TRANSPORTATION NETWORKS AND REGIONAL DEVELOPMENT: THE CONCEPTUAL AND EMPIRICAL FRAMEWORK IN GREECE

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Abstract
This paper examines the importance of transportation networks for the economic and regional development of Greece, focusing on the country's infrastructure and its road, rail, maritime, and air transport networks. Based on statistical and economic indicators and the application of a multivariate linear regression econometric model, the link between transport and economic and regional development and its complexity is highlighted. The study underlines that the structure and functionality of transportation networks reflect the social and economic needs of their user societies, providing important information on the development dynamics of a country. Through a literature review, technical reports, and empirical analyses, this information can serve as a thematic basis for examining transport networks at both research and policy levels. Overall, this article is addressed to regional researchers and policymakers, highlighting the need for responsible transport planning, which is associated with high opportunity costs and inelastic infrastructure sunk costs.

Keywords: road networks, railway networks, maritime networks, aviation networks.
JEL Classification Codes: R4, R41, R42.

1. Introduction

The movement of people is a historical phenomenon, which emerged from the innate need for communication and mobility and which has a lasting impact on the economic and social development of societies (Polyzos, 2011; Polyzos and Tsiotas, 2020, 2023). Within this conceptual framework, transport constitutes the set of organized human actions, which aim to satisfy the human need for communication and mobility and involve the coverage of spatial distances and generally spatial constraints that occur from the dispersion of the locations of social formations and social activities. Transport, which has always been an imprint of human activities in space, can be divided into three main categories (Polyzos, 2019; Polyzos and Tsiotas, 2020): (*i*) *Transport of people*: this category refers to the need to move people between areas for various purposes; (*ii*) *Transport of goods*: This category refers to the movement of material goods to cover geographical distances to promote the production process and to carry out commercial transactions; (*iii*) *Transfer of information, knowledge, and technology*: This category refers to the dissemination of information and technological knowledge between different spatial units as a result of the interaction of culture and civilization that takes place during communication

Historically, the development of transport and transport infrastructure has been closely linked to the development of human societies, constituting their footprint in space. Over time, it has been shown that the spatial resistance (Tsiotas and Polyzos, 2013; Polyzos and Tsiotas, 2020, 2023), to which transport is subjected, is constantly decreasing, promoting opportunities for communication and economic interactions (Capello, 2015; Polyzos, 2019). It also emerges historically that the development of large urban centers is closely linked to their geographical location, but also to the ability to exploit existing natural transport systems (riverside or coastal cities) or to the possibility of developing man-made transport infrastructure (Polyzos and Tsiotas, 2020). In general, transport infrastructure is the structural background within which the actions that take place in each of the aforementioned transport categories are implemented and which has played an important role over time in the development of social formations such as cities, regions, or, on a larger scale, countries (Polyzos, 2019).

The relationship between transport and economic development is characterized by a high degree of complexity. In terms of regional economics (Behrens and Thisse, 2007; Capello, 2015), transport contributes over time to linking land use, promoting the productive process, to the realization of trade by creating trade flows (Polyzos and Tsiotas, 2020), to the development of local economies, to the reduction of interregional inequalities and spatial asymmetry in general (Polyzos, 2019), to the growth of national economies and, more generally, to the promotion of international economic transactions. Transport can affect income distribution, the mix of production and inputs, employment levels, and technological progress. In many cases, the existence of an undeveloped transport system between undeveloped regions reflects the inadequacy of the corresponding demand (Rodrigue et al., 2013; Polyzos, 2019). Transport is instrumental in promoting economic interactions (economic development), but also in promoting interpersonal communication (social development)

In contrast to the view that transport infrastructure directly promotes regional development, some approaches argue that transport infrastructure contributes to increasing regional disparities. Drew (1990) argues that the transport system is not a sufficient and necessary condition for the development of regions, but acknowledges that it helps to bypass spatial barriers and creates conditions for further development. As a process, economic growth following the construction of transport infrastructure occurs initially in urbanized regions or regions close to urban areas, because they have the necessary human and natural resources and the economic structure required for the direct exploitation of this infrastructure. In a chain reaction, entrepreneurs are influenced to locate their businesses in regions with a comparative advantage in terms of transport costs, due to accessibility to markets and sources of raw materials. However, the overall benefits gained vary from one industry to another due to their different dependence on transport costs. As transport infrastructure contributes to increasing productivity, it also promotes growth. Plassard (1992) argues that the existence of a positive relationship between transport infrastructure and regional development lacks sufficient scientific evidence and that the views supporting it are sustained by the need to legitimize policy decisions to build transport infrastructure and the existence of continuity between short and long term changes, which have been difficult to distinguish between them. It also considers that the construction of transport infrastructure does not generate significant long-term regional changes. In a synthetic approach, Rephann (1993) distinguishes 3 competing views on the optimal regional conditions in which transport infrastructure should be implemented to maximize its efficiency. The first view argues that such infrastructure should be built in developing regions, the second proposes intermediate regions, and the third is based on the theory of growth poles, according to which the construction of transport infrastructure should be concentrated in regions with a predominantly urban population composition, which shows previous growth potential. Vickerman (1989, 1995) argues that further factors should be considered more in-depth than the standard approach which focuses on accessibility and the effect of changing transport costs on regional industries. According to the author, consideration should be given to the possibility of creating “corridor effects” (Rodrigue et al., 2013; Polyzos, 2023) so that a region is not affected by the transit induced through this transport infrastructure so that it is constrained to take advantage of the benefits offered by the infrastructure. Typical examples, according to Vickerman (1989, 1995), are the districts of Kent in the United Kingdom and Nord Pas de Calais in France, which are located at the two entrances to the Channel Tunnel. The author also recognizes the problem of the assumption that the economic structure of the regions is static.

In Greece, Petrakos (1997), codifying the above approaches, states that transport networks can contribute to regional development in combination with the other three development factors of a region, namely its location in geographical space, the existing economies of concentration and the sectorial composition of local production and employment. The magnitude of the benefits accruing to a non-central region that reduces its distance due to the development of transport infrastructure depends mainly on its productive base and its capacity to resist the pulling power that it will receive from the central ones to absorb its purchasing power and labor force and thus several of its economic activities. The effects can be positive or negative and the geographical location (central or peripheral) together with the dynamism of the economy of each region affected by interregional transport infrastructure are the key features that determine the direction of these effects. In terms of Network Science (Lewis, 2011; Brandes et al., 2013), transport constitutes interaction and communication systems, whose infrastructures represent networks and movements express the flows that occur within networks. For example, in road transport, road infrastructure constitutes a network, within which travel flows are developed serving each of the aforementioned transport categories. Similarly, the maritime transport system, which consists of the set of active ports of a country and its coastlines, describes a network of coastal transport (Tsiotas and Polyzos, 2015a), in which transport activities (flows) from all three transport categories are equally carried out. Similarly, the air transport system, which consists of a country’s active airports and air corridors (air movement paths), is an air transport network (Tsiotas and Polyzos, 2015b) in which all the aforementioned categories are also served, but mainly the transport of passengers.

A typical view expressed by Petrakos and Psycharis (2016) argues that the emphasis on transport infrastructure is exaggerated for its share in all communication systems (e.g. telecommunications, broadband networks) and is due to its material (tangible) nature, as opposed to infrastructure that is considered “intangible” (i.e. where information/signal is transmitted through channels that have no structured substance, e.g. in the air). This view relates to the “static” nature of transport infrastructures compared to other “intangible” communication systems which exhibit characteristic dynamics and adaptability to changes over time and of all kinds. However, the static nature of transport infrastructures, given their structured configuration, highlights the crucial importance of planning and design as tools for developing transport policy, since it is particularly difficult and costly to eliminate any errors and omissions.

From the above, transport networks can be defined (Tsiotas, 2016) as the systems of connections that are developed between different locations or spatial units (such as urban formations, cities, ports, and airports), take place within a specific spatial embedding (land surface, sea surface, air) and are designed to carry out transport and (by extension) regional development. The form, structure, and functions of transport networks vary according to historical, economic, and social conditions, the means of transport, and the spatial infrastructure. Finally, the interaction of land use systems and transport networks is one of the main phenomena that occur in areas of urban concentration (Polyzos, 2023). In general, it is observed that the development of transport networks is an attraction for the establishment of social and economic activities in adjacent areas. The development of areas (hubs) with high accessibility generally increases the overall demand for the establishment of activities, creating a comparative advantage over other competing areas. This development has a multiplier effect (Capello, 2015; Tsiotas, 2022), as high accessibility areas feedback new development and concentration of further economic activities.

In this context, this paper provides an overview of the main thematic axes that highlight the importance of transport and in particular transport infrastructures and networks in the economic and regional development of Greece. Transport networks constitute the fixed capital that extends in different forms throughout the country to interact, trade, and communicate between connected areas. For this purpose, longitudinal and cross-sectoral information is examined, which describes some fundamental macroeconomic variables and measures related to transport. The methodological approach of this paper is based on the presentation and processing of these measures using techniques of descriptive and inferential statistics, as well as on the construction of an econometric model for the empirical examination of the contribution of transport infrastructure to regional development. Furthermore, this paper attempts to highlight the structural and functional dimensions that define transport networks and to highlight the necessity of their joint consideration in scientific research. The paper stands at the intersection of a review article, technical report, and empirical paper, providing the reader with a thematic basis for the study of transport networks.

