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Addressing the Passenger Transport and Accessibility Enablers for Sustainable Development

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Abstract: Sustainable Development (SD) is a fundamental objective in the European Union (EU) and transport is considered one of the key challenges necessary to achieve it. Although transport is mostly contested from the environmental dimension, an investigation of peer-reviewed literature along with EU policy documents suggests that the transport and accessibility (T&A) criteria of infrastructure, accessibility distance, and multimodality can positively contribute to SD. However, despite this synergetic relation between T&A and SD, a practical analysis of such enablers is unknown at the regional European level. Therefore, this study investigates the Mediterranean as a study area by analyzing 79 identified passenger ports as passenger transport land-sea interaction points. Based on open access data, port infrastructure and ship accessibility, hinterland accessibility, and multimodality are evaluated as the passenger T&A enablers for SD. Comparative geo-spatial analyses are also carried out among the passenger ports' levels of enablers by using the data normalization method. These data driven comprehensive analytical results can bring added value to SD policy and planning initiatives in the Mediterranean. This study may also contribute to the development of relevant passenger port performance indicators for boosting port or regional competition and attractiveness towards SD.

Keywords: maritime transport; land-sea interaction; passenger ports; port infrastructure; accessibility; multimodality; port performance indicators; maritime spatial planning

1. Introduction

The opportunity for access and a fluidity of movement to and from an area are intrinsic to sustainable growth and mobility has a significant effect on a region's competitiveness and prosperity [1,2]. Accessibility is also a key factor in regional and rural development policy [3–7]. Transport accessibility is one of the decisive disparities between urban and rural communities [8,9] and its insufficiency or unavailability may lead to the social exclusion of a part of the population [10–13]. Insufficient transport and accessibility (T&A) options are claimed to have a depopulating effect in peripheral areas [14], which may result in a subsequent littorization. This urbanization process, due to demographic concentration in the coastal areas where cities play an important role [15,16], is considered a serious challenge to achieving sustainable development (SD) [17].

SD is a fundamental objective in the European Union (EU) and is recognized as a horizontal responsibility to be considered in all activities [18]. At a global scale, the United Nations (UN) also continually promotes SD initiatives through its different bodies [19]. Although often narrowed down to environmental concern [20,21], the SD concept is usually based on three pillars consisting of ecological,

social, and economical dimensions [19,22,23]. However, their importance may differ according to the contemporary economic and political climate of the region or authority [24,25].

The EU strategy on SD considers transport as one of the key challenges to achieving sustainability [26]. Furthermore, transport is considered to be one of the key sectors in the Green Economy (GE) transition and GE was embraced at the 2012 Rio+20 Summit and recognized as an important tool to achieving SD [14]. Mobility is a necessary pre-condition of social capital [27] and transport is a necessary activity that results in a significant rise in the productivity of the total capital base of an economy while increasing the welfare perception [20]. For the period between 1970 and 1990, Short [28] demonstrated that the economic growth for the European member countries of the Organization for Economic Co-operation and Development (OECD) in terms of Gross Domestic Product (GDP) was proportional to the rise of their passenger transport.

European integration leads to increased cross-border passenger transport and results in transport sector growth, however, this was claimed to conflict with SD because it consumes natural assets and positions itself at the crossroads of economic and environmental interests [20]. Nevertheless, claims have been made about possible countervailing measures, such as the multimodal transport system aimed at optimizing the performance of the transport system as a whole, technological advances and inter alia, and an increasing awareness of the effective strategies necessary to cope with the negative externalities of transport [20]. The European Commission (EC) 1992 Green Paper is one such initiative and it lays out a framework for a common strategy of sustainable mobility, aiming to contain the environmental impacts of transport while allowing it to fulfill its economic and social functions, which later results in a policy strategy for common transport in the EU [20,29].

Transport concerns are increasingly understood in the context of SD [20,28,30–34]. Based on the analysis carried out by Oberg et al. [21], T&A as an enabler of SD is well recognized in EU policy and legislative documents [31,35–38]. A rapid review of the passenger T&A criteria presented in the peer-reviewed literature along with EU legal and policy documents (see Table 1) suggests that infrastructure, hinterland accessibility distance, public transport and multimodality can positively contribute to the SD.

Table 1. Passenger transport and accessibility (T&A) criteria claimed to be the enablers of Sustainable Development (SD).

T&A Criteria	Reference
Infrastructure	Stastna and Vaishar [14], Oberg et al. [21], TEN-T Guidelines [36], Corridor Study ScanMed [37]
Distance to Urban Centers and Transport Nodes	Stastna and Vaishar [14], Oberg et al. [21]
Public Transport	Stastna and Vaishar [14], Oberg et al. [21], EU Transport White Paper [35], TEN-T Guidelines [36], Work plan ScanMed [38]
Multimodality	Stastna and Vaishar [14], Oberg et al. [21], EU Transport White Paper [35], TEN-T Guidelines [36], Corridor Study ScanMed [37]

While transport infrastructure is claimed to enable the ecological dimension of SD through capacity optimization [20], hinterland accessibility to other transport nodes contributes to its ecological and social dimensions [21]. Furthermore, multimodality fulfills the ecological and economic dimensions of the SD and also enables its social dimension when coupled with the accessibility of public transport [21]. Stupalo et al. [39] carried out a study on such passenger T&A enablers, limited to sustainability for the Croatian islands. With the development of the Trans-European Transport Network (TEN–T), the EU established its guidelines on sustainable transport synergies with SD by contributing to its socio-economic and territorial cohesion objectives [21,36]. Although the guidelines also encompass transportation infrastructure and passenger multimodality, this study identified a knowledge gap concerning practical analyses on T&A enabling factors for SD at the regional European scale. Therefore, the Mediterranean region is investigated as a study area to analyze the level of T&A enablers by

considering the trans-boundary relevance and land-sea interaction of passenger transport. Passenger ports are identified in order to carry out a quali-quantitative analysis (QQA) on their infrastructure, hinterland accessibility, and multimodality as enablers of SD. A comparative geo-spatial analysis is also carried out on the consolidated level of these enabling factors and on the level of insular regional accessibility based on the locations of the identified maritime passenger transport nodes. Taking advantage of the analysis carried out on the passenger ports, this study additionally explores the relevance of integrating T&A enablers with port performance indicators within the context of SD.

This paper is organized by framing the research within the concept definitions of accessibility and the relevance of passenger T&A to insular regions and to tourism. The data acquisition of the T&A enablers and the study results are supported by this theoretical framework, which is applied to the study area. The results presented in this study are discussed to explain the data gaps and data synergies, and are also validated by published analytical studies. Finally, we conclude the paper with future study recommendations and highlight the relevance of integrating this study's results with planning processes that aim to achieve SD.

2. Framing the Research

2.1. Accessibility Concept Definition

The concept of accessibility is of critical importance within the disciplines of transport geography, spatial planning, and topography or network analysis [40]. Despite this, a clear and unambiguous definition of accessibility does not exist [41]. Accessibility is related to the distance between destinations [40,42]. Accessibility can also be defined in terms of consumption possibilities [43]. However, there are two main types of accessibility: (i) positional; and (ii) personal [44]. While temporal accessibility falls on to positional accessibility, this may also be translated into economic accessibility, in the sense that the time spent travelling may not be considered productive in working hours [45]. A straightforward description of accessibility is related to connectivity [46]. A location is assumed to be accessible if it is connected to other locations via a link to a road or railroad network [47], or to an airport or harbor [40]. While connectivity has been considered an attribute of a network that indicates it is possible to reach all nodes from all other nodes [48], it can also be defined as the access to regular and frequent transport services and the level of competition in the service supply [49]. Limited options due to a lack of competition and therefore industry consolidation can have an impact on mobility, resulting in passengers enduring higher prices and poorer quality, which in turn lowers accessibility [40]. In the case of maritime transport, a reduction in the number of companies and ship calls while the transport cost per passenger is raised has an impact upon the quantitative and qualitative features, and even innovation, offered [50].

