

DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF MARITIME BUSINESS ADMINISTRATION
MARITIME BUSINESS ADMINISTRATION PROGRAM
DOCTORAL THESIS
Doctor of Philosophy (PhD)

**THE ROLE OF LOGISTICS INFRASTRUCTURE ON
TRADE DEVELOPMENT: AN APPLICATION FOR
TURKEY**

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İZMİR- 2021

THESIS APPROVAL PAGE



DECLARATION

I hereby declare that this doctoral thesis titled as “The Role of Logistics Infrastructure on Trade Development: An Application for Turkey” has been written by myself in accordance with the academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honour.

13/10/2021

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ABSTRACT
Doctoral Thesis
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Over the past two decades, Turkey has undertaken considerable investment in transport infrastructure to found a well-developed transport network and to get integrated into global supply chains. This study aims to evaluate trade expansion benefits of transport network investment in Turkey to get insights on transport and industrial policy dimensions. As a research strategy, an inductive content analysis integrated with a systematic literature review approach is performed for the empirical studies on the broader economic benefits of transport infrastructure to derive guidance for the quantitative analysis of the subsequent research phase. The quantitative methods consists of two separate analysis. Firstly, short-run and long-run dynamics between land transportation infrastructure, ICT development and trade expansion are investigated within ARDL framework as a preliminary causality analysis. Then, gravity models of trade are estimated for exports and imports with infrastructure investments in various transport modes as the main explanatory variables as well as other independent variables involving factors of bilateral trade flow, ICT development, control variables for Turkey and control variables for partner countries. A main inference from the analysis entails that transport infrastructure investment acts as a driver for import growth rather than export expansion. As another important insight, transport infrastructure investment should be carried out with all transport types considered, based on a long-term transport policy scheme with

special attention on road and rail infrastructure. Moreover, transport modes should be integrated to enhance network and connectivity of the overall logistics system, enabling prevalent practice of multimodal and intermodal transportation.

Keywords: International Logistics, Transport Infrastructure, Economic Integration, Trade Development, ARDL, Gravity Model, Logistics Networks, Transport Economics.



ÖZET

Doktora Tezi

Lojistik Altyapısının Ticaret Gelişimindeki Rolü: Türkiye İçin Bir Uygulama

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Son yirmi yılda Türkiye, iyi gelişmiş bir ulaşım ağı kurmak ve küresel tedarik zincirlerine entegre olmak için ulaşım altyapısına önemli yatırımlar yapmıştır. Bu çalışma, ulaştırma ve sanayi politikası boyutları hakkında fikir edinmek için Türkiye'deki ulaştırma ağı yatırımının ticareti genişletme yönündeki faydalarını değerlendirmeyi amaçlamaktadır. Bir araştırma stratejisi olarak, sonraki araştırma aşamasındaki nicel analiz için kılavuz elde etmek amacıyla, ulaştırma altyapısının daha geniş ekonomik faydaları üzerine ampirik çalışmalar üzerine sistematik literatür incelemesi yaklaşımıyla bütünleştirilmiş bir tümevarımsal içerik analizi yapılmıştır. Nicel yöntemler iki ayrı analizden oluşmaktadır. İlk olarak, bir ön nedensellik analizi olarak, ARDL modeli çerçevesinde karayolu ve demiryolu ulaşım altyapısı, bilgi ve iletişim teknolojileri gelişimi ile ticaret gelişimi arasındaki kısa ve uzun vadeli dinamikler incelenmiştir. Ardından, ihracat ve ithalat için ticaret çekim modelleri, başlıca açıklayıcı değişkenler olarak çeşitli ulaşım modlarına yapılan altyapı yatırımları ile ikili ticaret akışı faktörleri, bilgi ve iletişim teknolojileri gelişimi, Türkiye ve ticaret ortağı ülkeler için kontrol değişkenlerini içeren diğer bağımsız değişkenler kullanılarak tahmin edilmiştir. Analizden elde edilen temel bir çıkarım, ulaştırma altyapısı yatırımlarının ihracat artışından ziyade ithalat büyümesi için bir itici güç olarak hareket ettiğini göstermektedir. Bir başka önemli çıkarsama olarak, ulaştırma altyapısı yatırımı tüm ulaştırma türleri dikkate alınarak, karayolu ve demiryolu altyapısına özel önem verilen uzun vadeli bir ulaştırma

politikası planına dayalı olarak gerçekleştirilmelidir. Ayrıca, genel lojistik sistemi ağını ve bağlanabilirliğini geliştirmek için ulaştırma modları, çok modlu ve intermodal taşımacılığın yaygın uygulamasını mümkün kılacak şekilde birbirine entegre edilmelidir.

Anahtar Kelimeler: Uluslararası Lojistik, Ulaştırma Altyapısı, Ekonomik Entegrasyon, Ticaret Gelişimi, ARDL, Çekim Modeli, Lojistik Ağlar, Ulaştırma Ekonomisi.



THE ROLE OF LOGISTICS INFRASTRUCTURE ON TRADE DEVELOPMENT: AN APPLICATION FOR TURKEY

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ABBREVIATIONS

AGC	European Agreement on Main International Railway Lines
AGR	Declaration on the Construction of Main International Arteries
AGTC	European Agreement on Important International Combined Transport Lines and Related Installations
ARDL	Autoregressive Distributed Lag
ARMA	Autoregressive Moving Average
BRI	Belt and Road Initiative
BSEC	Black Sea Economic Cooperation
BTK	Baku-Tbilisi-Kars
CBA	Cost-Benefit Analysis
CBD	Central Business District
CP	Core-Periphery Model
DGCA	Directorate General of Civil Aviation
DTO	Chamber of Shipping
ECO	Economic Cooperation Organization
ECT	Error Correction Term
GCI	Global Competitiveness Index
GDP	Gross Domestic Product
GLM	Generalized Linear Models
GLS	Generalized Least Squares
GVC	Global Value Chain
ICT	Information and Communication Technologies
IMF	International Monetary Fund
ITU-D	Telecommunication Development Sector
JB	The Jarque-Bera Statistic
KGM	General Directorate of Motorways
KPSS	Kwiatkowski-Phillips-Schmidt-Shin Test
LM	Lagrange Multiplier
LPI	Logistics Performance Index
LSCI	Liner Shipping Connectivity Index

MNCs	Multinational Corporations
MNEs	Multinational Enterprises
OBOR	One Belt One Road
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
PPML	Poisson Pseudo-Maximum Likelihood
SFN	Scale-Free Networks
SWN	Small World Network
TAR	Trans-Asian Railway
TCDD	Turkish State Railways
TEM	Trans European South-North Motorway Project
TEN – T	The Turkish Trans-European Transport
TER	Trans-European Railways
TRACECA	Transport Corridor Europe Caucasus Asia
TTH	Trans Turkey Highway
TURKSTAT	Turkish Statistical Institute
UK	United Kingdom
UNECE	The United Nations Economic Commission for Europe
UNESCAP	The United Nations Economic and Social Commission for Asia and the Pacific
US	The United States
USA	The United States of America
VAR	Vector Auto Regressive Model
VECM	Vector Error Correction Model
WEF	World Economic Forum
WGI	Worldwide Governance Indicators

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INTRODUCTION

This thesis investigates the impact of transport infrastructure investment in different transport types on trade development in Turkey. In the introduction part, general framework of the dissertation is presented by explaining research background, research problem and aims of the study, theoretical foundations, scope of the study, significance of the study and structure of the thesis.

a. Background of the Thesis

The expansion of international trade in recent decades has fueled the importance of global value chains (GVCs) as propounded by Baldwin (2013); Kaplinsky and Morris (2016). GVCs transform the practices of trade conduction and value creation. By decomposing the production processes into different countries all over the world (De Marchi et al., 2018), GVCs have led to reductions in poverty (Van den Broeck et al., 2017), productivity surge (Pahl and Timmer, 2020) and income growth on a global scale (Jangam and Rath, 2021). Government policies have an important role in the participation of domestic firms in this global value system with supporting factors including geographical location, factors of production, organizational and institutional setting. The rapid globalization process within the last thirty years has interlinked countries to such an exceptional extent that governments have been developing policies to adapt to the fast-changing global business environment and its requirements. Within this context, investment in transportation infrastructure has begun to function as a fundamental policy tool to achieve national competitive advantage. A well-developed transportation system provides reliability, timeliness and predictability satisfying the needs of GVCs for cost-effective production and on-time delivery (Taglioni and Winkler, 2016).

According to World Development Report 2020 (World Bank, 2020a), improved logistics infrastructure is pointed out as an instrument in decreasing trade costs, expanding trade and promoting GVCs in a persistent way especially when strengthened by advancements in information and communications technology (ICT). The reinforcing effects of ICT infrastructure improvements provide higher advantages

for developing countries in overcoming greater costs and limitations in digital technology base. At the same time, transport infrastructure developments in the territory of an individual country refer to the expansion of networks not only on a domestic scale but also additional connectivity on a regional and global scale. So, a country is not the only beneficiary of investments in roads, railways, seaports and airports within its domestic borders. The economic impacts are also realized by neighbouring countries and trade partners in the global networks. In the case of large transport infrastructure projects encompassing multiple regions, all regions in the transportation system benefit from spillovers arising from transport infrastructure developments in a single country or region.

Transport infrastructure investment also contributes to the national competitiveness of a country. In the well-known book 'The Competitive Advantage of Nations', Porter (1990) attributes national competitiveness to the availability of four essential aspects: factors of production; demand; related and supporting industries; firm strategy, structure and rivalry within the concept of Diamond Model of National Advantage. When transport infrastructure enhances, a fundamental requirement for an efficient production process is provided in a more beneficial condition for the movement of raw materials, semi-finished and finished goods, as an immediate impact. The increased network also enables the higher mobility of skilled labor which is vital for some industries to survive and necessary to compete for others. The better connectivity also helps to the demand conditions by cheaper and faster freight/passenger transport networks. Agglomeration effects of transport infrastructure are likely to facilitate the availability of related and supporting industries which are well-equipped to contribute to the sectoral growth. Finally, improved logistics infrastructure might establish an environment where local firms learn from GVCs in terms of strategy and competition. So, transport infrastructure can fuel other factors involving private investment, production efficiency, collaboration, spillover effects to a further level through multiplier effects. Deng (2013) defines this notion as 'transport-led growth' in reference to the general prospects of policymakers on the prosperity benefits of transport infrastructure investments.

b. Introduction to Research Problem and Aims of The Study

Transportation acts as a catalyzer in economic development of a country as it enables the movement of goods all over the world. Transportation service can be performed upon the availability of necessary infrastructure. Significant attention has been paid to the benefits of transportation projects by scholars and policymakers from public and private sector to understand the implicit and not-easily-quantifiable economic impacts of transportation investments. The economic gains from transportation investments can be classified in two general categories as short-term gains and long-term gains (Meersman and Nazemzadeh, 2017). Short-term gains occur as a result of the economic activities during the process of construction in line with the Keynesian view that it shows a temporary rise in output which is expected to reach a theoretical equilibrium level in the long run (Lakshmanan and Chatterjee, 2005). Thus, the long-run gains from transportation infrastructure pose a deeper question as the benefits are realized with time-lags, in parallel to findings in Canning and Pedroni, (2008) as well as Cigu et al. (2019).

Beyond economic sphere of influence, infrastructure investment is an important aspect of public policy in which transportation is regarded as a primary element along with communication and electricity, all named as ‘core infrastructure’ (Kim, 2006; WTO, 2004). So, the linkage between transport infrastructure, increase in international trade and economic growth pose an important study area. Especially for developing countries, an adequate transport infrastructure along with efficient logistics services are fundamental factors to be competitive in the arena of global supply chains (World Bank, 2009; WTO, 2004). In case of lacking transportation infrastructure or having it with an inadequate quality, economic growth is adversely affected due to limited access - a result opposite to what the transport infrastructure provisions target. According to Banister and Berechman (2001), accessibility and proximity are the main channels through which the impact of transport infrastructure expansion displays. Additional links to the transportation system result in better connectivity and allow for accession to remote areas, eventually leading to increased employment and factor productivity. As for proximity, the specialization and agglomeration economies are concentrated in certain regions- a process occurs towards proximity. On the other hand,

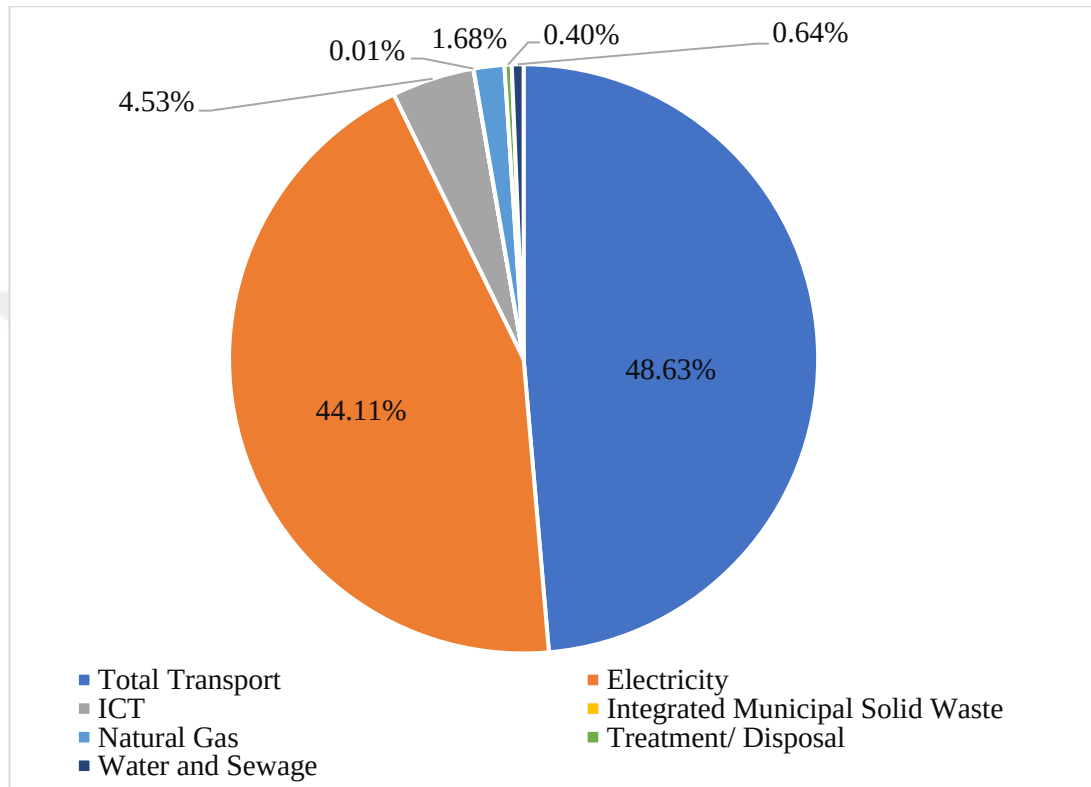
geographic proximity becomes trivial in a well-connected country by the opportunity to supply most services remotely.

The existing body of research on the benefits of transportation concentrates mainly on project appraisal aspects in the context of micro-level evaluations of mega-projects with respect to cost, time savings and return on investment under Cost-Benefit Analysis (CBA) (e.g., Ansar et al., 2016; Salling and Banister, 2009; Van Wee, 2007; Batley et al., 2019). Evaluation of return on investment for transportation initiatives has focused on direct user benefits and the economic impacts that arise from transportation cost savings in a narrow scope (Laird and Venables, 2017). Important insights can be obtained by estimating minutes of travel time saved for passengers and freight shipment or comparing the ex-post financial rate of return on the investment with the ex-ante prospects. On the other hand, some projects require more extensive exploration for the identification of realized long-term spatial coverage and broader economic benefits (Metz, 2017; Vickerman, 2007) beyond cost-benefit analysis by shifting focus to potential impacts on welfare from prospective traffic measurements (Vickerman, 2017). As the essence of the matter, transport infrastructure, which is accessible, affordable and reliable shows up as a strategic tool in economic development in multiple spheres (Luo and Xu, 2018). Hence, there are broader economic contributions of transport investment on the economy and welfare of the society to be considered. These benefits entail but are not limited to enabling clusters and agglomeration, enhanced productivity, increased market accessibility and implicit rise of supply chain efficiency (Chatman and Noland, 2011; Metz, 2008).

For a developing country, a well-structured transportation system provided by transport infrastructure investments, assists in participation and competition in global supply chains. This thesis aims to assess the benefits of transport network investment on international trade development in Turkey, with an integral objective to shed light on public and industrial policy directions on the grounds of trade expansion, global integration and export-led growth hypotheses. Thereby, the magnitude of the association between trade development and transportation infrastructure investment constitutes an important subject to survey for Turkey, as an emerging economy. In Figure 1, the distribution of private participation in infrastructure investment among sectors is presented for the period between 1990-2020 for Turkey. As the figure

demonstrates, transport infrastructure has a share of almost 50% in infrastructure investment with private participation among all projects in the last thirty years between 1990-2020. Thus, Turkey has long been pursuing a policy to advance its transport infrastructure.

Figure 1: Private Participation in Infrastructure Investment in Turkey



Source: World Bank (2019a).

In addition, ranking as the 19th largest economy in 2019 (World Bank, 2019b), transport infrastructure is an important public policy component on the pathway to achieving Turkey's sustainable development goals. Turkey has an exclusive geographic condition of being located partly in continents of Asia and Europe. Hence, Turkey is a natural platform connecting Central Asia, Europe, Russia, Middle East, the Mediterranean and North Africa. It participates in numerous international transport projects by prominent international institutions such as UNECE, UNESCAP, TRACECA, BSEC and ECO, entailed by this geographic position. Turkey increases its connectivity to global transport corridors as well as its domestic transport network in the region with its high economic integration to the world market.

Within this scope, the objectives of this thesis are outlined as

- to quantify the magnitude of the interrelationship between transport infrastructure and trade development,
- to disentangle the effects of different transportation modes on trade and
- to unfold policy implications to benefit from transport improvements better.

When Turkey's strategic importance in global networks and limited body of existing research on the trade-transport infrastructure nexus are considered, the research focus is framed for the case of Turkey with an emphasis on trade development and the unit of analysis involves trade impacts of logistics infrastructure investments. In line with the main objectives of the thesis, the theoretical foundations are constructed based on the literature on the areas of transport economics, transport geography, international trade and public policy.

In terms of methodological framework, this study is mainly based on testing the transport infrastructure-trade development theory, namely the 'a priori theory' derived from the scholarly knowledge towards later modifications based on the empirical findings. The quantitative research approach consists of a causality analysis in the first round, followed by a more in-depth exploration with a gravity model of bilateral trade flows, which are designed as separate inquiries. In the introductory analysis, the effects of land transportation system (road and railway) are examined by an Autoregressive Distributed Lag (ARDL) model to get preliminary insights on the short-run and long-run dynamics between major transportation types, exports and imports. After that, a more comprehensive model is developed to capture individual influences by each mode to understand spatial effects within a gravity model framework. The core analytical structure is based on quantitative methods however qualitative techniques are also utilized within the scope of this thesis. An inductive content analysis study integrated with a systematic literature review approach is conducted to categorize main themes, methods, geographical scale and to derive constructs used in the relevant empirical studies on the wider economic benefits of transport infrastructure. Guided by the information obtained from the content analysis, causality investigation and gravity regression analysis are conducted. Then, findings are discussed on the grounds of the initially outlined theories, searching for policy

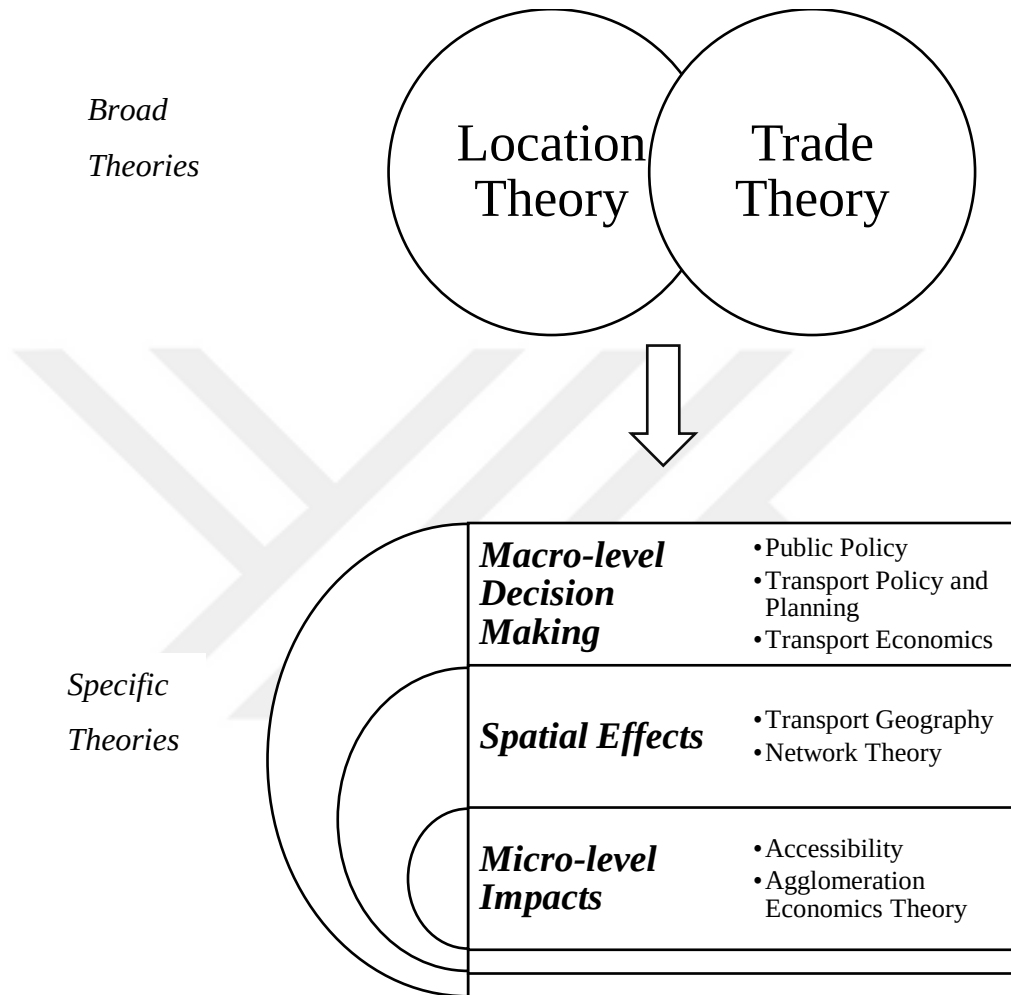
implications from diverse theoretical perspectives. The research design of this study is built upon a recently emerged research strategy ‘sequential transformative research design’ in which the results of the first phase (the integrated approach of systematic literature review and inductive content analysis) are used as inputs in the development of the second phase of research (quantitative analysis), holding the theoretical perspectives in the main focus. Although the main approach is deductive research design with quantitative techniques used for a country case- Turkey, an inductive method is also employed by going through the initial theoretical framework, the a priori theoretical setting- based on the findings with an attempt at revising the theory. Abductive reasoning emerges as a result of the combination of both inductive and deductive approaches and this reveals deeper comprehension on the topic (Kovacs and Spens, 2007), an approach embedded in the methodological strategy of this study.

c. Theoretical Foundations

Researchers have adopted a large variety of theories to explain the interrelation between transport systems, trade and economic welfare as outlined in Ferrari et al. (2019) in detail, corresponding to the multi-facet attributes of transportation as an extensive concept. By this token, theoretical foundations of this study are explained in a top-down approach as shown in Figure 2, beginning with the more comprehensive theoretical settings and finally going down to the more specific, narrower theories which are in closer connection to the scope of the thesis. To begin with, this thesis evolves out of two broad-range theories: location theory and trade theory, both representing the space-time dimension. A large branch of conceptual constructs has been developed from these two foundations in various sub-categories, although many of them are interconnected with overlapping scope and premises. The next echelon of the theoretical outline entails specific theories arising from these two baselines with three sub-categories as shown in Figure 2. In the top tier of the specific theories, the macro-level decision-making theme occupies a place with three theories: public policy, transport policy and planning along with transport economics. In the second tier, transport geography and network theory are categorized under the scope of spatial

effects. The bottom tier with the narrowest scope is related to micro-level impacts through the concepts of accessibility and agglomeration economics theory.

Figure 2: Relevant Theories



Source: Author's Own Compilation.

In the light of the mentioned theories and their interactions, the theoretical foundation of this study is grounded on the theory of new economic geography. The origins of this theory can be retraced to location theory- one of the fundamentals-, so a brief explanation about the connection of new economic geography and location theory would provide more clarity. Regarding its scope, location theory covers areas of transport geography, spatial economics, network theory and it links industrial organization with international trade theory. Location theory originated from the work

of von Thünen in 1826, concerns with the geographic location of economic activity, addressing the question of what economic activities are located where and why. In this context, with a renewed viewpoint to account for spatial effects and transport costs, new economic geography has been developed by Krugman (1991a, 1991b) to enrich the research agenda of the ‘general theory of location and space economy’ proposed by Isard (1949). At this point, it is also important to indicate that new economic geography is regarded as a part of a more specific theory, namely ‘transport geography’, despite being related to location theory in a broader sense.

