive accessibility). In this way, the lower the average costs in (8) the more accessible is the concerned zone. Eq. (8) have the advantage of being more readily interpretable than other accessibility measures, so they have been used to show the results of the transport accessibility analysis at a national level.

3.3. First/last-leg level accessibility / Analysis plan and modelling framework

This section describes the first/last-leg accessibility analysis conducted to assess the accessibility to/from each SEZ area within the Campania region with reference to relevant nodes of the regional network (see details below). This analysis presents a different degree of detail with reference to the national-level accessibility analysis.

Study area and zoning) The study area for the first/last-leg accessibility analysis is the Campania region. Such accessibility is computed with reference to relevant nodes of the Campania region network (tollgates, rail stations, airports, ports and interports). For this analysis, a denser zoning consisting of about 1′500 TAZs has been considered, in turn, obtained by clustering census sections of the ISTAT.

Identification of the elements of interest) The transport accessibility analysis performed at this local level is conducted to quantify the easiness to reach or depart from SEZ areas from/to relevant nodes of the network. In particular, as described in Section 4.3, the nodes of the network that are of interest for the analysis are: tollbooths, railway stations, ports, interports and airports.

Supply model for the road) The travel time on each generic link l was computed through a BPR function as $t_l = t_{l,0}\cdot(1+\alpha)\cdot(f_l/CAP_l)^{\gamma}$, with,$t_{l,0}$, f_l andCAP_l being the free-flow travel time, the traffic flow and the capacity of the link l, respectively, while α and γ are coefficients of the BPR function. Table 6 provides the values assumed for the latter coefficients. The values are considered standard in Italian applications. In particular, $\alpha = 0.3$ indicates that the free flow speed on the link is 30% higher than the critical speed value, while $\gamma = 4.0$ indicates aggressive driving conditions on the network.

Demand model per od pair and travel mode) The traffic volumes for each od pair and travel mode have been computed by resorting to the model by De Luca and Papola (2001), who implemented a system of travel demand models for the same study area, concerning generation, distribution, and modal choices, namely the first three choice dimensions of a four-step demand model. The models have been segmented by considering six travel purposes. The modal *od* matrices estimated with such a modelling framework have been updated with a set of aggregated traffic measures in the year 2019 on relevant links of the network, by resorting to an *od* matrix updating procedure through the generalized least square (*GLS*) estimator (Cascetta, 1984). The GLS considers the errors of the reproduced link flows with reference to the observed link flows, thus allowing us to assess the goodness of the updated modal *od* matrices in reproducing such traffic flows.

The analysis implemented in the current study concerns the time interval 5:00–6:00 P.M., namely the afternoon peak hour. The latter appears to be the most congested weekday hour from the traffic measurements observed on the network from the satellite, as it has the peak in terms of both systematic trips (i.e. trips to get home from work or study locations) and non-systematic trips (i.e. the trips for other purposes, such as shopping or leisure) and will be referred to as the *peak hour* in the following. The travel demand in the medium and long-term scenarios has been updated by coupling the estimated demand volumes of each origin with population and GDP coming from time series data, allowing us to forecast the variation in demand volumes at 2030 (medium-term) and 2040 (long-term).

Table 6
SUE-MNP traffic simulation settings.

Model	Parameter	Value
Supply model (BPR function)	α	0.3
	γ	4.0
Route choice model	ψ	0.3
MSA convergence	ξ	1%

Route choice model) The Multinomial Probit (MNP) model has been employed to model route choice. In particular, the MNP has been performed with an implicit enumeration procedure, resorting to the Monte Carlo algorithm, under the assumption of Daganzo and Sheffi (1977), i.e. variance of perceived link cost proportional to link cost by a proportionality constant, namely $Var\{\hat{c}_l\} = \psi\cdot c_l$. Table 2 indicates the assumption of $\psi = 0.3$, i.e. perceived link cost variance set as 30% of average perceived link cost, with a coefficient of variation decreasing with the average link cost. However, the variance of the results in terms of link volumes as the SUE-MNP constant ψ varies is not significant, so the SUE-MNP results are quite similar to those of the Deterministic User Equilibrium (DUE) assignment on this network.

SUE assignment/equilibrium criterion) For the first/last leg accessibility analysis, a stochastic user equilibrium (SUE) traffic assignment has been performed, to consider the effect of traffic congestion in the accessibility computation (see below). The current sub-section recalls the main settings assumed for the SUE assignment exercises. The method of successive averages (*MSA*) has been employed to search for the link flows at equilibrium. The convergence test at each generic MSA iteration k was performed as $\max_{l\in L}\left\{\frac{f_l^{k*}-f_l^k}{f_l^{k*}}\right\}<\xi$, being f_l^{k*}, and$f_l^k$the average of the values of the link flow for the link $l \in L$ in the previous (k-1) MSA iterations and the generic link flow at the iteration k for the same link respectively, while ξ is the convergence test value. As can be observed in Table 6, the value $\xi = 1\%$ for the convergence test on the maximum link flow relative difference has been considered. The latter can be considered a reasonably stringent threshold. In particular, the simulations were carried out with the aid of the Trancad 4.5 software.

Accessibility computation) The accessibility measure for the first/last leg has been computed as:

$$\overline{C}_i^{act,N} = -\theta\ln\sum_{j\in C^N}\exp\left(\frac{V_{j/i}}{\theta}\right) \quad \overline{C}_i^{pas,N} = -\theta\ln\sum_{j\in C^N}\exp\left(\frac{V_{i/j}}{\theta}\right) \tag{9}$$

where C^N is the set of all nodes of type N. In this case, the accessibility analysis for each SEZ area of the Campania region has been conducted with reference to a set of logistic nodes that represent the first/last mile connections, namely: tollbooths, stations, ports, interports and airports (see Section 4.3 for more details).

The systematic utility for the first/last-leg accessibility analysis has been computed as:

First/last-leg level)

$$V_{j/i} = -T_{ij} \quad V_{i/j} = -T_{ji} \tag{10}$$

In Eq. (10), T_{ij} is the minimum time (in minutes) for going from node i to node j (and vice versa for T_{ji}) on the given network. The latter has not been segmented by commodity class, as it is assumed that travel time is not influenced by the specific macro-commodity class under analysis.

The analysis for the first/last leg is different from the national analysis, because it is assumed that the former is influenced by travel time mainly. Furthermore, Eq. (10) allow for a more intuitive representation of accessibility in terms of equivalent travel time. It is worth noting that, in (10), the travel time coefficient is assumed to be unitary. This corresponds to working in the space of marginal rates of substitution with reference to travel time, being the variance parameter θ normalised to 1.

Note that Eq. (9), under specification (10), have the dimension of equivalent travel time and will be defined, in the following, as the active/passive average minimum disutility from/to the SEZ area i. Properties (6)-(7) still hold with the sign of inequality reversed, showing that (7): i) is always lower than that of the single T_{ij} (or T_{ji}), ii) always decreases when adding a further node to the set C^N iii) provides a smaller accessibility measure when it takes on a greater value.

To quantify the performance of the network, the following indicators have been considered in the successive analysis of future scenarios in Section 5:

$$\Omega_i^{act,N} = \overline{C}_i^{act,N,SUE} / \overline{C}_i^{act,N,SNL} \quad \Omega_i^{pas,N} = \overline{C}_i^{pas,N,SUE} / \overline{C}_i^{pas,N,SNL} \tag{11}$$

$\Omega_i^{act,N}$ and $\Omega_i^{pas,N}$ being the ratios amongst the accessibility indicators computed with a Stochastic User Equilibrium (SUE) assignment, namely $\overline{C}_i^{act,N,SUE}$ and $\overline{C}_i^{pas,N,SUE}$ (congested accessibility), and the accessibility indicators computed with a Stochastic Network Loading (SNL) assignment, namely $\overline{C}_i^{act,N,SNL}$ and $\overline{C}_i^{pas,N,SNL}$ (uncongested accessibility), in the active and passive scenarios, respectively. Eq. (11) are useful to highlight the critical issues in terms of traffic congestion, as values significantly greater than 1 (say greater than 1.5) indicate that average congested travel times are much greater than average uncongested travel times, highlighting a traffic pattern with a potential oversaturation on some links, which indicate the presence of link flows exceeding the concerned link capacity.

4. Accessibility analysis: current scenario

This section describes the results of the accessibility analysis on the SEZ areas of the Campania Region concerning the current scenario. In particular, Section 4.1 depicts the case study, listing the SEZ areas of the Campania Region and illustrating the current regional road and rail network, while Sections 4.2 and 4.3 show the results for the national and first/last-leg accessibility analysis, respectively.