2.2. Passenger T&A and Insular Regional Relevance

Within the geographical context of insularity, transport plays a key role in terms of territorial cohesion and economic development [51]. A destination's remoteness only seeks to amplify its dependence on transport connections, and transport services are critical for the sustainability of the local population in the insular regions [39,52]. The complications of these insular regions undermine accessibility to the mainland [40]. The barrier formed by the sea prevents the use of private vehicles, except via Ro-Ro ferries, and inter-island transport is limited to ships and airplanes [45]. However, as air transport is much faster but more expensive and more environmentally impacting [53], efficient maritime transport is a requirement for the socio-economic development of the insular regions [45]. Nevertheless, maritime transport is also a mode for achieving socio-economic integration, both between the islands and the mainland [45]. As suggested by the European Commission's (EC) White Paper [54], the development of the Motorways of the Seas (MoS) is highly supported by EU policies in order to promote an integral and efficient intermodal transport system that exploits the European sea basins [55]. The MoS concept also became one of the priority projects for the TEN–T Program [56], which aims

to improve accessibility and connectivity for all of the EU regions as well as takes into account the specific case of islands, sparsely populated, and peripheral regions. However, despite sea passenger transport by ferry being a worldwide phenomenon that involves also vehicles and goods, relevant information is less official in nature [57].

2.3. Passenger T&A and Tourism Relevance

While isolation can prohibit the movement of local people from out of an area, it can also curb the arrival of visitors, and thus have an impact upon the potential development of a tourism market and source of local income [1,58–62]. Similar to transport, tourism is also one of the key sectors considered essential for the transition to a GE [14] (see Section 1). Moreover, effective transport systems are fundamental to destination development and are also considered a key factor in the success of sustainable tourism development [63–65]. The EU funded CO–EVOLVE Project considers T&A to be one of the enabling factors for the co-evolution of human activities and a natural system to develop sustainable coastal and maritime tourism in the Mediterranean. Therefore, the passenger T&A, by its own virtue and by supporting tourism as well, contributes to the SD.

3. Materials and Methods

3.1. The Mediterranean as a Study Area

The Mediterranean represents one of the European sea-basin regions and is shared with the African and the Asian riparian states as well. The Mediterranean countries demonstrated their commitment to SD by adopting the Mediterranean Strategy for Sustainable Development (MSSD), along with the EU as the Contracting Parties to the Barcelona Convention [19]. The Mediterranean is the world's second largest cruise tourism region, with its ports accounting for 16% of global cruise ship deployment [66] and the most cruise passenger visits within Europe [67]. This region also comes with the highest share of European ferry passengers [66], accounting for 20.7% of the global share [57]. While 19% of the Greek territory consists of 3500 minor and major islands [40], Croatia has 718 islands [68], 50 of which are permanently inhabited year-round [39]. Therefore, characteristics such as geo-political status, regional insularity, cruise tourism popularity, and intensive maritime passenger makes the Mediterranean basin an ideal area for experimentation. Further considering these characteristics, the relevance of trans-boundary transport was taken into consideration by addressing the land-sea interaction in order to examine the infrastructure, hinterland accessibility, and multimodality as the T&A enablers of SD.

3.2. Identifying the Passenger Ports

Ports were regarded as the land-sea interface points [67] between the maritime and terrestrial passenger transports. Therefore, in order to analyze the T&A enablers, this study further identified the Mediterranean passenger ports by categorizing them into cruise and ferry ports (Figure 1). The cruise ports were identified from the member list of the Association for the Mediterranean Cruise Ports (MedCruise), representing over 80% of the cruise tourism activities per country [69]. The identified cruise ports were mapped by selecting the corresponding geo-referenced ports from the map layer developed by the European Marine Observation and Data Network (EMODnet). The UN Code for Trade and Transport Locations (LOCODE) [70] was identified for each of the cruise ports as the common criteria to carry out the selection. The identified cruise ports not listed by the EMODnet were added to the geo-database by using the editing function of the ArcMap (Version 10.1) geographic information system software under license. The ferry ports were identified from the open access industry initiative data provided by the Ferrylines and were mapped in a similar way as the cruise ports.

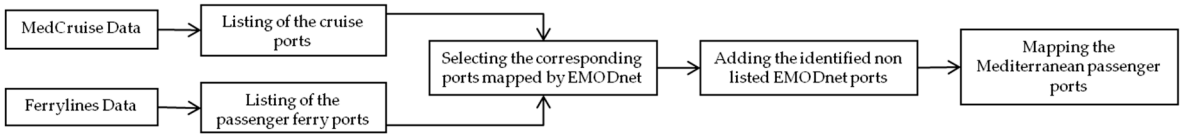

Figure 1. Schematic presentation of identifying and mapping the Mediterranean passenger ports.

3.3. Database Creation for Analyzing T&A Enablers

Based on the available data from the identified cruise ports, a database (see Tables A1–A3) of the passenger T&A enabling factors was created for a Mediterranean scale analysis. Ferry ports were excluded due to the unavailability of relevant information. However, cruise ports serving as ferry passenger ports were identified in order to maximize the scope of the analysis. Each of the enabling factors were analyzed based on a selected criteria supported by relevant data (see Table 2). Port infrastructure and hinterland accessibility data were collected from the recent statistical reports published by MedCruise [66,69], which are a compilation of data provided by individual member port authorities and their cruise terminal operators. Other supplementary sources included data from the European Sea Ports Organization (ESPO) and the Global Ports Holding, which claim to be the world's largest cruise terminal operator and are an established presence in the Mediterranean. Additionally, open access data sources (e.g., the Google Maps and Trip Advisor) were consulted in order to identify multimodal transports and bridge hinterland accessibility data gaps by measuring the distance between transport nodes.

Table 2. Analysis criteria for the T&A enabling factors.

T&A Enablers for the SD	Selected Criteria for Analysis	Source of Information
Port infrastructure (see Table A1)	Ship accessibility: 1. Maximum Allowable Ship Length 2. Maximum Allowable Ship Draught (i.e., the under water part of a ship) 3. Number of Berths	1. Pallis et al. [66] 2. Pallis et al. [69] 3. ESPO 4. Global Ports Holding
Hinterland accessibility (see Table A2)	1. Distance to the nearest city center 2. Distance to nearest intercity or international transport nodes (includes airports, bus terminals, and train stations)	1. Pallis et al. [66] 2. Pallis et al. [69] 3. ESPO 4. Global Ports Holding 5. Google Maps
Mutimodality (see Table A3)	1. Shuttle service 2. Taxi service 3. Car rentals 4. Car parking for private vehicles 5. Public Transport (includes bus, tram, metro, train, and water bus)	1. Google Maps 2. Trip Advisor

3.4. Normalizing the Database for Geo-Spatial Analysis

The level of the individual T&A enabling factors among the identified ports was geo-spatially analyzed. Additionally, a Mediterranean scale comparative analysis was carried out in order to examine the cumulative level of passenger T&A enablers for SD. This analysis was intended to identify the contrast among the individual ports, countries and within the different geographical contexts of the Mediterranean, such as (i) the insular regions; (ii) the Adriatic, East, and West Mediterranean basins, and (iii) the Northern, Southern, and Eastern Mediterranean shores.

The geo-spatial analyses were carried out by restructuring the database into common numeric proxy values by using the data normalization method. Therefore, the different data criteria for each enabling factor corresponding to each port were normalized into a normalized proxy value. The proxy values for each port were added together in order to analyze the level of their individual enablers.

Furthermore, the total individual enabling factor proxy values for each port were summed up together in order to analyze the cumulative level of the enablers.