With the expansion in the economic development strand of studies, researchers have sought new theories to unfold specific dynamics and interactions such as the wider economic benefits of transport systems. As this thesis is structured upon the exploration for the trade benefits of transport infrastructure investments for the emerging market case of Turkey, the theory of new economic geography forms an appropriate basis. The main assumption of this theory suggests that geographic distribution of economic activity depends on transport costs and income, also taking the distance factor into account. New economic geography suggests that network and scale effects of transport infrastructure promote economic welfare through trade expansion, mobility of high-skilled labor and increased productivity by connecting provinces for a country and integrating transport lines in the international market (World Bank, 1994). Trade expansion outcome of this mechanism propelled by developments in the transport infrastructure network is to be analyzed throughout the thesis.

d. Scope of the Study: Main Research Questions

The research interest of this thesis concentrates on the impact of the transport infrastructure system on export and import development in Turkey. Within this framework, the main research question of the study is formed as

RQ: What is the magnitude of the effect of transport infrastructure investment on exports and imports in Turkey?

Accordingly, the following research objectives are identified:

- to reveal the impact differences among the individual transport mode developments on trade in Turkey,
- to distinguish any disparity in the response to transport network expansion for exports and imports,
- to identify effects of other transport-related factors- distance to incorporate spatial patterns; existence of common language, common border and colonial relationship as standard variables in a trade flow model as well as ICT as a core infrastructure item, control variables for institutional and government quality in Turkey and other control variables for trade partners.

e. Significance of the Study

Turkey lies at the intersection point of Europe, the Middle East, the Caucasus, Black Sea, Mediterranean and Aegean, serving as a focal point in international freight and passenger movement. Turkey undertakes a considerable amount of investment in transportation infrastructure to benefit from this geographic position. The aim is to promote multimodal and intermodal connections, reduce transport costs, enhance trade and increase competitiveness by utilizing the strategic role of transport networks. Table 1 illuminates the policy emphasis on transport-related infrastructure development in the form of a national strategy. Turkey aims at more than tripling its total rapid and high-speed train lines within five years. Another goal is identified as to make the share of double-track railway lines more than twice in the duration of the development plan. Goals for road transportation encompass increasing the motorway stock by 32% and divided roads by 10%.

Table 1: Turkey's Infrastructure Stock (2018 and 2023 Expected)

	2018	2023
Length of Rapid and High-Speed Train Lines (km)	1,213	5,595
Share of Double-Track Railway Length in Total Main Line (%)	12.4	26.3
Multi-Lane Divided Highways (motorways included)	26,642	29,514
Motorways (km)	2,842	3,779

Source: Retrieved from PSB (2019: 130).

This thesis centers on Turkey as a developing country and explores the association between transport infrastructure development and international trade growth. Turkey is among the important players in the global market, as indicated by being a member of The Group of 20 (G20) forum which includes a mixture of advanced and developing economies accounting for 75% of world trade ⁽¹⁾ and being grouped as an upper-middle income country by World Bank. As for Logistics Performance Index (LPI), Turkey was in 34th place in 2007 and 47th place in 2018, with a score of 3.15 in both years. LPI is a measure of trade and logistics-related competitiveness of a country, on a scale between 1 and 5, representing poor and high-performance levels respectively. Turkey has an agenda to improve its ranking in LPI through the significant resources allocated for transport system developments in the form of a public policy. Quality improvements in the existing stock have also been on the development agenda as the quality in addition to the quantity of transport infrastructure is important as dysfunctional infrastructure prevents a country to cultivate potential economic benefits (Ismail and Mahyideen, 2015).

Although Turkey has been investing substantially to develop its transportation network to become more competitive in international trade, there is a limited number of studies investigating the relationship between transport and international trade expansion. Coşar and Demir (2016) explore the enabling mechanism of domestic infrastructure investment in roads for the accessibility to international markets with province level data for the period between 2003-2012. They find that capacity increase in roads result in significant cost savings of shipments and highlight the importance of an efficient logistics system to compete in global supply chains. In the framework of a causality analysis for the time horizon between 1970-2005, Kuştepe et al. (2012) identify a weak short-run association between highway infrastructure and exports but fail to detect long-run relationship between road inventory, trade and economic growth. Ülengin et al. (2013) perform an investment evaluation analysis for a set of 13 selected road projects in Turkey. Demand forecasting and scenario analysis are executed with macroeconomic indicators for the years between 2004-2009 to identify the projects which need supporting measures to uplift the projected low level of demand. These studies assess only road infrastructure investment; however, the

¹ <http://g20.org.tr/about-g20/g20-members/index.html>.

examination of the transport network effects on welfare gains entails a systems approach. Hence, it is vital to consider all modes in the analysis as transportation is a system comprising of inter-related and interdependent components, namely transport modes.

Upon the general overview introduced on the transport infrastructure and economic benefits nexus so far, the significance of this thesis resides in several aspects. First of all, this thesis is significant with its focus on Turkey as an emerging economy. Because a well-developed transportation system supports participation and competition in global supply chains especially for a developing country, which can be achieved by transport infrastructure investments. In this regard, this study aims to shed light on public and industrial policy directions for trade expansion, global integration and export-led growth bases through assessment of transport network investments in Turkey. As another significance, the thesis fills a scholarly gap as transport infrastructure research mostly investigate the benefits in two extreme country categories, first high-income countries having abundant transport infrastructure capital and second low-income economies which suffer from lack of resources to allocate in transport networks, indicating scarcity of research on developing countries for which transport infrastructure can act as an engine (Duranton et al., 2014).

Transport network corresponds to the overall connectivity entailed with arcs and nodes of physical structure of road, rail, air and maritime transport types. In this study, all modes are taken into consideration, constituting another significant aspect. As outlined above, studies on the relation between transport network and economic effects in Turkey rely on a single transportation type – road transportation in parallel to international studies predominantly focusing on highways and roads, such as Duranton and Turner (2012), Fraumeni (2009), Baum-Snow et al. (2020). Another significance relates to the geographic scale of the analysis, as this thesis adopts an overall country exploration contrary to the inquiry on regional effects with a fragmented perspective of the existing studies on Turkey.

Banister and Berechman (2001) stress the importance of inclusion of the spatial component in the attempts to quantify the effects of transport infrastructure investment to reach accurate findings. Besides, network attributes of a transport system demand spatial considerations as well, otherwise divergent conclusions on the economic effects

of transport infrastructure investment can be obtained when distance characteristics are omitted (Deng, 2013). Therefore, this thesis is based on a spatial interaction analysis by employing a gravity model of trade flows, which relies on the idea that the volume of trade between two countries depends on their economic masses and distance between them. The thesis differentiates from the mainstream line of research in the field using causality examinations as the main analytical approach as in Saidi et al. (2018), Pradhan and Bagchi (2013), Badalyan et al. (2014), Keho and Echui (2011), Mohmand et al. (2017) Pradhan (2010) and He et al. (2021). Continuing with the methodological aspects, another significance of the thesis involves methodological diversification. Initially, a causality investigation with ARDL models is conducted to reveal general insights on the effect of the land transportation ⁽²⁾ system on trade expansion without spatial terms. Then, various gravity models of trade are estimated using monetary values of investment in each mode for the main analysis as well as exploring the effects of interactions among modes and quality of transport types on trade development. In that way, the reliability and validity of the study are improved by the formation of methodological and analytical diversification.

f. Structure of the Thesis

The structure of this study consists of four chapters. In the proceeding part, Chapter 1, an overview of transport infrastructure development in Turkey is provided as suggested by the main theme and the analysis unit. After an outlook on the evolution of transport inventory for individual modes, the international transport projects in which Turkey participates are mentioned. The chapter is ended with an exploratory assessment of the trade and transport infrastructure relation in Turkey.

In Chapter 2, theoretical foundations of the thesis are scrutinized with an approach from broader theories to more specific concepts. Initially, broad theories on the space-time dimension- namely location and trade theories are reviewed with the explanations on the main branches originated from these two foundations. Then, specific theories are explained with a top-down approach. Specific theories begin with macro-level theories consisting of public policy, transport policy and planning and

² Data is available only for land transportation components, road and railway.

transport economics. After that, theories on spatial effects are investigated, which comprise transport geography and network theory. Finally, micro-level theories of accessibility and agglomeration economics are described.

Based on these exhaustive elaborations spanning a wide range of theories, the theoretical framework is derived from the literature, representing the mechanism on which transport infrastructure investment presumably leads to export and import expansion. In the direction of the main research question and objectives, this thesis primarily engages in the question of whether the causation from transport infrastructure investment to exports and imports holds, having a deductive approach.

Chapter 3 outlines the methodological framework throughout the research process including the data collection and econometric analysis procedures. Research design is explained by quantitative and qualitative approaches along with the mixed method approach employed to reinforce the soundness of the study. Moreover, an inductive content analysis integrated with systematic literature review approach is performed on Maxqdata software to identify major constructs and methodological aspects of empirical research on the transport-broader economic benefits link.

In Chapter 4, regression exercises are conducted and the findings are discussed. In the initial step, a non-exhaustive cointegration analysis for the effects of roads and railways on trade development is applied with ARDL modeling for exports and imports on Eviews software. This process provides a precursory understanding on the short-run and long-run impacts of the most prominent transport type-road transport as well as its follower-railway. Following this, the exhaustive exploration with the core modeling exercise involving gravity models of trade are estimated with all transport types as well as control variables on Stata software. The effects of transport infrastructure investment, interaction among modes and quality of modes on trade have been examined for exports and imports.

In the conclusion, after a brief summary of the research framework, the results are discussed concerning the contribution to the scientific knowledge and theory. In addition, practical implications are driven as the applied nature of the thesis exposes policy directions.

CHAPTER ONE

TURKEY'S TRANSPORTATION INFRASTRUCTURE DEVELOPMENT

1.1. OUTLOOK ON THE MODAL DEVELOPMENT OF TRANSPORT INFRASTRUCTURE IN TURKEY

The infrastructure development of different modes, namely road, rail, air and sea transportation has gone through different stages in Turkey. A brief understanding on the evolution of each mode would emphasize the focus of this study and the importance of transport infrastructure and trade relation with a firm background.

1.1.1. Road Transportation

Since its establishment in 2023, Turkey has engaged in planning activities for transportation concerning different modes to increase welfare and growth. Although transport network investments focused initially on railway mode, road transport infrastructure investment accelerated beginning from 1929 for an end-to-end connection with the regulations put into force. Turkey reached a total road length of 43,743 km in 1947, which was accumulated on the inventory of 18,350 km of road (of which 13,900 km stabilized and 4,450 km unpaved) and 94 bridges taken over in 1923. After the establishment of General Directorate of Motorways (KGM) in 1950, repair and maintenance of existing roads as well as new road projects have been carried out by this organization. In 1960s, the road network was extended to 60,000 km and increasing roads with asphalt pavement became a priority. During 1970s, expressways and high-capacity multilane road projects in congested and near-metropolitan areas became main issues. In 1980s, liberalized Turkey initiated accessibility-oriented road network and highway construction plans. In the beginning of 2000s, divided roads became the priority infrastructure as an urgent need to provide road safety, to integrate domestic and international networks and to increase capacity. Turkey has an inventory of a total of 68,170 km roads (26,879 km of divided roads and 2,969 km of highways) as of 2019. Since 2010, private participation has been the main financing scheme in road infrastructure in Turkey. Some examples of the recent Built – Operate – Transfer

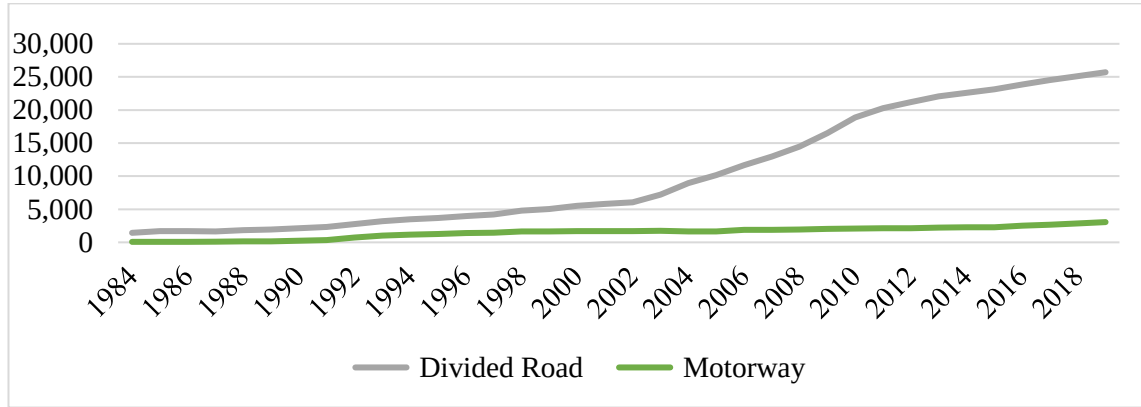
(BOT) projects include Istanbul-Bursa-Izmir Highway and Osmangazi Bridge, Ankara – Niğde Highway, Kuzey Marmara Highway and Yavuz Sultan Selim Bridge, Malkara - Çanakkale Highway and 1915 Çanakkale Bridge.

KGM chronologically summarizes the road transport policy in Turkey as follows:

1923	————→	Roads for Accessibility
1950	————→	All Season Roads
1960	————→	Roads with Asphalt Pavement
1970	————→	Roads with Hot Bituminous Mixture Pavement
1985	————→	Highways
2003	————→	Divided Roads
2013	————→	Smart Roads and Projects Financed with BOT

Today, road transportation is the prominent transportation mode in domestic freight and passenger transportation permitting door-to-door service in complement to other modes. Moreover, when implementation process of physical structure projects is compared, road transport infrastructure projects offer faster and cheaper delivery terms requiring fewer financial resources than other transport types. Road quality also matters as a driving factor in trade facilitation and in welfare increase as indicated by for example Li et al. (2017). In Figure 3, development of quality road length is shown for the time frame between 1984 and 2019 in Turkey. Motorways was in total of 77 km in 1984, which rose to 3,060 km in 2019. A more noteworthy uprise belongs to divided road stock which increased from 1,437 km in 1984 to 25,705 km in 2019. The ambitious strategy of network development by the government can be observed from the graph by the steep increase starting from early 2000s particularly in divided roads.

Figure 3: Divided Road and Motorways Length in Turkey (km)



Source: Turkstat (2021a).

With Figure 4 and Figure 5, Turkey's divided road map along with heavy vehicle and traffic volume maps are presented. In Figure 4, it can be observed that divided roads are concentrated around major cities close to important gateways, namely Haydarpaşa and Ambarlı Ports in Istanbul, Izmir and Aliğa Ports in Izmir, Gemlik Port in Bursa, Mersin Port and Iskenderun Port. Thus, this implies that divided road network provides fast and cost-effective door-to-door service for exports and imports transported within hinterlands of these gateways. According to Figure 5, roads are used for freight transportation between main sea gateways and the capital city of Ankara. The map highlights major industrial clusters and freight distribution centers in Marmara, Aegean, Mediterranean, East Black Sea and Central Anatolia regions. Both maps show that road is the principal mode used for port connectivity in place of rail, which is contrary to the mainstream practice in the world.

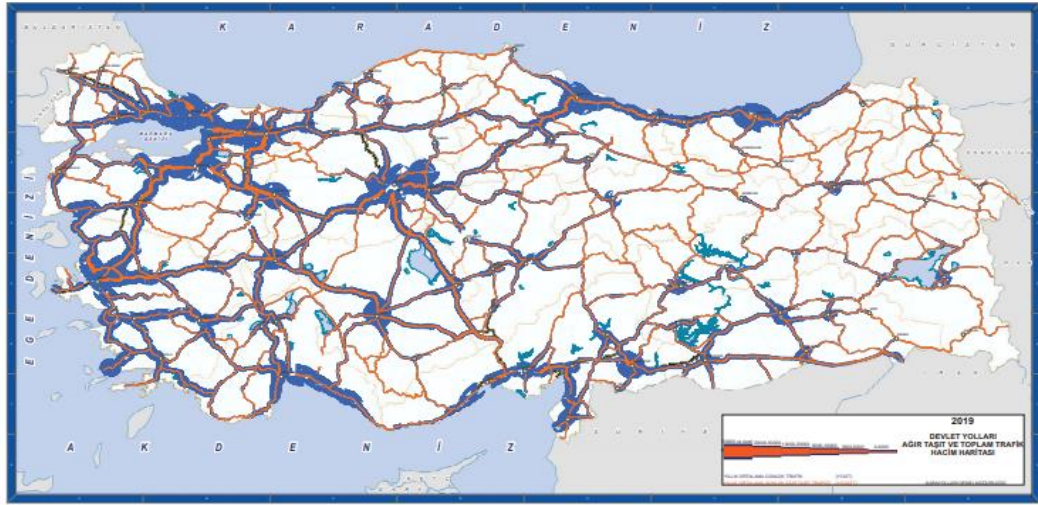
Figure 4: Turkey's Divided Road Map



Source: Retrieved from kgm.gov.tr,

<https://www.kgm.gov.tr/SiteCollectionImages/KGMimages/Projeler/BY-31.12.2021.pdf>.

Figure 5: Heavy Vehicle and Traffic Volume Map



Source: Retrieved from kgm.gov.tr, <https://www.kgm.gov.tr/SiteCollectionDocuments/KGMdocuments/Istatistikler/TrafikveUlasimBilgileri/19TrafikUlasimBilgileri.pdf>.

1.1.2. Rail Transportation

There is a consensus in the scientific deposition on that road is the primary mode of transport in merchandise shipment within countries (McKinnon and Piecyk, 2009; Asomani-Boateng et al., 2015; Alises and Vassallo, 2015), yet its negative externalities like noise, pollution and congestion have turned the attention to railway mode all over the world in the last few decades. Though, the proportion of railway transport for exports and imports in Turkey has remained around 1% between 2000-2019, meaning that despite of rising volume of transported goods by railway, the usage rate keeps at low levels (Turkstat, 2021b). Main export commodities of Turkey include vehicles, automobile parts, iron and steel products, construction materials as well as bulks like flour and main apparel products such as t-shirts, which are very convenient for rail transportation when aspects of volumetric properties, value-to-weight ratios, service level vs. cost trade-off are considered (World Bank, 2020b). However, the network structure of Turkey in Figure 6 demonstrates that rail lines are originally constructed to link geographic regions primarily with a traditional perspective. Upon this structure, the network has grown by incremental additions to the inventory over a century.

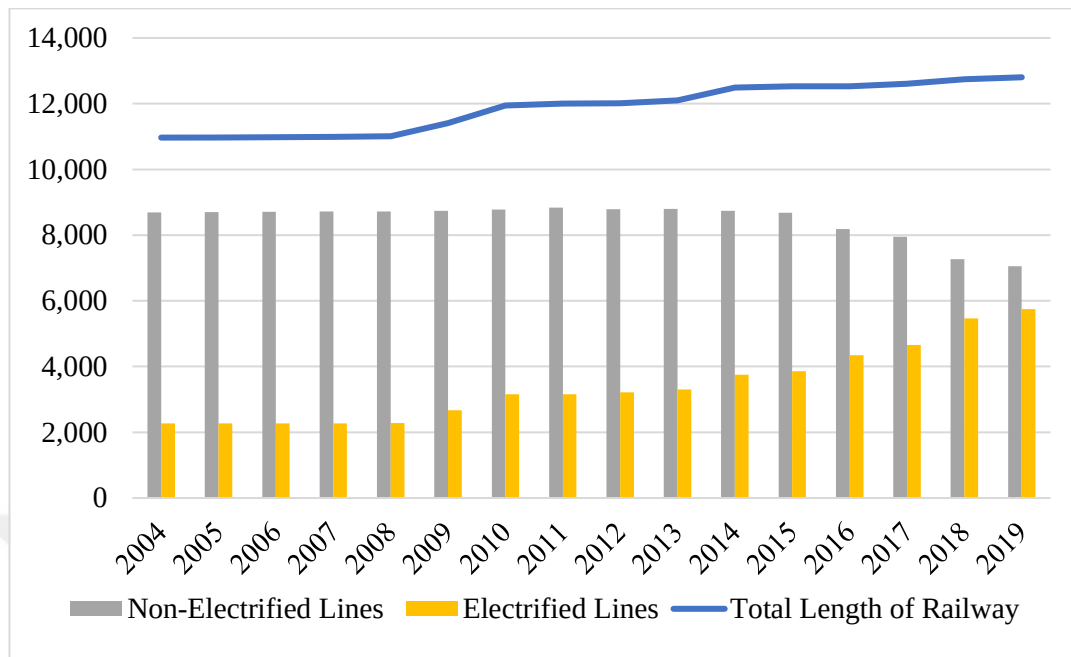
Figure 6: Railway Network in Turkey



Source: Retrieved from tcdd.gov.tr, <http://tcdd.gov.tr/uploads/demiryoluharitasi.jpg>.

Railway infrastructure investment dates back to 1856 for İzmir - Aydın railway line of 130 km. Turkey inherited a railway stock of 4,136 km within its national borders in the establishment year of 1923, however over half of this stock was being operated by foreign companies. A government report (MoTI, 2019) indicates that rail connection has been neglected in Turkey up until 2003 with a yearly network expansion of 18 km, with a total addition of 945 km to the stock between 1951-2004. With a closer look in Figure 7, development of total railways in Turkey is shown with a decomposition into electrified and non-electrified lines between 2004-2019. Beginning with the opening of first high-speed rail line in 2009, both total and electrified railway inventory is expanded continuously. High-speed rail infrastructure includes passenger transportation to a large extent, leaving a need for further reinforcement of freight transportation with advanced technology rail lines.

Figure 7: Electrified and Non-Electrified Railway Length in Turkey (km)



Source: Turkstat (2021c).

Regarding administration, management of ports and railways is pooled and assigned to a single entity under Turkish State Railways (TCDD) in 1927. Between 1928-1948, the foreign-operated railways were bought and nationalized by the state. Private sector participation is initiated for rail transport operations in 2003 and the privatization process is set off for 6 ports in 2004. The regulatory framework for the liberalization of railways has come into force in 2013. In the meantime, TCDD has undertaken organizational restructuring and divided into two institutions as TCDD becoming a railway infrastructure operator, TCDD Corporation being a train operator in 2017. With the establishment of TCDD Corporation, rail transport has been opened for private competition.

TCDD has responsibilities covering a wide range of areas as presented in Table 2. It deals with tasks concerning infrastructure, maintenance, traffic management, port management and intermodal integration. These duties suggest that TCDD takes an important part in logistics transformation and facilitation of intermodal connectivity.

Table 2: Responsibility Areas of TCDD

Responsibility Area	Service
<i>Railway Infrastructure Provision and Modernization</i>	High-Speed Rail Lines Express Rail Lines Branch Line Construction and Modernization Electrification, Signalization and Telecommunication Provisions Doubling of Existing Conventional Lines Logistics Center Construction
<i>Maintenance and Repair of Railway Infrastructure</i>	Renewal of Existing Lines Improvement of Existing Lines Material Production and Supply Station Maintenance, Repair and Restoration
<i>Capacity Planning and Traffic Management</i>	Network Notice Capacity Allocation and Pricing Traffic Management Station Management Service at Logistics Freight Centers
<i>Port and Ferry Management Intermodal Integration</i>	Materials Handling Vessel Services Ferry Operations

Source: TCDD (2019).

Rail network infrastructure to main freight hubs is not sufficiently provided in Turkey yet. For example, according to TCDD Inc. (2019), there is railway connection in 13 out of 191 concurrent ports and piers as well as in 11 from 295 existing organized industrial zones. However, some improvements are planned to reserve the forsaken economic value caused by inadequate railway connectivity. Specifically, logistics hubs are planned to connect major freight distribution points via railway as displayed in Figure 8 to enrich the use of combined transportation by improving ways of shipment, constituting necessary connections between modes, providing cost-effectiveness in logistics functions especially for warehousing, cargo and material handling. Under supervision of TCDD, there are 25 logistics centers, of which 11 are in operation (Halkalı in Istanbul, Köseköy in Izmit, Gökköy in Balıkesir, Kaklık in Denizli, Uşak, Hasanbey in Eskişehir, Kayacık in Konya, Yenice in Mersin, Gelemen in Samsun, Türkoğlu in Kahramanmaraş, Palandöken in Erzurum), 1 is completed (Kars), 2 are in

construction (Kemalpaşa in Izmir and Sivas), 5 are in project phase (Çerkezköy in Tekirdağ, Bozüyük in Bilecik, Karaman, Boğazköprü in Kayseri, Tatvan in Bitlis), 6 are in evaluation and planning phase (Yeşilbayır in Istanbul, Çandarlı in Izmir, Filyos in Zonguldak, Iyidere in Rize, Mardin and Habur). The centers in operation have mostly adjacent road connection except for Gelemen in Samsun (in 2 km distance), Palandöken in Erzurum (in 2 km distance), Hasanbey in Eskişehir (in 3 km distance), Yenice in Mersin (in 1 km distance). Moreover, all facilities have adjacent connection to branch lines apart from Gelemen in Samsun (in 3 km distance). Modal integration is planned as well in a way that centers are near points where air and sea shipments are available within a maximum 30 km distance from the nearest airport and maximum 366 km distance from the closest seaport.

Figure 8: Logistics Centers



Source: Retrieved from tcdd.gov.tr, <https://www.tcdd.gov.tr/kurumsal/lojistik-merkezler>.

1.1.3. Air Transportation

Air transportation as a logistics component has a key role in supporting development of manufacturing sector and in expansion of international trade (Nordas and Piermartini, 2004). Fast exchange of goods and services between remote locations all over the world, backed by production-oriented infrastructure investments yields

increasing trade competitiveness for regions which own airport facilities (Celbis et al., 2015). As an industry in which market entry requires high level of initial capital, air transport adopts technological changes immediately by keeping pace with the global developments.