4.1. Case study

The geographical location of the Campania SEZ areas (as defined by the Regional Strategic Plan) and the detail of the existing road and Campania rail network, considering only freight terminals as access nodes, are depicted in the following Figs. 1–4. Fig. 1 shows the position of the Campania region within Italy. Figs. 2–4 contextualize the SEZs with reference to the existing infrastructures and the main nodes of the network. In particular, the right and left sides of Figs. 2–3 show the correspondence between the SEZs areas and the relative Id number (from 1 to 29), while the right and left sides of Fig. 4 show the railway freight stations and the relative Id number (from 1 to 22).

As can be seen in Fig. 2, the primary network consists of the motorway network that crosses the Campania Region and includes the following motorways: A1, A2, A3, A16, A30 and A56. Furthermore, the regional and provincial primary networks have been considered suburban main roads. The analysis of the accessibility to railway nodes considers the stations in Fig. 4.

4.2. National accessibility analysis and SEZs

This section presents the results of the accessibility analysis at a national level. Preliminarily, the coefficients of the freight demand model have been estimated for 8 different macro-commodity classes. The estimation of the coefficients in (6) has been conducted through the

Fig. 1. SEZ areas in Italy and the Campania region.

Id SEZ	Name SEZ	Id SEZ	Name SEZ
1	Bagnoli Coroglio	16	PIP Fosso imperatore
2	ASI Aversa nord	17	Castel san Giorgio
3	Naples Est	18	Port of Salerno
4	ASI Arzano	19	Piattaforma Oliva
5	Naples Airport	20	ASI Fisciano
6	ASI Marcianise	21	ASI Pianodardine
7	ASI Caivano	22	ASI Ponte Valentino
8	Interport Sud Europa	23	ASI Salerno
9	ASI Acerra	24	PIP Salerno
10	ASI Pomigliano	25	Salerno Airport
11	ASI Foce Sarno	26	ASI Battipaglia
12	Interporto Campano	27	ASI Ufita
13	ASI Nola Marigliano	28	ASI Calaggio
14	Port of Castellammare	29	Port of Naples
15	PIP Sarno		

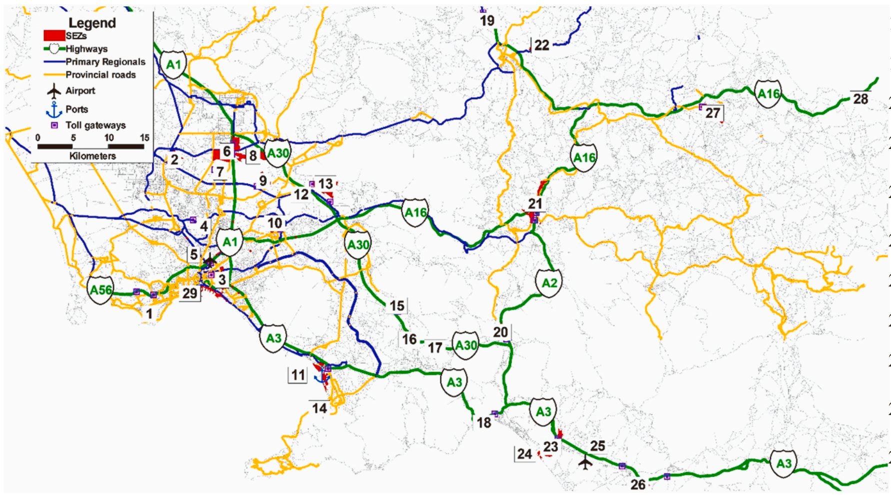


Fig. 2. SEZ areas and road network in the Campania Region.

Id SEZ	Name SEZ	Id SEZ	Name SEZ
1	Bagnoli Coroglio	16	PIP Fosso imperatore
2	ASI Aversa nord	17	Castel san Giorgio
3	Naples Est	18	Port of Salerno
4	ASI Arzano	19	Piattaforma Oliva
5	Naples Airport	20	ASI Fisciano
6	ASI Marcianise	21	ASI Pianodardine
7	ASI Caivano	22	ASI Ponte Valentino
8	Interport Sud Europa	23	ASI Salerno
9	ASI Acerra	24	PIP Salerno
10	ASI Pomigliano	25	Salerno Airport
11	ASI Foce Sarno	26	ASI Battipaglia
12	Interporto Campano	27	ASI Ufita
13	ASI Nola Marigliano	28	ASI Calaggio
14	Port of Castellammare	29	Port of Naples
15	PIP Sarno		

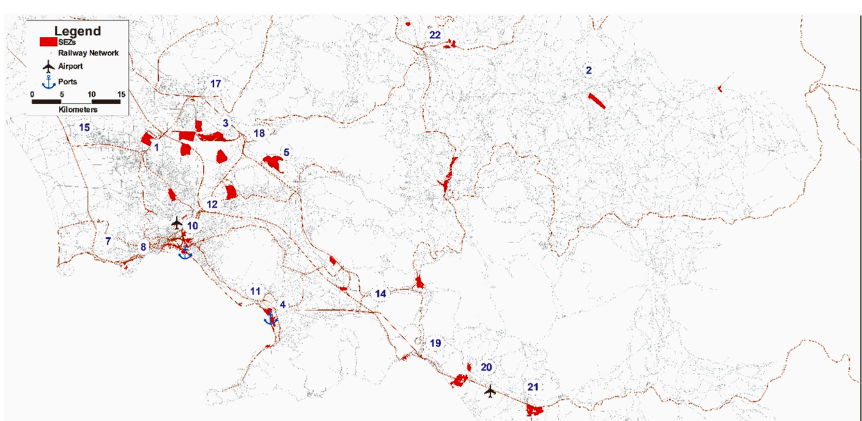
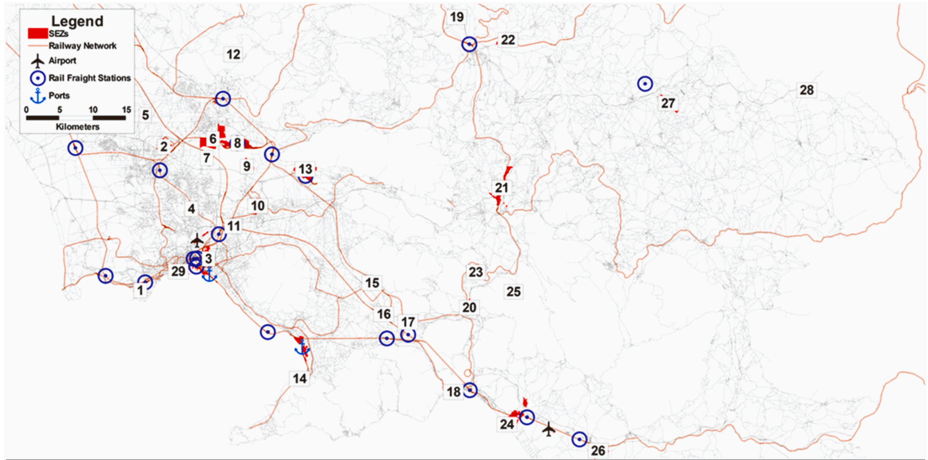


Fig. 3. SEZ areas and rail network in the Campania Region.

NLS estimator, based on aggregated data, in turn representing the observed origin/destination shares of attracted/generated freight volumes for each class *k*. The results of the estimation of the coefficients are reported in Table 7, which shows the coefficients of both the distribution model, which aims to estimate the percentages of distribution between the destinations of the zoning, and the provenance model, which aims to estimate the percentages of provenance between the origins of the zoning. Moreover, Table 7 shows a relative measure of goodness-of-fit (*GoF*) of the estimated models, in terms of the ratio between the explained and the total variance, which has been referred to as $R^2_{eq.}$, in

Id	Name Station
1	Aversa
2	Hirpinia
3	Interport Sud Europa
4	Porto Torre Annunziata
5	Interporto Campano
6	Port of Napoles
7	Pozzuoli Solfatara
8	Napoli Campi flegrei
9	Napoli Centrale
10	Gianturco
11	S.Maria la Bruna



Id	Name Station
12	PM Casoria
13	Nocera Inferiore
14	PM Torricchio
15	Villa Literno
16	Vairano-Caianiello
17	Caserta
18	Cancello
19	Salerno
20	Pontecagnano
21	Battipaglia
22	Benevento

Fig. 4. SEZ areas and rail freight stations.

Table 7
NLS estimates of the utility coefficients in the specification (6).