2. Transportation in Greece

Transport in Greece is a key component of the national economy and an important factor in its development (Tsiotas and Polyzos, 2015a,b; Polyzos, 2019, Tsiotas, 2021; Polyzos, 2023). At the policy level, over time, the Greek government structure has placed particular emphasis on the transport sector. For instance, according to the ministerial structure of Greece in 2012, two (Ministry of Shipping and the Aegean; Ministry of Infrastructure, Transport, and Networks) out

of the 18 Greek ministries were exclusively dedicated to transport. In addition, two more Ministries (the Ministry of Public Order and Citizen Protection; and the Ministry of Tourism) are entrusted with functions related to transport (such as road safety and transport security).
The existence of a quality transport system is a sufficient but not necessary condition for a country's economic development. On the contrary, the existence of an efficient transport network is a sufficient and necessary condition for the growth of the economy of less developed countries (Tsiotas, 2016). For this reason, the implementation of transport infrastructure upgrading projects is generally a top priority of development policies implemented in developing economies (Polyzos, 2019). The importance of transport infrastructure in the national economy leads countries to allocate annually a significant portion of government expenditure to its maintenance and upgrading (Polyzos and Tsiotas, 2020). This is also applicable to the level of economic policy-making in Greece. In particular, Figure 1 presents the share of the Greek Public Investment Budget allocated to the Ministry of Infrastructure, Transport and Networks for the period 2009-2016. As shown in Figure 1, Public Investment expenditure in Greece allocated to transport and network infrastructure is particularly significant, reaching 1/3 of the total Public Investment budget. This fact combined with the given economic tightness that Greece has been experiencing over the 2008 economic crisis (Polyzos et al., 2013), demonstrates the importance given (at the level of development policy) to the transport sector. This seems to be a key prospect for the Greek economic recovery, exit from the current economic crisis, and further economic growth.

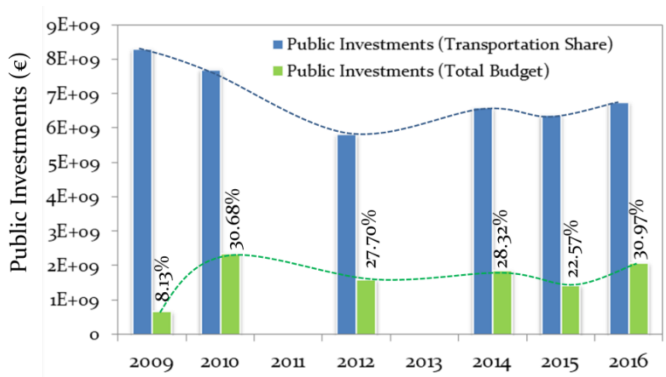

Figure 1. The share of the Greek Public Investment budget in the Ministry of Infrastructure, Transport and Networks, for indicative post-crisis years from the period 2009-2016 (source: Tsiotas, 2016; own elaboration).

Furthermore, Figures 2a, and b shows that transport accounted (on average) for 7% of Greece's Gross National Product (GNP) during the country's period of economic prosperity 1995-2004 (Tsiotas, 2016). The corresponding average participation rates in the main productive sectors were 6.96% for agriculture, 19.57% for industry, and 63.34% for services, while for the other sectors, there were 0.55% for mining, 10.54% for manufacturing, 1.75% for energy, 6.72% for construction, 12.16% for trade, 6.65% for hotels and restaurants and 4.48% for financial intermediation. Figure 2c shows the evolution of the contribution of the Transport and Communications sector to GDP over time, compared to the corresponding contribution of the main productive sectors of Greece (primary - agriculture, secondary - industry, tertiary - services), during the period 1995-2004. As can be seen, the dynamics of the Transport - Communications sector become equivalent to that of the primary sector, indicating the prominent importance of transport in the economic structure of the country. In addition, the graph shows that the dynamics of the Transport - Communications sector in the production of national products is about half that of the secondary sector and 10% that of the tertiary sector.

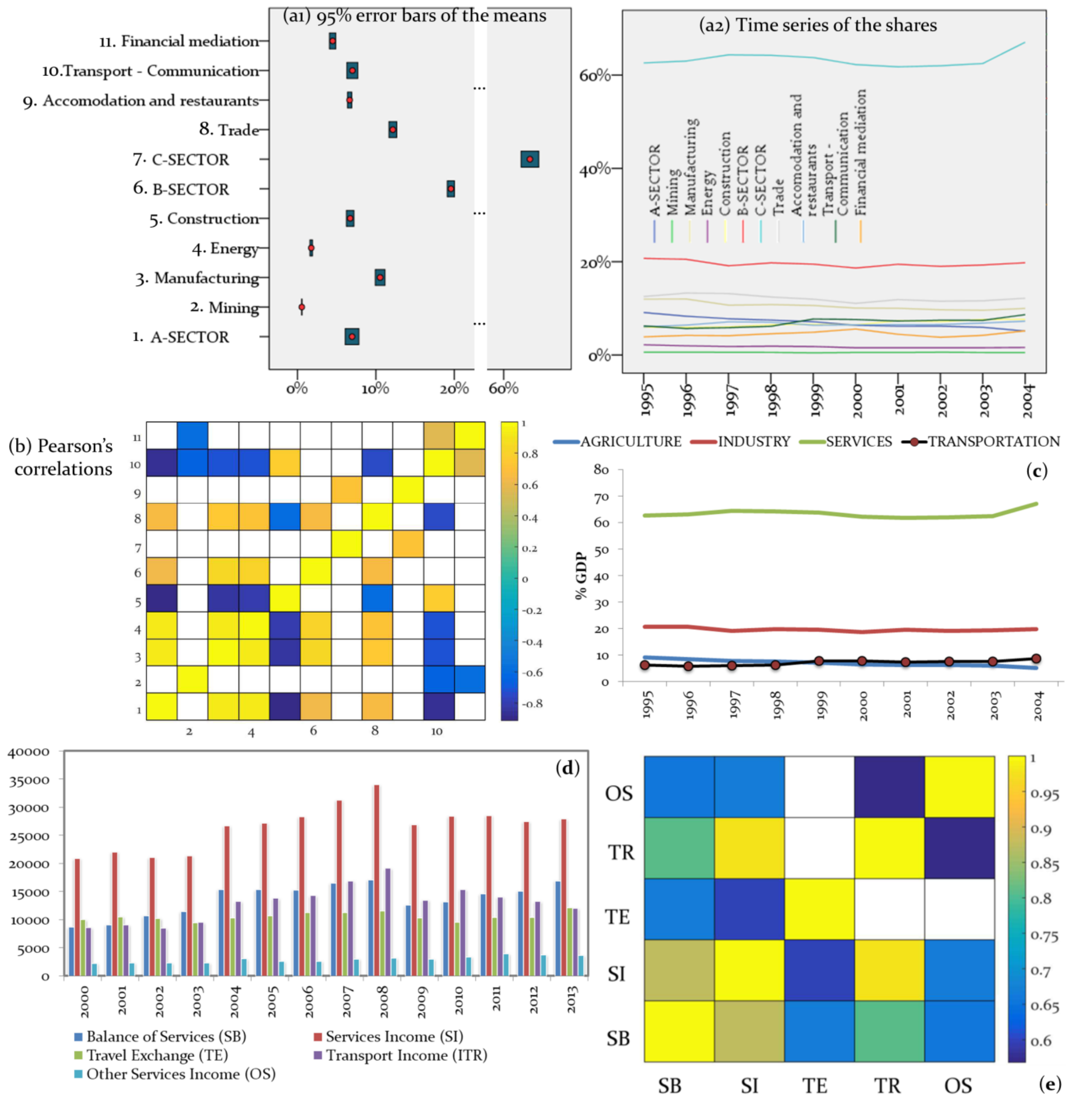

Figure 2. (**a**$_1$) The average and their time-series (**a**$_2$) percentage shares of production sectors in GDP over the pre-crisis decade 1995-2004; (**b**) Significant bivariate Pearson correlations between the production sectors; (**c**) Pre-crisis time series (1995-2004) of the percentage share of the main productive sectors (A_{sec}=Agriculture, B_{sec}=Industry, C_{sec}=Services) and the Transport sector in GDP; (**d**) Pre- and post-crisis time series (2000-2013) of Travel Exchange and Transport Receipts, compared to Services Receipts and Services Balance; (**e**) Correlation analysis for the sectorial variables shown (sources: Bank of Greece, 2014; Tsiotas, 2016; own elaboration).