According to Directorate General of Civil Aviation (DGCA), the institutional foundation of air transport was formed in 1925 in Turkey and air transportation began in 1933 with a fleet of 5 aircraft. The aircraft fleet as of 2021 is presented in Table 3, belonging to 10 private companies which are licensed for both passenger and cargo transportation. Thy A.O. owns over half of total fleet capacity in Turkey, with a share of 58%. The focus of Turkish aviation sector on passenger transportation can be seen by the distribution of passenger and cargo fleet numbers. Passenger transportation dominates the industry with a fleet share of nearly 95%, overriding freight transportation with an allocation of 5% from total fleet stock. The focus on passenger transportation has contributed to the extension of flight network of 50 countries-60 destinations in 2003 to 127 countries-329 destinations in 2020 (DGCA, 2020).

Table 3: Total Fleet Number of Airline Companies

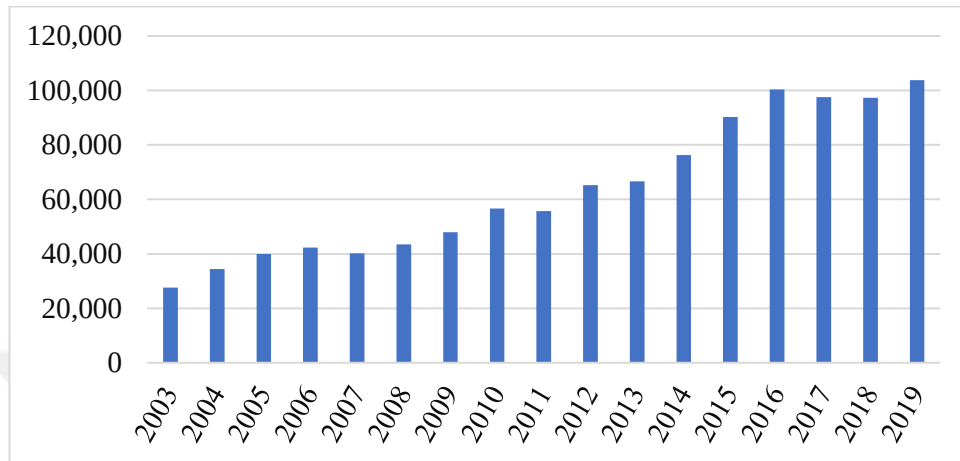
Company	Passenger/ Cargo	Fleet Size
Thy A.O.	Passenger	323
	Cargo	18
Pegasus Hava Taşımacılık A.Ş.	Passenger	93
Güneş Ekspres Havacılık A.Ş.	Passenger	58
Onur Air Taşımacılık A.Ş.	Passenger	23
Turistik Hava Taşımacılık A.Ş.	Passenger	13
Hürkuş Hava Yolu Taşımacılık ve Ticaret A.Ş.	Passenger	8
Tailwind Havayolları A.Ş.	Passenger	5
Mng Hava Yolları ve Taşımacılık A.Ş.	Cargo	5
Act Hava Yolları A.Ş.	Cargo	5
Uls Havayolları Kargo Taşımacılık A.Ş.	Cargo	3
Total		554

Source: DGCA (2020).

Between the period 2003-2019, change in seat capacity and cargo capacity of airlines have been demonstrated in Figure 9 and Figure 10, respectively. Seat capacity has increased from 27,599 to 103,763, expanding 275% in 16 years. Meanwhile, total cargo capacity has risen from 303 tonnes to 2,296 tonnes, escalating by 658%. Despite of the primary emphasis on passenger transportation, airway industry in Turkey has

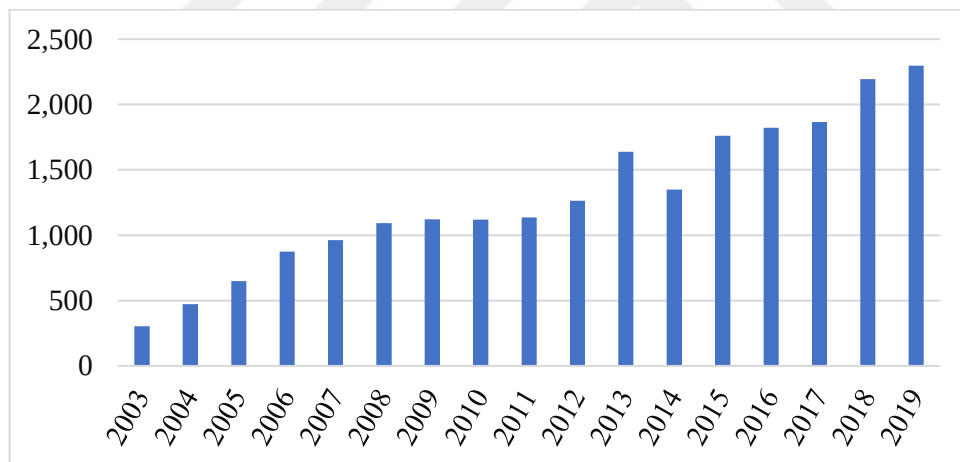
strategic goals to incorporate freight shipment as well, apparent by the growth of cargo capacity.

Figure 9: Total Seat Capacity



Source: DGCA (2020).

Figure 10: Total Cargo Capacity (Ton)



Source: DGCA (2020).

Between 2002-2019, both passenger and cargo traffic in Turkey has shown substantial growth as demonstrated in Table 4. The increase in domestic and international passenger traffic has been 1,045% and 333% with an overall passenger transportation growth hitting 517%. With respect to cargo traffic, domestic traffic has gone upward by 22%, international traffic moving up by 634%, leading to a total increase of 504%. The upward trend can be finely attached to persistent growth (excluding financial crisis of 2009) and capacity improvement investments covering

infrastructure and superstructure in Turkey. Referring management, 49 airports are directly operated by DHMI while Istanbul Airport, Gazipaşa Alanya Airport, Amasya Merzifon Airport, Zafer Airport and Zonguldak Çaycuma Airport are operated by private companies in supervision of DHMI, in addition to Eskişehir Hasan Polatkan Airport operated by Eskişehir Technical University, Istanbul Sabiha Gökçen Airport operated by private company under supervision of Presidency of Defense Industries (DHMI, 2021).

Table 4: Passenger and Cargo Traffic in Turkey (2002-2019)

	Passenger Traffic			Cargo Traffic		
	Domestic	International	Total Passenger Traffic	Domestic	International	Total Cargo Traffic
2002	8,729,279	25,054,613	33,783,892	53,640	198,347	251,987
2003	9,147,439	25,296,216	34,443,655	54,104	222,179	276,283
2004	14,460,864	30,596,507	45,057,371	70,998	253,590	324,588
2005	20,529,469	35,042,957	55,572,426	72,204	258,912	331,116
2006	28,774,857	32,880,802	61,655,659	70,698	286,523	357,221
2007	31,949,341	38,347,191	70,296,532	73,252	322,579	395,831
2008	35,832,776	43,605,513	79,438,289	66,554	335,485	402,039
2009	41,226,959	44,281,549	85,508,508	64,518	360,710	425,228
2010	50,575,426	52,224,966	102,800,392	71,216	470,141	541,357
2011	58,258,324	59,362,145	117,620,469	76,269	508,206	584,475
2012	64,721,316	65,630,304	130,351,620	84,431	539,627	624,058
2013	76,148,526	73,281,895	149,430,421	100,097	631,865	731,962
2014	85,416,166	80,304,068	165,720,234	104,941	737,300	842,241
2015	97,041,210	84,033,321	181,074,531	101,447	803,314	904,762
2016	102,499,358	71,244,179	173,743,537	81,587	951,356	1,032,943
2017	109,511,390	83,533,953	193,045,343	75,254	1,180,969	1,256,224
2018	112,911,108	97,587,056	210,498,164	52,807	1,335,815	1,388,623
2019	99,946,572	108,427,124	208,373,696	65,667	1,456,737	1,522,404

Source: DHMI (2021).

Airport inventory in Turkey has been shown in Table 5 with information of opening year, traffic type and whether there is cargo terminal or not. Airport infrastructure has expanded by 17 new airports between 1937-1989, 19 new airports between 1990-1999 and 20 new airports since 2000. In terms of traffic type, 16 airports have flights over domestic lines only whereas the rest of 40 airports have both domestic and international schedules. As previously mentioned, Turkish air transportation

emphasizes passenger transportation. This situation is also obvious from the concurrent level of infrastructure, there is cargo terminal enabling freight movement by airway only in 20 from the total of 56 airports.

Table 5: Airports in Turkey

Airport	Year of Operation	Traffic Type	Cargo Terminal
Istanbul Atatürk Airport	1953	Domestic/International Lines	X
Istanbul Airport	2018	Domestic/International Lines	X
Istanbul Sabiha Gökçen Airport	2001	Domestic/International Lines	X
Ankara Esenboğa Airport	2006	Domestic/International Lines	X
Izmir Adnan Menderes Airport	1987	Domestic/International Lines	X
Antalya Airport	1960	Domestic/International Lines	X
Gazipaşa Alanya Airport	2010	Domestic/International Lines	
Muğla Dalaman Airport	1981	Domestic/International Lines	
Muğla Milas-Bodrum Airport	1998	Domestic/International Lines	
Adana Airport	1937	Domestic/International Lines	X
Trabzon Airport	1957	Domestic/International Lines	
Isparta Süleyman Demirel Airport	1997	Domestic/International Lines	X
Kapadokya Airport	1998	Domestic/International Lines	
Erzurum Airport	1966	Domestic/International Lines	
Gaziantep Airport	1976	Domestic/International Lines	X
Adıyaman Airport	1998	Domestic Line	X
Ağrı Ahmed-i Hani Airport	1997	Domestic Line	
Aydın Çıldır Airport	2012	Domestic/International Lines	
Amasya Merzifon Airport	2008	Domestic Line	
Balıkesir Koca Seyit Airport	1997	Domestic/International Lines	
Balıkesir Merkez Airport	1998	Domestic Line	
Batman Airport	2010	Domestic Line	
Bingöl Airport	2013	Domestic Line	
Bursa Yenişehir Airport	2000	Domestic/International Lines	X
Çanakkale Airport	1995	Domestic/International Lines	
Çanakkale Gökçeada Airport	2010	Domestic Line	
Denizli Çardak Airport	1991	Domestic/International Lines	
Diyarbakır Airport	1952	Domestic/International Lines	X
Elazığ Airport	1940	Domestic/International Lines	
Erzincan Airport	1988	Domestic Line	
Eskişehir Hasan Polatkan Airport	1989	Domestic/International Lines	
Hatay Airport	2007	Domestic/International Lines	
Iğdır Şehit Bülent Aydın Airport	2012	Domestic Line	
Kahramanmaraş Airport	1996	Domestic Line	

Kars Harakani Airport	1988	Domestic/International Lines	
Kastamonu Airport	1959	Domestic Line	
Kayseri Airport	1998	Domestic/International Lines	X
Kocaeli Cengiz Topel Airport	2011	Domestic/International Lines	
Konya Airport	2000	Domestic/International Lines	X
Malatya Airport	1941	Domestic/International Lines	
Mardin Airport	1999	Domestic/International Lines	X
Muş Sultan Alparslan Airport	1992	Domestic Line	
Samsun Çarşamba Airport	1998	Domestic/International Lines	X
Siirt Airport	1994	Domestic Line	
Sinop Airport	1993	Domestic/International Lines	
Sivas Nuri Demirağ Airport	1957	Domestic/International Lines	X
Şanlıurfa GAP Airport	2007	Domestic/International Lines	X
Şırnak Şerafettin Elçi Airport	2013	Domestic Line	
Tekirdağ Çorlu Atatürk Airport	1998	Domestic/International Lines	X
Tokat Airport	1995	Domestic Line	
Uşak Airport	1998	Domestic/International Lines	
Van Ferit Melen Airport	1943	Domestic/International Lines	X
Zafer Airport	2012	Domestic/International Lines	
Zonguldak Çaycuma Airport	2007	Domestic/International Lines	
Ordu-Giresun Airport	2015	Domestic/International Lines	
Hakkari Yüksekova Selahaddin Eyyubi Airport	2015	Domestic Line	

Source: Author's own compilation from DHMI (2020, 2021) and airport information on DHMI website.

1.1.4. Maritime Transportation

Sea transportation accounts for shipping nearly 80% in volume and over 70% in value of international merchandise trade (UNCTAD, 2018). This weight goes up to higher values for the developing world, in which case maritime sector becomes a strategic industry.

There are several important aspects pinpointed by the government to be handled in line with development programs of Turkey in the direction of regarding maritime sector among strategic industries and taking it as the primary logistics chain in delivery of a balanced, accessible and cost-effective transport service for welfare increase (MoTI, 2020a). Firstly, railway connectivity to ports is a priority in transport policy of the country supported by improvement targets for road connectivity in addition. Another significant aspect is the implementation of Green Port Project in

which 19 ports are certified and other ports continue to the process of certification. This is an important development as it is essential to ensure environmental compliance of ports which are backbones of maritime transportation as they are located around city centers. Another target has been set to undertake the project ‘Three Ports in Three Seas’ including Izmir Çandarlı Port in Aegean Sea, Zonguldak Filyos Port in Black Sea and Mersin Container Port in Mediterranean Sea. When these projects are completed, the corresponding capacity of the ports will be 4 million TEU, 25 million tonnes, 10-11.4 million tonnes, respectively.

Ports are main infrastructure components to receive benefits of higher logistics performance driving seaborne trade growth in the process of welfare development (Munim and Schramm, 2018; Abe and Wilson, 2011). Maritime transportation is the most used method for international trade shipment in Turkey with around 60% share in both exports and imports in value. With reference to DTO (2020), Turkey embodies a total of 180 ports and piers on its long coastline of 8,333 km, with three different types of ports according to operating institutions: 20 public ports, 23 municipality ports and 137 private ports. Port administration has been under TCDD for a long time as aforementioned, but liberalization process is in effect for the last two decades.

In Figure 11, regional distribution of 167 cargo ports, irrespective of capacity level, is shown. As seen on the figure, 76 ports are situated in Marmara Region- in a zone incorporating large industrial cities such as Istanbul, Kocaeli, Bursa and Tekirdağ. This indicates that almost half of the country’s maritime infrastructure is concentrated in one region which has the highest development level providing easy access not only in terms of logistics but also financial resources, high quality labor and agglomeration opportunities. Following Marmara, ports are clustered in Mediterranean with 44 ports (26%), in Black Sea with 26 ports (15%) and Aegean with 21 ports (12%). Industrial piers are already located around Ambarlı area and Izmit Gulf in Marmara, near the district of Aliaga in Aegean and near Iskenderun in Mediterranean. Detailed information on the cargo ports can be found in Appendix 1.

Regarding cargo types, infrastructure covers a wide range of products involving drybulk, liquid bulk (fuel, LNG, LPG, chemicals, asphalt, liquified gas), container, general cargo with various transportation methods including Ro-Ro (MoTI, 2020b).

Figure 11: Geographic Distribution of Ports in Turkey



Source: Author's Own Compilation from DTO (2020), MoTI (2020b), turklim.org and searates.com.

In Table 6, handling volumes of cargo types are presented for the period between 2011-2019. The highest growth belongs to containerized cargo with a rise by almost 70%, drybulk cargo comes in the second place with 40%, then liquid bulk cargo by 19% and general cargo by 13%. Overall increase in volume of cargo handled aggregates to 33%. There is also a decrease in one category, namely vehicles dropping by 23%.

Table 6: Total Handling Volume of Cargo Types in Turkish Ports (Ton)

	Drybulk Cargo	General Cargo	Liquid Bulk Cargo	Container	Vehicles	Total
2011	107,167,803	46,507,986	129,992,302	70,381,257	9,305,395	363,354,743
2012	107,119,426	60,168,663	132,700,887	79,310,916	8,036,768	387,426,232
2013	103,655,819	66,093,252	122,560,729	84,656,192	7,964,766	384,930,758
2014	108,744,680	61,183,191	116,934,088	88,138,346	8,120,314	383,120,619
2015	110,701,538	63,505,731	146,554,192	87,025,857	8,249,377	416,036,695
2016	116,516,338	65,564,619	145,024,367	94,928,597	8,167,241	430,201,162
2017	128,842,715	72,147,186	152,897,347	107,917,908	9,368,740	471,173,896
2018	133,653,221	63,977,765	139,717,069	114,231,465	8,574,040	460,153,560
2019	150,344,563	52,672,991	155,253,914	118,768,010	7,128,934	484,168,412

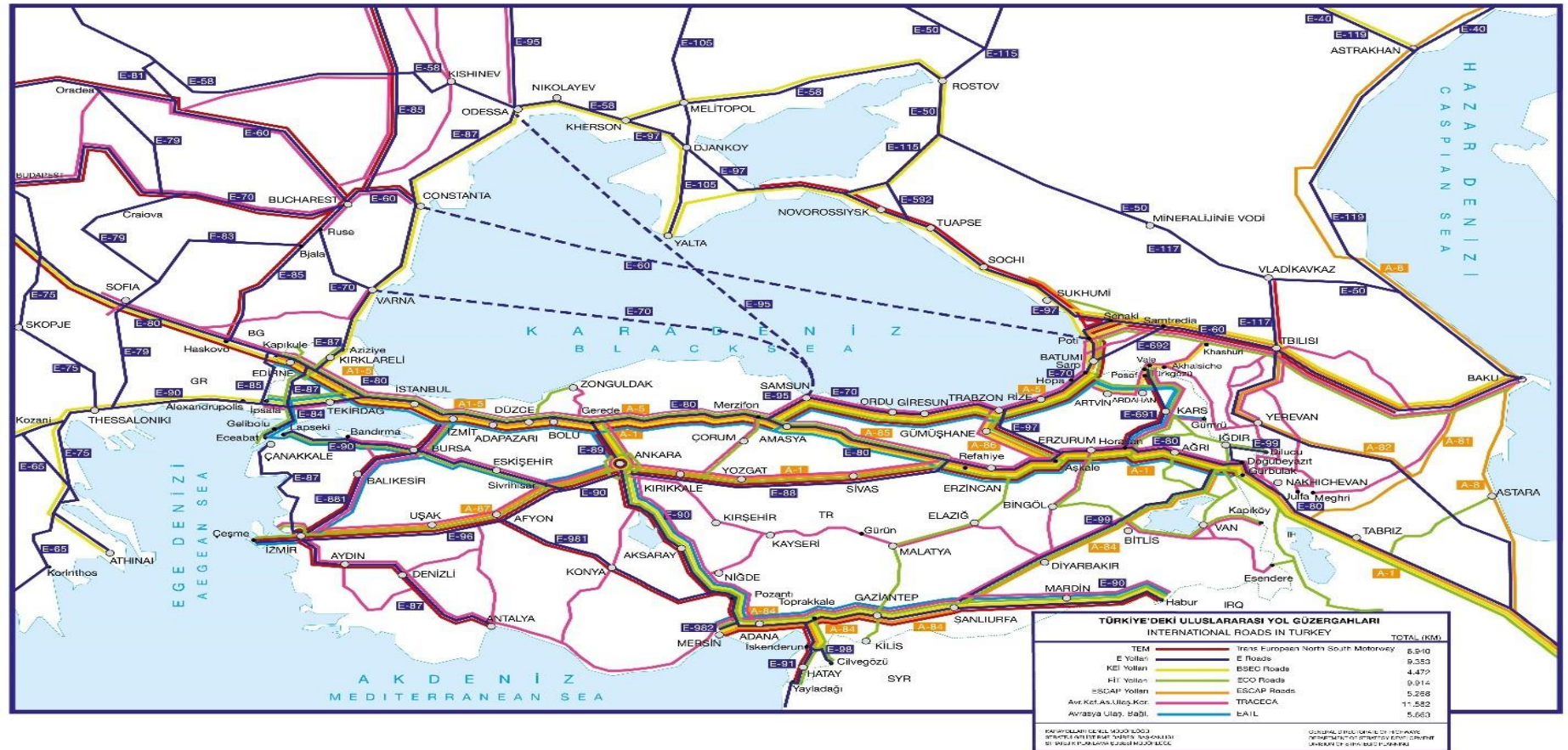
Source: MoTI (2021).

Turkey has a key position in East Mediterranean and Black Sea maritime routes imputing ports an important role in trade facilitation due to advantageous position of being at the intersection of commodity flow lines in East - West as well as North – South axes. Each territory in Turkey has a service capacity for different freight types and trade routes, diversifying business opportunities in transportation sector. Ports in Aegean and Mediterranean regions are close enough to main maritime routes between Asia and Europe, acting as a mediator in delivery of trade commodities to Southern Asia (countries including Iran and India). Besides, Black Sea ports connect Europe to landlocked countries of Central Asia, utilizing gains from increasing regional trade in the area. However, rail connectivity is essential to have a comparative advantage in maritime trade, an issue Turkey is profoundly disadvantageous as private ports which is responsible for 90% of container transport lack rail connection with few exceptions that Haydarpaşa, Derince, Bandırma and Tekirdağ are the only ports having railway connection in Marmara region where nearly 40% of total freight is handled (DTO, 2020: 145).

1.2. INTERNATIONAL TRANSPORTATION INFRASTRUCTURE PROJECTS

Turkey participates in international transportation infrastructure projects, mainly in road but also in railway and maritime transportation. Turkey implements international road projects such as Trans Turkey Highway (TTH), Trans European South-North Motorway Project (TEM), Economic Cooperation Organization (ECO) Routes, Black Sea Economic Cooperation (BSEC) Routes, Europe-Caucasus-Asia Transport Corridor (TRACECA), The Turkish Trans-European Transport (TEN-T) Highway Network, Economic and Social Commission for Asia and Pacific (ESCAP) Routes, E-Roads and the Declaration on the Construction of Main International Arteries (AGR). International highway projects and international transport routes are shown on a map in Figure 12.

Figure 12: International Road Network of Turkey



Source: Retrieved from [kgm.gov.tr](https://www.kgm.gov.tr/Sayfalar/KGM/SiteEng/Root/Gdh/InternationalProjects/InternationalRoutes.aspx), <https://www.kgm.gov.tr/Sayfalar/KGM/SiteEng/Root/Gdh/InternationalProjects/InternationalRoutes.aspx>.

Trans-European North-South Motorway (TEM) operates as a regional road network plan bridging between Southeast Europe and Middle East. TEM with its 6,954 km network starts at Kapıkule Border Gate with Bulgaria, passes through Istanbul then breaks into several lines, one going to Antalya spanning Bursa, Izmir and Denizli; the other connecting Ankara to cities in Eastern Black Sea and Eastern Anatolia regions ending up at Sarp and Gürbulak Border Gates. There is also a network going through Adana, Hatay, Şanlıurfa, reaching to Syria and Iraq via Cilvegözü and Habur Border Gates.

Economic Cooperation Organization (ECO) routes serve as a connector between Europe and Middle East, developed upon the cooperation founded by Turkey, Iran and Pakistan. Member countries of ECO highway network include Afghanistan, Azerbaijan, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkey, Turkmenistan and Uzbekistan. ECO highways of Turkey consist of short and high-quality routes in 9,915 km length. Considering railway projects, Turkey-Iran-Pakistan Railway is initiated under ECO to develop 6,500 km of rail line between Pakistan and Turkey via Iran, with 1,950 km line over the territories of Turkey integrating Istanbul and Islamabad through Tehran. Despite the starting date of 2009, the operation of the train line was suspended in 2011. Moreover, Istanbul-Tehran- Ashgabat -Tashkent-Almaty container train line which is in operation as a primary Trans-Asian network was constructed under the coordination of ECO.

Black Sea Economic Cooperation (BSEC) routes comprise a regional network linking Black Sea and Caucasus countries to ports in Mediterranean and Aegean, Central Asia and Far East. Turkey owns a stock of 4,472 km-long-highways developed under this cooperation.

Europe-Caucasus-Asia Transport Corridor (TRACECA) is an inter-regional infrastructure program to fuel economic relations and trade via multi-modal transport networks. Part of TRACECA in Turkey consists of road network of 11,582 km length. TRACECA network reaches to ports involving Izmir, Bandırma, Filyos, Mersin and to border gates of Gürbulak, Türközü, Kapıköy, Esendere, Kapıkule, Sarp. Regarding maritime leg of TRACECA, train ferry line between Samsun and Kavkaz (Russia) enables transit freight transportation to Mediterranean, Europe, Asia and Middle East since the launch in 2013. As an extension of TRACECA seeking the shortest path

connecting Europe to Middle East and Asia, Viking Train Project is a combined transport route between Baltic Sea and Black Sea linking Klaipeda (Lithuania), Odessa and Iliçevsk (Ukraine) ports by railway, on which Turkey stands as a transit point between Europe, Mediterranean, Middle East and Central Asia.

Turkey is an important party to international transportation corridors organized by United Nations. Turkey owns significant inventory of rail lines developed under European Agreement on Main International Railway Lines (AGC) and European Agreement on Important International Combined Transport Lines and Related Installations (AGTC). Additionally, Turkey's railway network stands as a key component of Trans-European Railways (TER) which aims to develop an integrated international transportation system in European countries as a part of Pan-European transportation infrastructure projects. Turkey is also a participant to Trans-Asian Railway (TAR) Project and Asian Highways. Economic and Social Commission for Asia and the Pacific Highway Network (ESCAP) is an inter-governmental project aimed at formation of sustainable transport linkages to Asia and Pacific to boost trade and tourism relations. The length of Asian Highway Networks is 5,268 km in Turkey. Turkish part of Trans-European Transport Network (TEN-T) has been implemented to build a well-developed transport network between Turkey and European Union countries for free movement of goods, services and people with a highway length of 16,799 km. Turkey belongs to South Eastern Europe branch of E-Roads and the European Agreement on Main International Traffic Arteries (AGR) network with three main linkages with Europe: Kapıkule Border Gate with Bulgaria, Ipsala Border Gate with Greece, sea-route between Port of Varna and Port of Samsun.