ID	Active accessibility model			Passive accessibility model		
	R^2_{eq}	ω^k_M [€/million tons/ton]	β^k_c [ton/€]	R^2_{eq}	ω^k_M [€/million tons/ton]	β^k_c [ton/€]
1	0.263	-10.30	-0.119	0.248	-10.06	-0.120
2	0.322	-9.89	-0.069	0.279	-9.99	-0.068
3	0.317	-7.23	-0.109	0.281	-7.35	-0.107
4	0.290	-4.20	-0.139	0.284	-4.62	-0.128
5	0.273	-1.48	-0.141	0.263	-1.52	-0.146
6	0.245	-0.62	-0.144	0.248	-0.62	-0.143
7	0.286	-3.13	-0.077	0.277	-2.98	-0.080
8	0.324	-1.98	-0.088	0.309	-2.03	-0.090

analogy with the R^2 commonly used in ordinary least square regressions.[3]

The coefficient ω^k_M can be interpreted as the average amount of money per ton of goods that logistic providers are willing to spend to have destinations attracting (in the case of the distribution model) or origins generating (in the case of the provenance model) a million tons more of goods. As the monetary cost C_{ij} has been considered in [€/ton] in (6), the corresponding coefficient β^k_c has the dimension of [ton/€], while the coefficient ω^k_M has a unit dimension of [€/million tons/ton].

The interpretation of the coefficients in Table 7 is useful in itself and will be commented on in the following. For instance, looking at the results for the first commodity class in the case of the active accessibility model, the value of ω^k_M testifies that if the destinations of the study area would attract, on average, a million tons more of goods, and transport service providers would spend 10.30 €/ton more to move goods towards the destinations, the observed destination shares would not be altered. In other words, an increase in the average attractivity of the destinations within the study area would allow an increase in transport costs that companies are willing to spend on moving goods. Analogously, concerning the provenance model, the value of ω^k_M means that if the origins in the study area would generate, on average, a million tons more, and transport service providers would spend 10.06 €/ton more to move from the origins, the observed provenance shares would not be altered. In summary, the coefficients of the models allow us to take into account the effects of increased produced volumes for the companies established in SEZ areas on the exchanged freight volumes between zones. Since the effect of SEZ implementation may have an impact on the volumes produced by the companies within the SEZ areas, assuming fixed transport monetary costs, the attracted/generated goods by/from such areas would increase. On the other hand, the modelling framework embeds the effects on freight distribution of an eventual variation in transport costs.

Results in Table 7 also emphasize the econometric differences in the coefficients per each commodity class. For instance, there is a very high rate of substitution for macro-commodity class 1 (more than 10 €/tons per every million tons, as seen above), while very low for macro-commodity class 6 (0.62 €/tons per every million tons). This result is strictly dependent on the unit economic value (by weight) of goods in each macro-commodity class. Indeed, goods of macro-commodity class 6 have the smallest economic value per kg and thus the smallest ω^k_M. Thus, it can be stated that the marginal rate of substitution across monetary cost and generated/attracted mass is increasing with the unit economic value of the goods in each commodity class.

This points out the importance of estimating the model by considering a segmentation in different commodity classes, otherwise, a significant bias would be introduced in the modelling framework.

Quantifying the marginal rates of substitution allows also for assessing the factors to be leveraged by policymakers. Indeed, considering the zones where SEZ areas are implemented, results quantify how much an increase in produced volume in those zones may compensate for eventual higher transport costs per ton of goods, with reference to zones without SEZ areas.

On the other hand, the modelling framework allows us to estimate how a reduction in transport costs for SEZ areas leads to an increase in the amount of the attracted/generated shares. However, the SEZ implementation impacts the production costs of the companies located within the SEZ areas, but usually not transport costs. However, soft measures may be implemented to incentivise the trips departing from and moving to a SEZ area, e.g. discounts at tollbooths for trucks. Also, some incentives for fleet renewal for the companies operating in SEZ areas could be provided, thus impacting the vehicle depreciation cost rate.

The active and passive transport accessibility measures of each of the 605 zones of the local labour system zoning and each of the 8 macro-

[3] It is worth remarking that the values of the R^2_{eq}. cannot be interpreted by considering the value 1 as the bound representing the perfect model (i.e., the model perfectly predicting each observed outcome), as done in the R^2 used for the ordinary least square regression, because in the former case, the explained and residual variances do not sum up to the total variance.

commodity classes have been computed through Eqs. (5) and (8). Figs. 5–6 shows the results of the transport accessibility computed through Eq. (8), while Figs. 7–8 shows the results in terms of average transport monetary costs computed through Eq. (5). The results have been shown by resorting to box plots, indicating each macro-commodity class and distinguishing the following sets of zones: a) SEZ areas of the Campania region, b) the other SEZ areas in the rest of Italy, and c) all the other zones of Italy. In particular, the boxplots report the dispersion of the values of transport accessibility, with the boxes including the values from the 25th to 75th percentile (interquartile range), the whiskers indicating the values outside the range and further points indicating other outliers.

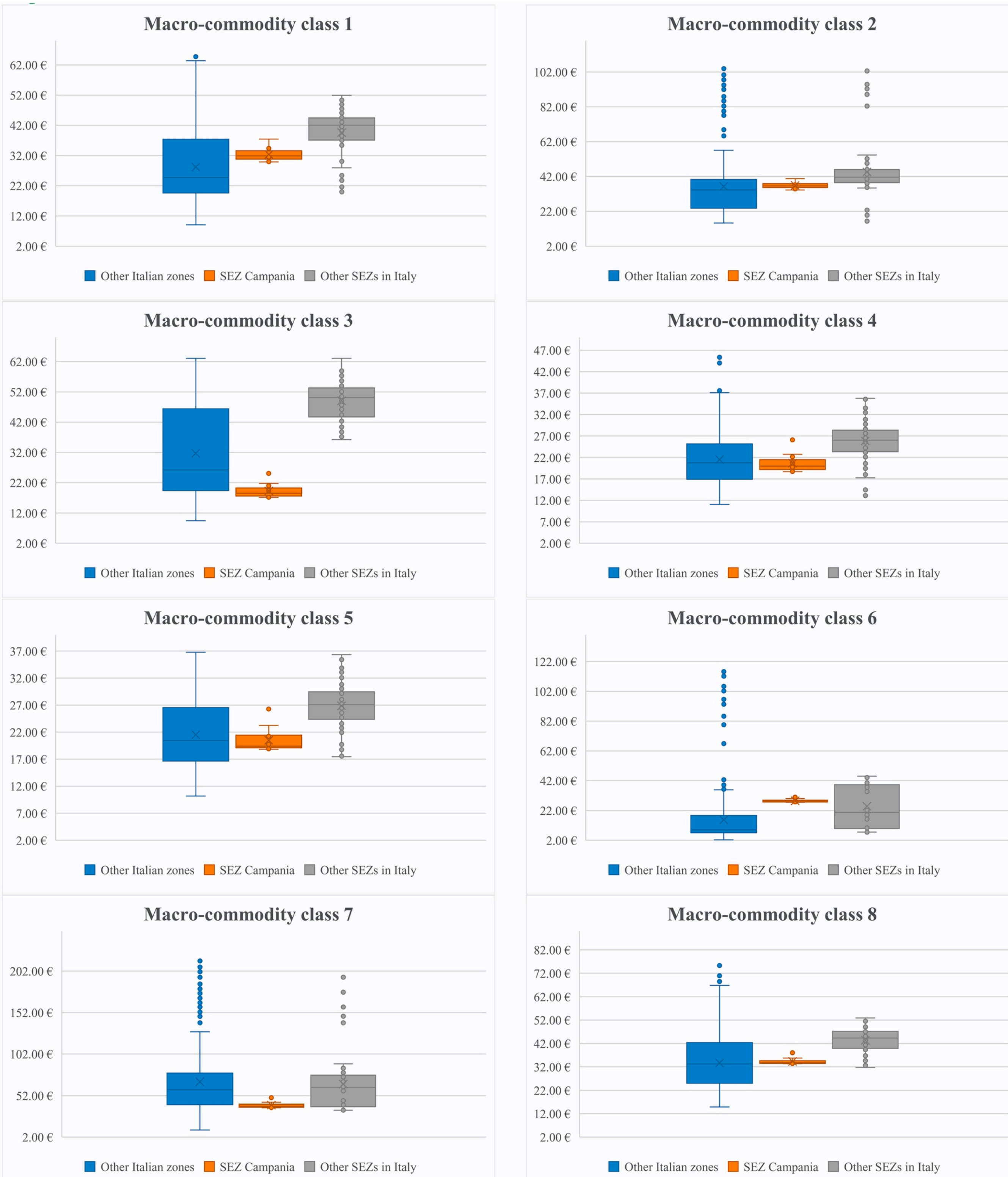


Fig. 5. National-level active accessibility analysis– results of the application of Eq. (8).