Enabling factor datasets on port infrastructure (see Table A1), hinterland accessibility (see Table A2), and passenger multimodality (see Table A3) were represented sequentially as "α", "β", and "γ". Corresponding to each port, the numeric value in a cell of "α" and "β" was represented by "n". For the multimodality database "γ", only the affirmative values "Y" (see Table A2) in a cell were replaced with "1". By representing the minimum and maximum values in the same data column of "n" as "V_{min}" and "V_{max}", the data for each cell (n) of "α" and "β" was normalized by using the following formula:

$$N_C = (n - V_{min})/(V_{max} - V_{min}) \quad (1)$$

and for "γ", N_C = 1 or 0. where *Nc* is the normalized individual data cell for a port. Representing the data columns of each T&A enabling factor dataset as "C_1, C_2, ..., C_L"; the normalized individual data cells in the same row corresponding to a port (N_C) were added together by using the following formula:

$$N_p = \sum N_C = N_C C_1 + N_C C_2 + \ldots . + N_C C_L \quad (2)$$

where *Np* is the total normalized value for a port which adds together all the normalized individual cell values (*Nc*) under each criteria (see Table 2) data column corresponding to an individual enabler. Equation (2) was replicated for each enabling factor category to calculate the total normalized value of each port resulting in "$N_{p\alpha}$" for "α", "$N_{p\beta}$" for "β", and "$N_{p\gamma}$" for "γ". As accessibility is inversely proportional to the distance [40], the "$N_{p\beta}$" was considered as a negative value. Therefore, the consolidated normalized value involving all the passenger T&A enabling factors for each port was calculated by using the following formula:

$$N_{con} = N_{p\alpha} + (-N_{p\beta}) + N_{p\gamma} \quad (3)$$

where N_{con} is the consolidated normalized value for each port. The normalization process is illustrated for the passenger port of Venice (see Table 3), which serves both the cruise and ferry traffic (see Section 4). The normalized values for each cell were calculated using the Equation (1), except for the "γ" as explained before. Using the Equation (2), the total normalized values for Venice associated to datasets "α", "β", and "γ" were calculated as the sum of each normalized value (i.e., $N_{p\alpha}$ = 0.435 + 0.313 + 0.185 = 0.933; $N_{p\beta}$ = 0.002 + 0.091 + 0.024 + 0.030 = 0.147; and $N_{p\gamma}$ = 1 + 1 + 0 + 1 + 1 + 1 + 1 + 1 + 1 = 8.0). Similar values calculated for the other ports were used to carry out the geo-spatial analysis on their level of individual enabling factors. The cumulative T&A enabling factor value for Venice was calculated as 8.786 (i.e., 0.933 + (−0.147) + 8) by using the Equation (3). Such values derived for all other ports were used to carry out the geo-spatial analysis on their cumulative level of passenger T&A enabling factors.

Table 3. Passenger port of Venice as an example to illustrate the data normalization process.

Port Infrastructure ("α")	**Max_Length**				**Max_Draught**			**Number of Berths**	
Original data	340 m				9.1 m			6	
Normalized value	0.435				0.313			0.185	
Hinterland Accessibility ("β")	**City Center**		**Airport**		**Bus Terminal**			**Train Station**	
Original data	0.5 km		14 km		0.3 km			1 km	
Normalized value	0.002		0.091		0.024			0.030	
Multimodality ("γ")	**Bus**	**Tram**	**Metro**	**Train**	**Water Bus**	**Shuttle**	**Taxi**	**Car Rentals**	**Car Parking**
Original data	Y	Y	N	Y	Y	Y	Y	Y	Y
Reference value	1	1	0	1	1	1	1	1	1

4. Results

4.1. Enabling Factor: Port Infrastructure

This study identified a total of 79 cruise ports in the Mediterranean with 58 of them also serving as passenger ferry ports. The port infrastructure analysis on ship accessibility reports that 40 ports, representing a little more than half (50.63%) of the identified cruise ports, are able to host passenger ships with overall lengths exceeding 350 m (Figure 2). Whereas a total of 37 ports, representing 46.84% of the identified cruise ports, are capable of handling passenger ships with more than 10 m draughts. Concerning berthing capacities, the majority of the cruise ports (28) provide 3–5 dedicated berthing places for passenger ships. While 15 ports offer less than 3 berths, 2 ports provide only anchorage (i.e., no berthing arrangements) and passengers are transported by a ship tender service. However, 4 of the identified cruise ports offering more than 10 berths include also the cargo piers, which are occasionally used by passenger ships.

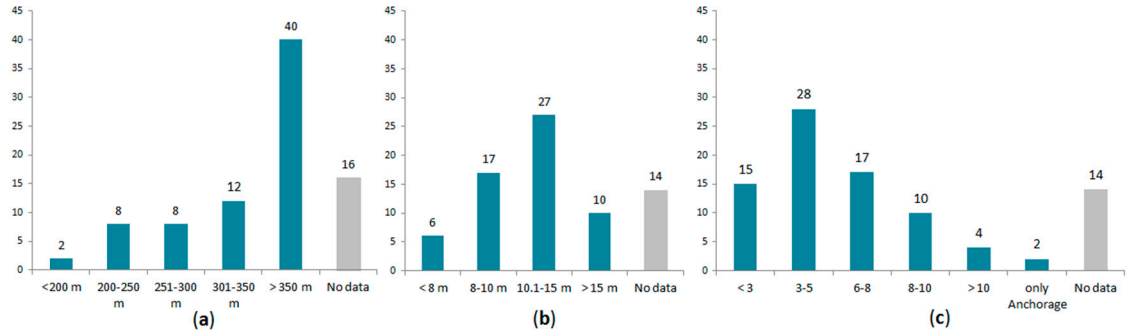

Figure 2. Number of passenger ports with (**a**) maximum allowable ship lengths; (**b**) maximum allowable ship draughts; (**c**) available number of berthings.

The geo-spatial analysis on the port infrastructure shows that 12 ports offer a "very high level" of ship accessibility (Figure 3). The insular regions of Sicily, Crete, Corfu, and the island state of Cyprus each host at least one of these ports that are determined to be a "very high level". Except for a French port, the mainland ports analyzed do not record any "very low level" on the enabler category. Concerning the nine identified insular ports with a "very low level" of ship accessibility infrastructure, the Balearic Islands host three of them, among which two are also ferry ports. The rest of these ports are distributed among Corsica and Cyprus with two ports each, Sicily, and one of the Croatian islands, which all serve ferry traffic except for the Cypriot ports. The geo-spatial analysis also presents the West Mediterranean basin ports as leaders on the level of ship accessibility, followed by the Adriatic Sea basin ports. While comparatively the East Mediterranean records the lowest number of cruise passenger ports, with four ports registering a "very high level" of ship accessibility, they are, however, higher than the two similar ports found in the Adriatic Sea basin.

4.2. Enabling Factor: Hinterland Accessibility

The hiniterland accessibility analysis from the passenger ports reports that more than half of the identified cruise ports (48) are located within a half kilometer distance from the nearest urban center (Figure 4). While a total of 39 ports are located within a kilometer distance from the nearest intercity bus terminal, a total of 34 ports record the same distance for the intercity train stations. However, the analysis reports that a total of 23 ports do not have passenger accessibility to any train station. Additionally, while a total of 21 cruise ports provide access to the nearest airport in less than a 10 km distance, only 3 ports are more than 100 km away from their nearest airports.

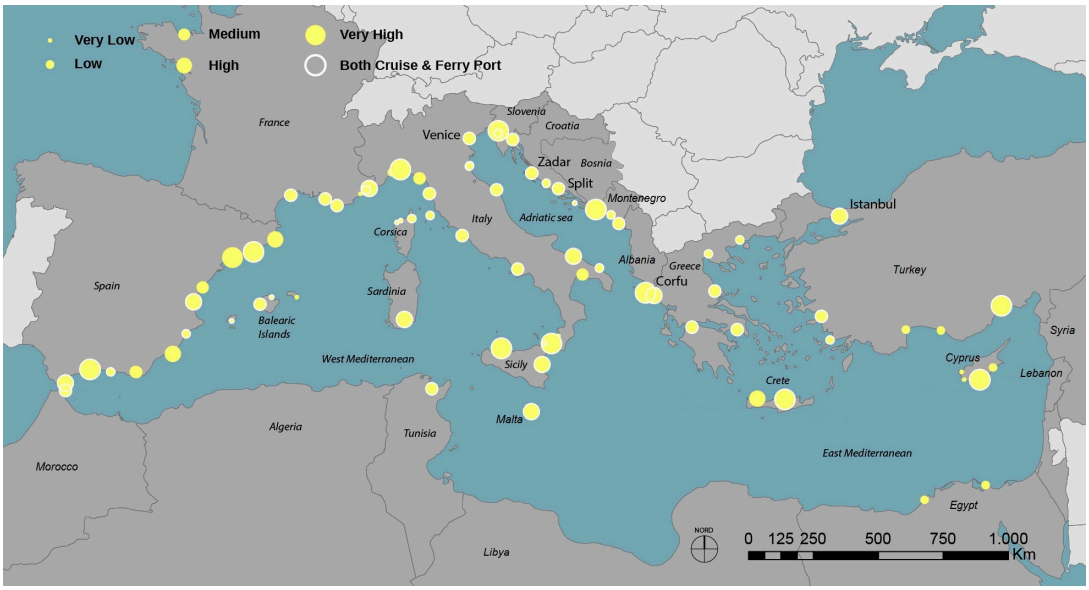

Figure 3. Geo-spatial analysis on the identified passenger ports' level of ship accessibility infrastructure.