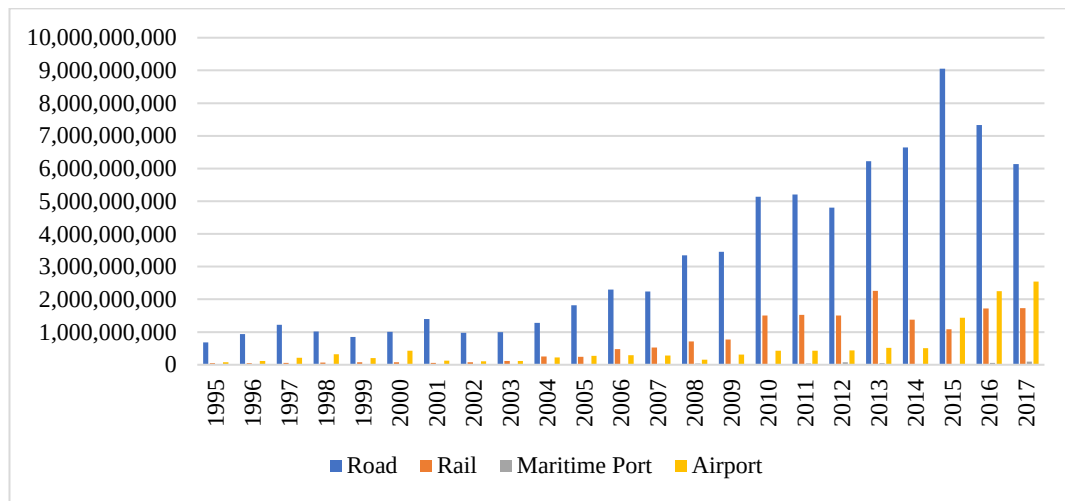
Within the Belt and Road Initiative (BRI), there are also ongoing projects for international routes passing across maritime connections in Turkey. In that regard, Trans-Caspian East-West Middle Corridor connects Europe to China on the routes of Turkmenistan-Uzbekistan-Kyrgyzstan or Kazakhstan. It starts via maritime legs of Tekirdağ, Derince, Izmir, Samsun in Turkey, continues with road connection to Baku Port in Azerbaijan and maritime connection to ports in Kazakhstan and Turkmenistan to access China. Another essential part of the corridor is Baku-Tbilisi-Kars (BTK) Railway opened in 2017, having a beginning freight capacity of 6,5 million tonnes which is expected to triple in the upcoming 20 years. In the revival of Silk Road,

Turkey undertakes infrastructure projects to support Europe-Asia connection by recent projects of undersea railway of Marmaray, Yavuz Sultan Selim Bridge in Istanbul, Eurasia Tunnel and Istanbul Airport. To strengthen the maritime connection of Middle Corridor, Turkey put three major port developments into program, specifically Filyos (Black Sea), Çandarlı (Aegean Sea) and Mersin Container Port (Eastern Mediterranean).

1.3. INTERCONNECTION BETWEEN TRADE AND TRANSPORT INFRASTRUCTURE

A well-developed transport system is essential for a country to gain competitive advantage in international trade. This situation holds even stronger for developing countries such as Turkey. To provide an advanced transportation network, Turkey has undergone important investments in transport infrastructure in the last two decades. As shown in Figure 13, the areas tackled by investments comprise all modes in the period between 1995 to 2017. However, road infrastructure has taken the highest proportion to increase interconnectivity of cities and rural areas while maritime port infrastructure investment is the lowest all along the period. In the current decade, railway infrastructure investment fluctuates around a certain annual level. Beginning from late 2000s, investment in all modes except for airway has risen sharply and there is a rapid increase in airport investment in the last few years. The upward trend in airport infrastructure investment since 2014 attracts attention as a demonstration for Turkey's flight network expansion policy.

Figure 13: Turkey's Transport Infrastructure Investment (in Euros)



Source: OECD (2018).

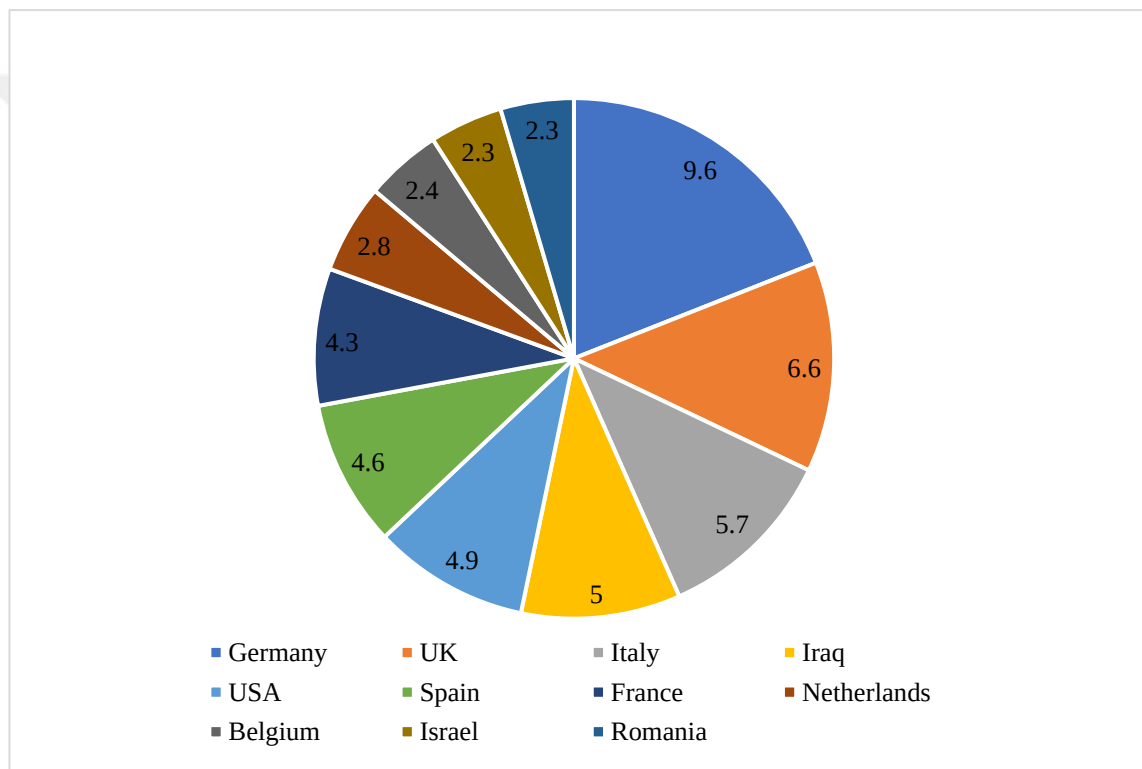
Modal distribution of foreign trade shipment manifests significant differences between modes of transport concerning their weight in international merchandise transportation (Turkstat, 2021b). In regard of exports and imports, shipping holds its predominant position as the main mode of transport in international trade. Share of shipping has gone up from 47% and 51% in 2000 to 62% and 63% in 2019 for total export and import values respectively, exhibiting a rising trend during the period. The mode of road transportation accounts for 43% of export and 34% of import transportation in 2000, the shares have fallen to 28% and 16% in 2019 in the same order. This drop might have happened as a result of increasing international corridors in the region which offer multimodal transportation opportunities and a shift from road transportation to other modes for environmental concerns. Air transportation comes in third place with a rising share from 11% to 14% during the period. Rail transportation accounts for around 1% of export and import shipments all along the period, a case probably emerging from the inadequate infrastructure and unsystematic application of modal integration efforts.

For the facilitation of international transport, Turkey is implementing an intense reconstruction and expansion policy of transport networks with public-private partnership models. Partly because of these efforts to improve logistics network, Turkey's international trade has grown substantially in the period, exports increasing 517% reaching to 171 billion US dollars, imports going up to 202 billion US dollars with 272% boost.

In Figure 14, countries which account for 50% of the aggregate export value of Turkey in 2018 are shown. Overall, Germany ranks first with a share of 9.6%, UK is in the second place with 6.6% share. Then, the following countries come respectively: Italy with 5.7%, Iraq with 5%, the USA with 4.9%, Spain with 4.6%, France with 4.3%, Netherlands with 2.8%, Belgium with 2.4%, Israel and Romania both with 2.3%.

In 2018, Turkey has made 80% of total exports to a set of 36 countries among 112 trading partners, so Turkey has export concentration in a set of countries.

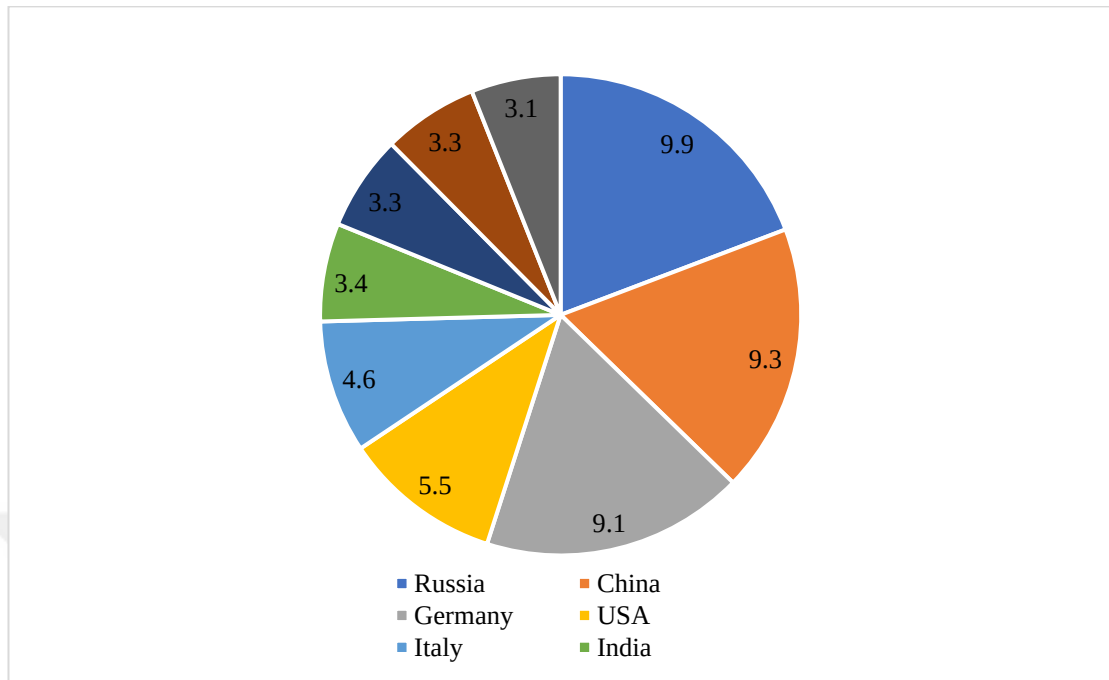
Figure 14: Turkey's Major Export Partners in 2018 (50% of Total Exports)



Source: www.trademap.org.

Figure 15 demonstrates higher concentration of imports of Turkey as shown by the fact that 9 partner countries constitute 50% of total imports. 9.9% of imports come from Russia due to import dependency of energy and 9.3% of import share belongs to China which is a dominant player in international trade, Germany stands in third place with 9.1% as a major trade partner of Turkey. These three countries compose almost 30% of total imports, followed by the USA with a share of 5.5%, Italy with 4.6%, India with 3.4%, France and UK with 3.3%, Iran with 3.1%.

Figure 15: Turkey's Major Import Partners in 2018 (50% of Total Imports)



Source: www.trademap.org.

Turkey is located at the intersection of Asia and Europe and at the center of important transport corridors such as TRACECA, TEN-T and Middle Corridor. Taking a step forward on the trade potential demonstrated in Figure 14 and Figure 15, Turkey has a strategic vision to use this geographic placement in a more beneficial way, in favor of trade expansion. This strategy shows itself in the form of heavy infrastructure investment in transport modes to strengthen logistics network as a public policy in addition to supportive institutional reinforcements including the establishment of necessary regulations. Based on the discourse about Turkey's prioritization policy for logistics network and budget program in large investment in transport infrastructure, the scope of this thesis is framed as the impact analysis of transport infrastructure investments for different modes on trade development in Turkey.

CHAPTER TWO

THEORETICAL FRAMEWORK

2.1. BROAD THEORIES ON THE SPACE-TIME DIMENSION

The theoretical setting starts with an overview of more general theories on the space-time dimension. Although there are numerical constructs outgrown from location and trade theories, the most prominent theories in line with the main theme of the thesis are briefly discussed.

2.1.1. Location Theories

Location theory has a central place in economic geography and regional economics research, as well as being commonly blended with trade theory and industrial organization. As the topic of this thesis pertains partly to economic geography and trade theory, the theoretical framework is explained with a general introduction to location theories which is closely related to the study's main theories. Despite being highly integrated, the main lines of location theory can be categorized as in Table 7. Location theory has strong ties with theories in economics, industrial organization and operations research as can be seen from Table 7.

Table 7: Main Categories of Location Theory

Research Strand	Main Focus
Neo-Classical Approach	Interplay of free market conditions based on supply-demand equilibrium.
Behaviouralist Approach	Firm behavior under imperfect information leading to sub-optimal location decisions.
Institutional Approach	Inherent characteristics of institutions are among main drivers for economic activity.
Economic Base Models	Exporting industries in a region.
Location Theories	Concerning agglomeration and particular location factors in a region.
Cumulative Causation Theory	Success breeds success in an upward spiral (opposite also holds, lack of success also breeds lack of success in a downward spiral)

Core-Periphery Theory	Linkages between core regions and peripheral regions with a focus on accessibility and transportation which are the factors identifying a region as core or periphery.
Industrial District Models	Clusters cultivating the benefit of co-operating networks thorough spillover on entrepreneurship, innovation and specialization.
Innovative Milieu Models	The role of the cultural factors and institutions on collaboration among actors for innovation in a region.
Competitive Advantage Theory	Competition based on labor, natural resources, capital and proximity to markets as suggested by Porter's model.

Source: Adapted from McQuaid et al. (2004: 12-13).

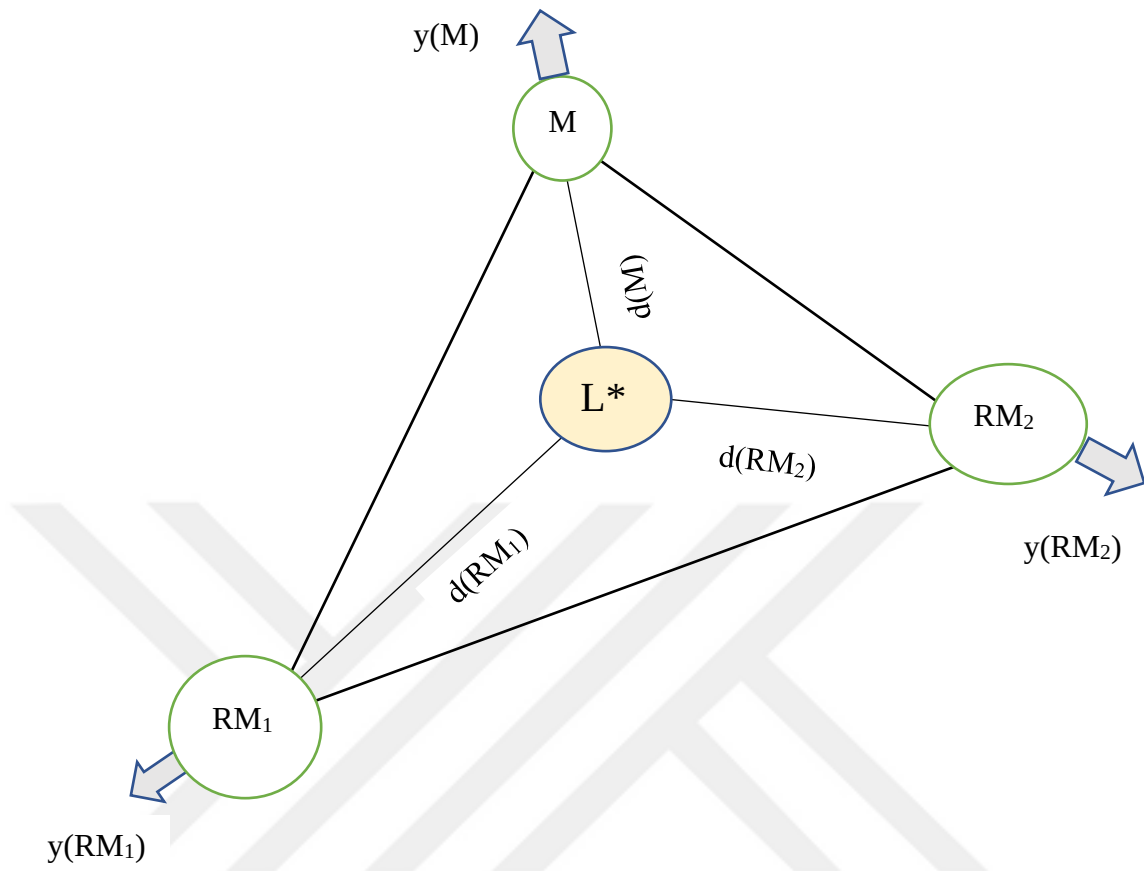
The foundations of location theory have been laid by Von Thünen's model on agricultural land use patterns and observation of a tendency to rising rents when gradually moving closer to the center (i.e. central market) in 1826 (cited in O'Kelly and Bryan, 1996). Alonso (1960) adapted an extended version of this model for urban land use, i.e. the bid-rent function theory explores the relationship between land and capital in the market for space. Urban land use, density of land use, population density and employment are explained according to the distance to the so-called Central Business District (CBD). In this model, a substitution effect between land and capital is observed. The closer a building is to the city center, the taller it gets by substituting capital for expensive land. When business is in a frontier part of a city, there will be a substitution of land for capital as land is cheaper. On the assumption that jobs are available in CBD, labor's housing preferences are also considered with a bundle of indifference curves. Households choose between living in the city center for higher rents and saving from transportation costs for short-distance travel to jobs or living far from the city center and commuting long distances. This framework explains the possibility of preference for diverse housing sizes in different locations with the compensation of housing size for distance to the urban center as a trade-off. In the spatial growth of cities, the urban area gets larger with the increase in income or population, shifting the bid-rent function to the right. This time, there will be a propensity to increase the density of land use with higher capital by constructing denser and taller buildings and a propensity to expand the city through the formerly fringe areas.

Growth poles theory developed by Perroux in 1949 and further extended by Boudeville (1966) is based on the idea of uneven development patterns in a region and

the presence of locomotive industries which propel growth by spreading their capabilities on other industries (Vazquez-Barquero, 2002; Briassoulis, 2020), through the concept of ‘spatial polarization’. Three aspects are notable in the notion of ‘propulsive’ firm/industry (Darwent, 1969). Firstly, the growth mechanism is dependent on the degree of individual activities of clusters as well as on the degree of interlinkages between them. Secondly, to be a pioneering cluster (firm, industry, etc.), ‘dominance’ is a necessary condition, which means that industry B is said to dominate industry A if the flow of materials from A to B constitutes a higher proportion in the total production of A. As the last point, the propulsive power will be higher for a larger industry/firm, so industry size also matters. This theory fits well with the properties of the transport industry as the polarization process occurs around a core industry and its supporting industries with upstream linkages (from core industry to supporting ones) and downstream linkages (from supporting industries to the core one).

Theory of industrial location which is conceived by Weber (1929) on the groundwork of Launhardt (Perreur, 1998) has been a fundamental framework in the examination of firm location choice. Weber has formulated the theory on the grounds of neoclassical theory under assumptions of perfect competition (with price-taker firms, not price setters) and constant returns to scale. The theory is based on the premise that industry location is chosen where transportation costs of input materials are at minimum ensuring total cost minimization and profit maximization. Labor, transportation and agglomeration are three essential elements in the cost of acquiring raw materials, transportation costs being the key factor. Figure 16 shows the optimal location problem of Weberian theory with the objective of shipping cost minimization. For the production of $y(M)$ amount to supply for the demand in market M , raw materials $y(RM_1)$ from RM_1 and $y(RM_2)$ from RM_2 are inputs to be obtained. The optimal production facility location is within the sphere of L^* based on relative distances and relative transportation costs of raw materials and final commodity depending on $d(RM_1)$, $d(RM_2)$ and $d(M)$.

Figure 16: Weber's Industrial Location Triangle



Weber's fundamental guidelines for factory location are acknowledged but found not inferential by Predöhl (1928) and Isard (1949). Similar critiques are also raised for the idea of taking transport costs as the core of the location problem and treatment of labor cost and agglomeration as subordinating factors (Greenhut, 1956; Pred, 1967). Adding up to Weber's location triangle, Isard (1956) considers substitution effect in the theory of industrial location and Moses (1958) develops a location-production model based on a neoclassical production function. Further theoretical updates are carried out by McCann (1993) considering minimization of total logistics costs rather than just transportation costs, namely costs of obtaining and keeping inventory. Different functions of logistics including ordering, inventory holding as well as inbound and outbound transportation are integrated into the location-production problem. Hotelling (1929) analyzes spatial competition between two retailers in an interdependent location and proposes 'principle of minimum differentiation' by keeping with identical products and jointly running business in the city center. Hotelling (1929) and later Palander's 1935 study (cited in McCann and

Sheppard, 2003) constitute foundations with their market area research to understand the effect of location on inter-firm competition when firms are interdependent. Contributions on industrial location are closely interconnected with agglomeration economies, so some overlapping theories will be discussed later in this chapter of the thesis.

‘Central place theory’ is introduced by Christaller in 1933 to explain the characteristics of geographic areas and the factors for their formation as cities, towns, villages etc., extended later by Lösch (1954). Further revisions have set a rich analytical material for transport studies through the research on the properties of Lösch’s and Tinbergen’s theorems (Mulligan, 1981; 1982); theorization efforts for sound economic foundations (Eaton and Lipsey, 1982), modeling exercises for the shocks on the economic activity between areas of low-density populations (Chalmers et al., 1978); developing a location-allocation framework considering transport cost factors (Kuby, 1989).

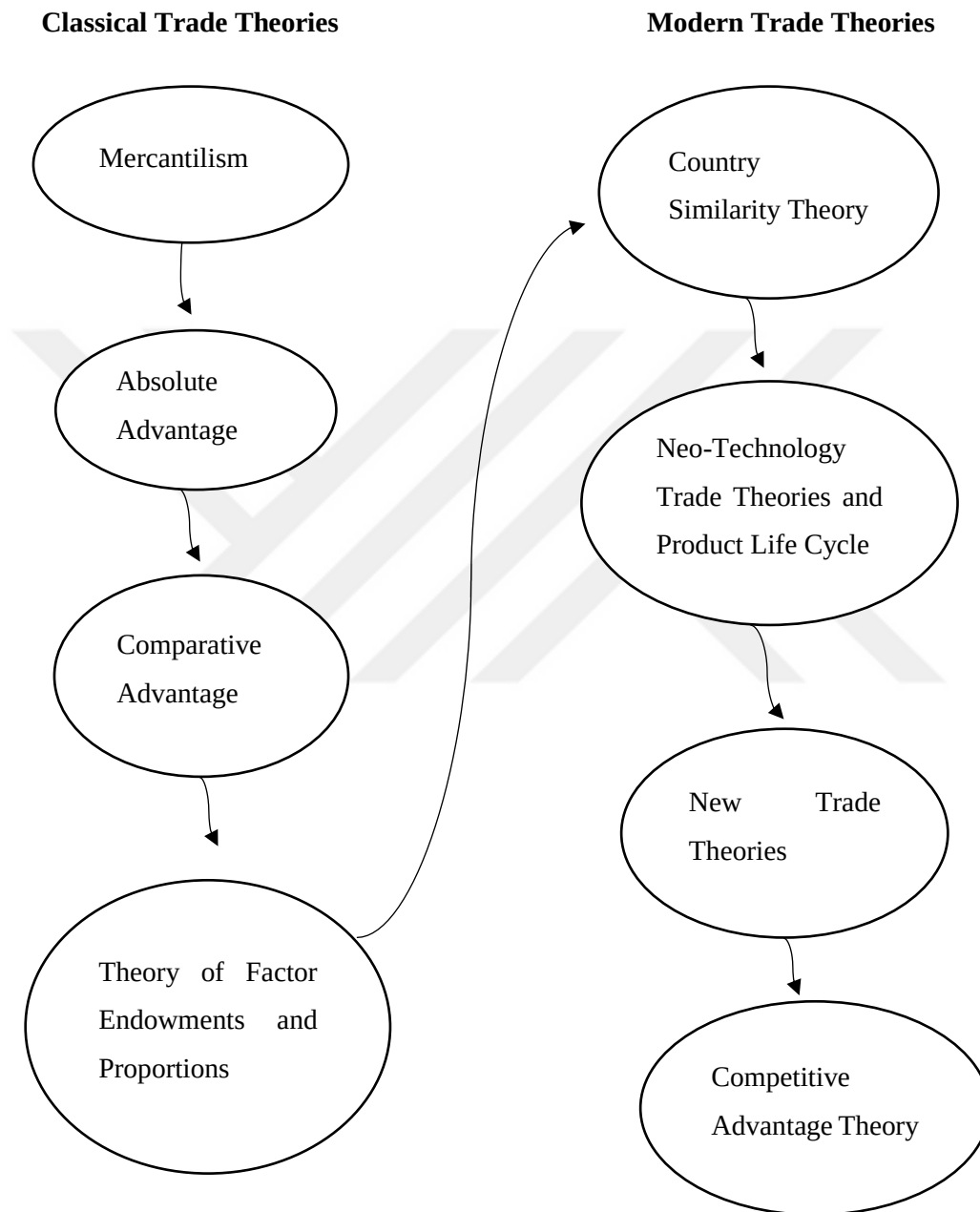
Considerations for transport infrastructure expansion involve the determination of location for main interchange points and transport hubs as well as optimal location decisions on agglomeration economies such as industrial clusters and logistics centers. Thus, applications of location theory occupy an important place in the interaction between transport infrastructure investment and trade development relations.