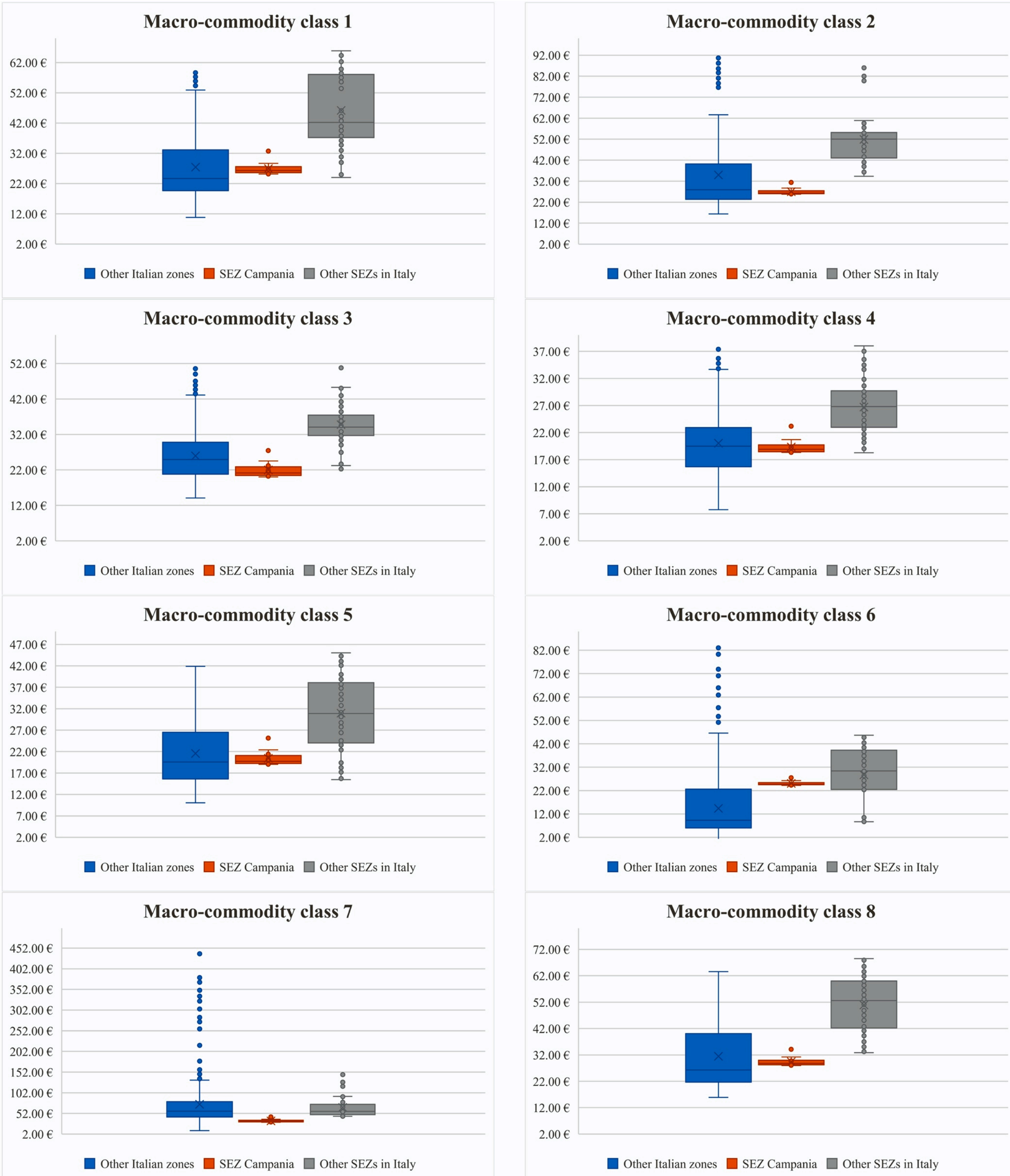


Fig. 6. National-level passive accessibility analysis– results of the application of Eq. (8).

The results emphasize several aspects. Concerning the transport monetary costs, it can be observed that the SEZ areas in the Campania region have lower average transport monetary costs than those of the other Italian SEZ areas, in 7 out of 8 macro-commodity classes (class $k = 6$, which has the lower unit economic value per weight, being an exception to this trend) for the active accessibility case and all the macro-commodity classes for the passive accessibility case. When comparing the SEZ areas in the Campania region with those of the other Italian zones, the Campania region has better transport accessibility in half of the cases. The comparison with the other Italian zones should be made by keeping in mind that transport costs for a certain commodity-class k depend on the location of production centres. Just to give an

Fig. 7. National-level active accessibility analysis– results of the application of Eq. (5).

example, the zones of the Campania region containing SEZ areas have better average transport accessibility that the average value of the other national zones in the case of the commodity-class $k = 3$ because the main production centres for the latter are located in the centre of Italy. A further aspect concerns the comparison between the average transport monetary costs between different commodity classes, which confirms that the transport cost (and thus the accessibility) increases (decreases) with the unit economic value of the goods. For instance, commodity-class 6 in Figs. 5–6 has the lowest average transport costs (and thus the best value transport of accessibility) and the lower unit economic value per weight.

Concerning the logsum formulas (5), the SEZ areas in the Campania

Fig. 8. National-level passive accessibility analysis– results of the application of Eq. (5).

region have greater transport accessibility, on average, with reference to the other SEZ areas in Italy, and it is also above the median value of the other (non-SEZ) zones in Italy for all the macro-commodity classes. Looking at the dispersion of the results, instead, there are also zones with greater accessibility than those of the SEZ Campania. Eq. (5) allow for quantifying more robustly the accessibility, as the effect of masses and monetary costs are weighted by the concerned coefficients, in turn, estimated on data, and have a solid theoretical background, as seen in Section 3. On the other hand, the monetary transport costs computed through (8) have the advantage of being more readily interpretable. Thus, the joint presentation of the two types of measures provides a good framework for the accessibility of SEZ areas.

However, whatever the accessibility measure adopted, the implementation of a SEZ implies fiscal/economic advantages that can fill the economic gap due to transport accessibility for some less accessible zones. This aspect is crucial, as the implementation of a SEZ is not expected to modify the infrastructural network in the short term. On the long-term horizon, instead, policymakers can evaluate further interventions to make each SEZ more accessible, e.g. an upgrade of existing infrastructure or even ad hoc new infrastructure. The considerations in the case of passive accessibility are similar. Single accessibility results may differ quite significantly in active and passive accessibility cases. However, average and dispersion tend to be similar between the two cases.

4.3. Accessibility analysis for the first/last leg

This section shows the results of the accessibility analysis for the first/last leg of trips. The objective is to compute the accessibility from relevant nodes to /from each SEZ area in the Campania region. In particular, the active and passive accessibility analyses have been conducted by resorting to Eq. (9), where the sets C^N represent the following nodes:

Motorway's tollgates and access ramps to the primary road network;
Railway stations used for freight traffic;
Ports handling freight traffic (Naples and Salerno);

Table 8
Active accessibility analysis of SEZ areas in equivalent travel time – Results on the current scenario.

ID SEZ	SEZ area name	Equivalent travel time [min] - eq. (7) Road	Railway	Port	Airport	Interport
1	Bagnoli Coroglio	8.1	4.7	37.2	45.8	59.1
2	ASI Aversa nord	1.3	8.0	21.3	26.4	16.1
3	Naples Est	6.0	4.8	4.9	18.5	29.6
4	ASI Arzano	5.9	12.9	19.8	15.0	21.6
5	Naples Airport	8.0	13.4	20.2	0.0	29.3
6	ASI Marcianise	3.0	8.4	21.7	26.8	8.4
7	ASI Caivano	1.4	9.1	18.6	23.7	9.1
8	Interport Sud Europa	5.6	0.0	22.3	27.5	0.0
9	ASI Acerra	8.0	8.9	22.9	28.0	13.4
10	ASI Pomigliano	1.8	12.1	15.7	21.8	17.1
11	ASI Foce Sarno	2.4	0.0	17.0	33.0	35.0
12	Interport campano	6.6	0.0	29.2	34.3	0.0
13	ASI Nola Marigliano	3.7	6.5	24.8	29.9	6.5
14	Port of Castellammare	9.2	9.8	23.7	39.6	41.5
15	PIP Sarno	2.5	12.3	24.7	32.8	19.1
16	PIP Fosso imperatore	2.2	7.2	23.4	33.4	21.9
17	Castel san Giorgio	1.9	6.6	20.9	31.7	23.0
18	Port of Salerno	5.8	7.8	0.0	25.7	39.2
19	Piattaforma Olivola	4.7	9.2	57.8	64.8	53.0
20	ASI Fisciano	3.2	15.6	19.1	30.0	27.9
21	ASI Pianodardine	2.3	26.6	32.6	41.0	29.9
22	ASI Ponte Valentino	1.4	10.5	54.9	61.8	50.0
23	ASI Salerno	2.1	3.1	15.8	11.0	40.7
24	PIP Salerno	2.4	7.1	12.6	12.0	42.3
25	Salerno Airport	10.1	9.1	24.0	0.0	48.6
26	ASI Battipaglia	8.3	8.0	27.7	19.0	50.7
27	ASI Ufita	2.2	28.7	51.0	57.8	45.9
28	ASI Calaggio	1.4	37.0	58.9	65.9	54.2
29	Port of Naples	6.6	0.0	0.0	21.7	33.3
5th percentile		1.4	0.0	2.0	4.4	2.6
median		3.2	8.4	22.3	28.0	29.6
95th percentile		8.8	27.8	56.7	63.6	53.7

Airports handling freight traffic (Naples Capodichino);
Interports (Campano and Sud Europa).