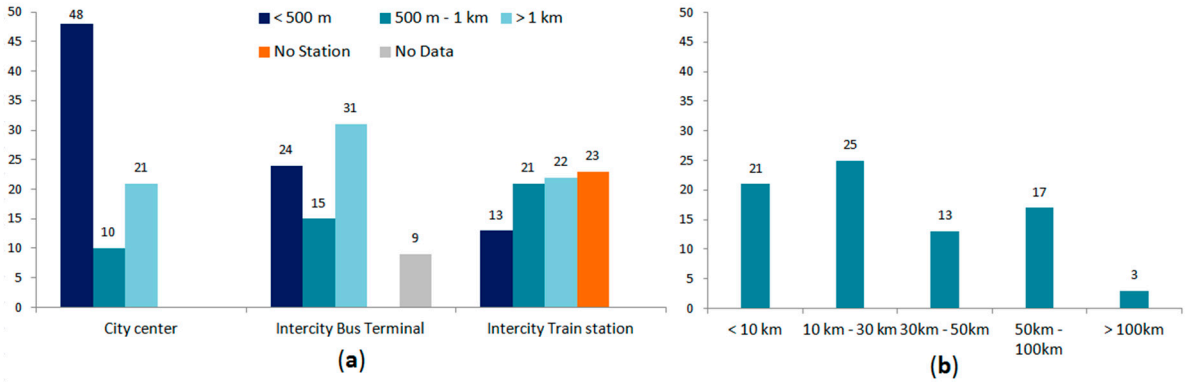

Figure 4. Number of passenger ports with their hinterland accessibility distance to (**a**) nearest urban centers, intercity bus terminals, and train stations; (**b**) nearest airports.

The geo-spatial analysis on the level of hinterland accessibility distances registers a "very high level" for most (46 ports) of the analyzed Mediterranean passenger ports (Figure 5). The insular regional ports from the Balearic Islands, Corsica, Sardinia, Sicily, Crete, Corfu and the island states of Malta, and Cyprus all represent their passenger ports with a "high level" to "very high level." However, only a total of three ports—one from Spain and two from Italy—record a "very low level" on the level of hinterland accessibility distance. The North African ports from Tunisia, Egypt, and Spanish territory of Ceuta register from "medium level" to "very high level."

4.3. Enabling Factor: Multimodality

This study reports that all of the 79 analyzed ports provide access to taxi service and private car parking space (Figure 6). While 75 ports are confirmed to provide car rental service, this provision cannot be confirmed for a total of 4 ports due to data unavailability. While passenger shuttle service is provided by 48 cruise ports, a total of 18 ports do not offer such service. Bus travel is identified as the most available mode of public transport provided with a total of 62 ports. Concerning metro service, a total of 10 ports offer this transport mode while the rest do not. High data unavailability is observed for the tram, train, and water bus as modes of public transport. However, the port of Venice is identified as the only port with a confirmed water bus service.

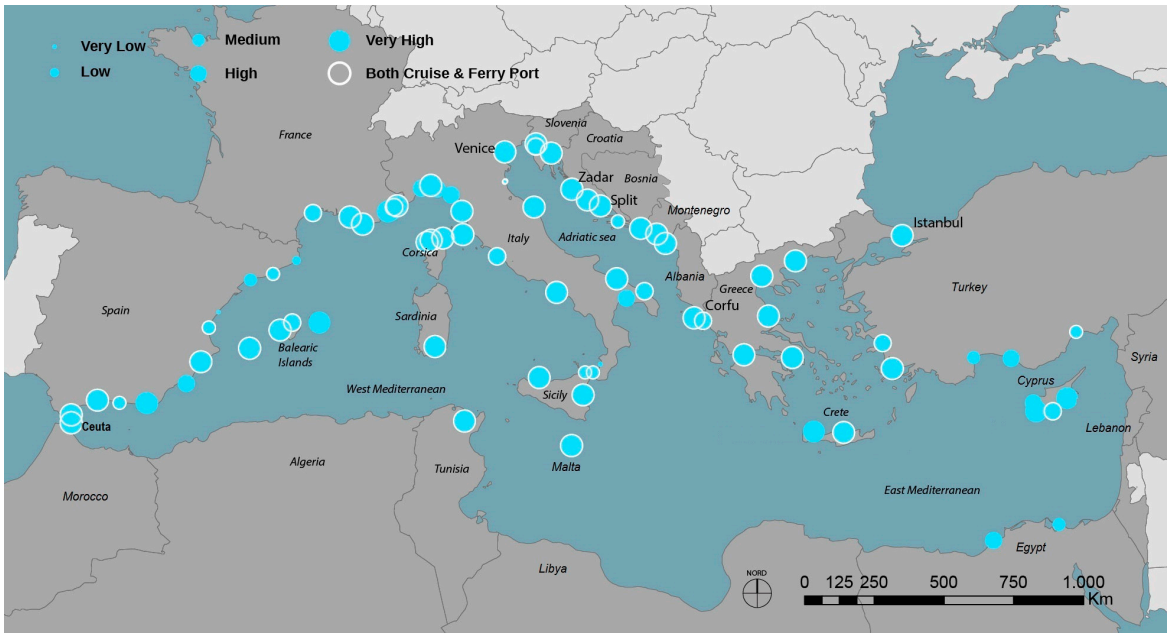

Figure 5. Geo-spatial analysis on the identified passenger ports' level of hinterland accessibility distance.

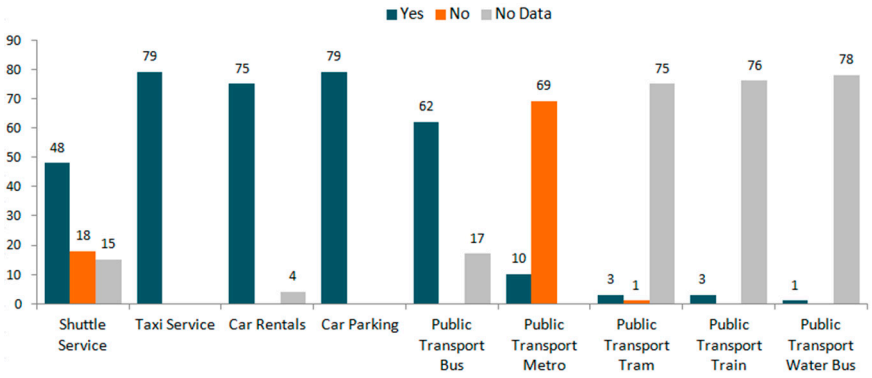

Figure 6. Number of passenger ports with available multimodal transport options.

The geo-spatial analysis on the level of passenger multimodality records Venice as the only port that provides a "very high level" (Figure 7). Among the insular cruise passenger ports, only one port from the Balearic Islands provides a "high level." The port of Corfu registers a "medium level" and is the only such port among the Greek insular regions. Additionally, a total of six ports from the mainlands of Spain, France, Italy, Turkey, and Egypt are found to provide a "high level." Sea-basin wise, five ports from the West Mediterranean record a "high level." Such a level is registered only for two ports in the East Mediterranean (Istanbul and Alexandria) while the Adriatic sea basin has zero. Seven Adriatic ports record a "very low level" and eight ports from the Italian, Greek, and French insular regions of Sicily, Crete, and Corsica also register the same level.