2.1.2. Trade Theories

The focus of this thesis centers on investigating the association between trade and transport infrastructure investment in Turkey. After a brief overview of location theories, another exhaustive research area - international trade theories are discussed as dictated by the objectives and framework of the study. Trade literature can be categorized from many different perspectives; however, the baseline of this research suggests categorization for the classical and modern approaches as the most appropriate classification method. Classical trade theories are grounded on the field of economics in a country-based view. In contrast, modern trade theories emerge from firm-based research in the field of business studies starting with the development of

MNCs (multinational corporations). The most prevalent theories of each category are shown in Figure 17.

Figure 17: Categorization of Trade Theories



2.1.2.1. Traditional Trade Theories

2.1.2.1.1. Mercantilism

Mercantilism dominated international trade and economic policies between 16th-18th centuries when the wealth of a country was defined with the amount of gold and silver assets held, degree of colonial expansion and size of mercantile marine fleet. The term refers to an economic system distinguished by interventionist economic policies based on the idea that exporting is the only way to receive the gains from trade and that protectionist measures on international trade are essential to hold the gains in the country (Irwin, 1991). In practice, each country aimed to end up with a trade surplus referring to a case when value of exports exceeded value of imports. According to Irwin (1992), mercantilist trade policy involves setting up export promotion measures to have a higher portion of the world's trade in the search for national power and unification of principles for state-building as referenced in Heckscher (1955). Perceiving mercantilism as a rent-seeking social system in line with Baysinger et al. (2008), mercantilism has also a dimension connected to government investment (for transport infrastructure and other trade facilitating social fixed assets) which are prone to influences by lobby groups. They analyze the outcome of lobbying efforts by power groups (so-called monarchs) to control government's interference for their profit maximization necessities. The findings show that favorable government regulations empower the rise of monopolies as a result of these group's rent-seeking behaviors in a mercantile economy. This situation results in possession of the wealth effects of government policies (like investment or export promoting-import restricting policies) by only a certain privileged sphere of society without an impact of majority, hurting the overall welfare of society. Despite the unification arguments within a single country in terms of state control, mercantilism causes divergence in the social structure. Also, isolation from a multinational economic system results in the case that prosperity from international trade is discarded, promised by the constructive principle of trade surplus corresponding to another country's trade deficit (Blitz, 1967). A contemporary term, neo-mercantilism, refers to orientation of a country to stockpile foreign reserves (Van Berkum and Van Meijl, 1998). China has been at the center of

recent debates and criticized for applying neo-mercantilist policies and damaging the system of global trade (e.g. Lind and Press, 2018; Atkinson, 2012; Rodrik, 2013; Atkinson et al., 2017). China's outstanding economic performance originates from the prolonged export subsidies to support export-led growth strategies and subsequent accumulation of massive amounts of foreign currency reserves with continuous trade surpluses (Aizenman et al., 2018). The so-called 'One Belt One Road (OBOR)' initiative raises questions in that sense, as a mega infrastructure project to develop transport corridors between China and Europe including land, maritime and pipeline routes for freight transportation and resilient supply of energy to promote trade. It is claimed that China is pursuing mercantilist policies to increase market share in its trading partners, opening the way for Chinese firms for the overtake of markets against foreign companies, bypassing competition in the global trade (Holslag, 2017).

2.1.2.1.2. Classical Theories: Absolute Advantage and Comparative Advantage

Adam Smith has initiated the phrase 'mercantile system' in the chapters criticizing the interventionist manifestations based on unrealistic ideals in contrast with the principles of laissez-faire capitalism in his landmark book 'Wealth of Nations' (Gomes, 1987). The liberal thought claims that interaction between market forces will offset monetary concerns on international trade by a natural mechanism ruling out the requirements of trade surplus and accumulation of foreign currency holdings. Smith claims that trade can occur in the case of absolute cost differentiation between two countries, i.e. when a country can produce a product more efficiently than another country. Assuming a world with two countries (X,Y) and two goods (A,B), if country X can produce A with less labor than country Y, then country X has an absolute advantage in A and country Y has in B. So, country X specializes in A and country Y specializes in B, both countries exporting the specialized good and importing the other product.

In query of what happens when a country has absolute advantage in both goods, Ricardo has theorized the concept of comparative advantage composing main principles of a theory of free-trade (Ricardo, 1817). Main proposition of Ricardian

theory is that in the case of a country having absolute advantage in all goods, both countries can benefit from trade provided that there is a difference in relative productivity. Based on Ricardian theory, Balassa (1965) has pioneered a measurement framework as ‘revealed comparative advantage’ proposing that country A has a revealed comparative advantage in product i when its export ratio of product i to its total exports of all goods is higher than the same ratio for the world – the ratio of total exports of product i in the world to the world’s total exports in all goods. This index shows the strength of a sector in a country’s exports relative to the same sector’s share in the world’s exports. Different variations of this measure are applied to various fields like manufacturing, technology etc. including Yeats (1985), Van Hult et al. (1991), Malerba and Montobbio (2003).

2.1.2.1.3. Neo-Classical Theory: Heckscher – Ohlin Model

A more concrete ground for free-trade theories has been constructed by Heckscher-Ohlin model based on Pareto-optimality principle (Sen, 2010). This theory has a focus on gaps in factor-endowments rather than orientation on relative efficiency of production factors (labor) as in classical theories. Neo-classical theory considers factors of production other than labor in terms of homogenous production technologies for all countries and holds the assumptions of perfect competition, constant returns to scale, factor immobility and homogenous preference of consumers. This leads to the factor endowments to be the sole expository of trade. As a main assumption of the model, as countries trade, factor prices converge to an ‘absolute factor price equalization’ between trading partners. A country exports the good produced intensively with the factors relatively most abundant. For instance, a country with abundant capital will export a capital-intensive good and import labor-intensive good. However, Leontief (1953) found that despite being a capital-intensive country, the US exports relied on labor-intensive products and imports comprised mainly of capital-intensive products. This controversial phenomenon has taken a substantial place in the literature as ‘Leontief paradox’. As another conceptual contribution, Stolper and Samuelson theorem has formed a general equilibrium model to analyze the link between factor and product prices, concluding that a rise in the price of labor-

intensive products results in rising wages in higher proportions. (Stolper and Samuelson, 1941).

2.1.2.2. Modern Trade Theories

Modern trade theories involve firm-level aspects on the contrary to the classical trade theories with a country focus. Corresponding to the focus of this thesis, the theories to be discussed are country similarity theory, neo-technology trade theories and product life cycle theory, new trade theories and Porter's competitive advantage theory. This theory line is associated with the theme of this thesis in that it is important to understand transport infrastructure investment's effect on the transport sector which forms the supply-side of transport services in the facilitation of trade.

2.1.2.2.1. Country Similarity Theory

Beginning with Linder (1961), trade patterns are addressed based on a demand-side perspective leaving the former supply-side angle (as in Heckscher-Ohlin model). Main hypothesis of country similarity theory is that companies essentially produce for domestic markets and they would export to similar countries as corresponding consumer preferences offer feasibility for trading both intra-industry goods and final products. Also, it is argued that demand patterns shift towards more sophisticated products when income rises. This theory is important for taking consumer demand at the core in explaining international trade and putting the demand similarity with close but differentiated goods at the heart of trade formation. This notion is empirically tested for example by Economides (1984); Kleiman and Kop (1984) showing higher volumes of trade between the more similar countries. Barker (1977) pays attention to the trend that trade grows in higher proportions to income and propose 'variety hypothesis' that rise in income entails increased demand for more various goods imported from abroad, causing an increase in trade more than proportionally. Both Linder's 'sophistication' (corresponding to differentiation) notion and Barker's 'variety' hypothesis imply more demanding consumers, central to the development of global supply chains and integrated transport systems in the rise of globalization.

2.1.2.2.2. Neo-Technology Trade Theories and Product Life Cycle Theory

The line of technology-based trade theories highlights how the difference and change in technology impact patterns of trade. Firm-level innovations in product and production processes result in both cost efficiency and the release of new products to the market. Diffusion of new technology and innovation across countries happens with a time delay giving the innovating country an advantageous position in terms of production and exporting. Unlike traditional theories which assume trade as a result of the technology gap (due to productivity differences), these theories relate the occurrence of trade with the inability to produce recently launched products at least for some time.

A precursor study by Kravis (1956) in this line has proposed the concept of ‘availability’ in the explanation of international trade, asserting that a country imports domestically unavailable products. The unavailability may come from the absence of natural resources or the inability to produce at an acceptable cost level referring to absolute and relative unavailability, respectively. The availability gap between countries stems from the degree of technological improvements and product differentiation. In the ‘technology gap model’ of Posner (1961), a technologically more improved country will benefit from exporting its new products to its trading partners until the partners find ways to imitate the product. Eventually, the innovation and related technology will be transferred all over the world, ending the advantage of the innovative country for this particular product. But as research and development activities will result in continuous innovations and launch of new products, the cycle will last and be beneficial to the advanced country. ‘Imitation lag’ is the time elapsed until the follower country imitates the new good, consisting of these elements:

1. foreign reaction lag: the time required for some domestic firms in the importing country to be aware of a potential competition brought by the new product,
2. domestic reaction lag: the time passed until all domestic firms realize the new product imported as a competitor for its domestic substitutes,
3. learning lag: the time for the learning to imitate the production process of the new good and produce it in the home country.

The relationship of international trade with technology and foreign direct investment has given rise to the generation of 'product life cycle theory' by Vernon (1966), adopted from the marketing discipline. Articulations are developed on the baseline that a product has three stages in its life cycle: new product, maturing product and standardized product. A new product is produced and exported by a leading developed country through innovations in this country. During the maturing phase, technology and capital transfer make other advanced countries produce and export the product while less developed countries still import. When the product becomes standardized, less developed countries can become a production location, offering a competitive advantage. Hirsch (1967) grounds the product life cycle hypothesis on factor proportions between labor and capital. In the early stages, a new product requires labor-intensive techniques with a high proportion of skilled labor. However, as the manufacturing volume increases, there will be a shift to capital-intensive production processes. When the product becomes standardized gradually, less skilled labor is employed in production.

Krugman (1979) explores the technology gap and trade relation in a general equilibrium setting in the 'North-South model' based on Vernon's framework, with the innovator country North and imitator country South. South can produce the new product with time lags after the product is innovated and launched to the international market by North. Trade is generated as an outcome of the lagged technology transfer imposed by North's monopoly on new product development. North makes continuous innovations of new products to export and start to import the previously innovated products from the South. This model is also assessed by Dollar (1986) using the theoretical background of Heckscher-Ohlin paradigm. The main implication states that if relative production volume can be kept stable, a steady ratio of factor prices and terms of trade will be maintained between countries. Another extension by Jensen and Thursby (1987) includes endogenous rate of innovation suggesting a reallocation of labor in product innovation because of raised competition in labor market by the South.

2.1.2.2.3. New Trade Theories

New trade theories have used assumptions of increasing returns to scale (as alternative to constant returns to scale) and imperfect markets with monopoly and oligopoly (as an alternative to perfect competition) to overcome contradictions between empirical work and theoretical framework of neo-classical theory. The introduction of scale economies has been quite an innovation to analyze increasing returns in production on the form and benefit of trade. This line of research encompasses various paradigms from fields of industrial economics, new growth theory and political economy (Deraniyagala and Fine, 2001). The premise of free trade as a policy is explored with conditions of scale economies and imperfect competition. The proposition of 'strategic trade policy' underlines the role of export subsidies to draw excessive profits from foreign firms to domestic firms (Brander and Spencer, 1985; Dixit and Kyle, 1985; Eaton and Grossman, 1986). Brander and Krugman (1983) point to oligopolistic competition as a source of international trade with the characteristics of 'bidirectional dumping' behavior. Spencer and Brander (1983) investigate the effect of government policies including R&D incentives and export subsidies on the composition of trade markets with imperfect rivalry. Krugman (1984) exhibits the usefulness of a protectionist trade policy with a tariff when the foreign country has no protectionist measures, in such a case an import restriction behaves like an export subsidy. Dixit and Grossman (1986) propound in favor of protectionism if the information about the return of protection is available for the most promising industries, otherwise, all parties are better off with free trade.

Product differentiation is a primary conceptual tool in the analysis of intra-industry trade in new trade studies. Product differentiation can be on the 'desire for variety' as in Dixit-Stiglitz (1977) or appeal to consumer's 'diverse preferences' as stated in Lancaster (1980). Vertical differentiation describes variation in quality and horizontal differentiation means discrepancy in realized or perceived attributes of a product. Helpman (1981) and Krugman (1980) synthesize product differentiation with scale economies and factor proportions theory, later putting forward in Helpman and Krugman (1985) that trade is a result of differentiated product development resulting from scale economies in the search for higher earnings in international markets.

2.1.2.2.4. Porter's Competitive Advantage Theory

Porter (1990) has built a distinctive construct to define national competitiveness in international trade based on the main findings from the benchmarking field studies of business practices. The main premise holds that the competition skills of an industry are not inherited but generated by innovation and improvement. The model interconnects trade theory with competitiveness attempting to explain the success of certain industries via a new paradigm named 'the competitive advantage' to replace the traditional 'comparative advantage'. The theory asserts that firm-level and nation-level competitive advantage springs from the existence and the quality of four main factors: factor conditions; demand conditions; related and supporting industries; firm strategy, structure and rivalry. These attributes and their interaction establish the 'diamond model of national advantage'.

Factor Conditions: A country's position on human, knowledge and physical resources in companion with capital and infrastructure determine the competitiveness of domestic firms, industries and also the country. Basic factors like natural resources, unskilled labor are relatively easily attainable contrary to advanced factors which require constant and heavy investment in terms of human and physical resources (as in the case of transport infrastructure).

Demand Conditions: Nature and size of domestic demand, growth of demand and its tendency to internationalization are important attributes in national trade competitiveness.

Related and Supporting Industries: Competitive power is endorsed with the synergy between industries through access to least-cost production factors, knowledge spillovers and joint-innovation activities.

Firm Strategy, Structure and Rivalry: Country-specific cultural and institutional settings frame the managerial and organizational ability of stakeholders in society. A firm's business process should be coordinated and optimized to gain competitive advantage, an ability conditioned upon the strategy and structure of the firm which is highly dependent on the cultural and institutional background of a country.

Two external factors ‘chance and government’ are also influential in national competitiveness. Chance includes unexpected events happening outside the control of firms and authorities (e.g. global financial turmoil, pandemic, disruptive innovations). Government also has a role as a policy-making institution, impacting the system and being affected by the interaction within the system in a bidirectional relation (with a feedback connection departing from perspectives of ‘mercantilism’ and ‘strategic trade policy’ in economics).

Despite its usefulness to extract competitive factors in large exporting countries, Porter’s home-diamond model is found not applicable to small countries in the integrated system of trade (Hodgetts, 1993; Brouthers and Brouthers, 1997). Some extensions by Rugman and D’cruz (1993) have been made on the original version of Porter’s diamond framework in a way to grasp the competitiveness of small, open, free-trade partner economies considering actions of multinational enterprises (MNEs) and foreign actors. On this so-called ‘double diamond model’, Chang Moon et al. (1998) have developed a more generalized version. This new theme acknowledges the crucial role of globalization in international competition and the strategic differences between domestic and international firms. Contributions of Bellak and Weiss (1993); Dunning (1993) result in the development of ‘multiple diamond framework’ in consideration of regional aspects. The model is based on the rationale that operations of MNEs are fragmented in many regions making national borders irrelevant, in which case outsourcing activities by MNEs in the home country constitute also a source of competitiveness.

2.2. SPECIFIC THEORIES: A GENERAL-TO-SPECIFIC OUTLINE

Specific theories are outlined to shed light on different aspects of transport infrastructure and trade development relationship in different scopes. Through a top-down approach, starting with the explanation of macro-level theories, the discussion continues with theories on spatial effects and finalizes with theories covering micro-level impacts.

2.2.1. Macro-Level Theories

Macro-level theories are instrumental in the understanding of transport infrastructure-trade nexus in a comprehensive scope. These theories involve public policy, transport policy and planning as well as transport economics.

2.2.1.1. Public Policy

In a broad sense, the scope of public policy can be defined as what the government (and its representatives) does about a problem brought to be solved, including doing nothing. In the light of several perspectives, public policy can be defined as a general structure for government actions in the realization of public targets, a research ground of government decisions and actions for resolution of public interest (Cochran and Malone, 2009). Besides, Birkland (2019) outlines essential features of public policy as below:

- Public policy is generated in response to an issue that deserves government response,
- Public policy aims at public interest,
- Public policy is directed towards a predefined goal like preventing an incidence, making a compromise for the public interest, undercutting negative impacts of an event,
- The supreme authority of policy building is government,
- Actors from public and private arena will have dissimilar views on issues, solutions and policies.

Public policies are organized under a certain policy procedure, executed through laws, regulations, government actions along with funding decisions and administered by a public organization. As another attribute of public policy highlighted by Rinfret et al. (2018), policy-making process takes place under the influence of four factors: political environment, economic environment, social-cultural environment and administrative environment.

Research on public policy drastically concentrates on theory development in a multidisciplinary approach to develop a baseline for the definition of the policy

process. Initial attempts belong to Lasswell (1951, 1956) with the establishment of 'policy orientation' as a methodology and systematization of policy process in a model consisting of seven stages: intelligence, recommendation, prescription, invocation, application, appraisal and termination. Further modifications have standardized a well-structured analytical system called 'the cycle model' with five stages: agenda-setting, policy formulation, decision making, implementation and evaluation (ultimately termination) as stated in Jann and Wegrich (2007). In a nutshell, agenda-setting stage stands for the recognition of problem and consideration for action; policy formulation refers to clear expression of problems and attachment of the problems into the government program; implementation is taking the course of action preferably with decision and timetable details along with a plan for resource provisions; evaluation is the comparison stage between the actual and projected output of action, leading to modification or termination. Transport infrastructure investment is an issue subject to large state intervention under the scope of public policy and obligated to provisions of fiscal policy, budget planning, transport policy and strategic planning by government agencies. The cycle model provides an explanation mechanism for assessing transport investment decisions. After a brief introduction to public policy in general, the following concepts which are in parallel to the scope of this study are reviewed: 'institutional theory, incremental theory, political system theory and public choice theory'.

1. Institutional Theory

Institutional view emphasizes the government's role as an ultimate decision-making body in terms of constitutional obligations, judicial rulings, common law duties and as an enforcement body through which different state institutions participate in the adoption, implementation and execution of policies. This view is based on the premise that the structure and organization of institutions determine the nature of policies and the participants that are influential on policy process in the interplay between interest groups such as markets, companies, corporations, national or local state institutions, civil associations, lobby groups (Kraft and Furlong, 2019).

2. Incremental Theory

Set out by Lindblom (1959), incrementalism describes a policy-making process characterized by continuous small changes from the status quo by accepting current

policies as legitimate against the uncertainty of new or modified policies. This view incorporates a heuristic way of policy process in the search for a way that is working. According to Lindblom (1979), incremental theory prescribes maneuver of conservatism with a fast sequence of changes in three different ways:

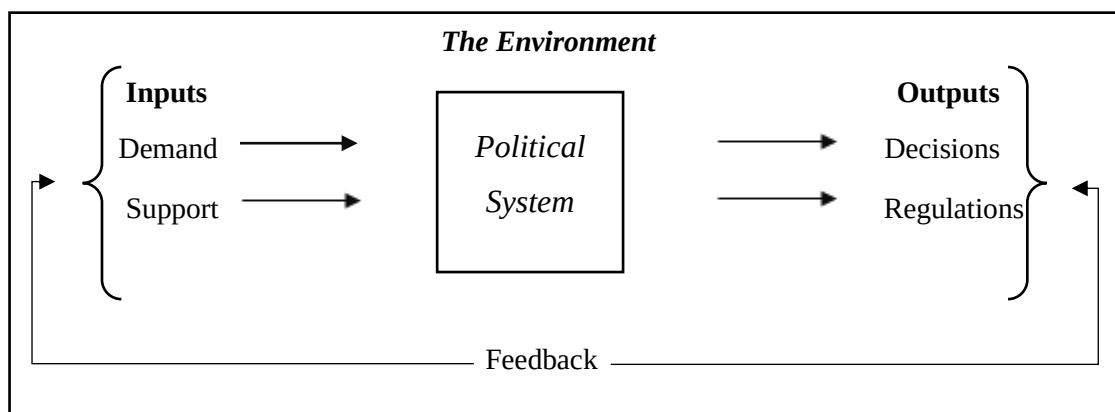
- a. simple incrementalism: policy changes are limited to only very insignificant levels.
- b. disjointed incrementalism: a few recognizable policy alternatives are subject to complex analytical methods, analytical aspects are important with priority for fixing ineffective components of a policy, smoothing is carried out by trial-error-retrial loops.
- c. strategic incrementalism: simplification of policy process is realized by analyzing only a few sets of tactics chosen after calculations.

Transport investment is a long-term commitment containing many actors and changes in the programs are very difficult and impracticable to be executed, so disjointed incrementalism in the evaluation phase and strategic incrementalism in the decision-making step is relevant for transport investment.

3. Political System Theory

In system theory, public policy is constructed within a framework attributed to responsive actions of a political system to needs and pressures received from actors in different environments as in Figure 18.

Figure 18: A Framework for Political System



Source: Taken from Easton (1957: 384).

As shown in Figure 18, this model is based on a basic input-output analysis incorporating behavioral approach to public policy process. The model fits with the theme of transport investment appraisal studies in which return (output) on investment (input) is measured for policy evaluation (feedback).

4. Public Choice Theory

With a foundational base of ‘rational theory’ from microeconomics, public choice theory is interested in how different decision rules and decision-making processes change the output of ‘public goods and services’ provided by the government (Ostrom and Ostrom, 1971). This approach presumes ‘methodological individualism’ from Buchanan and Tullock (1965) in which policy process is analyzed around a representative individual, not a community, where these individuals are assumed to be rational, self-interested, utility maximizer decision-makers on a given level of information. In this regard, individual citizens’ perceptions and voting potentials are decisive in decisions on transport infrastructure investment.

2.2.1.2. Transport Policy and Planning: A Matter of Public Policy

Transport policies are a key part of modern civilization and they are to be built optimally for highest gains and lowest level of unplanned externalities. Hence, both public and private actors must make attentive planning of provisions, layout and construction of transport infrastructure and accompanying services. Despite their frequent use of interchange, Slack and Notteboom (2013) make a distinction between two terms with the following definitions:

Transport policy pertains to generation of structures and schemes to reach certain development goals concerning social, economic and environmental objectives, and the operation and performance of the transport system.

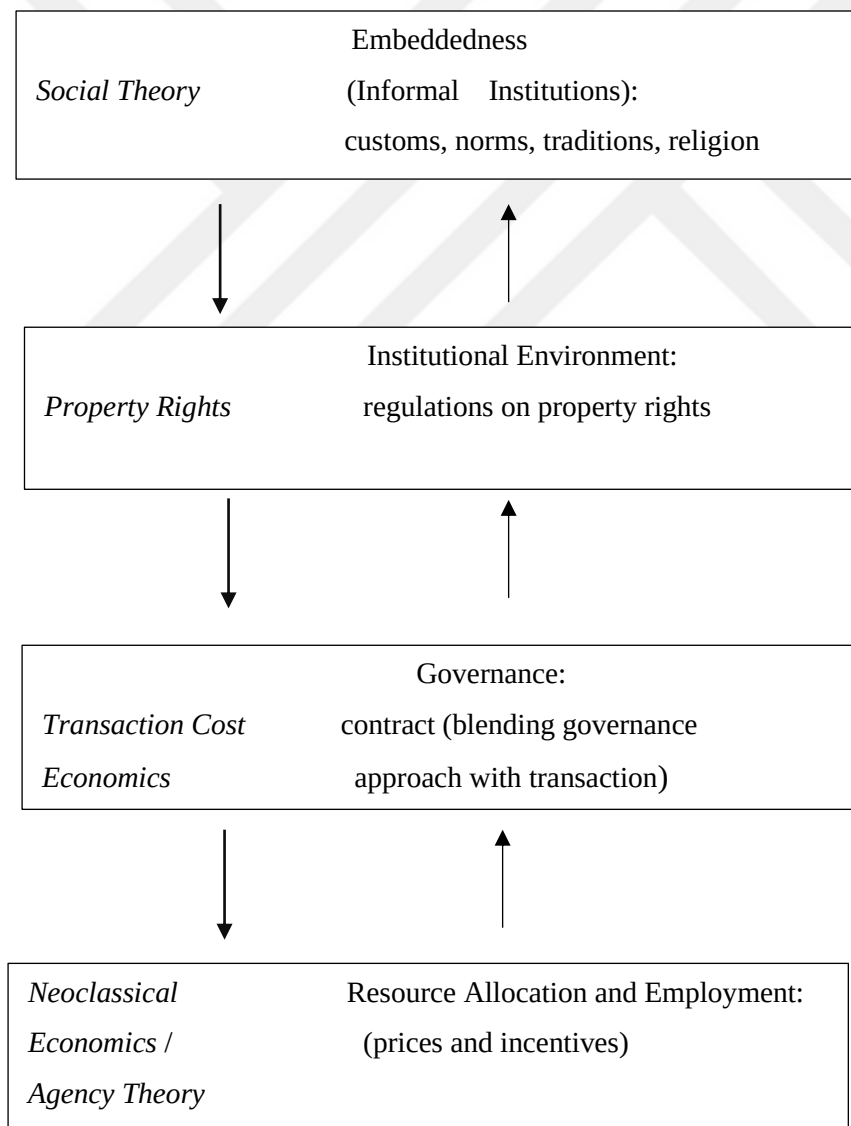
Transport planning relates to the organization and execution of actions aimed at tackling particular issues.