The results of the accessibility analysis (9) under the utility specification (10) for the current scenario are presented in Tables 8–9, for the active and passive accessibility, respectively. As mentioned in Section 3, the average minimum disutility is expressed in equivalent minutes. by emphasizing the 5th, 50th (median) and 95th percentiles of the distribution of the transport accessibility values. In particular, the values exceeding the 95th percentile for each mode will be referred to as criticalities on the network. In general, the analysis highlights a limited number of criticalities.

More in detail, access to the primary road network is always very fast for all SEZ areas, with maximum accessibility always below 10 min of equivalent travel time, with the port of Castellammare and Salerno airport being an exception for the active accessibility, and the latter and port of Naples being an exception for passive accessibility. The same holds for most SEZs with reference to the railway network, except the ASI of Ufita and Calaggio, whose equivalent access time exceeds 27–28 min (i.e. the 95th percentile values). On the contrary, the equivalent access time increases in the case of ports, as these are much less widespread on the territory (the main regional port nodes are those of Naples and Salerno). All the SEZ areas have relatively fast access to ports, with equivalent travel times close to 30 min in most cases, except

Table 9
Passive accessibility analysis of SEZ areas in equivalent travel time – Results on the current scenario.

		Equivalent travel time [min] - eq. (7)				
ID SEZ	To SEZ	Road	Railway	Port	Airport	Interport
1	Bagnoli Coroglio	7.8	4.8	29.6	32.4	45.3
2	ASI Aversa nord	1.3	7.5	33.9	29.5	15.1
3	Naples Est	8.1	5.9	5.9	17.3	22.4
4	ASI Arzano	5.5	12.9	30.7	15.8	21.7
5	Naples Airport	10.1	14.5	21.7	0.0	27.4
6	ASI Marcianise	1.5	7.3	30.3	25.9	7.3
7	ASI Caivano	3.6	9.4	30.8	26.4	9.4
8	Interport Sud Europa	5.6	0.0	33.8	29.4	0.0
9	ASI Acerra	3.8	11.8	33.0	28.6	16.8
10	ASI Pomigliano	1.8	11.6	27.1	25.3	17.5
11	ASI Foce Sarno	2.3	0.0	25.3	37.8	39.5
12	Interport campano	4.8	0.0	36.4	35.4	0.0
13	ASI Nola Marigliano	3.7	6.8	35.4	34.2	6.8
14	Port of Castellammare	9.4	10.0	32.3	44.5	46.2
15	PIP Sarno	2.5	12.5	26.7	35.1	24.0
16	PIP Fosso imperatore	1.7	6.7	24.4	34.6	25.1
17	Castel san Giorgio	1.9	6.9	23.4	32.9	26.8
18	Port of Salerno	5.4	5.6	0.0	24.0	41.1
19	Piattaforma Olivola	5.1	9.4	63.5	69.1	58.8
20	ASI Fisciano	2.8	16.1	19.8	29.3	33.1
21	ASI Pianodardine	2.2	26.9	33.6	41.7	33.3
22	ASI Ponte Valentino	1.4	10.7	58.5	64.2	54.5
23	ASI Salerno	1.8	3.4	16.8	11.1	43.5
24	PIP Salerno	2.4	7.8	15.1	12.0	44.0
25	Salerno Airport	10.2	8.1	25.7	0.0	51.6
26	ASI Battipaglia	8.3	7.5	27.9	17.7	53.8
27	ASI Ufita	2.2	27.8	54.3	60.2	50.3
28	ASI Calaggio	1.4	35.6	62.0	67.6	57.9
29	Port of Naples	10.2	0.0	0.0	20.2	22.3
5th percentile		1.4	0.0	2.4	4.4	2.7
median		3.6	7.8	29.6	29.4	27.4
95th percentile		10.2	27.4	60.6	66.3	56.5

for the SEZs Piattaforma Olivola and the ASI Calaggio whose equivalent access times to ports are approximately 57–59 min.

The same applies to the Campania Region's airport node, i.e. Naples Capodichino airport. In this case, the average equivalent access times are less than 30 min for most of the SEZ areas, except for the farthest SEZs mentioned in the case of ports. Finally, the analyses on the two interport nodes penalise the SEZ areas in the south of the region, being the two interports located in the northern part of Campania, with equivalent travel times that in some cases exceed 40 min. This is the case of the SEZ areas Piattaforma Oliva, Salerno Airport, and the ASI of Battipaglia, Salerno, Ufita and Ponte Valentino, PIP Salerno, with the main criticalities (above 95th percentile) being at Bagnoli Coroglio (a SEZ in the west-area of Naples) and the ASI Calaggio.

Similar observations can be made when referring to passive accessibility concerning all modes but road. The results summarized in Table 9 differ slightly from those reported in Table 8 (a few minutes of equivalent travel time on average). However, the differences are negligible, since the routes considered to reach the SEZ areas from the nodes are similar to those considered in the computation of active accessibility. Indeed, it is worth remarking that logsum-based measures are a function of the utilities of all the alternatives (routes) available and are more sensitive to the maximum utility value, which is the minimum travel time under the utility specification (10). Therefore, this overall symmetry for rail, ports, interports and airports, when comparing active and passive accessibility values, implies that the minimum travel time for going from a node *i* to a node *j* is similar to the minimum travel time for going from *j* to *i*. A slightly different comment relates to the road, where, for instance, the port of Naples has a criticality in the case of road, while having an acceptable value for active accessibility. This is essentially due to the effect of congestion, as travel time in the considered time horizon has been computed through a SUE procedure. Indeed, as verified on real-time data, there can be some criticalities in accessing the ports, due to both a non-symmetry in paths connecting tollbooths and the port within the city and to the effect of the traffic congestion.

5. Accessibility analysis: medium/long-term scenario

This section describes the results of the accessibility analysis on two simulation horizons: a medium-term scenario (year 2030) and a long-term scenario (year 2040). The purpose of the analyses is to assess the situation of the transport accessibility to/from the 29 SEZ areas analysed downstream of the 'programme of the interventions on road and rail infrastructures in the Campania Region' (Campania Region, 2018). In particular, the two simulation scenarios represent time horizons in which the planned interventions are partially and totally implemented, respectively.

All the relevant planned interventions have been analysed. The final list of relevant interventions has been drawn up considering the location of the infrastructure in relation to the transport accessibility of the SEZ areas. The selected interventions are listed below and subdivided by the time horizon of the simulation.

Interventions implemented in the medium-term scenario / year 2030).

1. Naples ring road link (Via Campana) - Port of Pozzuoli;
2. extension of the Contursi - Lyons to Grottaminarda, including the Grottaminarda variant;
3. completion of the 4th Isclero FV Lot;
4. port of Salerno – West Gate Transportation System: Lot 1st, construction of a twin-tube, double lane, the one-way tunnel between the Cernicchiara area and via Ligea/Porto;

Interventions implemented in the long-term scenario / year 2040).

1. realization of the 3rd Lot Equipped Axis "Valle Caudina-Pianodardine";
2. doubling of the lanes of the Caianello – Benevento motorway;
3. doubling of 4 lanes of the variant to state road 268 (Strada statale del Vesuvio);
4. Scandinavia – Mediterranean Corridor: HS/HC Naples – Bari line;
5. Hirpinia Station.

The supply model has been updated to take into account the presence of new road and rail infrastructure, as well as planned nodal interventions, to compute active and passive accessibility in the future scenario.

Fig. 9 and Fig. 10 depict the results of the first/last-leg active and passive accessibility analyses for the medium-term scenario, respectively. Similarly, Fig. 11 and Fig. 12 show the results of the accessibility analyses for the long-term scenario. All results are shown with reference to indicators (11), which, as highlighted in Section 3, are useful to emphasize some critical issues in terms of traffic congestion.

As reported in Section 3.3, to simulate road congestion in the medium and long-term scenario, a stochastic user equilibrium with a Multinomial Probit as the route choice model (SUE-MNP; Sheffi and Powell, 1982) has been implemented, considering the time interval 5:00–6:00 P.M. Since the MNP requires a Monte Carlo simulation (see Daganzo, 1979) to estimate traffic link flows, it has an inherent bias due to the number of draws used for the simulation. Therefore, even when the input variables have equal values, small differences can be observed. For this reason, it only makes sense to comment on significant differences in values.

In general, the results in Figs. 9–12 show that there is no significant difference amongst the values of the indicators (11) for medium- and long-term scenarios.