4.4. Cumulative Level of the Enabling Factors

A Mediterranean basin-wide comparison shows that the West Mediterranean ports lead the analysis, with 12 ports providing a "high level" of consolidated passenger T&A enablers (Figure 8). However, the Adriatic port of Venice, along with the East Mediterranean port of Istanbul, stand out as the only ports with a "very high level" of consolidated T&A enablers. Countries from the Northern Mediterranean shores are mostly host passenger ports. This is followed by countries from the Southern shores while Eastern shore countries (i.e., Syria, Lebanon, and Israel) record the lowest share. Along

the Southern Mediterranean shore, only one Egyptian port records a "high level" of consolidated passenger T&A enablers. The insular passenger ports of Limassol, Larnaca, Corfu, and Heraklion from the Eastern Mediterranean Sea basin register a "high level" of consolidated T&A enablers. Whereas among the insular passenger ports from the Western Mediterranean Sea basin, only two ports from the Balearic Islands and Sardinia register a "high level."

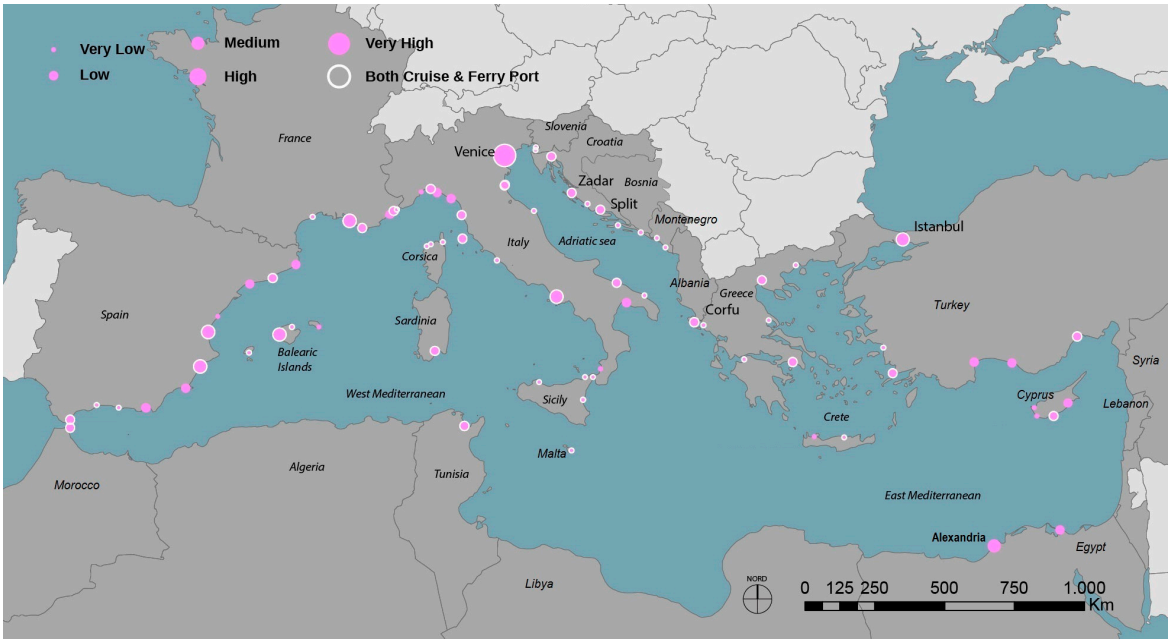

Figure 7. Geo-spatial analysis on the identified passenger ports' level of passenger multimodality.

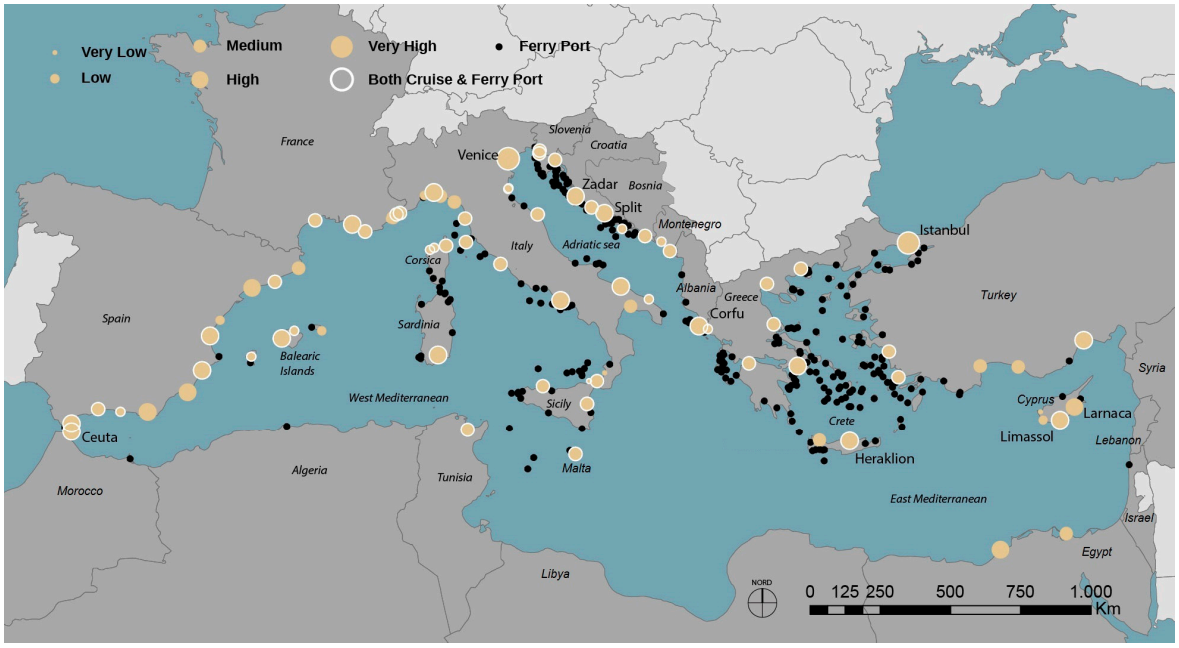

Figure 8. Identified Mediterranean passenger ports and the cumulative level of T&A enablers.

This study additionally identifies 362 ferry passenger ports in the Mediterranean. The locations of the ferry ports show that Greece and Croatia are the two leading Mediterranean countries with the

most insular region maritime transport nodes under their jurisdiction. This is followed by the insular regions for Italy, France, and Spain.

5. Discussion

The results of the geo-spatial analysis carried out on the individual enablers suggests that the level of passenger multimodality is comparatively lower among the analyzed ports in relation to other enablers, such as ship accessibility infrastructure and hinterland distances.

The study findings on the maximum allowable lengths, draughts, and multiple berthing places suggests that most of the analyzed Mediterranean ports are capable of handling multiple sized passenger ships simultaneously. The majority of the cruise ships have an average maximum passenger capacity of 1000–3000 persons and some larger ships may carry up to more than 4000 passengers onboard [71]. Therefore, considering the volume of passengers carried onboard a single cruise ship, this study's findings on satisfactory levels of ship accessibility infrastructure may be also translated into the availability of a sufficient passenger handling infrastructure for the analyzed ports.