Interest groups in transport policy involve participants both from public and private sectors. On the one hand, government ownership and controlling of numerous elements of transport system along with its regulatory role leads to heavy government engagement in transport policy process, making transport a public good as proposed

by Stopher and Stanley (2014). On the other hand, private sector holds the major share in some transport businesses such as airline, obtaining power on the policy process.

Berg et al. (2017) specify three broad transport policy means: infrastructure investment (adding new connections in the transport network, increasing accessibility, enhancing quality of transport infrastructure assets and services), pricing to influence the behavior of transport actors (price incentives including price discriminations - e.g. student ticket reductions, ecological taxes of fossil fuels, clean energy incentives) and regulations (emission standards, driving limits, market controls for fair competition and prevention of monopolistic-oligopolistic behavior).

Figure 19: New Institutional Economics Theory



Source: Adapted from Williamson (2000).

As denoted by Button (2010), the inconvenience of neoclassical theory for transport studies is offset with the introduction of ‘new institutional economics’, giving a broader analytical framework for transport policy. In an overlay of the economizing process as illustrated in Figure 19, traditional institutions such as norms, rules, laws on property rights transform only in the long-run; however governance, prices and incentives can alter in shorter terms (Hasselgren, 2013).

The transformation of transport planning paradigms with related actions and approaches are summarized in Table 8. In consistence with notions of new institutional economics, transport planning paradigm is affected by the social and political trends of the time. For instance, structuralism is bringing positive discrimination as a remedy for social inequalities whereas the domination of market economy results in reliance on performance evaluation. In all eras of transformation, actions involve various ways of transport infrastructure investment.

Table 8: Evolution of Transport Planning Paradigms

Era	Main Theme	Actions	Methodology/Approach
1970-1980	✓ Location Theory (Weber) ✓ Structuralism	✓ Highway Building ✓ Public Transport and Subsidies ✓ Transport Management	✓ Systems Analysis ✓ Incrementalism ✓ Mixed Scanning Approach
1980-1990	✓ Managerialism ✓ Structuralism ✓ New Economic Geography	✓ Market Dominance	✓ Positive Discrimination ✓ Pragmatism
1990-2000	✓ Company State ✓ Social Market	✓ Road and Rail Construction ✓ Partnership Investment	✓ Performance Indicators ✓ Return on Investment ✓ Social Welfare
2000-beyond	✓ Integrated Transportation ✓ Sustainability ✓ Inclusive Transport Policy	✓ Regional Mega-Infrastructure Projects ✓ Investment on Different Modes ✓ Multimodal and Intermodal Developments ✓ Deregulation and Privatization	✓ Transport Network Connectivity ✓ Efficiency Analysis ✓ Transport Demand Management

Source: Developed based on Banister (2002) and Schiller et al. (2010).

The sub-categorical relation of transport policy to the public policy can be observed retrospectively in the transition of transport infrastructure policy

implementation as well. A brief historical explanation of transport infrastructure as a public policy tool is important to highlight the main theme of this study. Technological developments have been the main engine in the pathway to contemporary industrialization. The advances in new technologies enabling the use of new materials, the invention of engines working with alternative energy sources, division of labor and specialization contributed to mass manufacturing. The rising demand for goods and services and the continuous supply with mass production have nourished the developments in transport infrastructure and its complementary technology. This reciprocal interplay is still ongoing. Furthermore, the emphasis on transport infrastructure investment compounds as a means of public policy in macro decision-making. Millward's 2005 and 2011 studies (cited in Hasselgren, 2018) recognize three profound stages in the evolution of transport infrastructure in many countries. In the first stage, initial infrastructure is developed by private corporations and government becomes interested in the network effects when the investments turn into profitable systems. Theories on government intervention in transport infrastructure provisions have been a main area of research during this phase, which have a considerable impact on transport infrastructure expansion, financing and ownership structures (Meyer, 1906; McCormick, 1933; Nelson, 1938; Roberts, 1959; Dearing, 1950). The second stage involves nationalization trend for transport infrastructure provisions in the middle of the 19th century. Land transportation ownership is transferred to government with the implication that government would be better at cultivating wider economic benefits of the system. The third stage is characterized by liberalization and deregulation waves in 1980s all around the world. In this stage, transportation has become a market-driven industry with a hybrid model consisting of public and private influence. The regulations and organizations are adapted to free-market requirements after the liberalization of transportation services. All of these stages are determinant in the broader economic benefits of transport infrastructure investments.

2.2.1.3. The Evolution of Transport Economics

Transport economics is an outgrown field from economics to address specific characteristics of transportation, namely the spatial separation and the travel time to

overcome this separation in the economic analysis; complications arising from derived demand nature; non-transferability and inseparability as a service which means that production and consumption are simultaneous (McFadden, 2011; Stubbs et. al., 1984). This specialized discipline is mainly applied microeconomics (Button and Pearman, 1985; Prentice and Prokop, 2016). Application areas of transport economics include but are not limited to agricultural production, manufacturing, trade, government policy and location choice. Thus, it utilizes a prosperous depository of knowledge in other applied economics disciplines like production theory, consumer theory, spatial economics, behavioral economics, international trade theory, public finance and public policy (Prentice and Prokop, 2016). There are several aspects that separate transport economics from mainstream economics (De Palma et al., 2011), which are:

- It deals with real-world problems to obtain practical implications as guidelines for decision-making;
- new theories are put into practice for the latest issues quickly;
- it is an area characterized by rapid change driven by technological and social development.

Transport economics provides a useful background in the evaluation of transport investment appraisal and by extension resource allocation issues related to investment decisions at all levels from a mega-project appraisal to construction of a small bridge (Sharp, 1973). This study deals with the interconnection between transport infrastructure investment and trade development; therefore the focus of this study stands as a main topic of transport economics.

Within the context of transport economics, the evolution of transport-trade nexus is briefly mentioned to understand their transformational relationship in a historical perspective. In the first place, trade and transport routes have been in an interplay with globalization all along the history, which means that as trade grows on new routes, globalization steps up to an upper level. Vanham (2019) provides an overview of globalization eras with an emphasis on trade patterns and logistics. Accordingly, the earliest version of globalization was around the 1st century with the transportation of Chinese luxury products to Rome through the Silk Road. Spice and silk were the main commodities of this intercontinental trade engagement. The next pattern of trade was started by Muslim traders in the 7th century and trade flows

expanded from the Arabian Peninsula in all routes until 15th century. Spice was the main item in these dealings and it was mainly shipped by maritime routes to Europe. In that way, the Belt and Road connection of trade has emerged. Between 15th and 18th centuries, explorers discovered new geographic zones of the world through scientific developments in shipping, astronomy, mechanics and so on, making the way for the industrial revolution. The first era of globalization (1800-1914) was realized as an outcome of the First Industrial Revolution and it was reinforced with logistics technologies like steamships and trains which were carrying highly demanded products all over the world from Britain. With new inventions in ship technologies, other nations also boosted their exports through product specialization. The revolution created a raise in transport infrastructure demand for an upgrade on the scale, capacity and usage of transport systems. This introduced intense competition between modes. Although global integration through trade was hampered heavily by the world war, the second era of globalization began following World War II with inventions of the war-time period in terms of military logistics and advancements in air and land transportation. In the third era of globalization, the invention of the ‘internet’ has brought excessive weight on value chains with the availability of fast and accurate flow of resources among regions. This was the milestone of the ever-increasing level of international trade and logistics activities in the 2000s. With recent developments in information technology, a concept called ‘Industry 4.0’ has appeared and resulted in ‘Globalization 4.0’. In this era, digitalization and trade competition between two dominant powers (the US and China) in the world is shaping global trade and logistics.

Outlined by the phases of globalization, infrastructure of transportation networks has functioned as a core instrument for government/ruling authorities in the fulfillment of cheaper and faster shipping requirements by the private sector with an escalating focus, as international trade and the demand for transportation increase through globalization.

As mentioned earlier, technological improvements are pivotal in the development of transportation systems, so a summary of the technological advances in transport infrastructure and related equipment is presented in Table 9 in chronological order.

Table 9: Developments in Transportation Infrastructure and Equipment

Period	Technological Event
Around 3000 B.C.	Domestication of the Horse Horse-drawn Vehicle with Wheels Sailing Ships in Egypt First Aqueduct Bridge by Assyrians
300 B.C. to A.D. 500	Wheelbarrow Road Infrastructure by Romans Canals are Constructed by Chinese
500 - 1000	Viking Ships Crossing the Atlantic The Invention of Compass by Chinese
1000 - 1500	First Contemporary Steering Three-Mast Ships (1450)
1500 - 1800	Steam Engine (1712) and Steamcar (1769) Balloon Flight (1783)
1800-1850	Fulton Steamboat (1807) The Bicycle (1816) Surfaced Roads (1816) and Steam Railroad (1825) First Electric Car (1834) Iron Ship (1843)
1850 – 1875	Airship (1852) Compound Steam Engine (1854) London Subway (1863) Oil Pipeline (1864) and Internal Combustion Gasoline Engine (1866) Transcontinental Railway (1869) Asphalt Paved Road (1872)
1875 - 1900	Steam Turbine Engine (1884) Benz Gasoline Car (1885) Diesel Engine (1895) and Truck (1895)
1900 -1925	Wright Brothers Airplane (1903) First Helicopter in the Air (1907) Ford Model T (1908) Zeppelin Scheduled Passenger Flights (1910) First Electric Traffic Signal System in the US (1914) Diesel-Electric Locomotives (1917) First Radio-Controlled Aircraft – First Drone (1917) Passenger Airplane Flights (1919)
1925 - 1950	Liquid Propelled Rocket (1926) Autobahn (1933) Sikorsky Helicopter (1939) Jet Engine (1941) and Passenger Jets (1949) Tractor-trailers
1950 - 1975	Hovercraft (1956) Intermodal Container Service (1957) Sputnik I (1957), Boeing 747 (1966), Concord SST (1969) High Speed Rail System (1964) Maglev Train (1969)

1975 - 2000	Satellite Dispatch Trucks Space Shuttle (1981) Double-Stacked Container Train Service (1984) Unmanned Air Vehicles (1991) Toyota Fuel Cell Forklift (1996) Prius Hybrid Electric Car (1997)
2000 - beyond	Self-Driving Vehicles High-Tech Drones

Source: Prentice and Prokop (2016: 4-5).

According to Table 9, firstly the industrial revolution has had a groundbreaking impact on the scope of transport infrastructure. The second effect through the invention of the internet has been even larger, changing exponentially the context of infrastructure and equipment. In recent decades, the degree of ICT development has become essential for a quality transport system. To account for the relationship between technology and transport infrastructure, this study employs ICT as a complementary infrastructure in the exploration of trade effects of transport infrastructure investment in Turkey.

2.2.2. Spatial Spillovers

As outlined in Figure 2, theories that explain spatial spillovers compose the second line of specific theories. These theories include transport geography and network theory which provide a rich body of knowledge contributing to the understanding of transport infrastructure-trade relation.

2.2.2.1. Theory of Transport Geography

Transport geography is defined as ‘the movement of people, goods and information across time and space where this movement’s spatial arrangement depends on characteristics and constraints related to the origin and destination, scope, nature and aim of the mobility’ (Rodrigue, 2021a). Hanson (2003) projects space as a commodity in response to restrictions of distance in spatial and temporal dimensions, portraying transportation like a medium of exchange buying space and time in return for a monetary value, taking geography as an integral part of transportation.

Transport geography is based on several principles (Rodrigue, 2021a), such as:

- Transportation stems from the spatial interaction of derived demand for goods and services.
- Distance is a function of space, time and effort.
- Space is both a generating and limiting factor for mobility.
- There can be convergence or divergence between space and time.
- A location can be central or an intermediate transit point.
- Transportation uses space to cope with geographical constraints.
- Transportation seeks large scales however is constrained by microscale.
- Velocity is a modal, intermodal, and organizational force.

As a multi-disciplinary research field, transport geography is studied under three main approaches: positivism, structuralism and post-structuralism (Coe et al., 2019). With positivism, quantitative line of studies has dominated the field with a scientific, solid and systematic knowledge-generation view. Generalized rules and analytical frameworks are searched in spatial configuration of economic landscape; formal mathematical models are abstracted based on proven axioms, statistical methodologies are employed for empirical evidence. The principles of positivism in geography are discussed in the influential work of Harvey (1969). These techniques are exercised on urbanization, regional science, location analysis, international trade patterns, travel behavior, migration and all varieties of spatial structure and interaction. This thesis concerns with the characteristics and mechanism of spatial flows for an emerging market economy, thus the positivist paradigm is to be the main ground for the analytical framework. Nevertheless, the other two approaches draw noteworthy attention in academia as well. According to the structuralist view, implied characteristics disguised under the structures are the reality and they are to be unveiled with a normative attitude to reach a better world. Structuralists question the role of observation, measurement and mathematical modeling in the understanding of social structures as well as the premises of neoclassical economics. Main structuralist discussions comprise gender, capitalism and social class structure, race, social justice, inequality (e.g. Massey, 1984, 1994; Harvey, 1973, 1996; Hanson and Pratt, 1995; Mackenzie, 1989). The last approach, post-structuralism postulates the co-existence of multiple realities in any fact at the denial of a sole truth, accepting integration of partial truths biased by the perception of the reasoner. This recent strand's main areas are the

discourse of power, subjectivity and social potential (e.g. Pratt, 1999; Gibson-Graham, 2000; Radcliffe, 2006; Gibson et al., 2018).

The area of transport geography builds upon ecological, regional and spatial themes of geography, of which the last context has occupied a cardinal standing as of mid-1900s with a myriad of theoretic, empirical and quantitative work (Taaffe and Gauthier, 1994; King, 1976). Research concerning spatial examination of location issues and regional science has revisited earlier German models (namely concepts on land use, central place theory and industrial location theory), especially Christaller's central place theory for the survey of urban systems. At the outset of this discipline, Ullman (1956) conceptualizes three controlling principles of interaction among locations: complementarity, transferability and intervening opportunity. Complementarity describes the effective demand in a place for over-supply of a product in another. Transferability is possible if cost-effective transportation of a product is available in terms of time and monetary value. Intervening opportunity refers to the condition that closer alternatives impede interaction between distant locations.

A mass of studies has grown upon the context of Ullman's spatial interaction framework (Krmenc and Esparza, 1993). Olsson (1965) has made contributions to the generalization of spatial interaction theory, by combining central place and migration theories to investigate variations in individual migration distances. Wilson (1970) has modified the standard Newtonian gravity model with entropy-maximizing principles on statistical foundations. Fotheringham (1983) develops a theory of competing destinations (CD) with unbiased friction of distance parameters and later the framework is empirically tested regarding different flow patterns between nodes in a hierarchical network in Fik and Mulligan (1990). According to these models, the interaction between supply node x and demand node y is described by a function of production possibility in x , demand level in y , flow impedance factor (caused by intervening places-a choice for proximity) and competition of suppliers.

Dacey (1966) posits 'county – seat model' for the distribution and arrangement of places in urban areas considering the influence of the political process. Another pile of research has been dedicated to behavioral evaluation of distance-decay (friction of distance) parameters in response to effects from spatial structure and interaction, both

theoretically and empirically (Johnston, 1973; Fotheringham, 1981; Cliff et al., 1974; Curry et al, 1975; Fotheringham and Webber, 1980).

Krugman (1991a, 1991b) has broken novel grounds on transport geography by the introduction of ‘new economic geography’, a philosophy about space-economy dimension, founded on various back-and-forth linkages between transport costs and scale economies. Although related to new trade theories and with the main arguments of location theory, this notion has been a starting point of a new paradigm in transport geography to understand spatial differences in the light of a general equilibrium theory better than the previous partial equilibrium models (Gaigne and Thisse, 2013), a divergent assessment from mainstream economics. As a main progression, transportation costs are absorbed into Dixit-Stiglitz type competition model in an ‘iceberg technology’ form, referring to the assignment of transportation costs in the loss of goods during shipment, i.e. the good transported incurs the transportation cost itself. Krugman has integrated increasing return in scale economies, merchandise trade flows and mobility of production factors into the renowned ‘core-periphery (CP) model’. CP setting involves two regions: the core in which manufacturing is clustered as the main economic activity and the periphery which supplies agricultural products to the core. Ottaviano et al. (2001) make alterations with a different demand system to obtain a more suitable framework for spatial development gaps and raw materials required for production to the core. In Fujita et al. (1999), extensions within a three–region construct for the CP model have been established and its practicality is shown with the new insights provided by multiple-region cases. Ottaviano and Thisse (2001) build a simple model with monopolistic competition and increasing returns to scale to obtain a more suitable framework for spatial development gaps. Baldwin et al. (2003) draw inferences from new economic geography concerning prosperity and policy.

Transportation is keenly connected to new economic geography since it takes transport costs as the main explanatory factor in agglomeration advantages in the search for a profound understanding of structure and behavior of agglomeration (MacKinnon et al., 2008; Docherty and MacKinnon, 2013). Thus, in the part dedicated to agglomeration, concepts of new economic geography are explained in more detail in the context of the relationship between transport costs and agglomeration.

2.2.2.2. Network Theory

Networks are a major subject of study in disciplines such as mathematics, biology, transportation, geography, sociology, physics and computer science as most systems can be defined in terms of nodes (vertices), links and edges. For instance, the internet is a global network of networks. Similarly, the famous term global market is a network composed of local market networks in which manufacturers and consumers interact and all of the nodes are interlinked via transportation links, altogether composing global supply chain networks.

Regarding, conceptual baselines, Euler laid the theoretical foundations for graph theory with the very first transportation network problem of ‘Seven Bridges of Königsberg’, a network formed by islands as nodes and bridges as links. Based on graph theory, Euler has mathematically demonstrated the impossibility to walk through the town by going across bridges only once, as a result of the characteristic nature of graphs. A graph symbolizes an abstract network expression such as $G = \{N, L\}$ where N denotes nodes and L denotes links. Graphs can be in spatial/nonspatial form; involve undirected/directed and weighted/unweighted modules (Anderson and Dragičević, 2020). Various properties of graph theory are uncovered and utilized in real spatial network systems; however, the majority of real networks do not show homogeneity conflicting with the main attributes of low heterogeneity and low randomness. In consequence of efforts for a more realistic network form, two major theoretical models are constructed recently, namely ‘small world network’ (SWN) developed by Watts and Strogatz (1998) and ‘scale-free networks’ (SFN) built by Barabási and Albert (1999). Local clusters and the distant decreasing shortcuts are attributes of SWN whereas skewed and highly heterogenous distribution along with hierarchical ‘power-law’ are the main properties of SFN (Aarstad et al., 2013). To illustrate, neural networks of brain are in SFN class while transportation networks are from SWN group. Social psychologist Milgram’s additional work to SWN is worth mentioning with the notion of ‘six degrees of separation’ which posits that every individual is connected one another through several intermediaries. Network optimization is another pillar of complex networks, encompassing typical statistical

models of hub-spoke structure, congestion and centralization problems, minimum spanning tree and shortest path tree (Barthélemy, 2011).

A line of network studies has been committed to the integration of space and cost paid for distance. Gastner and Newman (2006) have worked on optimal facility location with an objective function of minimizing total costs associated with travel and maintenance. Barthélemy (2011) recognizes the relevancy of space for complex networks and the effect of space on topological structure of these networks because of the cost burden imposed by space as a spatial constraint for the path length between vertices (distance). Yerra and Levinson (2005) analyze the main characteristics of transportation networks in the orientation of main roads with a dynamic network model and argue that induced demand, gains from scale economies, revenue from additional number of trips and investment rules are the underlying factors leading to a hierarchical pattern for roads. Ducruet et al. (2011b) augment analysis of port performance and network parameters in categories of circulation (vessels, calls and operators), foreland (distance-related indicators), connectivity, centrality (betweenness/centricity) and neighborhood structure (clustering). Port throughput is found dependent mostly on centrality followed by the degree of connectivity to other ports. Wu and Miller (2001) highlight methodological developments for accessibility issues in dynamic transport networks. In this vein, Luo et al. (2019) review the theme of accessibility evaluation of public transport networks from the lens of network theory.

Monteiro et al. (2012) pinpoint two application areas of graph theory in transportation problems: routing and networks. Examples of routing problems are given as the one-way street problem, the Königsberg Bridge problem, the Chinese postman problem, the traveling salesman problem. Routing problems involve for instance, the maximum flow problem, the minimum cost flow problem and the transportation problem. As for Levinson (2005), the evolution of transport networks at micro-level happens around three issues: node location problem, link formation problem and link expansion/contraction problem. Location of network nodes can be determined according to their proximity to natural resources (raw materials, energy), degree of advantage as a trans-shipment point (intersections of rivers, seas, oceans etc.) and national strategy (political and security issues). The building process of new

links can be carried out by neural network procedures by allowing algorithmic selection of links on the initial level of large nodes and few links or by a choice model simultaneously generating new links and nodes. The final problem is explained in the light of the ‘induced (latent) demand’ of transport infrastructure growth. To the extent of connectivity increase, transport demand and trip number/length grow with lower transport costs. Further reinforcement may come from population and income growth, forcing generally government to act upon network expansion.

2.2.3. Micro-Level Theories

The realization of the wider economic benefits of transport infrastructure improvements-including trade development happens through the resultant spatial advantages for firms and consumers. Putting in another way, micro-level theories relate to the last phase of the mechanism on which transport infrastructure system affects trade formation. Considering the scope of this study, the surveyed micro-level theories are accessibility and agglomeration.

2.2.3.1. Accessibility

The economic and social well-being of individuals and communities rely on the existence of accessible opportunities and alternatives. Travel demand originates from the actions to satisfy the need to reach opportunities and activities in spatially distant points. Accessibility measurements analyze the availability of opportunities and the travel choices to attain them. Standing in a central place in spatial organization of opportunities, accessibility has become a main research topic in different disciplines like economics, transportation, regional planning, tourism and spatial science (Kwan, 1998; Van Wee et al., 2001; Chien and Qin, 2004; Card et al., 2006; Chen et al., 2007; O'Kelly, 2007; Levinson and Wu, 2020).

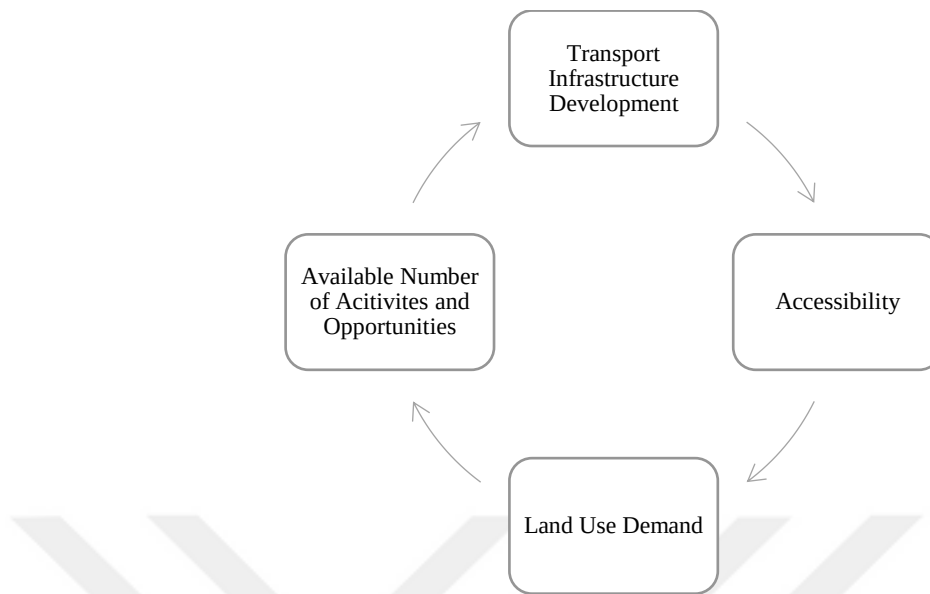
Accessibility is a measure of the ability of a certain location for connecting to and being connected by other destinations, more broadly a ‘set of spatial opportunities and benefit potentials’ (Hansen, 1959; Burns, cited in Berechman, 1981). It requires a monetary cost to overcome obstacles of spatial separation in the exchange of goods

and services. Geurs and Van Wee (2004) extracts four categories of accessibility measurement approaches from numerous definitions and methods:

1. Infrastructure-based measures: competence and service quality of a transport infrastructure system, generally utilized in transport planning.
2. Location-based measures: degree of accessibility for a location to get goods, services, activities, destinations in the spatial configuration of opportunities (generally used for urban and regional planning).
3. Person-based measures: degree of accessibility for an individual to activities limited by time-distance constraint.
4. Utility-based measures: level of the economic value attained through access (used in comparing modes and destinations).