According to data from the Bank of Greece (BoG, 2014), transport revenues for the period 2000-2013, constituted an important component of tertiary sector receipts, averaging 48%, while their size covered on average 94% of the country's services balance. Further, from the data in Table 3, it is estimated that transport receipts exceeded in size those of travel by an average of 122%, but also exceeded by an average of 435% the receipts from other services recorded in the country's balance of payments. Figure 2d shows a graphical representation comparing travel foreign exchange, transport receipts, services receipts, and the services balance. As can be seen, the dynamics of transport receipts are stronger than those of travel foreign exchange and comparable to those recorded in the country's services balance. To further detect the structural correlation in the variability of the variables in Figure 2d, a correlation analysis (Norusis, 2004; Devore and Berk, 2012) is performed using Pearson's bivariate correlation coefficient r_{xy}. This coefficient ranges in the interval [-1,1] and detects a linear relationship between two variables *x*, *and y*. When $r_{xy}=1$ there is a full positive linear relationship, for $r_{xy}=-1$ there is a full negative linear relationship, while for $r_{xy}=0$ the variables are linearly uncorrelated. The results of the correlation analysis are shown in Figure 2e, which shows that transport revenues (TR) are almost entirely linearly correlated with tertiary sector (SI) revenues ($r_{TR,SI}=0.976$, with significance $p\leq 0.01$) but also highly correlated with the services balance ($r_{TR,SB}=0.809$, with significance $p\leq 0.01$). The corresponding values for travel foreign exchange (TE) and other services revenue (OS) are significantly lower than the above, in the range of 20-40%. These results highlight an association between the SI and TR variables. The same stands (but slightly weaker) for the SB and TR variables. This observation, together with the smaller results for the variables TE and OS respectively, suggests the stronger involvement of transport receipts in shaping the volatility of tertiary sector revenue and the balance of services.

To form a more complete picture for the comparison between TR (transport receipts), TE (travel foreign exchange), and SB (services balance), we apply a paired-sample t-test (Norusis, 2004) to statistically test the equality of their averages. The procedure calculates the differences between the values of the two variables for each case and tests whether their mean is statistically different from zero. In this test, a 95% confidence interval is chosen for the difference in means. The available data shall be administered pair-wise, implying that each t-test is calculated on a case-by-case basis on the largest possible number of samples (degrees of freedom) which may vary from test to test. The results of this test are shown in Table 1, where (*i*) the statistically significant difference TR-TE>0 expresses that in the period 2000-2013 the average value of transport receipts is statistically higher than that of the tourism exchange; (*ii*) the statistically zero difference TR-SB=0 expresses that the average value of transport receipts does not differ from that of the balance of services; whereas (*iii*) the statistically significant difference TE-SB<0 expresses that, in the period in question, the average value of tourist foreign exchange has been lower than that of the services balance. The results of the pairwise statistical test (statistical test) indicate that the transport sector had a greater impact on the national economy than the tourism foreign exchange earnings, during the period 2000-2013, but also that its size is similar to that of the country's services balance.

Table 1

Paired-sample t-test for the comparison of the means μ_i and μ_j between payment balance variables

4a. Summary

Pair		Pair Correlations		
		d.f.	r_{xy}	Sig.[(a)]
1	TR[(b)]-TE[(c)]	14	0.449	0.108
2	TR-SB[(d)]	14	0.809	0.000
3	TE-SB	14	0.664	0.010

4b. Test Results

Pair		**Pair Differences**					*t*	d.f	sig.[b]
		Mean	*s*	s_e[e] of the mean	95% CI[f] for the mean difference				
					Lower Bound	Upper Bound			
1	TR[b]–TE[c]	2357.2	2911.56	778.15	**676.14**	**4038.3**	3.029	13	.010
2	TR–SB[d]	-768.5	1880.25	502.52	-1854.1	317.10	-1.529	13	.150
3	TE–SB	-3125.7	2382.48	636.74	**-4501.3**	**-1750.1**	-4.909	13	.000

a. 2-tailed significance
b. Transport Income
d. Tourism Exchange
d. Services Income
e. Standard error
f. Confidence Interval
(data source: Bank of Greece, 2014)

Further, the scatter plots (TR,SI | transport receipts, service sector revenue) and (TR,SB | transport receipts, balance of services) in Figure 4 illustrate that there is a stronger structural relationship between the variables (TR,SI) than (TR,SB). This observation expresses that almost all (95.3%) of the variation in transport revenue data is also described by the variation in tertiary sector revenue data, while in the case of the (TR, SB) difference this ability falls to 65.4%.

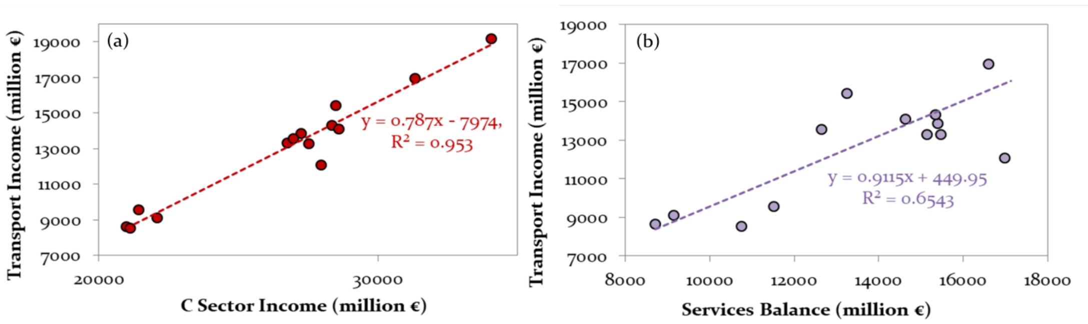

Figure 3. (**a**) Scatter plots of Transport Receipts and Services Receipts (2000-2013); (**b**) Scatter plots of Transport receipts and the Balance of Services (2000-2013) (source: Bank of Greece, 2014; own elaboration).

3. Transportation networks in Greece

As can be deduced by the previous examination, the transport sector in Greece seems to be a key component of growth. In this context, the following subsections focus on the case of Greece, providing more technical evidence on the structure of transport networks.

3.1. The road transport network

In historical terms, the development of road transport networks over time is symbiotically related to the history of mankind. Initially, human travel was carried out by exploiting natural transportation channels (e.g. by following the course of rivers or other natural crossings). However, the historical criterion for the emergence of road transport was the exploitation of human thought and labor in the design and construction (Tsiotas, 2016) and generally in the development of road infrastructure (Kaltsounis, 2007). According to Kaltsounis (2007), the first indications of the use of human thought and labor in the design and construction of roads are recorded in the cobbled roads built in Mesopotamia, which date back to around 4000 BC (the period of the wheel discovery), followed chronologically by the cobbled roads in India (around

3000 BC) and the cobbled roads of the Minoan period in Crete. The oldest road that survives today is in Crete, built around 1700 BC, and has a total length of about 50 km (Tsiotas, 2016). The road connected Knossos with the city of Gortyna and the southern coast of the island. The foundations of urban road planning were laid in the era of Ancient Greece (Polyzos, 2023). During this period, the urban road ceased to follow the randomly shaped territorial contours, becoming a product of planning, adapted to the needs of settlements, which constituted an organized road network. Further, at that time, the city was divided into blocks of flats, in which care was taken to design the public spaces and the required road infrastructure, with the city of Miletus as a typical representative (Kaltsounis, 2007). The dominant vehicle of this period was the wheeled horse-drawn carriage. Alexander the Great's contribution to the road-building of Ancient Greece was significant, since he maintained, improved, and expanded, with his Thracian craftsmen, the road network of the Persians that he received during his empire (Tsiotas, 2016). The development of road-building during the Roman era was decisive, driven by the need to control this vast empire, since its road network stretched from the North Sea to the Sahara and from the Atlantic to Mesopotamia, with Rome as the focal point (Kaltsounis, 2007; Polyzos, 2023). The excellence of the construction of this network enabled it to function for many centuries after the collapse of the Roman Empire. The main feature of the road network of that period was the hierarchy in the construction of its sections, the primary section being paved with stones (90,000km long), the secondary section being paved with gravel (300,000 km long) and the remaining sections being paved with wood (sandstone). It was noteworthy that the network was signposted, kilometre-marked, systematically maintained, and had stopping and overnight accommodation facilities (hostels). A characteristic feature of the network was its extensive alignment (the so-called "Roman alignments"), which served safety and distance reduction purposes and were only bypassed to better adapt the project to the ground (Tsiotas, 2016). The network was also characterized by frequent longitudinal gradients of up to 10%, which are still used today as permissible gradients in road design for design speeds of less than 60 km/h. The invention of the automobile was a milestone in the evolution of road construction, which contributed to the upgrading of both the geometric design and the quality of road construction (Rodrigue et al., 2013; Tsiotas, 2016). Before the advent of the motor car, there were no strict requirements for the geometric design of roads, due to the low speeds of travel of horse-drawn vehicles and other means of transport. But the advent of the car marked a new era in travel at ever-increasing speeds. Since then, road construction has aimed to build quality road networks, with the safety of users as the primary concern (Tsiotas, 2016).