The results of the hinterland accessibility distance from the cruise passenger ports also reports impressive results, as the nearest urban centers, intercity bus, and train stations are in many cases only a walking distance away. This could also be one of the reasons why relatively less passenger multimodality (i.e., shuttle service or public transport) was recorded for some ports located in close proximity to urban centers. Taking into account the distance between destinations as a measure of accessibility [40,42], this close proximity largely improves the positional, temporal, and economic accessibility (see Section 2.1) of the passenger ports and their hinterlands. Additionally, a location's accessibility can also be measured by the level of its connectivity [46] via a transport node that connects other locations in a transport network (see Section 2.1). Therefore, this study's findings on the distance to identified transport nodes (i.e., the intercity bus and train stations, and the nearest airports) also reports an overall satisfactory level of hinterland accessibility from Mediterranean passenger ports. Concerning the connectivity between the mainland and insular regions, the locations of the identified ferry ports also suggest good accessibility by sea for the Mediterranean insular regions. Again, connectivity can also be measured by access to transport services and their level of service supply competition [49]. The results of passenger multimodality suggest the Mediterranean passenger ports provide access to a variety of transport services, ranging from car rentals, taxi and shuttle service to different public transport modes. Moreover, the number of ports with a higher availability of taxi and shuttle service, car rentals, public transport and buses suggest a desired level of competition in service supply among these modes. This in turn indicates a satisfactory level of connectivity and therefore good hinterland accessibility in the sense that, the longer distance hinterland destinations (e.g., the urban center) can be reached from the passenger ports by accessing the available multimodal transport options.

The Statistical Office of the EU (EUROSTAT) claims that cars are the principal mode of passenger transport in the EU that contribute to urban pollution and traffic congestion. However, cars are attractive to passengers as they offer a sense of freedom and shorter journey times [14]. The results of this study support this claim: a relatively higher number of passenger ports provide accessibility to car rentals and car parking. However, despite identifying and analyzing a variety of multimodal passenger options, the results of this study suggest the high data unavailability of several public transport services. This finding supports the claim made by Langen and Sharypova [48], that there is an absence of reliable public data concerning public transport in Europe.

Ferries are considered to be an important contributor to European cohesion and integration. They provide occasions to cross intra-European borders for both passengers and goods [67]. The geo-spatial data of the Mediterranean ferry network, which connects the insular maritime nodes identified in this study and is provided by the European Atlas of the Seas (Figure 9), supports our findings that satisfactory levels of insular regional accessibility exist. More detailed individual studies on the level of connectivity have been carried out for the Greek [40], Croatian [39], and Italian (only Sicily) [72] insular

regions in terms of the number of ferry operators, ship calls, voyage times, distances, seasonality, and fares.

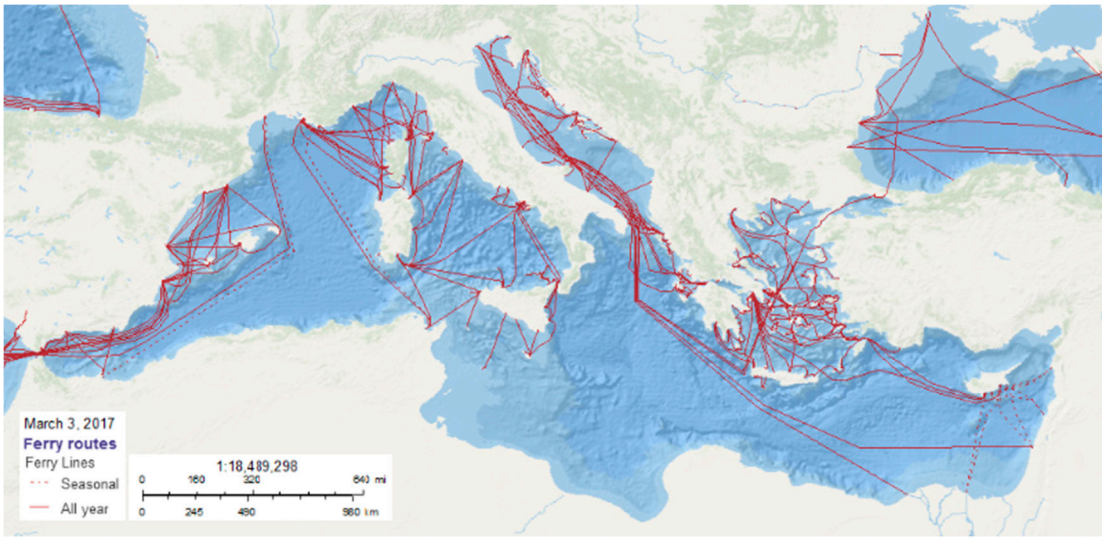

Figure 9. Mediterranean passenger ferry network by the European Atlas of the Seas.

On such study, carried out by Stupalo et al. [39], identified 94 Croatian passenger ports from the islands (73 ports) and mainland (21 ports) and suggested a satisfactory level for their port infrastructure and hinterland accessibility, as most of the island ports are located close to the city centers. While they further claim sufficient passenger multimodality for the busiest Croatian passenger ports of Split and Zadar, the rest of the ports are claimed to have inadequate multimodal passenger service. The individual geo-spatial analyses on the T&A enablers carried out in this study supports their claim on the Croatian ports and additionally, provides a holistic analysis of such T&A enabling factors for the passenger ports on a Mediterranean scale. The locations of the identified ports suggests that maritime passenger transport activity is mostly concentrated among EU member states (except Turkey) along the Northern Mediterranean shores. The locations of the cruise ports also dictate the same for the activity of cruise tourism. The authors of [57] claimed a satisfactory level, both in quantitative and qualitative terms, for the average services provided by the Adriatic passenger ports situated along the Italian East coast, Slovenia, Croatia, Montenegro, Albania, and the North-Western coast of Greece. The geo-spatial analysis carried out in this study on the level of cumulative T&A enablers for the Mediterranean passenger ports also supports their claim on the Adriatic passenger ports.

Furthermore, Langen and Sharypova [48] observed that the development of intermodal connectivity was a performance indicator for containerized cargo ports. The data driven analysis carried out in this study provides a panoramic view of maritime passenger transport in the Mediterranean concerning the capacities and offerings for the analyzed ports. Therefore, our analysis on passenger multimodality may also bring added value to operationalize the intermodal connectivity indicator for the Mediterranean passenger ports. Additionally, the T&A enablers on ship accessibility infrastructure and hinterland accessibility distance supported by this study data can be also considered as passenger port performance indicators. While the performance indicators appear to have an influential role on the competitiveness and attractiveness of the ports or regions [48], competition itself was considered inclusive within a holistic view of SD [21]. Therefore, integrating these passenger T&A enablers as port performance indicators will enable the passenger ports to boost mutual competition in their transition towards SD. It is also believed that the value of this experimentation can orient future planning in the relationship between city and port areas, as well as with regards to regional transport networks or multimodal connections at a supra-national level. Therefore, the passenger ports included within the TEN–T core network corridors

can directly benefit from the study of the Mediterranean (Med), Scandinavian–Med, Baltic–Adriatic, Orient–East Med, Rhine–Alpine, and the North Sea–Med corridors (Figure 10).

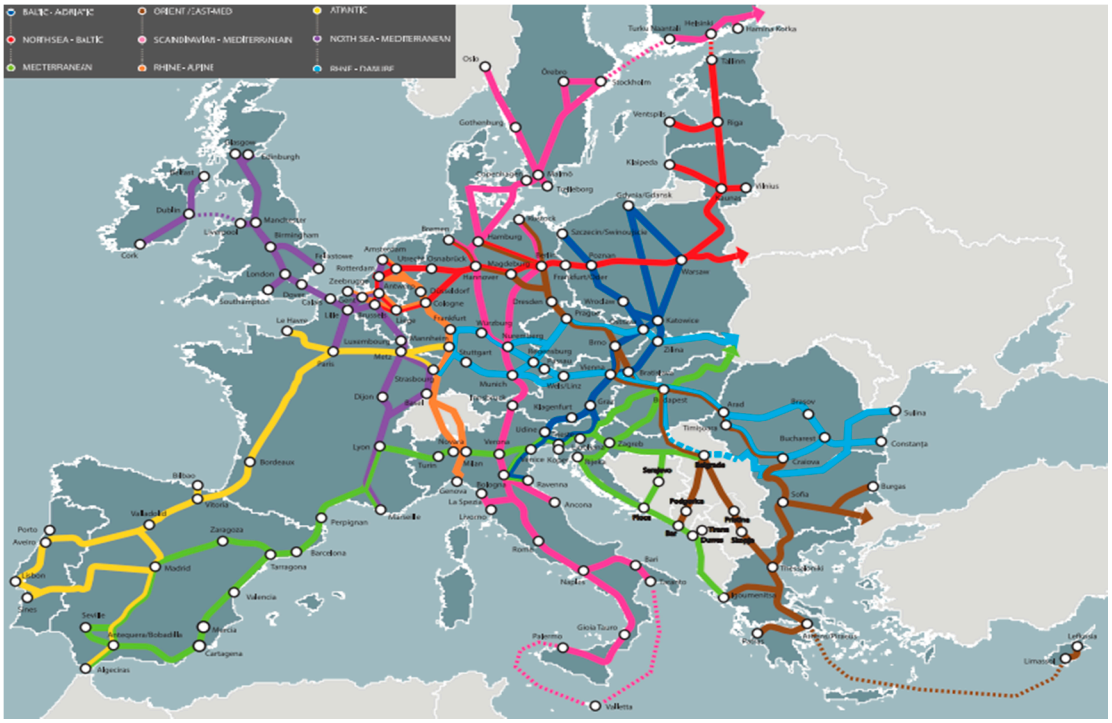

Figure 10. TEN–T core network corridors by the European Commission.