Research on accessibility evaluation surveys the way accessibility affects land use and uses mathematical inspections for its spatial effects on economic activity (Martínez and Viegas, 2013). Transportation networks and land use are interlocked facets of accessibility. Availability of transport choices makes a particular location more attractive through accessibility, requiring more land use for the construction of facilities to offer new activities and opportunities. This will in turn increase the need for a more connected transport network again stimulating land use by improved access opportunities. Figure 20 illustrates the cyclical interaction between land use and transportation infrastructure. Accessibility and the growth in available opportunities are the triggering channels in the continuous reinforcement effect on land use and transport infrastructure development cycle.

Figure 20: Land Use and Transportation Infrastructure Cycle



Source: Adapted from Al Kahtani et al. (2016).

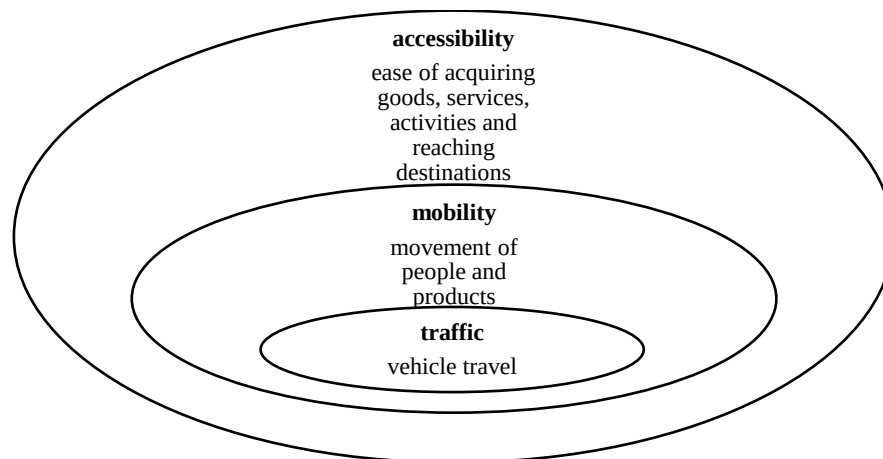
On methods for accessibility measurement, Hansen (1959) has set out a mathematical formulation based on gravity specification with a ‘measurement of accessibility’ indicator. Bhat et al. (2000) ascertain five comprehensive methods in accessibility measurement: graph theory and spatial separation measures; cumulative-opportunities models; gravity-type models; utility models (log-sum models); time-space models. In the performance comparison of cumulative opportunities and gravity-type measures using an actual data set, all four gravity specification types (Gaussian, composite-impedance factor, distance as impedance factor, in-vehicle travel time) demonstrate superior representation of real conditions for different policy assessments (Bhat et al., 2002). Another study for accessibility measures categorization is conducted by Baradaran and Ramierji (2001). The identified groups involve travel-cost, gravity, constraint-based, utility-based and composite approaches. Besides, critical aspects to be addressed in accessibility modeling are reported as the measurement of spatial friction, measurement of attraction, preference on separation area, unimodality/multimodality, agglomeration effects, dimension problem and time of day.

Koenig (1980) disaggregates accessibility indicators into two generic components, a) an impedance component (in the form of a decreasing function of

constraints by time and cost of travel to reach the opportunities), b) a component for available activities at a point (termed as ‘isochronic definition’, a set of attainable opportunities within a given time). Halden et al. (2000) describe three main types of indicators: simple indicators, opportunity measures and value measures. Simple indicators are scaled in terms of thresholds for a given space-time horizon like the set of affordable activities with a certain travel cost, travel time to achieve a given set of opportunities, job opportunities within a defined area. Opportunity measures signify deterrence weighted aggregate measure of feasible opportunities. Value measures embody the benefits of available opportunities based on utility in terms of transport preference.

As for Litman (2021), there is a nested relationship among the aspects related to accessibility as shown in Figure 21, which are to be considered in the development of transport policy: traffic being a subset of mobility, mobility being a subset of accessibility. Accessibility is the broadest concept that offers the highest potential benefits when integrated into transport policy and planning.

Figure 21: Transport Perspectives



Source: Litman (2021).

2.2.3.2. Agglomeration Economics

Agglomeration decisions are highly dependent on the availability of access to spatially fragmented markets and the cost incurred for the access. In terms of spatial

interaction (which is mainly trade flows), Spulber (2007) identifies four main types of costs decisive in the spatial distribution of firms and markets:

1. *Transaction costs*: borne as a result of engaging in international business in geographically distant areas with different political and legal environments (e.g. customs dispositions and regulations on doing business),

2. *Tariff and non-tariff costs*: trade barriers and protective measures imposed by governments (such as import quotas, export subsidies, licensing regulations),

3. *Transport costs*: trade-off between proximity, transportation costs,

4. *Time costs*: shipment delay of goods, time required to conduct an international business, time for the reaction to different market conditions.

In the canonic book exploring the evolution of firms and industries, Marshall (1890) describes agglomeration in a way that firms situated in close distances can take advantage of increasing returns as an outcome of agglomeration effects arising from the regional reservoir of skilled labor supply, supplier linkages and knowledge externalities. Within location theory, agglomeration is assumed to provide reduction in transportation costs according to Weber (1929). Duranton and Puga (2004) identify the micro-scale building blocks for urban agglomeration as sharing, matching and learning processes. Kerr and Komminers (2015) theoretically show that clustering spreads to a larger area from the actual interaction zone of agglomeration through overlapping relations of interactive clusters and validate this suggestion on technology clusters. As a relatively new phenomenon, urban space configuration also draws increasing attention with a specific emphasis on ‘megapolis, urban agglomeration, city group and city cluster’ (Fang and Yu, 2017). Besides, referenced as a semi-organic system participating in the absorption and diffusion of capital, labor and knowledge; future of agglomeration in urban areas is to be designated by the degree of inclusion in transportation and ecological networks.

As previously mentioned, new economic geography points out transport costs in the generation of conditions for agglomeration or dispersion forces (Krugman, 1991; Fujita et al., 1999; Fujita and Thisse, 2002; Combes et al., 2008). In other words, the spatial arrangement of economic activity occurs as a result of two competing forces, one centripetal and one centrifugal. Centripetal (agglomerating) characteristics make the center an attraction point with Marshallian externalities, namely large markets,

thick labor market and external economies (Krugman, 1998). Centrifugal (dispersion) forces consist of push-away factors from the center like factor immobility and land rents (Martin, 1999). These pushing and pulling factors are pivotal to the spatial distribution of industrial and economic activity depending on the nature and structure of these forces, affecting both customers and firms (Lafourcade and Thisse, 2008). Transportation costs at a sufficiently high level deter interregional demand and reduce transportation of manufactured goods, having dispersion forces in operation. On the other side, if transportation costs are low, manufacturing activity will be concentrated in the 'core' and agricultural products (raw materials) will be supplied by the 'periphery'. Firms will receive increasing returns to scale by entering in larger markets, thus the core will be a manufacturing center and the spatial inequality will be the long-run equilibrium between the core and the periphery.

Some scholars explore the agglomeration and transportation link from different perspectives. Mori and Nishikimi (2002) analyze the agglomeration effect of a transportation hub in a general equilibrium model and show that scale economies can be received from the density of transport activities with an implication that transportation itself, can be a main driver for agglomeration. Population concentration and industrial clustering take place around a transport hub, through the mechanism of 'economies of scale from transport densities' because of the so-called 'hub effect'. Similarly, Mori (2012) argues that transportation costs are determined endogenously by scale economies from transportation and agglomeration. Improvements on the transportation system in already developed regions are prioritized to establish further connectivity, so agglomeration benefits from transport infrastructure start around big cities and then can spread to other regions (Fujita and Mori, 2005). Behrens (2006) evaluates the effects of a decrease in transport costs and a reduction in tariffs on agglomeration and arrives at an insight that transport is a strong player in stimulating clusters.

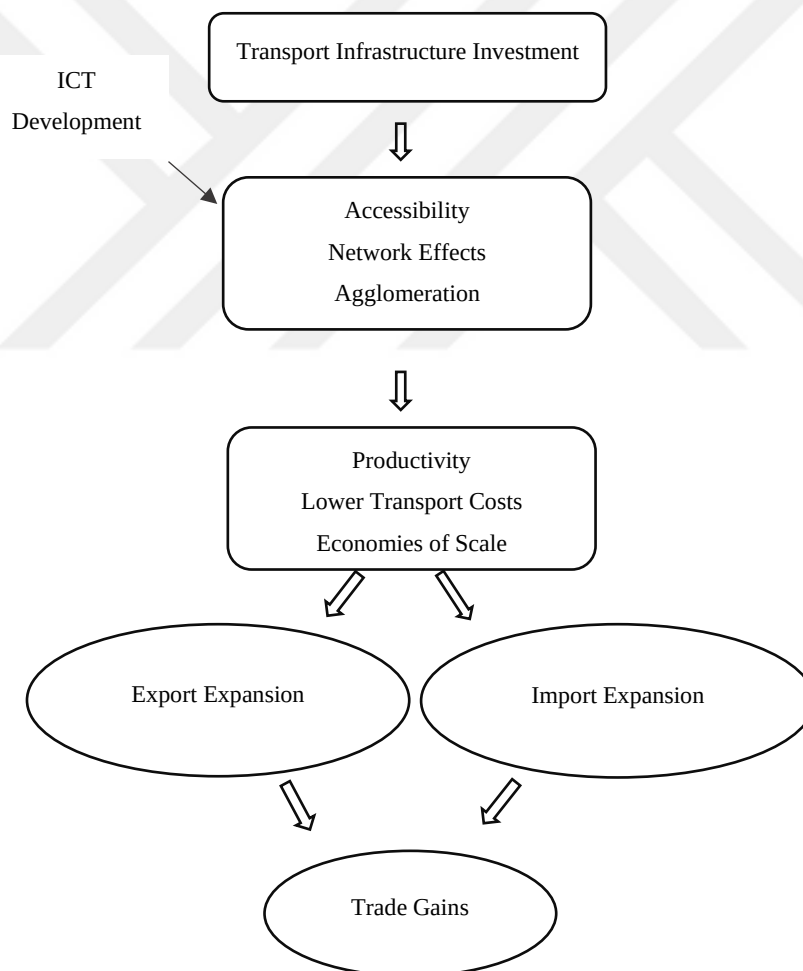
2.3. TOWARDS A THEORY OF SPATIAL INTERACTION: TRANSPORT NETWORK-ORIENTED TRADE DEVELOPMENT

Transport infrastructure investment is accepted as an important tool of fiscal policy and as a key application area of transport policy. Investments can be realized in various ways like developing new infrastructure of railways, roads, highways, airports, inland waterways, maritime ports; enhancing existing links; renewing transport technology; integrating new technologies in the transport system and improving transport services. These policies mainly aim at growth stimulation on the benefits from declining transport costs, advantages of scale economies, agglomeration and network effects to achieve trade development, hence higher welfare. Following the scope of this thesis, it is aimed to explore the impact of transport infrastructure investment on the level of trade growth in Turkey, within a developing country case. Furthermore, differences in the effects between exports and imports are also investigated. Albeit being grounded on the theory of new economic geography, a wide range of theories concerning the benefits of transport infrastructure has been examined to this point and consequently, an a priori theoretical model is built as a synthesis based on the constructs of the aforementioned theories. Within a general scope, the theories blended involve industrial location and central place theory (Weber, 1929; Christaller, 1933), new economic geography (Krugman, 1991a, 1991b), principle of comparative advantage (Ricardo, 1817), notion of strategic trade policy (Brander and Spencer, 1985; Dixit and Kyle, 1985; Eaton and Grossman, 1986), Porter's competitive advantage theory (Porter, 1990), the cycle model of public policy (Laswell, 1951,1956), principles of new institutional economics theory (Button, 2010), paradigms of transport planning (Banister, 2002; Schiller et al., 2010), transport economics (Prentice and Prokop, 2016; De Palma et al., 2011), principles of small world network structure of transportation networks (Watts and Strogatz, 1998), accessibility (Litman, 2021) and agglomeration economics (Krugman, 1998).

In the context of this thesis, an a priori theoretical model as portrayed in Figure 22, has been developed based on the theories from different perspectives. This conceptual model is constructed to address the research question and objectives of this study. In Figure 22, transport infrastructure investment (reinforced by the ICT

development as a complementary core infrastructure) functions as a trigger for the two-segment channels in the contribution of ultimate benefits of export and import expansion, namely trade gains. In the process leading to trade development, the first phase involves advantages of accessibility, network effects and agglomeration which transform into productivity, lower transport costs and economies of scale enabling superior trade performance, eventually enhancing gains from trade. The a priori model is tested by the empirical findings of gravity regressions to revise the theoretical setting built for the connection between transport infrastructure and trade, with an inductive approach.

Figure 22: Transport Network-Oriented Trade Development



Source: Author's Own Construction based on Lakshmanan (2011), Banister and Berechman (2001), Meersman and Nazemzadeh (2017).

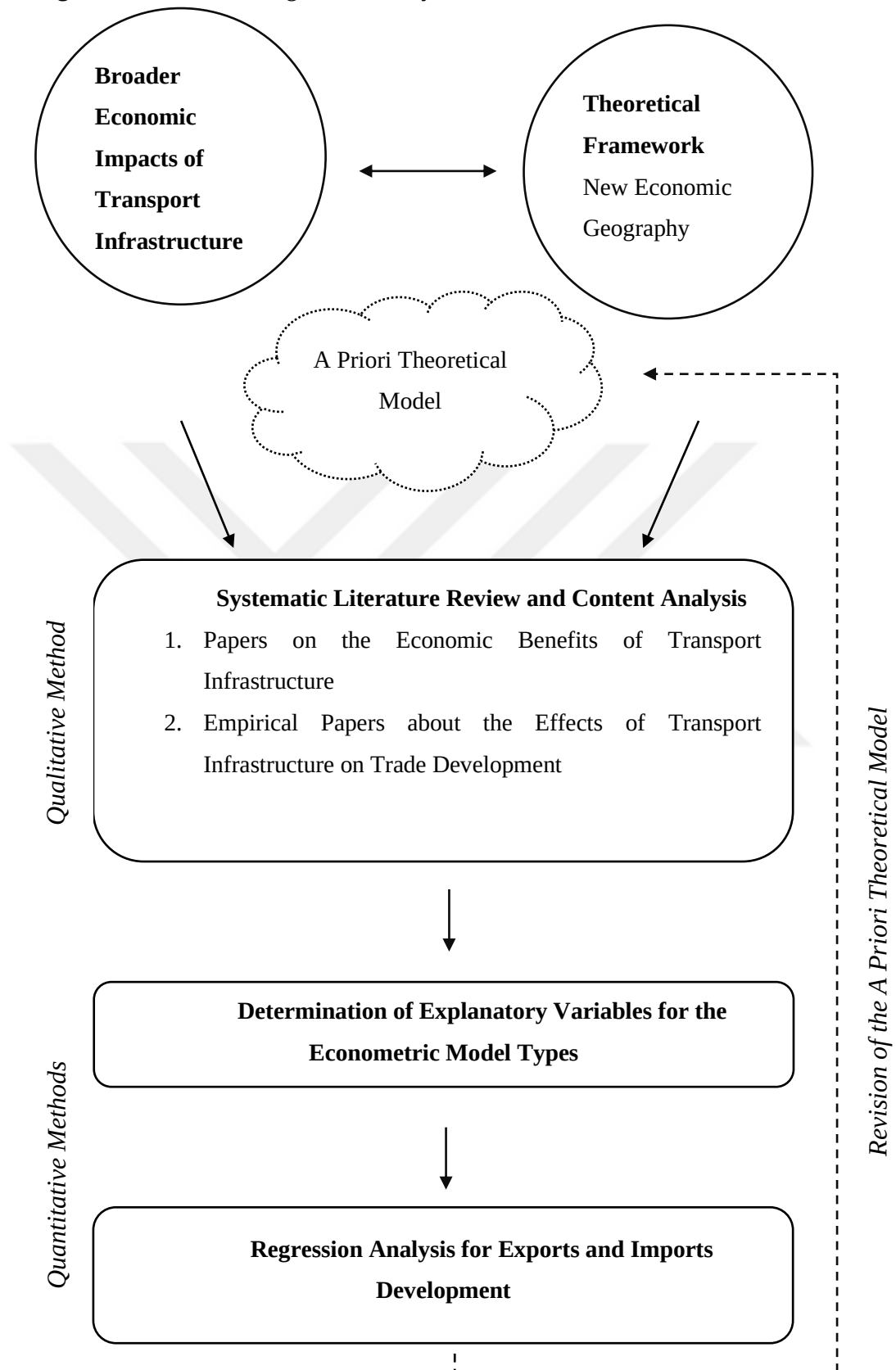
CHAPTER THREE

METHODOLOGY

3.1. DESIGN OF THE RESEARCH

The main research foundation of this study consists of regression analysis by employing two different approaches, with a focus on trade development impact of transport infrastructure in Turkey. In this regard, the initial analysis with ARDL approach is conducted as a preliminary investigation and gravity models of trade are estimated as the main analytical tool, with a comprehensive set of factors to capture various dimensions for the impact mechanism of transport infrastructure on trade. For the research purpose of this study, a research design is developed with an initial qualitative technique followed by quantitative methods as shown in Figure 23. Firstly, a systematic literature review is conducted in combination with inductive content analysis to find out research approaches for the investigation of economic benefits of transport infrastructure. Based on the guidelines drawn from the content analysis, explanatory variables, control variables, scale for the measurement of all factors and model specifications are identified to carry out the empirical processes. Conclusions are derived from the regression analysis executed for exports and imports separately. Moreover, insights from the results of gravity regression analysis are used to assess and revise the a priori theoretical model shown in Figure 22, which was developed following the theoretical framework of the study.

Figure 23: Research Design of the Study



3.1.1. Multiple Methods Research Strategy

Mixed methods research is a relatively recent paradigm of knowledge which attempts to take multiple perspectives, positions and viewpoints from qualitative and quantitative research. It involves merging and blending approaches from qualitative and quantitative research models, mainly standpoints, data collection procedures, analytical strategy and inference techniques for the objectives of deeper and more extensive comprehension and justification of the research phenomenon (Johnson et al., 2007). Mixed methods research moves back and forth between qualitative and quantitative methods starting with an initial research approach (qualitative or quantitative) formerly determined based on the scope of the research, going forward with procedures of that method and switching to the other approach to acquire new perceptions in a single study (Golobic and Davis, 2012).

3.1.1.1. A Brief Definition of Qualitative and Quantitative Methods within the System of Inductive and Deductive Reasoning

Scientific method entails two main systems of logic as inductive and deductive approaches. Induction and deduction are two different and often complementary means for expanding scientific knowledge (Rothchild, 2006) standing as the foundations of reasoning for various approaches in scientific inquiry. Inductive approach refers to a process of knowledge generation by drawing general meanings from individual observations. Concerning the contemporary debate between naturalism and positivism in scientific philosophy, research approaches encompass both inductive and deductive, subjective and objective perspectives (Newman and Benz, 1998). Deductive approach proceeds from general theory to specific observations whereas inductive approach proceeds from individual observations to general theory. Newman (2000) makes a distinction between qualitative and quantitative research paradigms in the context of scientific reasoning. Accordingly, quantitative research embraces a positivistic viewpoint to knowledge and holds the assumption that hypotheses are drawn from theory or a construct, corresponding to a given deductive nature related to theory testing. On the contrary, qualitative research

is based on the premises of constructivism with the objective of theory building to explain research phenomena instead of testing the existing theories. The following conceptualizations are developed in Newman (2000) on the systems of logic in qualitative and quantitative research:

Quantitative Research (Deductive Approach):

Theory → General Hypotheses → Specific Hypotheses →
Data Collection → Data Analysis → Results →
Conclusion → Theory Confirmation/Revision.

Qualitative Research (Inductive Approach):

Data Collection → Data Analysis → Conclusions →
Hypotheses Development → Theory Generation.

Qualitative research paradigm grounds on the premise that a single absolute reality does not exist, instead there are multiple truths formed by individual perceptions. Thus, concerning the inquiry of social phenomena, qualitative paradigm takes its foundations from interpretivism (Altheide and Johnson, 1994) and constructivism (Guba and Lincoln, 1994). The purpose of the qualitative paradigm is to gain exhaustive and illustrative perspectives on the subject to comprehend different dimensions of a given problem at inquiry. This approach is mainly employed for dimensions of reality that is not suitable for quantification because of soft characteristics, with a focus on a deep understanding of a given social aspect. The interest areas of qualitative research is dominated by a deep sphere of relations and processes which cannot be directly expressed in numerical terms, such as meanings, opinions, beliefs, attitudes, views, values and motives (Maxwell, 2013).

On the other side, quantitative paradigm is based on the principle of objectivity and suitable for a research structure in which quantifiable measures for the research problem can be collected from samples of the population in an objective and systematic way (Queirós et al., 2017). Quantitative research relies on positivism which holds on the concept of a single truth, corresponding to an objective reality unbiased by individual perceptions. In the search for causal relations between factors randomization and well-structured research procedures are applied within empirical frameworks for large sample sizes to enable statistical inference (Sale et al., 2002). In quantitative research, data is represented in formerly defined standards and operational

form where the research process involves control of variables, valid and reliable measures for the generalization from the sample to the population (Newman and Benz, 1998).

Park and Park (2016) make a comparative evaluation of quantitative and qualitative methods as instruments of justification and discovery in the scientific knowledge processes, designating the former method for justification and the latter one for discovery. Accordingly, quantitative paradigm involves an objective, unbiased, researcher-neutral, well-structured, deductive and value-free framework with the main purpose of theory-testing. On the other hand, qualitative research is a subjective, biased, researcher-involved, unstructured, inductive and value-laden framework with the main goal of theory development.

3.1.1.2. About Mixed Methods Research Approach

In the research design process, the aim of the research firstly establishes the research questions and then shapes the methodological strategy, where research design is heavily determined by the research questions (e.g., Newman and Benz, 1998; Brewer and Hunter, 2006; Creswell and Plano Clark, 2007). In case of having blended research questions covering qualitative and quantitative dimensions, the study inevitably involves both approaches (Tashakkori and Creswell, 2007). Newman and Benz (1998) find making a dichotomous distinction between qualitative and quantitative research approaches inconsistent with the scientific thinking and suggests the concept of continuum which coincides with the philosophy of science. Moreover, the ultimate purpose of employing mixed methods research strategy is to reinforce conclusions drawn from the study as well as to expand the knowledge and validity of the research (Schoonenboom and Johnson, 2017). For example, design validity is confirmed when the researcher acknowledges that there is no superiority of quantitative paradigm over qualitative one or vice versa, embracing both approaches in the conduct of research when appropriate (Newman and Benz, 1998). On the emphasis of purpose for mixed methods research, Greene et al. (1989: 259) identify the following objectives:

1. *Triangulation* searches for convergence, justification, agreement of results from different methods;
2. *Complementarity* search for explanation, enrichment, demonstration, elucidation of the results from one method with the results from the other method;
3. *Development* searches for ways to apply the results from one method to help develop or inform the other method, where development is broadly understood for sampling and implementation, as well as measurement decisions;
4. *Initiation* searching for the detection of paradox and conflict, new assessments of frameworks, the reorganization of questions or results from one method with questions or results from the other method;
5. *Expansion* seeks to extend the scope and size of the investigation by using different methods for different investigation components.

Besides, a hierarchy of flexibility for research design options is constructed from the most restricted purpose to the least in the following order: triangulation, complementarity, development, initiation and expansion. According to Flick (2018), triangulation has been very popular in social sciences as a tool for the evaluation of empirical findings and a way of gathering deeper understanding and information about the research phenomenon. Denzin (1970) conceptualizes four types of triangulation: triangulation of data, investigator, theory and method. Data triangulation refers to the use of different data sources for the same phenomenon. Investigator triangulation involves participation of multiple observers or researchers to avoid bias by a single researcher. Theory triangulation consists of exploiting several theoretical stances in the data collection and analysis as well as evaluating the appropriate theoretical stances for interpretation. Triangulation of methods refers to within-method (by using different scales of measurement for the same research problem) and between-methods (by blending different methods for the same issue) triangulation. Creswell and Plano Clark (2007) identifies four main types of mixed methods research designs that are triangulation design, embedded design, explanatory design and exploratory design. In the triangulation design, qualitative and quantitative methods are applied simultaneously with equal weight in a one-phase process. Embedded design involves two data sets of which one of them functions in a supportive role for a study conducted primarily on the other data set, especially beneficial when embedding a qualitative

element in a quantitative design is necessary in addressing different research questions. Explanatory design consists of a two-stage procedure in which the first stage involves collection and analysis of quantitative data, followed by the second stage of collection and analysis of qualitative data for the results obtained from the quantitative phase. The exploratory design refers to a two-stage procedure in which qualitative data is utilized to investigate a research issue to establish the second, quantitative phase of research.

When there is a theoretical fragmentation rather than coherence in a field theoretical triangulation is relevant with an application of a solid set of data interpreted multiple theoretical perspectives which can have related or contradicting views (Flick, 2018).

3.1.2. On the Research Design of This Study: Sequential Transformative Research Design

The main purpose of scientific inquiry is generating new theories and concepts or testing-revising the prevailing theories within a view that research processes are deliberately identified according to several possible research strategies (Arlbjørn and Halldorsson, 2002). As for this study, the objective involves the derivation of an a priori theoretical model for the relationship between transport infrastructure and trade development, then testing this presumed causal relation with quantitative analysis to obtain guidance for modification if applicable.