In Greece, the construction of the road network in its present form also began after WW2 (Tsiotas, 2016). In 1963, by a decision of the Minister of Public Works (G.25871, 1963), a list of the country's national roads was drawn up, with the aim of "systematic mileage measurement and better service of the country's increasing tourist traffic", which included sections that had not yet been paved. The wording of the purpose of the above decision expresses (as early as 1963) the legislative and political perception of the worldwide known interaction between transport and tourism (Tsiotas and Polyzos, 2015a; Amoiradis et al., 2021; Beha and Ruxho, 2023) and their expected contribution to the economic development (Tsiotas, 2016). In 2006, the General Secretariat for Public Works (GSGE) of the Hellenic Ministry of the Environment, Spatial Planning and Public Works (YPEXODE) drew up the "Guide to the Mileage Distances of the Road Network of the Country", to meet the needs of officials and private individuals, to facilitate the work of the Financial Control Services of the Ministries and Public Services in general, and to facilitate the issuing of mileage certificates between municipalities and communities in the country. The guide includes tables showing the kilometric distances of the capital cities of the NUTS II prefectures of the country from Athens and the distances of cities, villages, and settlements of each prefecture from its capital (YPEXODE, 2006; (Tsiotas, 2016). In technical terms, road transport networks belong to the family of infrastructure networks (Barthelemy, 2011; Tsiotas, 2021), because the road links that make up them take place on built surfaces and constitute national infrastructure projects. According to the Presidential Decree 401/93, the road network is classified into the following categories, with the following main criteria (Tsiotas, 2016): (*i*) The main national road network: this is the part of the national road network that connects the main urban centers with each other and the country with other territories, either directly or through the intervention of ferries; (*ii*) Secondary national road network: means that part of the national road network which connects major national roads with each other or with major urban centers, ports, airports or places of outstanding tourist interest, or which are roads which have been upgraded to the main national road network; (*iii*) Tertiary national road network: this is the part of the national road network that has been replaced by new national road network markings or serves travel to areas of archaeological, tourist, historical or development interest; (*iv*) Primary provincial road network: is the part of the provincial road network that connects urban centers with the national road network, as well as areas of archaeological, tourist, historical or developmental interest; (*v*) Secondary provincial road network: is that part of the provincial road network which connects municipalities or communities outside the capital of the county with each other. In the same presidential decree (401/93), the classification of the national road network into primary, secondary, and tertiary networks is made according to the above criteria and by a decision of the Minister of YPEXODE, after the agreement of the Public Works Council and published in the Government Gazette. In addition, the classification of the provincial road network into primary and secondary is made by a Decision of the Minister and a recommendation of the General Secretary of the Region, following a proposal of the locally competent Prefects and the concurring opinion of the Prefectural Public Works Council, and is published in the Government Gazette (Tsiotas, 2016).

According to the data available in the database of the Hellenic Cadastral and Cartographic Organization (OKXE, 2015), the national and provincial road network of Greece has a total length of 35,860 km and serves all 51 capital cities of the Greek Kapodistrian prefectures. Figure 4 shows the mapping of the Greek road network and its central nodes in terms of betweenness centrality. As it can be observed, the places structured to undertake the major traffic load in the road network nationwide are located in the east coastal forehead of the country, shaping a characteristic S-type linear pattern (Tsiotas et al., 2013) illustrating the spatial dynamics of regional development in Greece. Today, Greece has about 1900 km of motorways, and with the completion of the sections under construction; it is expected to exceed 3,100 km (YPEXODE, 2006). The main road axes in Greece, as derived from the Strategic Plan for the Development of Transport Infrastructure in Greece for the year 2010 (MINFIN, 1993; Tsiotas, 2016) and the codification carried out by the Ministerial Decision, with protocol number DMEO/o/7157/e/1042 (YPEXODE, 2008).

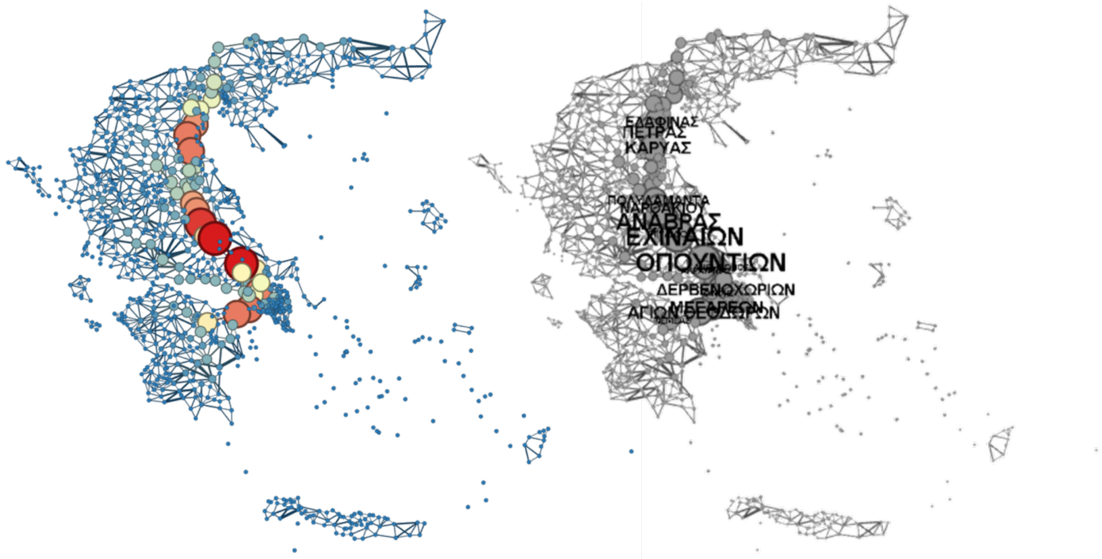

Figure 4. Graph model $G_{(1115,2264)}$ of national and provincial road transport network in Greece. Nodes (shown proportional to their betweenness centrality) represent cities and links represent road connections (database source: OCSE, 2005; Tsiotas, 2021; database labels are only available in Greek).

In particular, the main roads in Greece are described in brief as follows (YPEXODE, 2006, 2008; Polyzos et al., 2014; Tsiotas, 2016): (*i*) The *Patras - Athens - Thessaloniki - Euzoni – PATHE/ΠΑΘΕ motorway* (Codification: A_1, A_8). It has a total length of 770km, and is the main road axis of mainland Greece, running through six (out of 13) NUTS II regions. The PATHE connects the three most populous cities of Greece (Athens, Thessaloniki, Patras) and along it a grid of the most important urban centers and settlements of the country, with a population of more than 50% of the total population; (*ii*) The *Egnatia Motorway* (A_2). It is arranged almost perpendicular to the PATHE, it has a total length of 670km and runs through five NUTS II regions of Greece. Its construction started in 1997, except a common 26 km with PATHE (which was built before 1994). The Egnatia Motorway starts from Igoumenitsa (Thesprotia) and ends at the exits of Kipoi and Kastania (Evros), running through the whole geographical area of Northern Greece, as well as the periphery of Epirus. As a project, it connects most of the urban centers in the northern part of Greece; (*iii*) The *Ionian Motorway* (A_5). It starts from Kalamata (Messenia) and runs along the geographical area of Western Greece, ending at the Greek-Albanian border. The Ionian Motorway has a designed length of 424 km (200 km completed) and crosses three NUTS II regions. The completion of the Ionian Road is expected to form the backbone of the transport infrastructure of Western Greece, upgrading the quality of transport and promoting regional development; (*iv*) The *Central Greece motorway* (A_3, E_{65}). With a total length of 175km, it runs from Lamia to the Egnatia Motorway; (*v*) The *Peloponnese Central Axis* (A_7). It serves exclusively the Peloponnese region, with a total length of about 200km. It starts from Corinth and extends to Kalamata, branching off vertically to Sparta; (*vi*) The *Northern Axis of Crete* (A_{90}). With a total length of about 300 km, the axis covers the northern part of Crete, from Kastelli (in the west) to Sitia (in the east), passing through all four capitals of the NUTS III prefectures of the island (Chania, Heraklion, Agios Nikolaos, and Rethymnon).

In operational terms, the road network in Greece undertakes a large load, which is increasing over time. Figure 5 shows the time evolution of the number of vehicles registered for circulation in the country in the period 1990-2010, along with the estimated number of passenger vehicles number based on the 2020 trends (YPEKA, 2011; ELSTAT, 2018).

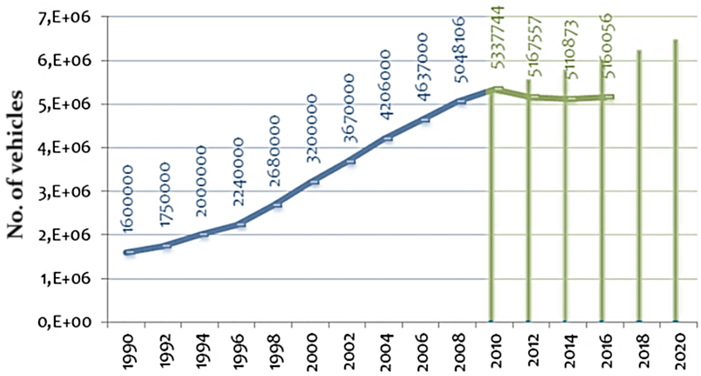

Figure 5. Number of passenger vehicles in circulation in Greece. The values of the bars are the YPEKA's forecast for the number of passenger vehicles in 2011 (Sources: YPEKA, 2011; ELSTAT, 2018).