6. Conclusions

We acknowledge the multiple impacts of transportation and maritime transport in coastal and marine environments [73,74] and the related environmental costs [53]. This study focused on transport as an enabling factor for SD to be further incorporated with environmental considerations. Our results can empower Mediterranean regional, national, and local efforts to make necessary improvements to the analyzed passenger T&A enablers. However, due to the fact of data unavailability, this study neither rules out the presence nor confirms the absence of certain passenger multimodal options among the analyzed ports. Nevertheless, this can be seen as an opportunity to further investigate the least numbered available transport modes. Future studies on the T&A enablers concerning the infrastructure, hinterland accessibility, and passenger multimodality among the identified ferry ports, specifically those that are located in the insular regions, are also recommended.

The comprehensive analysis carried out by this study is also expected to bring added value to Mediterranean SD policy and planning initiatives as it provides useful T&A information that explains the present situation of passenger ports and their hinterlands. Moreover, considering synergies with the maritime passenger transport, the analytical processes and maps presented in this study can provide information on T&A enablers to any Maritime Spatial Planning (MSP) process, which has been adopted as the most popular planning mechanism for SD in the marine environment [75]. Therefore, this study can contribute to the EU funded SUPREME and SIMWESTMED Projects, which are intended to support EU Member States from the Eastern and Western Mediterranean basins in implementing the MSP Directive. Nevertheless, this study also establishes a paradigm of empirical research on the passenger T&A enablers for SD, which can be replicated without any limitation to the Mediterranean region or maritime transport.

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Author Contributions: Nazmus Sakib conceived the study, performed the research, collected and analyzed the data, and wrote the paper. Federica Appiotti and Filippo Magni contributed to structuring the manuscript. Denis Maragno contributed to the data normalization process and prepared the maps. Alberto Innocenti designed the maps. Elena Gissi revised the manuscript and Francesco Musco designed the research.

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Appendix A

Table A1. Port infrastructure data on ship accessibility.

Port_Name	Country	Port_Type	Max_Length_m	Max_Oraught_m	Berth_Numbers
Adria Bar	Montenegro	Cruise_Ferry	330	12	2
Alanya	Turkev	Cruise	**300**	**8.5**	6
Alcudia	Spain	Cruise_Ferry	200	**8**	
Alexandria	**Egypt**	Cruise	250	10	**4**
Alicante	Spaio	Cruise_Ferry	339	**8.8**	
Almeria	Spaio	Cruise	**450**	10	
Ancona	**ltaly**	Cruise_Ferry	275	10.5	11
Ant alya	Turkey	Cruise	340	9.5	
Antibes	France	Cruise			
Barcelona	Spain	Cruise_Ferry	**430**	16	9
Bari	ltaly	Cruise_Ferry	330	12	Cruise_3 Ferry_9
Bastia	France	Cruise_Ferry	230	9	**8**
Bodrum	Turkey	Cruise_Ferry	340	9	3
Brindisi	ltaly	Cruise_Ferry	**300**	**8**	
Cagliari	**ltaly**	Cruise_Ferry	Unlimited	10	
Calvi	France	Cruise_Ferry			
Cannes	France	Cruise	140	5.5	
Cartagena	Spaio	Cruise	560	12	
Caste116n	Spain	Cruise	**300**	**14.5**	
Catania	lt aly	Cruise_Ferry	Unlimited	10	
Ceuta	Spaio	Cruise_Ferry	416	14	**1**
Civitavecchia	lt aly	Cruise_Ferry			**28**
Corfu	Greece	Cruise_Ferry	770	11	
Oubrovnik	Croatia	Cruise_Ferry	Unlimited	11	
Genoa	**ltaly**	Cruise_Ferry	Unlimited	10.5	12
Gibraltar	United Kingdom	Cruise_Ferry	Unlimited	9.6	
Gioia Tauro	**ltaly**	Cruise			
Heraklion	Greece	Cruise_Ferry	>350	14	**8**
lbiza	Spain	Cruise_Ferry	392		**4**
lgoumenitsa	Greece	Cruise_Ferry	**420**	10.5	**18**
l'ile-Rousse	France	Cruise_Ferry			
Istanbul	Turkey	Cruise_Ferry	Unlimited	**8.6**	**8**
Kavala	Greece	Cruise_Ferry	360	10	
Koper	Slovenia	Cruise_Ferry	350	10	
Korcula	Croatia	Cruise_Ferry	170	6.5	
Kotor	Montenegro	Cruise_Ferry	**280**	7.8	5
Kusadasi	Turkey	Cruise_Ferry	370	10	**8**
La Spezia	ltaly	Cruise	625	10.5	
Larnaca	Cyprus	Cruise	250	**11.4**	
Latsi	Cyprus	Cruise			Anchorage
Limassol	Cyprus	Cruise_Ferry	Unlimited	15	5
Livorno	**ltaly**	Cruise_Ferry	250	12	9
Mahon	Spaio	Cruise		**8**	**4**
Malaga	Spain	Cruise_Ferry	555	17	
Marseille	France	Cruise_Ferry	**200**	**14.5**	**8**
Mersin	Turkey	Cruise_Ferry	**360**	15.5	21_indudingcargo berths
Messina	ltaly	Cruise_Ferry	**>300**	12	5
Milazzo	ltaly	Cruise_Ferry			
Monaco	Monaco	Cruise_Ferry	**300**	Unlimited	
Motril	Spaio	Cruise_Ferry	250	10.5	
Naples	**ltaly**	Cruise_Ferry	**388**	12	**4**
Nice	France	Cruise_Ferry	240	7.8	5
Palamos	Spaio	Cruise	553	12	
Palermo	ltaly	Cruise_Ferry	Unlimited	12	9
Palma de Mallorca	Spain	Cruise_Ferry	**440**	10	**8**
Paphos	Cyprus	Cruise			Anchorage
Patras	Greece	Cruise_Ferry	340	10.5	**4**
Piraeus	Greece	Cruise_Ferry	395	11	9

Table A1. *Cont.*

Port_Name	Country	Port_Type	Max_Length_m	Max_Oraught_m	Berth_Numbers
Port Said	**Egypt**	Cruise	220	11	
Portoferraio	**ltaly**	Cruise_Ferry	**200**	**7.5**	
Portofino	**ltaly**	Cruise			
Ravenna	ltaly	Cruise_Ferry	330	**8.8**	
Rijeka	Croatia	Cruise_Ferry	360	10.5	
Savona	ltaly	Cruise	310	**8.5**	
Sete	France	Cruise_Ferry	250	13	**6**
Sibenik	Croatia	Cruise_Ferry	260	9	**5**
Souda Chania	Greece	Cruise	**>300**	10	
Split	Croatia	Cruise_Ferry	320	9.5	6
Taranto	**ltaly**	Cruise	**300**	11	**4**
Tarragona	Spaio	Cruise	560	18	
Thessaloniki	Greece	Cruise_Ferry	370	**8**	
Toulon	France	Cruise_Ferry	340	10	**4**
Trieste	ltaly	Cruise_Ferry	Unlimited	18	
Tunis	Tunisia	Cruise_Ferry	330	9	**8**
Valencia	Spaio	Cruise_Ferry	**400**	17.5	**s**
Valletta	Malta	Cruise_Ferry	360	13.7	6
Venice	**ltaly**	Cruise_Ferry	340	9.1	6
Volos	Greece	Cruise_Ferry	445	11	5
Zadar	Croatia	Cruise_Ferry	375	12	5

Table A2. Hinterland accessibility distance data.