In both scenarios, a strong difference between active and passive accessibility is observed, due to the imbalance of demand during the peak hour (many vehicles move away from Naples). The most critical bottlenecks during the peak hour can be observed on the main traffic arteries going from the Port of Naples towards the SEZs in the northern area of Naples. In particular, the most critical bottlenecks are observed in the highway junctions Napoli-Salerno (Highway A3 in Fig. 2), Napoli-Bari (Highway A16 in Fig. 2) and Afragola exit, as can be observed from the values of congestion (*VoC*)– i.e. the ratios among link traffic flow and link capacities – that have been depicted in Fig. 13. Indeed, as can be seen, the VoC for those links are greater than 1, emphasizing that queues are expected to form during the time horizon analysed.

In particular, the grey bars in Fig. 10 and Fig. 12 show that the most significant criticality lies in the connections between the port and the SEZs in the area north of Naples, that is, in the passive accessibility of these latter SEZs with respect to the port node, as shown by the omega values that are significantly greater than one ($\Omega_i^{pas,Port}>1.8$ for all those SEZs), namely: ASI Aversa Nord, ASI Arzano, ASI Marcianise, ASI Caivano, Interport Sud Europa, ASI Acerra, ASI Pomigliano. Finally, the active accessibility analysis in Fig. 9 and Fig. 11 shows a significant criticality for the SEZ area of Bagnoli Coroglio (West Naples) with reference to the ports ($\Omega_i^{act,Port}>2.6$), because the main route connecting this SEZ with the port of Naples passes through the urban centre, which is heavily congested during the peak hour analysed. To solve these congestion problems without involving impracticable structural interventions, additional channelling lanes may be designed or advanced traveller information systems (*ATIS*) may be implemented (Bifulco et al., 2009), to avoid the formation of queues before accessing the main arteries.

In addition, an emissions analysis has been performed to compare CO_2 emissions in the current and future scenarios, by resorting to the software COPERT, obtaining that the emissions are not significantly different across the three analysed time horizons and equal to about 2′000 tons in the regional study area.

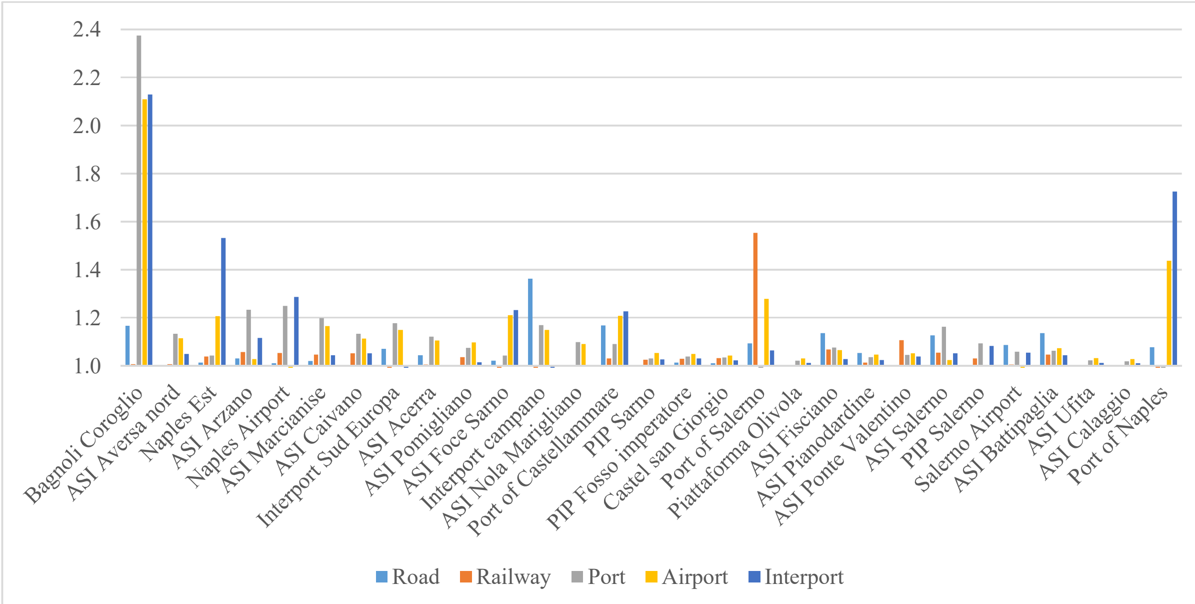


Fig. 9. Active first/last-leg accessibility analysis of SEZ areas – Results on the medium-term scenario in terms of $\Omega_i^{act,N}$.

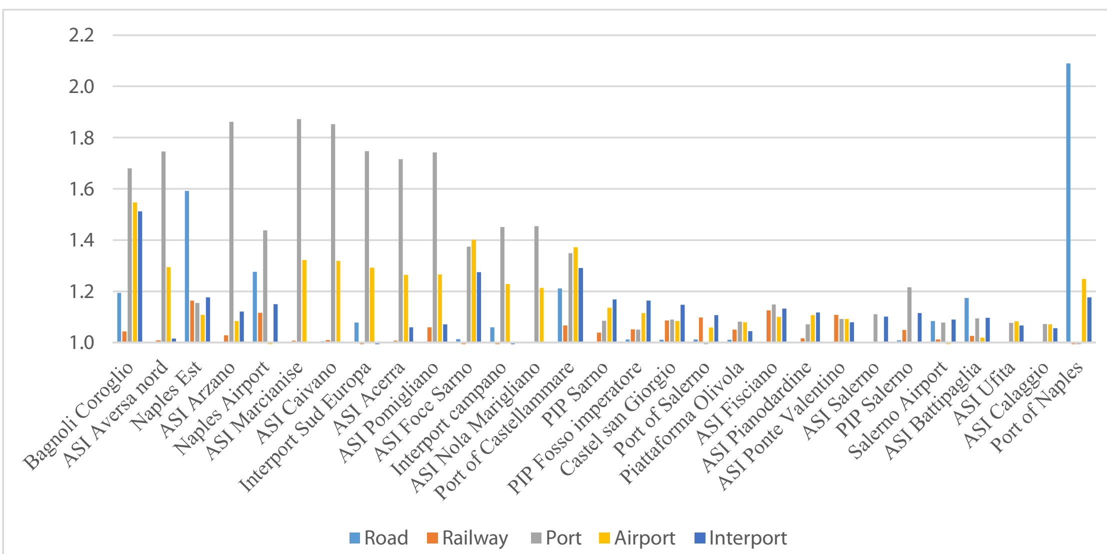


Fig. 10. Passive first/last-leg accessibility analysis of SEZ areas - Results on the medium-term scenario in terms of $\Omega_i^{pas,N}$.

6. Discussion

This section provides a discussion on both results of the transport accessibility analyses and relevant aspects concerning economic and land use implications.

Transport accessibility) The results of the accessibility analyses performed at a national level emphasize how the SEZ areas within the Campania region have a good average (active and passive) accessibility when compared to the other Italian local labour systems and the other SEZ areas within the Italian territory. First, the results differ in values between the cases of accessibility computed through the average transport monetary costs (8) and the logsum formulas (5). The former depicts a framework where the local labour systems with the presence of SEZ areas in Campania are more accessible (lower average transport monetary costs) than the local labour systems with SEZ areas in the rest of Italy in 7 out of 8 macro-commodity classes for the active accessibility and all the macro-commodity classes in the case of passive accessibility. Some differences in transport accessibility remain with reference to the other local labour systems in Italy depending on the macro-commodity class. Concerning the logsum formulas, the results differ in values between the 8 macro-commodity classes, but not in their power relations.

The first/last-leg accessibility analysis has emphasized the presence of a limited number of criticalities, in turn, indicated as the 95th percentile values of transport accessibility, which are the same as those detected when considering future scenarios. The solution to the latter criticalities implies the implementation of soft/hard measures to pull traffic away from the road. These represent general interventions apt to solve congestion problems and go beyond the objective of the paper, which focuses on the national and first/last-leg accessibility of SEZ areas within the Campania region.