In terms of load, the road network in Greece in 2010 served approximately 155 passenger vehicles/km of the national and provincial road network in Greece. This number is particularly high, considering that the length of 155 private vehicles in a row is more than 650m. Finally, according to the Hellenic Statistical Authority (ELSTAT, 2008), of the vehicles registered for the first time in 2006-2007, 67% were passenger cars, 11.5% were trucks, 0.25% were buses, and 21.10% were motorcycles. These values indicate the distribution of the type of vehicles making regular use of the Greek inter-regional network, which provides further information on its structure and operation.

3.2. Railway network

According to the Hellenic Railways Organization – OSE/ΟΣΕ (2015a), the history of Greek railways begins in 1869 when the inauguration of the train for the start of the Thiseio (Athens) - Piraeus service took place. Fourteen years later (1882), the Athens-based joint-stock company called "Athens - Piraeus - Peloponnese Railways" (SPAP/ΣΠΑΠ) was established. In 1884, the Thessalian Railway was inaugurated with the first route between Volos and Larissa. Seven years later (1890), the Railway Company of Northwestern Greece (SVDE/ΣΒΔΕ) was founded, which inaugurated the operation of the Messolonghi-Agrinio (Aetolia-Acarnania) line. Until the beginning of the 20th century, rail transport in Greece was carried out under the auspices of regional organizations, without the supervision of a central state body. To meet this need, the Hellenic State Railways was founded in 1920 as a legal entity under public law to consolidate the previously active regional railways of the Hellenic State and their reconstruction. This process was completed in 1965, and six years later (1970), the Hellenic Railways Organization (OSE) was established in its present form, to organize, operate, and develop the country's rail transport (Tsiotas, 2016). The modern history of OSE can be traced back to the operation of the first electrified railway line between Thessaloniki and Idomeni (Kilkis) in 1997, while eleven years later, in 2007, the organizational division of the Infrastructure from the Railways Management was carried out, with the creation of the companies EDISY SA (ΕΔΙΣΥ ΑΕ) and TRAINOSE SA. The latter became independent from the Group in 2008, being directly subordinated to the Greek State. At the beginning of the current decade, the absorption of the former subsidiary EDISY SA by OSE SA was completed, which marked the immediate implementation of the new institutional framework for the restructuring and modernization of OSE. In 2011, a rationalization of the costs, human resources, and organizational structure of the Agency took place, resulting in positive operating results for the first year, compared to previous years (Tsiotas, 2016). In 2012, OSE's operating result was also positive for the second consecutive year, and the new organizational structure was implemented, which regulated the separation of the rolling stock maintenance business and its absorption by the newly established Hellenic Railway Rolling Stock Maintenance Company - EESSTY SA (ΕΕΣΣΤΥ ΑΕ), the transfer of OSE's rolling stock to the State or a public entity and the transfer of the shares of GAIAOSE SA to the Greek State.

In technical terms, rail transport networks belong to the family of infrastructure networks (Barthelemy, 2011). According to OSE (2015b), a railway network (Figure 6) is defined as "the entire railway infrastructure managed by the company responsible for its installation and maintenance". The railway network in Greece serves 28 (out of 51) capital cities of Greek NUTS III prefectures.

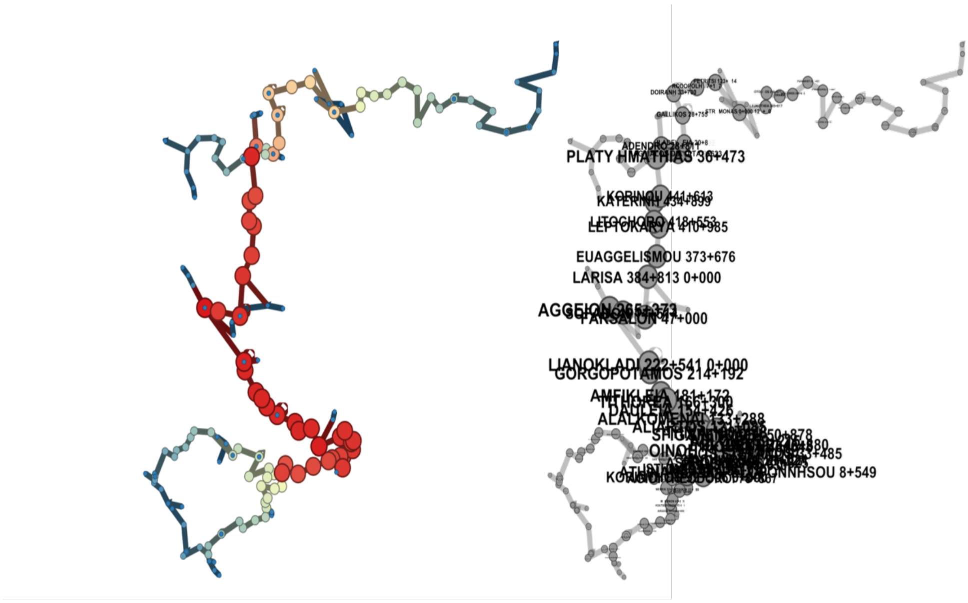

Figure 6. The graph $G_{(179,168)}$ of the rail transport network in Greece. Nodes (shown proportional to their betweenness centrality) represent rail stations and links represent rail routes (source: geodata.gov.gr, 2010; Tsiotas, 2017; own elaboration).

In the Agency's Network Statement (OSE, 2015b), the concept of the path is defined as "the capacity of the infrastructure required to move a train between two locations in a given time", which corresponds to the concept of the path (Barthelemy, 2011) in terms of complex network analysis. Further, the concept of a transport hub is defined as "a specific geographical location/station in the network that serves to provide traffic and/or customer (passenger and/or freight) services". Since the last decade (OSE, 2013), OSE's railway network has a total length of 2,773 km, of which 2,265 km correspond to active lines, 321 km to a suspended network, and 187 km to a discontinued network, as shown in Table 2.

Table 2
The OSE Network

Route type	**Length** (km)			
	Active Network		**Deactivated**	**Total**
	In commission	*Temporarily Suspended*		
Standard width, single, electrified	82	0	0	82
Normal width, single, non-electrified	1,200	34	74	1,307
Normal width, double, electrified	355	0	0	355
Standard width double non-electrified	168	0	0	168
Metric width	393	275	113	782
Combined range	29	0	0	29
Width 0.75m	22	0	0	22
Width 0.60m	16	12	0	28
Σύνολο	**2,265**	**321**	**187**	**2,773**

(source: Tsiotas, 2016)

The maximum speed of traffic within the network is 160km/h, applied in 18% of the railway network. In 18% of the rail network a speed of less than 79km/h is applied, in the rail network's 40% a speed of 80-119km/h is applied, and in the remaining 24% a speed of 120-159km/h is applied (OSE, 2013). According to the Network Statement of the Organization (OSE, 2015b), the total number of nodes served by the Greek railway network includes border, terminal, passenger, and freight stations. Border stations are the network's connection points with the respective railway networks of neighboring countries, terminals are the termination nodes of the railway infrastructure, and passenger and freight stations are the hubs for passenger boarding and freight loading respectively (Tsiotas, 2016). The operation of the Greek rail network is subjected to priority criteria for specific services (OSE, 2015b), to ensure the provision of appropriate transport services, taking into account the social importance of the priority service for the excluded ones. The main priority criteria are to serve first of all intercity lines, then suburban lines, then regular passenger lines, and finally freight lines. Finally, the rolling stock of the railway network is divided, according to its mechanical role, into traction (wagons) and trailers (wagons). In turn, traction rolling stock is divided, according to its economic role, into passenger and freight rolling stock (OSE, 2013).

3.3. The maritime network

In the Greek etymology (Mandala, 1988), the Greek synonym of maritime (ακτοπλοϊκός) derives from the compound words coast (ακτή) + sailing (πλους), literally referring to sailing near the coast and (more generally) to maritime transport between ports within the same country. Along with walking, coastal shipping was probably the earliest mode of transport in coastal areas, since the construction of floating platforms and ships did not require the invention of the wheel (Tsiotas, 2016). Navigation in coastal shipping is essentially "coastwise", namely the (geographical) ship position is determined each time by visual contact with the geomorphology of the land and with the additional use of aids (such as compass, nautical charts, lighthouses, etc.). Coastal navigation is included in all types of maritime transport because the beginning and end of a voyage always refer to a land location, i.e. the place of origin and destination (Tsiotas, 2016). Greece is a Mediterranean country with a long tradition of maritime transport, due to its geographical location and geomorphology, as well as to the restless spirit of the Greeks, who from ancient times have been inclined towards adventure and knowledge.

Geographically, it is located in the intersection of two continents (Europe, Asia) and three seas (Black Sea, Mediterranean, Adriatic) and is covered by the Aegean archipelago, which has more than 1,350 islands and islets, of which more than 230 are inhabited (Psaravtis, 2006; Tsiotas and Polyzos, 2015a). The Greek geomorphology has favored the development of a strong navigation system, and as a result, it is now included among the world's strongest maritime powers. Dating back to Homer, information is being drawn from the works of Homer that substantiates the power of Greek navigation at that time. Even the prevalence in international terminology of words such as nautical, nautilus, nave, etc., indicates the prominent importance of Greek navigation and its considerable influence worldwide.