Port_Name	Distance _CityCentre_km	Nearest _Airport_km	lntercity _Bus_Tenninal_km	lntercity _Train_Station_km
Adria Bar	0.05	51		0.8
Alanya	0	45	2	
Alcudia	3	70	0.7	
Alexandria	1.5	32	5	1.5
Alicante	1	10	1.8	2
Almeria	0	13	0	1
Ancona	0	18	1	1
Antalya	15	16	11	
Antibes	0	19	0.7	0.6
Barcelona	2.5	14	8.9	8.4
Bari	0.8	10	1	1
Bastia	0	21	0.1	0.3
Bodrum	2	37	1.3	
Brindisi	1	5	6	6
Cagliari	0.5	10	0	0.5
Calvi	0	6	0.1	0.2
Cannes	0	4	1	1
Cartagena	0.2	30	3.9	1
Castell6n	4	40.5	12.5	12.4
Catania	0.5	6	0.6	0.5
Ceuta	0.1	1	1.1	0.8
Civitavecchia	0.5	68	2	2
Corfu	2	6	1	
Dubrovnik	2	26	0.2	
Genoa	1	5	0.2	0.5
Gibraltar	1	1.2	0.3	
Gioia Tauro	7	79	12	12
Heraklion	1.5	6	0.2	
lbiza	0	6		
lgoumenitsa	1	90	0.5	
l'ile-Rousse	0.8	14		0.5
Istanbul	0	19	0.05	0.3
Kavala	0	32	0.3	
Koper	0.1	66		1.2
Korcula	20	106		
Kotor	0.5	6	0.45	
Kusadasi	0.05	76	2.3	

Table A2. *Cont.*

Port_Name	Distance _CityCentre_km	Nearest _Airport_km	Intercity _Bus_Tenninal_km	Intercity _Train_Station_km
LaSpezia	0.2	84	1	1
Larnaca	0	5	0.25	
Latsi	0	56	1.8	
Limassol	5	60	4	
Livorno	0.5	27	2	2
Mahon	0	5.5	1.2	
Malaga	1	20	1.8	1.5
Marseille	8	30	1	1
Mersin	0	93	1	3
Messina	0	111	0.4	0.3
Milazzo	0	143	1.5	1.5
Monaco	0.5	19		0.6
Motril	2	81	3	5
Naples	0	16	0.1	2
Nice	0	4	3.5	3.5
Palamos	0.5	48	0.6	30
Palermo	0.5	32	0.3	0.3
Palma de Mallorca	1	5	4.5	
Paphos	0	19	0.08	
Patras	0	40	0.1	1.2
Piraeus	0.5	50		0.05
Port Said	180	6		1
Portoferraio	0	14	0.2	
Portofino	0.2	47	1.5	6
Ravenna	14	69	11	11
Rijeka	0.5	31	0	1
Savona	0.35	51	1.5	1.5
Sete	0.2	35	3	1
Sibenik	0.3	56	0.08	0.1
Souda Chania	7	18		
Split	0.2	24	0.1	0.1
Taranto	0.5	79	1	1
Tarragona	1	85	4.5	0.55
Thessaloniki	0	21	0.8	0.8
Toulon	0	21	0.8	0.8
Trieste	0	50	0.5	0.5
Tunis	10	14	1.2	0.6
Valencia	4	10	10	5
Valletta	1.5	8	1.1	
Venice	0.5	14	0.3	1
Volos	0.3	26	0.65	0.65
Zadar	3	11	1.5	1.5

Table A3. Available passenger multimodality data.

Passenger Port	Multimodal Options								
	Public Transport					Shuttle Service	Taxi Service	Car Rentals	Car Parking
	Bus	Tram	Metro	Train	Water Bus				
Adria Bar			N			y	y	y	y
Alanya	y		N			y	y	y	y
Alcudia	y		N				y	y	y
Alexandria	y	y	N			y	y	y	y
Alicante	y		N	y		y	y	y	y
Almeria	y		N	y			y	y	y
Ancona	y		N				y	y	y
Antalya	y		N			y	y	y	y
Antibes	y		N			y	y	y	y

Table A3. *Cont.*

Passenger Port	Multimodal Options								
	Public Transport					Shuttle Service	Taxi Service	Car Rentals	Car Parking
	Bus	Tram	Metro	Train	Water Bus				
Barcelona	y		y			y	y	y	y
Bari	y		y				y	y	y
Bastia			N			y	y	y	y
Bodrum	y		N			y	y	y	y
Brindisi	y		N				y	y	y
Cagliari	y		N			y	y	y	y
Calvi			N				y	y	y
Cannes	y		N			N	y	y	y
Cartagena	y		N			y	y	y	y
Castell6n	y		N			y	y		y
Catania			N			N	y	y	y
Ceuta	y		N			y	y	y	y
Civitavecchia			N			y	y	y	y
Corfu	y		N			y	y	y	y
Dubrovnik			N			y	y	y	y
Genoa	y		y			N	y	y	y
Gibraltar	y		N			y	y	y	y
Gioia Tauro			N				y	y	y
Heraklion	y		N			N	y	y	y
lbiza lgoumenitsa	y		N				y	y	y
lgoumenitsa			N			N	y	y	y
l'ile Rousse	y		N				y	y	y
Istanbul	y		y			y	y	y	y
Kavala	y		N			N	y	y	y
Koper	y		N			N	y	y	y
Korcula	y		N			N	y	y	y
Kotor			N			N	y	y	y
Kusadasi	y		N			N	y	y	y
La Spezia	y		N			y	y	y	y
Larnaca	y		N			y	y	y	y
Latsi			N			y	y		y
Limasso1	y		N			y	y	y	y
Livorno	y		N			y	y	y	y
Mahon	y		N				y	y	y
Malaga	y		N			N	y	y	y
Marseille	y		y			y	y	y	y
Mersin	y		N			y	y	y	y
Messina	y		N			N	y	y	y
Milazzo			N				y	y	y
Monaco			N			y	y	y	y
Motril	y		N			y	y		y
Naples	y		y			y	y	y	y
Nice	y		N			y	y	y	y
Palamos	y		N			y	y	y	y
Palermo	y		N			N	y	y	y
Palma de Mallorca	y	y	y				y	y	y
Paphos	y		N			y	y		y
Patras			N			y	y	y	y
Piraeus	y		y			N	y	y	y
Port Said	y		N			y	y	y	y
Portoferraio	y		N			y	y	y	y
Portofino	y		N			y	y	y	y
Ravenna	y		N			y	y	y	y
Rijeka	y		N			y	y	y	y
Savona			N				y	y	y
Sete			N			y	y	y	y
Sibenik	y		N			N	y	y	y
Souda Chania	y		N			N	y	y	y
Split	y	N	N			y	y	y	y

Table A3. *Cont.*

Passenger Port	Multimodal Options								
	Public Transport					Shuttle Service	Taxi Service	Car Rentals	Car Parking
	Bus	Tram	Metro	Train	Water Bus				
Taranto	y		N			y	y	y	y
Tarragona	y		N			y	y	y	y
Thessaloniki	y		y			N	y	y	y
Toulon	y		N			y	y	y	y
Trieste	y		N				y	y	y
Tunis	y		N			y	y	y	y
Valeneia	y		y			y	y	y	y
Valletta	y		N				y	y	y
Venice	y	y	N	y	y	y	y	y	y
Volos	y		N			N	y	y	y
Zadar	y		N			y	y	y	y

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