Economic implications) In terms of economic evaluation, the considerations that can be made for the 8 macro-commodity classes are

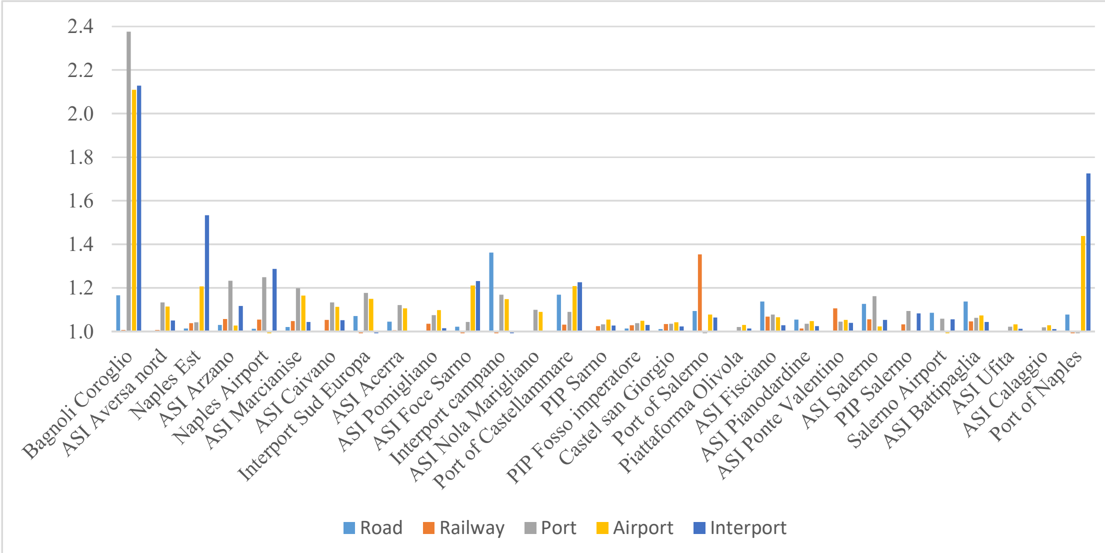


Fig. 11. Active first/last-leg accessibility analysis of SEZ areas - Results on the long-term scenario in terms of $\Omega_i^{act,N}$.

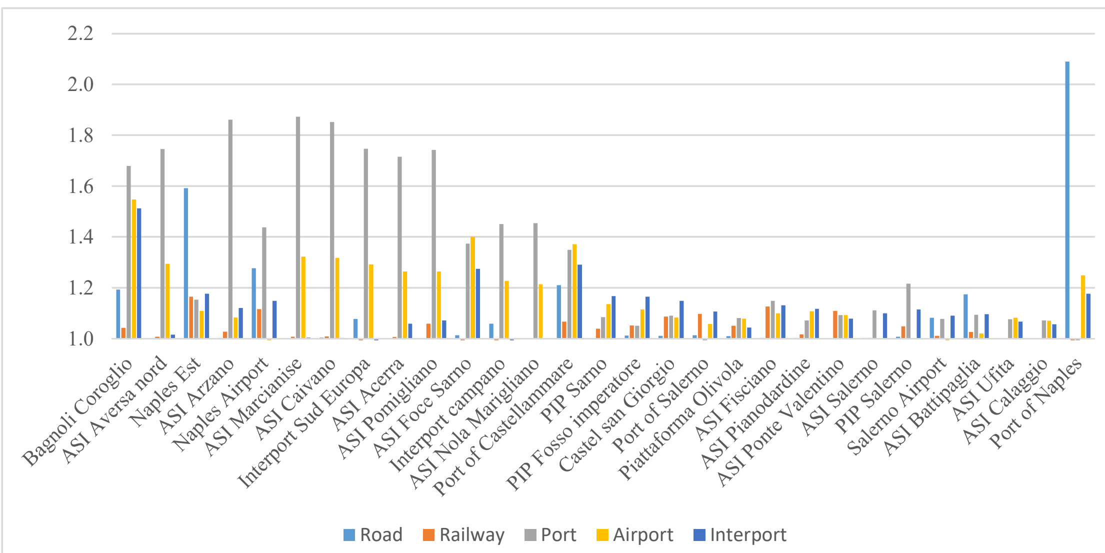


Fig. 12. Passive first/last-leg accessibility analysis of SEZ areas - Results on the long-term scenario in terms of $\Omega_i^{pas,N}$.

significantly different. From the coefficient estimates presented in Table 7, it is evident that marginal rates of substitution between transport costs and generating/attracted masses in origins/destinations differ as a function of the inherent economic unit value of the goods in each macro-commodity class. The marginal rates of substitution are helpful to assess the characteristics that can be leveraged by policymakers. For instance, discounts at tollbooths for trucks reaching or departing from SEZ areas or incentives for fleet renewal for those companies not providing third-party services may be implemented. This would act on fuel and depreciation costs sustained by the companies operating within SEZ areas, which have been directly embedded into the multi-modal supply model described in Section 3.2.

Incentives) Economic literature frequently analyses land use planning issues to justify investment in transport and logistics facilities as a stimulator of economic growth (Carlucci et al., 2018). In particular, this is an important matter in Italy, as the distribution of incentives nationwide is not entirely uniform. The 2016 Stability Law established a tax credit (hereinafter the 'Credit') in favour of companies that purchase new capital goods intended for production facilities located in the regions of Campania, Puglia, Basilicata, Calabria, Sicily, Molise, Sardinia and Abruzzo, to the maximum extent of 20 per cent for small companies, 15 per cent for medium-sized companies and 10 per cent for large companies. In particular, to be eligible for the tax credit, the companies must have the following requirements:

- be already established and duly registered in the commercial register on the date of submission of the application;
- have to carry out their activities within the SEZs;
- not be in a state of liquidation or dissolution;
- maintain their activity within the SEZ for at least seven years after the completion of the subsidised investment;
- have their local unit within the SEZ.

Comparison with other experiences worldwide). Economic literature has emphasized the role of the Special Economic Zone (SEZs) in increasing local economic development and improving land use (Berlinguer, 2016;

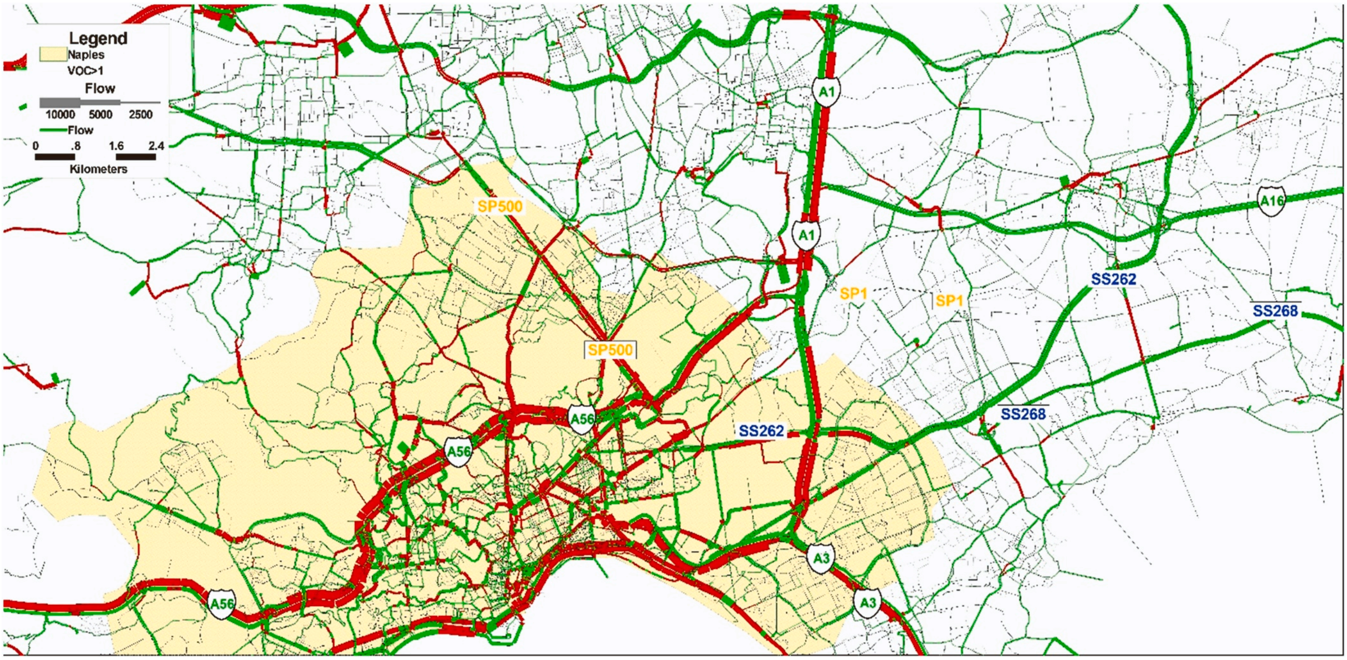


Fig. 13. Illustration of the critical points of the network, in terms of the ratio between link flow and capacity (VoC in the legend).