In technical terms, Greek-owned merchant shipping consists of Greek-owned ships registered either under Greek or foreign flags, with a fleet of over 3,400 ships (weighing more than 1 teratonne - 1ttn) of all types and a total capacity of almost 10^8 gtn (gigatonnes). Greek shipping has been ranked (for many decades) amongst the top positions of the world's major shipping powers, holding about 5% of the registered fleet capacity worldwide (YNA, 2015a,b). The Greek-flagged fleet currently numbers over 1,400 vessels, with a total capacity of almost $3.3 \cdot 10^7$ gtn, placing the country in the top-10 world ranking, in terms of the capacity of the shipping fleet. At the European level, the Greek merchant fleet occupies the first place and has a capacity share of approximately 25% of the European fleet and about 40% of the total capacity of the EU merchant fleet. The age of ships registered in the Greek registries is relatively half of the worldwide fleet, indicating a modernization trend of the Greek fleet (YNA, 2015a). Furthermore, Greek ocean-going merchant shipping is active at an international level, serving more than 95% of the fleet's capacity to the transport needs of third countries, an activity known internationally as cross trade. Finally, Greek registered ships employ a significant number of workers, more than 25,000 (YNA, 2015b. The infrastructure of Greece's coastal transport network is labyrinthine, due to the Greek rich maritime geomorphology, which requires the servicing of numerous destinations. In particular, on an annual basis, the operation of the Greek coastal network is specialized in meeting the needs of the residents of the Greek islands and freight traffic, while during the summer period, it is also charged with seasonal tourism, which multiplies the coastal traffic and the operational needs of the coastal infrastructure (Tsiotas and Polyzos, 2015a). According to Tsiotas and Polyzos (2015a), the Greek maritime network counts 229 ports (Figure 7), from which almost half exclusively develop freight activity. The modeling and study of the Greek maritime network is particularly complex since the route determination is a result of the private initiative of the numerous shipping companies and is regulated by the rules of the free market (Tsiotas, 2016). The seasonal variation of ferry traffic is particularly important, depriving many routes of the Greek coastal transport network, resulting in issues of management of the barren routes that are subsidized on a case-by-case basis by the state to maintain transport and communication with remote and arid areas (Tsiotas and Polyzos, 2015a).

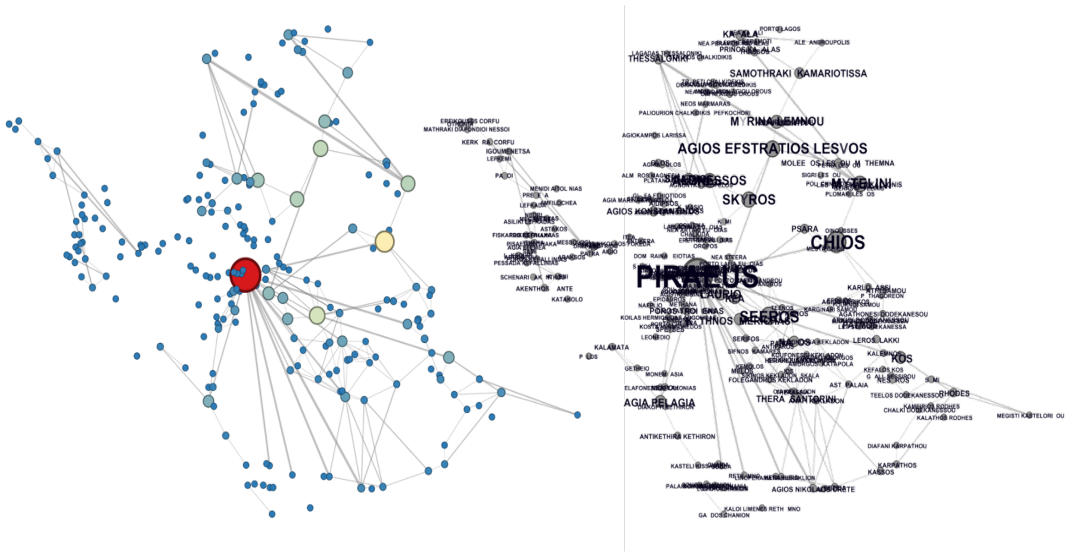

Figure 7. Graph $G_{(229,231)}$ of the maritime ferry network in Greece. Nodes (shown proportional to their betweenness centrality) represent ports and links represent ferry routes (source: Tsiotas and Polyzos, 2015a; own elaboration).

The port of Piraeus plays a key role in the operation of Greece's coastal shipping network. In particular, Piraeus hosts more than 1,200 foreign shipping companies, which manage the entire Greek-owned fleet (more than 3,200 seagoing vessels under the Greek flag), employing more than 12,300 people in their activities. In addition, Piraeus port is home to numerous companies related to shipping, as well as to shipping-related activities (such as charterers, shipyards, shipyards, agencies, catering and fuel companies, maritime courts, etc.) (YNA, 2015b). According to Law 2932/01 and European Regulation 3577/92/EEC, Greek and Community shipowners can freely operate their vessels in maritime cabotage, on routes of their choice, depending on their business initiative. Vessels are operated annually - with exceptions considered on a case-by-case basis - following a declaration submitted by the shipowners within the first month of the year, indicating the desired routes to be served during the scheduling period from 1 November of the same year to 31 October of the following year (YNA, 2015c). Within this context, state control is limited to verifying the existence of the legally required routing conditions and ensuring the protection of the public interest. In particular, the competent Ministry (Ministry of Maritime Affairs and the Aegean) has the possibility, exceptionally and to the extent necessary, to intervene in the free movement of ships, in cases where issues of safety of navigation in ports and order in the land zone arise, but also in cases where the regular provision of services on specific routes is impeded (YNA, 2015c). On routes not selected for service, based on the business criteria of the shipowners, calls for public service contracts of up to 12 years are issued. The invitations to tender are issued based on the opinion of the Maritime Transport Council, which is composed of representatives of the professional and social bodies involved in the shipping sector and of local and county authorities (Tsiotas, 2016). By the decision of the Minister, following an opinion of the Council, public service obligations may be imposed on shipowners concerning ports, regularity, continuity, capacity to provide transport services, seafarers' logbook, and manning (YNA, 2015c). Finally, issues relating to the labor force of ships are covered by the provisions of Greek legislation. Those seafarers who do not hold Greek nationality are required to be certified as Greek. The Competition Commission is responsible for competition issues in maritime cabotage (YNA, 2015c).

3.4. Greek aviation network

According to Fragoudaki (2000), the business of commercial air transport began in Greece in 1931 with the operation of a single air carrier, the Hellenic Air Transport Company (EES/EEΣ), which operated a fleet of four Junkers G24s, each with twelve seats. With Eleftherios Venizelos, the Prime Minister of Greece, as its first passenger, EES operated for nine consecutive years until the beginning of World War II, serving a total of 6,690 domestic passengers. In 1946, after the end of World War II, air operations resumed, this time by a different company, and in 1947 three additional air carrier licenses were granted. In 1951, the Greek government decided to merge these three companies to create a national carrier, while in 1955, in an attempt to overcome the financial problems that arose, it granted the exclusive right to operate domestic air transport to the tycoon Aristotle Onassis, by selling the exclusive right to operate domestic air transport, creating a monopoly in the operation of Greek air transport. This concession included all flight operations, helicopter flights, aircraft repair, and maintenance and ground handling services. This event marked the beginning of the historical journey of Olympic Aviation (Tsiotas and Polyzos, 2015b). In 1975, the Greek government regained full ownership of Olympic Airways from Onassis, continuing the established monopoly of national air transport. One of the main consequences of this monopoly was the restriction of the operation of charter flights, which - among other things - were deprived of the right to provide services starting in Greece and were obliged to serve incoming tourists to their destination by making a stopover in Athens and transferring to a domestic Olympic flight. Due to these restrictions, Athens Airport received over 70% of international arrivals during that period (ETEM, 2010; Tsiotas, 2016). Since the 1980s, the Greek state gradually began to recognize the importance of charter airlines in the tourism and general economic development of the country, relaxing the existing restrictions on their operation. In particular, in 1982 the airports of Lemnos, Lesvos, Mykonos (in the Aegean Sea), and Zakynthos (in the Ionian Sea) were allowed to host the first international charter flights. In addition, in the context of harmonizing national legislation with the relevant EU directives and regulations, in 1992, PD.276/91 was passed, which marked the beginning of the liberalization of national air transport. This Presidential Decree allowed flights from Greece to destinations in EU member states, as well as the operation of unscheduled domestic flights by Greek private airlines. However, the final liberalization of air transport took place shortly afterward, when the government withdrew Olympic Airways' monopoly on scheduled domestic flights, first in 1996 for routes within the mainland and then in 1998 for the Greek islands (ETEM, 2010; Tsiotas and Polyzos, 2015b).

Olympic Airways operated under a monopoly for almost 35 years, based in Athens. During the time under state ownership, it developed two subsidiaries, the first of which operated as the main carrier and the second as a Low-Cost Carrier (LCC). During the period 1976-1999, the company underwent 30 top management changes, each with an average life span of 9 months, and its strategic orientation was largely driven by social and political motivations. Indicative actions of government interventions in the management of Olympic Airlines were the operation of regular flights to remote and isolated areas, such as small islands and areas with insufficient alternative transport coverage, and the offering of tariff privileges, such as ticket discounts, to selected social groups (Fragoudaki, 2000; Tsiotas and Polyzos, 2015b). Aegean Airlines was founded in 1987 under the name Aegean Aviation, with its headquarters in Athens. In 1992 it was the first private Greek carrier to obtain a pilot's licence and in 1994 it began operating VIP flights around the world with a fleet of privately owned small aircraft. In 1999, the company was officially inaugurated with the first flights from Athens to Thessaloniki and Heraklion, using 2 privately owned large aircraft. In 2001 it merged with another private company, Cronus Airlines, increasing its fleet and airline network. In 2004, Aegean Airlines homogenized its fleet by retaining two aircraft types and in 2005 it further increased its fleet by entering into a partnership with one of the largest German airlines. In 2007 Aegean Airlines was listed on the stock exchange and in 2008 it further increased its fleet, obtaining ISO certification. In 2010, it became a member of a major global airline alliance network (Star Alliance). The continuous growth, combined with the aforementioned pathologies of its competitor Olympic Airlines (formerly Olympic Airways), and the introduction of the economic crisis in Greece, led Aegean Airlines, in October 2013, to make the acquisition of Olympic Airlines, which marked a new era in the domestic aviation market (Tsiotas and Polyzos, 2015b).

In Greece, in the period after 2000, a total of 10 small companies were active, mainly operating occasional charter flights. Today, three LCC companies are operating in the domestic air transport market, Sky Express, Astra Airlines, and RyanAir. Sky Express is based in the city of Heraklion, Crete. It was founded in early 2005 by a consortium of two investors who were former members of Olympic Airways. In July 2005 Sky Express started charter and cargo flights, air taxi services, emergency medical services, excursions, and tours. The company operates from its main base at Heraklion Airport, with over 20 destinations (Tsiotas, 2016). Astra Airlines is based in the city of Thessaloniki. It is an LCC company supported by a Greek travel agent and started operating in the domestic airline market in 2008. Today it operates in the Greek market with regular annual flights, from Thessaloniki and Athens, having 10 main destinations (Tsiotas and Polyzos, 2015). Finally, the RyanAir LCC company of Irish interests operates in the European air market. It is based in Ireland (Dublin) and its operational base is Stansted Airport in London. Founded in 1985, the company has developed a fleet of 300 aircraft and operates to more than 110 destinations in Europe, making it the largest European low-cost airline. In 2010 it started operating from Greek airports to European destinations, while in the summer of 2014, it launched domestic flights from Athens and Thessaloniki to Chania and Rhodes, which are currently seasonal.

In technical terms, there are currently 45 airports in Greece (Figure 8), of which 39 are active and the remaining 6 are suspended. Of the 39 airports in operation, 34 are state-owned and managed by the Hellenic Civil Aviation Authority (HCAA), 4 are owned by local authorities but managed by the HCAA, while Athens' Eleftherios Venizelos airport is operated under a concession to the private company Hochtief and is due to become state-owned after the expiry of its contractual operating period. In addition, 28 airports are located in island regions, while only 11 are located on the Greek mainland, which indicates the competitiveness of the air transport mode over the maritime transport mode and also reflects the increased volume of the country's tourism needs on the islands. In particular, 73% of all foreign tourists visiting the country arrive by air, while 60% of the available tourist accommodation is located in the island territory (ETEM, 2010; Tsiotas, 2016).

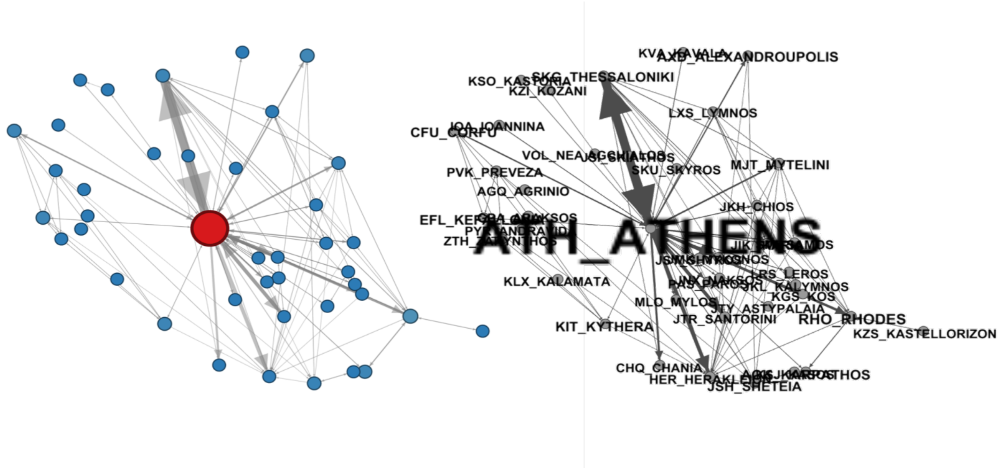

Figure 8. The graph $G_{(41,231)}$ of the air transport network in Greece. Nodes (shown proportional to their betweenness centrality) represent airports and links represent flight routes (source: Tsiotas and Polyzos, 2015b).

In terms of the geography of flights, 15 of the 39 active airports are designated as international, 11 domestic, while 13 are occasionally designated points of entry to and exit from the country. Figure 9a shows the evolution over time of the number of active airports in Greece over the period 1978-2008, which shows a doubling of island airports serving domestic traffic and a tripling of island airports serving international traffic, while the corresponding situation for mainland airports shows a subtle increase. In 2008, over 40 million passengers traveled to Greece, of which 31.23% were domestic and 68.77% international. Furthermore, of the total volume of flights in that year (Figure 9b), approximately 39.42% were covered by charter flights (ETEM, 2010). According to the Community airport classification system (HCAA, 2013), Athens Airport is a category A airport (annual traffic of more than 10 million passengers), which serves 39.79% of the country's total passengers. Heraklion Airport is a category B airport (annual traffic of 5-10 million passengers), serving 13.39% of the total traffic. Furthermore, 5 airports (Rhodes, Thessaloniki, Corfu, Chania, Kos, Corfu) are category C airports (with an annual traffic of 1-5 million passengers), handling 34.84% of the traffic. Finally, 32 Category D airports (with annual traffic of less than 1 million passengers), handle 11.99% of traffic. Several of the Category D airports owe their operation to the subsidies granted through the Public Service Obligation (PSO). The above categorization shows that the Greek aviation landscape is characterized by a high degree of concentration, with the two largest airports in the country, Athens and Heraklion, accounting for more than 50% of all passenger traffic (Tsiotas, 2016; Tsiotas et al., 2020). On the other hand, several large airports operate to serve local needs, without always ensuring their economic viability (ETEM, 2010).

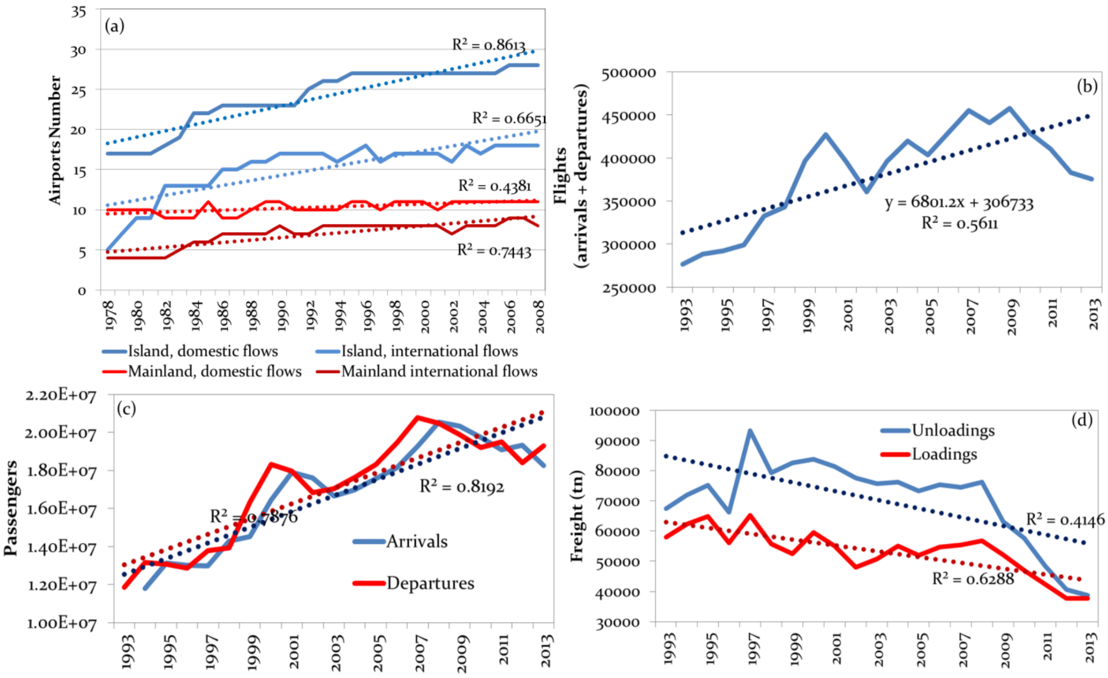

Figure 9. (**a**) Number of Greek airports in operation for the period 1978 – 2008; (**b**) Aircraft traffic over time (arrivals + departures) at all active airports in Greece, 1993-2013; (**c**) Air passenger traffic evolution at all active airports in Greece, 1993-2013; (**d**) Air cargo traffic evolution at all active airports in Greece, 1993-2013 (sources: ETEM, 2010; HCAA, 2013; Tsiotas, 2016).