Zeng (2016); Aniello and De Santis (2018)). As remarked in Section 1, all SEZs benefit from tax and administrative concessions to boost the local economy. The application of fiscal and administrative advantages varies from state to state depending on local policies. For instance, in the case of Uzbekistan (Abdusharipovich (2018)) subject to the value of foreign investment, companies are eligible for allowances of varying duration on: land tax, property tax, corporate profits tax, tax on improvements and the development of social infrastructure and others. In Bangladesh, incentives have been provided for areas in the backward regions, ranging from a 50 per cent subsidy for land and factory rent to a 30 per cent cash incentive for agribusiness (Aggarwal (2005)). Even different is the case of India (2007), where land grabbing for the use of land by private companies has generated abuses and a real 'land war', considering that the SEZ Act stipulated that only 35 per cent (later increased to 50 per cent) of the area acquired for SEZs was to be used for productive purposes. This left developers free to use the remainder to build high-end housing and related 'social infrastructure', such as shopping complexes, public schools and golf courses, for what would essentially be privately developed cities on agricultural land in the peri-urban periphery (Levien, 2012). It is clear that decisions regarding land allocation and use encompass a number of different issues that may go beyond considerations of economic growth (Bhagwati and Panagriya (2013); Patnaik (2008)), but in the case of the Campania SEZ, this problem did not arise, as it did in the case of India or other states, as the SEZ areas were already located in production areas, transport or industrial hubs. The study by Yani et al. (2021) also showed that in Shenzhen SEZ, the location and land use planning of redevelopment was determined directly by the government, and urban sites with high land rental gaps and low transaction costs were more likely to be redeveloped sooner. Di et al. (2023) proposed a new planning support system to predict Land Use and Land Cover change (LULC) at local and system levels for the case of SEZs in China, using a new machine-learning-based, multi-source spatial data modelling framework for sustainable planning. For Shenzhen, the strong pioneering effect of the SEZ on urban land growth lasted until the 1990 s and urban land areas in both Guangzhou and Shenzhen have experienced magnificent annual growth rates at 8.1% and 11%, respectively between 1975 and 2015, Liting et al. (2020), and land values also increased significantly. These aspects of planning affect Campania to some extent, considering also that derogations to environmental and landscape authorisations are applied, in turn potentially having direct repercussions on the territories. However, to date, no elements to measure or quantify them are available, as they are in their implementation phase.

7. Conclusions and future steps

Improving the economic efficiency of SEZs influences local land use planning in terms of land-saving and land use sustainability (Meng et al., 2020). At the Italian level, the scientific debate has paid very little attention to the implementation of SEZs, despite their potential importance in terms of economic development, particularly for the southern and island regions of Italy. However, the assessment of the economic effects of SEZs can be difficult. Indeed, SEZs need to be implemented and managed properly to ensure their economic success and proper land use. Assessments of the direct and indirect economic impacts of SEZs are crucial to support local policymakers in defining strategies to stimulate the efficiency and competitiveness of the involved territories. On the other hand, (SEZs) are conceived as land use and 'zones of advantage' for the establishment of new companies to attract investment, economic growth and job creation and direct policymakers to the best of land use. Nevertheless, in the Campania Region, which is one of the main Southern Italy regions, a special role should be assigned to SEZs as policy tools aimed at ensuring the competitiveness of firms in the global context, according to the specificity of local production systems. However, it is impossible to plan infrastructural investments for economic development purposes without a detailed transport accessibility analysis, being transport accessibility, both active and passive, a key factor in spatial planning and decision-making. In terms of land use policy, this assumption should have critical consequences in the Southern Italy regions because of the transport infrastructure gap compared to the Northern Italy regions.

The accessibility analysis has been conducted both at a national level and at the first/last-leg level (i.e. to/from relevant nodes of the multimodal network). For the national level analysis, the zoning of local labour systems of the ISTAT has been considered and a detailed modelling framework for both supply (multi-modal national network) and demand (generation-distribution models estimated on observed flows on each od pair at a national level for 8 macro-commodity classes). The results of the model estimation allow us to derive the marginal rate of substitution among transport costs (in €/tons) and freight volumes (in million tons) for each commodity class, allowing us to derive several policy implications for policymakers in the short and long-term horizon. The accessibility analysis has been performed with both the average monetary transport cost to reach/depart from each destination/origin of the national study area, weighting the latter with observed attracting/generating freight volumes, and with the more robust logsum accessibility measure. The accessibility results allow us to compare the Campania SEZ area with both the local labour systems including SEZ areas in other regions and the other Italian local labour systems. These results testify how, according to the logsum, the SEZ areas within the Campania region are more accessible, on average, with reference to both the other SEZ areas (especially the other SEZ areas in Southern Italy and the islands) and the other local labour systems in Italy for all the macro-commodity classes. Despite the positive average trend, the dispersion of the accessibility values in Figs. 5–6 shows that some SEZ areas in Campania are slightly less accessible than other Italian zones. This is also confirmed by the transport accessibility analysis performed with average monetary transport costs, where the SLL within the Campania region have average accessibility (i.e. average transport costs) that is greater (namely lower transport cost) than the Italian average value for some commodity-class, while lower (namely greater transport cost) for others. However, the SEZ implementation provides fiscal and economic advantages, that may fill the gap in transport accessibility.

The first/last-leg accessibility analysis provides a more detailed picture of the accessibility to/from relevant nodes - i.e. ports, interports, airports, tollgates and freight stations – from/to SEZ areas in the Campania region. The analysis has considered regional road and rail networks, as well as ports, interports and the Capodichino Airport (Naples), both in the current scenario and in a medium/long-term (10/20-years) one and has computed the accessibility in terms of equivalent travel time in the peak hour of the afternoon (5:00–6:00 PM). The analyses on future scenarios have been carried out by considering the 'Programme of the interventions on road and rail infrastructures in the Campania Region' (Campania Region, 2018). The accessibility analysis shows that, in the current scenario, there are a few critical issues concerning the passive accessibility of SEZs of the north of Naples with respect to the ports (namely the port of Naples alone), as well as the active accessibility of the Bagnoli Coroglio SEZ with respect to the ports (namely the port of Naples alone). Such criticalities could potentially be solved by resorting to additional channelling lanes.

This paper has conducted a quantitative analysis of the accessibility characterizing SEZs established in the Campania Region. The results of this study represent an important starting point to support: 1) regional public decision-makers in the planning of land use for the improvement of existing infrastructures and in planning the possible implementation of new ones; 2) national public decision-makers in the possible establishment of other SEZs in the country; 3) investors who have robust information on the access time to the planned SEZs.

With regard to the first point, the analysis of the accessibility of the first/last stage provides a picture of the current criticalities, both in absolute terms and in terms of the comparison between the values of active accessibility (ease of moving away from an SEZ area) and passive accessibility (ease of reaching an SEZ area). In particular, the criticalities are those noted in Tables 8–9 and Figs. 9–12. In this sense, these criticalities may highlight the need to fill certain infrastructural gaps in certain areas, and/or to update existing ones, which policymakers may take into account when planning future regional infrastructures.

Concerning the second point, the modelling framework adopted in this paper may be transferred to other regions, to push further the policymakers to take into account the first/last leg transport accessibility when locating SEZ in other geographical areas, considering this methodology as valid and supportive for future infrastructure planning. Finally, regarding the third point, the paper provides a detailed assessment, both at the national and local level, of the most accessible SEZ areas, in order to help possible foreign investors, choose whether or not to locate their company within an existing SEZ area, and which area in particular.

In addition, the paper discussed some potential economic implications, such as possible discounts/incentives at toll booths for companies providing transport services to/from SEZ areas, or incentives for fleet renewal for companies moving goods without third-party services. Finally, Section 6 discussed some experiences of SEZ land use worldwide, to highlight what impacts can be expected from their implementation and what are the potential elements of uncertainty.

While the transport accessibility analysis carried out by Zeng (2015) brings economic and political considerations that can be considered common lessons, the findings of this study are strictly circumscribed to the local reality, being the infrastructural configuration, the traffic data and the programming taken into consideration, not easily transferrable in terms of results. However, from a land use planning point of view, the methodology can be certainly transferred to other case studies. Since the case of the Campania SEZ is the first pilot case at the national level and since there are no other studies that specifically deal with the analysis of transport accessibility to and from a SEZ, it is not possible to compare the results with other studies at the time.

Future research steps will focus on the analysis of externalities from the environmental standpoint and the drafting of guidelines for green design and accessibility (green ports, use of liquefied natural gas, incentives for intermodality). More detailed models can be considered to refine the analysis, e.g. by incorporating data on the movement of goods to/from abroad, as well as input-output models. Evaluation of the actual impact of SEZ implementation on land use, such as the planning of new infrastructure (in addition to that already planned by the region) and/or other SEZ establishments. In addition, it is possible to quantify the difference in impact that SEZs will have compared to Simplified Logistic Zones (SLZs) in Italy.

Moreover, the centrality role of SEZs may be evaluated with the aid of centrality measures, as made in previous studies for ports (Wang and Cullinane, 2016; Tocchi et al., 2022), airports (Wang et al., 2011; Rodríguez-Déniz et al., 2013) and interregional road networks (Tsiotas and Polyzos, 2015).

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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