As shown in Figure 9b, air traffic (aircraft traffic) in Greece has increased by 50% over time (since 1993), but it is evident that it has been affected by the onset of the economic crisis (since 2009), recording a decrease of 18%. In addition, air passenger traffic (Figure 9c) has shown an increase of more than 80% over time but has also been affected by the onset of the crisis, with a decrease of 10% over the same period. By contrast, air freight traffic has declined by 60% over time (Figure 9d), with the rate of decline increasing during the crisis. According to these data, air traffic in Greece seems to be specialized in passenger services, as freight transport is decreasing over time. This is apparently due to the competitiveness of maritime transport as a mode of freight transport in Greece (Tsiotas and Polyzos, 2015b; Tsiotas, 2016), which lags in terms of speed but outperforms in terms of transport costs, and the relatively short sea distances that exist in the Greek seas.

4. Empirical analysis

In this section, an empirical analysis is carried out to establish the existence of a correlation between transport infrastructures and their socio-economic environment. The analysis is based on the construction of a multivariate linear regression econometric model, which expresses the level of welfare of the counties (dependent variable y) as a function ($y = f(x_1, x_2, ..., x_n)$) of a set of independent variables ($x_1, x_2, ..., x_n$) related to the transport infrastructure and the socio-economic context of the counties of the country. The variables used in the analysis are shown in Table 3 and are grouped according to their relevance into three categories, socio-economic, transport network variables, and mixed variables (containing information from both of the previous two categories).

Table 3

Variables participated in the empirical analysis

Variable	Symbol	Description
Dependent Variable		
Y	WELF	Welfare level of the prefecture's population.
(*i*) Socioeconomic (SE) Variables		
X_1=SE_1	T_{GDP}	Participation of the prefecture's tourism in the national GDP.
X_2=SE_2	B_{SEC}	Participation of the prefecture's secondary sector in the national GDP.
X_3=SE_3	C_{SEC}	Participation of the prefecture's tertiary sector in the national GDP.
X_4=SE_4	EDU	Level of education of the prefecture's population.
(*ii*) Network (N) Variables		
X_5=N_1	$ROAD_{DENS}$	Road network density. Calculated by the ratio of the length of the road network to the region's area.
X_6=N_2	$RAIL_{DENS}$	Rail network density. Calculated by the ratio of the length of the road network to the region's area.
X_7=N_3	PORTS	Number of ports in a region.
X_8=N_4	AIRPORTS	Number of airports in a region.
(*iii*) Mixed Socioeconomic and Network (SEN) Variables		
X_9=SEN_1	TPP	Total population potential of a region. Calculated by the ratio of population to the distance of a region to its own and neighboring markets. It expresses the potential influence of markets in a region.

Sources: Tsiotas and Polyzos (2015a,b); Tsiotas (2017); Polyzos, 2019; Tsiotas, 2021

The welfare level (WELF) is chosen as the dependent variable in the econometric model because it is considered to be a more representative indicator of the level of development of a region than, for example, GDP, which is expressed more in terms of economic growth (Polyzos, 2019). The method used in the econometric model is the backward elimination method (BEM) (Norusis, 2004; Walpole et al., 2012) in which the process starts with the set of available variables, producing a sequence (series) of subsamples with successive elimination of the most statistically insignificant variable (p-value > 0.1) in each cycle. The method terminates at the point where all the remaining variables are statistically significant for the model. For the set $\mathbf{X}=\{X_1, X_2, ..., X_9\}$ of dependent variables in Table 3, the model sequence the $(Y_k)_{k\geq 0}$ is described by the following mathematical relations:

$$\left(Y_k\right)_{k\in\{1,\ldots,n\}\subseteq\mathbf{N}} \middle| Y_k = \sum_{i=1}^{9-k+1} b_i \cdot X_i + c_k \cdot \mathbf{1}$$

$$\begin{cases} \mathbf{X}_9 = \{X_1, X_2, ..., X_9\}, \\ X_i \in \mathbf{X}_{9-k+1}, \\ \mathbf{X}_{9-k} = X_{9-k+1} - \{\mathbf{x}_p\} \\ X_p \in \mathbf{X}_{9-k+1} : P[b(X_p)=0] = \max\{P[b_i = 0] \geq 0,1\} \end{cases} \quad (1),$$

where Xi, i=1,....,9, is any variable in Table 3 of length 51 (each corresponding to one value of the variable for a particular NUTS III region). The results of the multivariate BEM analysis are shown in Table 4. The determination (see sub-table a) of the model is R^2=0.638 and expresses that 63.8% of the variability of the independent variables is described by the model (i.e., the variability of the dependent variable).

Table 4
Results of the econometric model for the welfare level of Greek prefectures

a. Summary

Model	R	R^2	Adjusted R^2	SE of estimation
Backward Elimination (6th loop)	0.799	0.638	0.607	12.59

b. Coefficients[(a,b)]

Model		Non-standardized coefficients		Standardized coefficients	t	Significance
		B	Std. Error	Beta		
6	(constant)	11.710	6.258		1.871	0.068
	T_{GDP}	-0.018	0.007	-0.537	-2.743	0.009
	EDU	0.696	0.190	0.597	3.671	0.001
	PORTS	1.763	0.332	0.564	5.315	0.000
	$ROAD_{DENS}$	0.051	0.026	0.274	1.965	0.056

a. Response/dependent variable: WELF
b. Predictor/independent variables: TPP, TGDP, EDU, B_{SEC}, C_{SEC}, PORTS, AIRPORTS, $RAIL_{DENS}$, $ROAD_{DENS}$

As shown in Table 4b, the statistically significant variables involved in the final model are tourism product (TGDP), education level (EDU), number of ports (PORTS), and road density (ROADDENS) of the counties. The relationship of the variable TGDP is negative in the model and expresses that regions with an increased tourism product tend to have a lower level of welfare. The other variables have a positive contribution and express that regions with a high level of welfare tend to have a higher level of education in the population, a larger number of ports, and a denser road network. Overall, it can be observed that two of the four variables involved in the econometric model describe transport network infrastructure, which outlines the importance of the transport infrastructure category in shaping the variability of the dependent variable (level of prosperity). As can be seen from the values of the standardized coefficients, this contribution is of the order of 60% of the positive contribution of the dependent variables in the model. The above analysis seems to validate the previous overview and highlights in quantitative terms the contribution of transport network infrastructure to the economic and regional development of the country.

5. Conclusions

The importance of transport in the economic life of Greece is evident in many aspects of its existence and activity, such as its administrative structure; the allocation of resources; and its productive constitution. In this light, this article attempted to highlight this importance by examining longitudinal and cross-sectoral statistics describing some fundamental macroeconomic indicators and measures. The focus of the study was placed on transport infrastructure and transport networks, which constitute a fixed structural capital that extends, in different forms, throughout the country. The networks studied are the road, rail, maritime, and air transport networks of Greece, focusing both on their geometry and technical characteristics and on their historical, traffic, and political context.

In the part of the empirical analysis, an econometric multivariate linear regression model was constructed that described the welfare level of the counties as a function of a set of independent variables related to the transport infrastructure and the socio-economic context of the counties of the country. The analysis revealed the significance of the transport infrastructure variables in the model, both in terms of their number and size, which suggests the importance of the transport infrastructure category in shaping the variability (as described by the model) observed in the level of well-being of counties. This importance is measured in the model as positive, expressing that regions with a higher level of prosperity generally tend to show an improved picture in their road and port transport infrastructure. However, under a combined reading of the approaches in this paper, it is recognized that how transport networks contribute to the promotion of regional development is governed by a high degree of complexity and takes place in combination with the other development factors of a region (geographical location, concentration economies, sectoral composition of local production and employment). As the previous analysis has shown, the productive base of the Greek regions appears to be structured in such a way as to benefit positively from road and port infrastructure. The notable absence of aviation infrastructure in the model outlines the existence of a development model based on basic infrastructure.

In addition to the focus on the case of Greece, the literature and empirical study conducted in this paper highlighted some key conceptual and theoretical axes regarding the relationship between transport networks and economic and regional development. First, it became apparent that transport networks reflect in their structure information that describes the society using them. In this light, the study of transport networks can provide information on the socio-economic needs met by a country's transport infrastructure and on the mechanisms that have worked diachronically to overcome spatial constraints. It then became apparent that the structure of transport networks is a fixed resource for economic, social, and regional development so their study can provide information on the development dynamics of a country, both at national and regional level. The ultimate aim of the article was to highlight, from a macro perspective, the structural and functional dimensions that make up the concept of transport networks, the need to consider them together in scientific research, and the various aspects of the study of transport infrastructure and networks.

5. References

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