Aside from that, research design of this study involves several other important and unique aspects as well. First of all, the scientific investigation starts with an exhaustive literature review spanning a wide range of theoretical settings from relevant branches of trade and location theories to public policy, transport policy and planning, transport economics, transport geography, network theory, accessibility and agglomeration economics. On the basis of this comprehensive overview, an a priori theoretical model for the connection between transport infrastructure and trade has been generated within a deductive approach. In that way, theoretical triangulation has been incorporated into the study as outlined by Denzin (1970) by not only benefitting from multiple theories in the construction of the theoretical model but also forming a

rich theoretical background in early stages of research to explain empirical findings later. This situation is especially relevant as logistics research is known for its functional perspective in research conduct and with its dependence on other disciplines for a scientific foundation (Kovacs and Spence, 2007; Arlbjørn and Halldorsson, 2002), requiring multi-disciplinary perspectives for opportunities of cross-validation and cross-fertilization of research processes and the outcomes. A second distinguishing aspect of this study is the combination of systematic literature review method with an inductive content analysis approach as an integrated methodology to obtain an in-depth analysis for the nature of mainly empirical research on the wider economic benefits of transport infrastructure, as in Khirfan et al. (2020). The outlined premises, model development strategies, variable types and their definitions have informed the modeling procedure for the causality analysis through an Autoregressive Distributed Lag Model (ARDL) as well as the spatial analysis with the gravity model of trade flows for exports and imports. In that regard, employment of the qualitative procedure of inductive content analysis integrated with systematic literature review and the utilization of outcomes for the establishment of the quantitative procedures have served in the development and expansion purposes of mixed methods as pointed out by Greene et al. (1989). Findings of the empirical analysis are explained in the light of the wealthy source of literature outlined before and policy implications are driven accordingly.

Considering all the aspects explained above, this thesis embraces a recent mixed method strategy referred as ‘sequential transformative research design’ which has a two-phased procedure with a theoretical orientation covering progressive approaches (Creswell, 2009). The starting phase (either qualitative or quantitative) informs the subsequent phase, so the second phase is built on the earlier phase. In the case of this study, the following phase of quantitative analysis is built on the earlier phase of qualitative approach of integrated systematic literature review and content analysis. This strategy functions as a beneficial tool for the theoretical viewpoints of the investigator, facilitating an in-depth understanding of a phenomenon or a process (Creswell, 2009). The overall aim of this study involves a sound understanding of the effect of transport infrastructure on trade development in Turkey, shedding light on the theoretical framework behind this causal mechanism as well as developing policy

implications from the perspectives of different theories outlined. Thus, the purpose, perspective and design of ‘sequential transformative research design’ with a dominance of quantitative approach corresponds finely to the mixed method strategy of the study.

3.2. A RESEARCH ON THE BROADER ECONOMIC IMPACTS OF TRANSPORT INFRASTRUCTURE

Following the early survey by Aschauer (1989), the economic effects of public capital including transport infrastructure are inspected by numerous studies such as Lynde and Richmond (1992), Garcia-Mila and McGuire (1992) and Ozbay et al. (2003). Particularly on the wider economic impacts of transport infrastructure, the stream of studies can be categorized in three different lines: growth, regional and trade. As for analysis units, transport infrastructure research mostly seeks for the benefits in two extreme country categories, first high-income countries having abundant transport infrastructure capital and second low-income economies which suffer from lack of resources to allocate in transport networks, indicating scarcity of research on developing countries for which transport infrastructure can act as a growth engine (Duranton et al., 2014).

The goal of this thesis is to address the research gap on the trade development benefits of transport infrastructure extensions for a developing country, specifically for Turkey. For this purpose, a line of mainly empirical coverage of literature according to the scope of this thesis is analyzed through a qualitative approach with a combination of systematic literature review and inductive content analysis to obtain guidelines for the quantitative models developed in the successive analysis.

3.2.2. Stepwise Procedure Applied within the Combined Approach

In the methodological construct of this thesis, a combined approach of systematic literature review and inductive content analysis is carried out for a deeper investigation of mainly quantitative studies on transport infrastructure and its broader economic effects. The guidelines for material, methodology and analytic framework

for the relevant empirical research are examined within an inductive content analysis (Khirfan et al., 2020) by evaluating the main surveys with clear and replicable approaches within a systematic literature review procedure (Greenhalgh, 1997; Fink, 2019).

With the influence of Cerchione and Esposito (2016), the combined approach is executed in two main steps, each involving two integrated phases, as follows:

1. Step: Collection of Research Materials

- a. Comprehensive Search: determining the keywords to use, creation of search strings, selection of search databases, realization of the search process.

- b. Selection of Research Materials for Analysis: description of standards to include/exclude, realization of the selection procedure.

2. Step: Descriptive and Content Analysis of Selected Materials

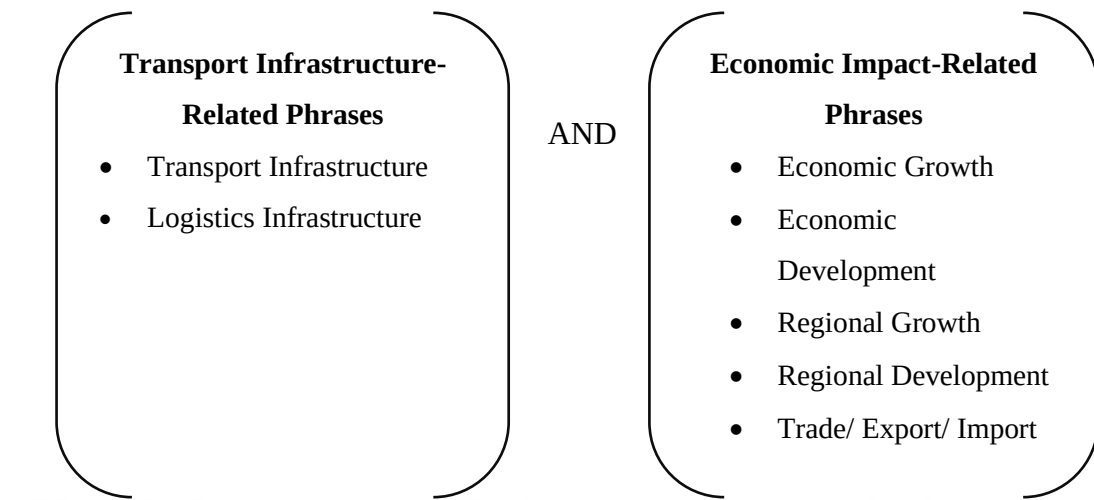
- a. Descriptive Examination: summary and preliminary analysis of selected research materials with respect to author information, publication name, published year, main theme, study type and research approach.

- b. Content Analysis: detailed latent analysis of research to reveal embedded premises, sampling units and geographic coverage, scope of transport types and their measurements as well as main analytical methods of the selected studies to highlight the research gaps in the area; and finally a comprehensive variable analysis for the studies on trade flows to apprehend guidelines for the subsequent quantitative analysis part of this study.

3.2.2.1. Collection of Research Materials

Considering the research question and objectives of this study, search keywords are constructed as the combination of ‘transport infrastructure-related phrases’ and ‘economic impact-related phrases’ to select relevant research papers in line with the a priori model of transport network-oriented trade development, as shown in Figure 24. Therefore, “transport infrastructure” or “logistics infrastructure” terms are merged with “economic growth” or “economic development” or “regional growth” or “regional development” or “trade” or “export” or “import” in the exhaustive search process on two databases, namely Scopus and Google Scholar.

Figure 24: The Keywords Used in the Search Process



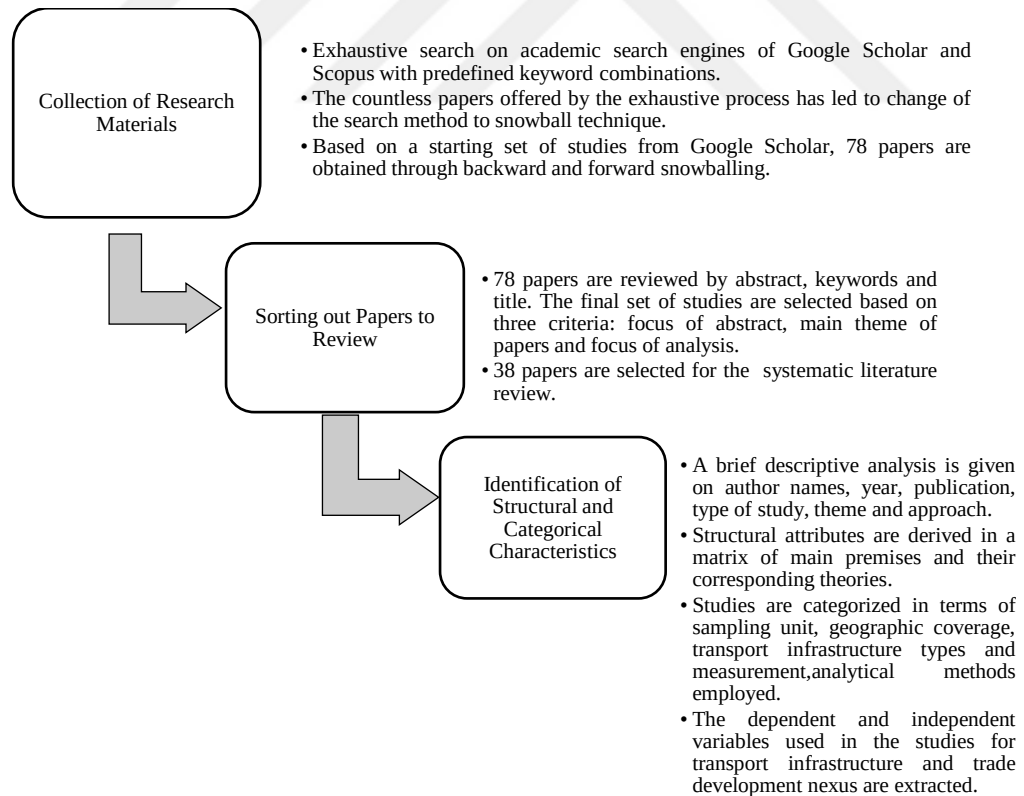
As previous studies are mainly related to growth theory which diverts from the focus of this study, the search is conducted for a more recent period from 2000 to the present (2020) to primarily capture analytical research in wider economic effects and policy implications in a logistics-dominant research agenda. The keyword combinations have yielded countless papers, disabling to proceed within the stepwise approach. This situation has resulted in the use of snowballing technique which is proven to be a good alternative to exhaustive database search, by Wohlin (2014). Forward snowballing means finding citing studies to a paper while backward snowballing means finding the reference studies of a paper (Jalali and Wohlin, 2012). In snowballing technique, Van Wee and Banister (2016) highlight the need for an explicit description of the paper selection procedure applied. In that regard, at first, a starting set of studies are identified by the most relevant and cited work from a tentative initial set of research from Google Scholar as suggested by Wohlin (2014). At this point, relevancy refers to the analytical research on the economic impacts of transport infrastructure in a broad sense. Final studies are iterated by three rounds of backward and forward snowballing and in the final round, the set of potential review materials has been reduced to 78 papers. As for the sorting process, the assessment is performed based on three inclusion/exclusion criteria listed in Table 10. Overall, 38 papers are included in the pile for the combined procedure of systematic literature review and inductive content analysis.

Table 10: Criteria for Inclusion/Exclusion Decision

<i>First Criterion:</i> focus of abstracts.	Papers with abstracts focusing on transport infrastructure and economic benefits are included.
<i>Second Criterion:</i> main theme of papers.	Papers that are interested in aggregate economic benefits are included. Studies interested only in specific sectors and their efficiency are excluded.
<i>Third Criterion:</i> focus of analysis.	Papers with a predominant focus on the stock of transport infrastructure (monetary or physical) are included.

The process for the collection of research materials has been established inductively during its application with procedural modifications as well as continuous revision and control for the correspondence of the search materials firstly to the main focus of the study and then to the criteria for exclusion/inclusion decision. Figure 25 shows a summary of the steps taken so far as well as the subsequent step of descriptive and inductive content analysis, overall an approach adopted from Narayanamurthy and Gurumurthy (2016).

Figure 25: Steps Followed for the Combined Method



3.2.2.2. Descriptive Information and Inductive Content Analysis of the Selected Materials

An overall outlook is provided on the 38 reviewed papers about the extensive economic benefits of transport infrastructure with a brief descriptive analysis. In Table 11, the summary information of the studies is presented. Each study is displayed with information for author and publication year, publication name, type of study, main theme addressed and research approach for investigating the economic impacts of transport infrastructure. In terms of study type, the vast majority of studies are journal articles, in total of 35 out of 38 selected papers. The three exceptions include a PhD thesis, a conference proceeding and a report. The articles are published in mainly transportation journals followed by economic journals on the topics such as development and regional science. The journal articles are published in “Research in Transportation Economics” (4), “Transportation Research Part A” (3), “Transport Policy” (3), “Transportation” (3), “Transport Reviews” (3), “The Annals of Regional Science” (2), “Journal of Development Economics” (2), “World Development” (2), “Journal of Transport Geography” (1), “Journal of International Logistics and Trade” (1), “Journal of the Transportation Research Forum” (1), “Economics of Transportation” (1), “Case Studies on Transport Policy” (1), “Transportmetrica” (1), “American Economic Review” (1), “Journal of Asian Economics” (1), “Journal of Comparative Economics” (1), “Renewable and Sustainable Energy Reviews” (1), “The World Bank Economic Review” (1), “İşletme Fakültesi Dergisi” (1) and “Journal of Economic Development” (1)³.

Main themes of the studies can be divided into three main categories as economic growth, regional development and trade flows. 12 papers investigate mainly the topic of economic growth related to transport infrastructure, 11 studies deal with trade flows solely, at the intersection 2 papers survey both effects and there are 13 studies on the theme of regional development. In the context of research approach, 33 papers use quantitative methods with empirical models whereas 5 papers articulate new perspectives based on state-of-the-art literature review and case study analysis,

³ Numbers in brackets refer to the number of studies of the relevant category in all parts of the content analysis.

which is also relevant to the scope of the thesis due to the public policy nature of transport infrastructure decision.

Table 11: Summary of the Papers Reviewed

Study	Published in	Study Type	Theme	Approach
Achour and Belloumi, 2016	Renewable and Sustainable Energy Reviews	Journal Article	Economic Growth	Quantitative Analysis
Banerjee et al., 2020	Journal of Development Economics	Journal Article	Regional Development	Quantitative Analysis
Bensassi et al., 2015	Transportation Research Part A	Journal Article	Trade Flows	Quantitative Analysis
Berechman et al., 2006	Transportation	Journal Article	Regional Development	Quantitative Analysis
Bottasso et al., 2018	Transportation Research Part A	Journal Article	Trade Flows	Quantitative Analysis
Cantos et al., 2005	Transport Reviews	Journal Article	Regional Development	Quantitative Analysis
Chatman and Noland, 2011	Transport Reviews	Journal Article	Regional Development	Conceptualization
Coşar and Demir, 2016	Journal of Development Economics	Journal Article	Trade Flows	Quantitative Analysis
Demurger, 2001	Journal of Comparative Economics	Journal Article	Regional Development	Quantitative Analysis
Deng et al., 2014	Transportation	Journal Article	Economic Growth	Quantitative Analysis
Donaldson, 2018	American Economic Review	Journal Article	Trade Flows	Quantitative Analysis
Duranton, 2015	Economics of Transportation	Journal Article	Trade Flows	Quantitative Analysis
Elburz, 2018	Dokuz Eylül University Graduate School of Natural and Applied Sciences	PhD Thesis	Regional Development	Quantitative Analysis
Farhadi, 2015	Transportation Research Part A	Journal Article	Economic Growth	Quantitative Analysis
Francois and Manchin, 2013	World Development	Journal Article	Trade Flows	Quantitative Analysis
Hong et al., 2011	Transportation	Journal Article	Regional Development	Quantitative Analysis
Jiwattanakulpaisarn et al., 2011	Transportmetrica	Journal Article	Regional Development	Quantitative Analysis
Kuştepe and Akgüngör, 2010	İşletme Fakültesi Dergisi	Journal Article	Regional Development	Quantitative Analysis
Lakshmanan, 2011	Journal of Transport Geography	Journal Article	Economic Growth	Conceptualization
Lem, 2002	Economic Development	Report	Trade Flows	Conceptualization

	Administration or the Department of Commerce			
Li and Qi, 2016	Journal of International Logistics and Trade	Journal Article	Regional Development	Quantitative Analysis
Lima and Venables, 2001	The World Bank Economic Review	Journal Article	Trade Flows	Quantitative Analysis
Meersman and Nazemzadeh, 2017	Case Studies on Transport Policy	Journal Article	Economic Growth and Trade Flows	Quantitative Analysis
Na et al., 2013	The Annals of Regional Science	Journal Article	Economic Growth	Quantitative Analysis
Ozbay et al., 2007	Transport Policy	Journal Article	Regional Development	Quantitative Analysis
Park et al., 2019	Research in Transportation Economics	Journal Article	Economic Growth	Quantitative Analysis
Pereira and Andraz, 2007	Journal of Economic Development	Journal Article	Economic Growth	Quantitative Analysis
Pereira and Andraz, 2012	The Annals of Regional Science	Journal Article	Regional Development	Quantitative Analysis
Portugal-Perez and Wilson, 2012	World Development	Journal Article	Trade Flows	Quantitative Analysis
Pradhan and Bagchi, 2013	Research in Transportation Economics	Journal Article	Economic Growth	Quantitative Analysis
Pradhan et al., 2013	Procedia - Social and Behavioral Sciences	Conference Proceeding	Economic Growth	Quantitative Analysis
Pradhan, 2019	Research in Transportation Economics	Journal Article	Economic Growth	Quantitative Analysis
Short and Kopp, 2005	Transport Policy	Journal Article	Economic Growth	Conceptualization
Tong et al. 2014	Journal of the Transportation Research Forum	Journal Article	Economic Growth and Trade Flows	Quantitative Analysis
Vickerman, 2017	Research in Transportation Economics	Journal Article	Economic Growth	Conceptualization
Wessel, 2019	Transport Policy	Journal Article	Trade Flows	Quantitative Analysis
Yu et al., 2012	Transport Reviews	Journal Article	Regional Development	Quantitative Analysis
Zhai, 2018	Journal of Asian Economics	Journal Article	Trade Flows	Quantitative Analysis

Table 12: Categorization of Main Premises Derived from the Papers

	Economic Development	Agglomeration Economics	Network Theory	Location Theory	Trade Theory	Transport Economics	Public Policy
Appraisal optimism							X
Central planning problem of logistics networks							X
Comparative advantage					X		
Competitive relationship between modes						X	
Complementary investments							X
Complementary relationship between modes						X	
Coordination failure							X
Creation and commercialization of new knowledge		X					
Crowding in effects	X						
Crowding out effects	X						
Cumulative causation				X			
Diminishing marginal returns to transport infrastructure	X						
Dynamic adjustments and feedbacks	X						
Export-led growth	X						
Facilities consolidation		X					
General equilibrium effects	X						
Geographical heterogeneity					X		
Graph theory				X			
Growth-led transport	X						
Innovation through networks		X					
Intermodality						X	
Intra-industry reallocation of resources		X					
Lack of accountability in the decision-making process							X
Lagged effects	X						
Logistics costs effects		X					
Nonlinear relationship between transport and growth	X						
Optimism bias in most new projects							X
Paralysis in decision making over new investments							X
Policy intervention							X
Positive external effects			X				
Regional economic integration			X				
Regional spillovers			X				
Reverse causality	X						
Reverse causation	X						
Risk negligence							X
Scale effect	X						
Spillover effects			X				

Substitution effect	X		
Sustainable transport			X
Trade openness		X	
Transport as a derived demand			X
Transport connectivity		X	
Transport policy			X
Transportation intensive industries			X
Transport-led economic growth	X		

A further outline of papers is provided in Table 12 above to show the theoretical categorization of main premises extracted from the systematic review process. The premises are carefully drawn from the main focus, research objectives, arguments and findings of the studies. The knowledge on the wider economic benefits of transport infrastructure has backgrounds from economic development, agglomeration economics, network theory, location theory, trade theory, transport economics and public policy. The intensity on the topic of economic development together with the limited appeal to trade theory indicates a need for research expansion in this area, confirming the research gap identified and validating the main objectives of this thesis.

This thesis is structured based on quantitative methods, thus a more detailed analysis of the empirical body of research is important to have a better understanding of analytical approaches towards the topic. In Table 13, information on sampling units and geographic coverage of the reviewed papers is presented to emphasize any research tendency on specific countries/regions as well as any common proneness on the type of geographic scope of analysis units, if exist. Considering the sampling units in the studies, it can be derived that research has been conducted on individual countries or country groups. Individual countries studied include Colombia (1), Brazil (1), Portugal (1), Belgium (1), Tunisia (1), India (3), Turkey (3), Spain (2), the US (5) and China (6). For country groups category, one study uses a macro-region framework for 20 EU Countries (1), other groups consist of G-20 countries (1), OECD and Non-OECD countries (1), Belt and Road Initiative (BRI) and Non-BRI countries (1), mixed set of countries (3), and OECD countries (2). Moreover, regarding development level, there is a research interest in developing countries (14), then developed countries (9), an underdeveloped country (1) and groups consisting of different development levels (9). Geographic coverage ranges in a wide spectrum: district (1), municipality (2),

county (3), province (6), state (4), region (4), country (7), macro-region (1) and the world (8), some studies investigating multiple types of geographic coverage. The main theme of this study is on Turkey, which is a developing country, in parallel to the mainstream development level of the study units in the reviewed papers, but the scope includes the country as a whole, unlike the three studies on Turkey with a focus on the provincial or regional effects of transport infrastructure. Besides, 20 out of 33 studies focus on micro-scale geographic coverage which might be misleading as transport infrastructure is a public policy component portrayed with a holistic view embedded into transport policy decisions.

Table 13: Sampling Unit and Geographic Coverage of the Reviewed Papers

	Samplin g Unit	Geographic Coverage								
		Distric t	Municipalit y	Count y	Provinc e	Stat e	Regio n	Countr y	Macro- Region	Worl d
Achour and Belloumi, 2016	Tunisia							X		
Banerjee et al., 2020	China			X						
Bensassi et al., 2015	Spain						X			
Berechman et al., 2006	US		X	X		X				
Bottasso et al., 2018	Brazil					X				
Cantos et al., 2005	Spain						X			
Coşar and Demir, 2016	Turkey				X					
Demurger, 2001	China				X					
Deng et al., 2014	China				X					
Donaldson, 2018	India	X								
Duranton, 2015	Colombi a		X							
Elburz, 2018	Turkey						X			
Farhadi, 2015	OECD Countrie s									X
Francois and Manchin, 2013	Mixed Set of Countrie s									X
Hong et al., 2011	China				X					
Jiwattanakulpaisarn et al., 2011	US					X				
Kuştepli and Akgüngör, 2010	Turkey						X			
Li and Qi, 2016	China				X					
Lima and Venables, 2001	Mixed Set of Countrie s									X
Meersman and Nazemzadeh, 2017	Belgium							X		

account. In short, the modal distribution of analytical papers shows evidence of fragmented research for the effects of transport infrastructure with partial interpretations by considering a limited type of modes, mainly various forms of road transportation (highways, streets, paved roads, divided roads, etc.), railway transportation or only land transportation system. This situation is also recognized by a recent study (Park et al., 2019) by asserting shortcomings of such a partial view and the need for studies which enable comparisons of various modes of transportation at the same time. This thesis contributes to the accumulated research in the area not only by aiming to understand bilateral trade effects in a developing country context but also by pondering on all types of infrastructure development simultaneously to differentiate specific mode effects as well. Regarding the measurement of transport infrastructure, physical capacities are employed in 24 studies, the remaining 9 papers applying monetary values. The common quantification in terms of physical measures can be the reason for fragmented analysis because of data unavailability and this scale can fail to account for public policy and transport policy aspects whose connection to transport infrastructure is well established in the literature (see, Lakshmanan, 2011). As a conclusion of these arguments, this thesis uses the capital amount of investments for each mode in consideration of government policies to quantify the effect of transport infrastructure on trade.

A closer examination of 12 empirical papers interested in trade effects of transport infrastructure related to mode coverage reveals the concentration on land transportation with the papers considering only road (3); only rail (1); land transportation (2); a combination of road and air (1); a combination of road and maritime (1); a combination of road, rail and maritime (1); all individual infrastructure types (2) and all modes in aggregate (1). Besides, the dominating measurement relies on physical scale with 10 papers, out of which 1 paper considering both scales. The nature of studies on the measurement manifests a necessity for more comprehensive analysis involving the scarcely employed monetary measurement of investments in various modes for a deeper understanding of the issue.

Table 14: Transport Infrastructure Types and Measurements

	Modes					Measurement	
	Road	Rail	Air	Maritime	All in Aggregate	Monetary	Physical
Achour and Belloumi, 2016	X	X					X
Banerjee et al., 2020	X	X					X
Bensassi et al., 2015	X	X					X
Berechman et al., 2006	X					X	
Bottasso et al., 2018	X			X			X
Cantos et al., 2005	X	X	X	X		X	
Coşar and Demir, 2016	X						X
Demurger, 2001	X	X		X			X
Deng et al., 2014	X						X
Donaldson, 2018		X					X
Duranton, 2015	X						X
Elburz, 2018	X						X
Farhadi, 2015	X	X	X	X			X
Francois and Manchin, 2013	X		X				X
Hong et al., 2011	X	X	X	X			X
Jiwattanakulpaisarn et al., 2011	X						X
Kuştepli and Akgüngör, 2010	X						X
Li and Qi, 2016	X	X					X
Lima and Venables, 2001	X	X					X
Meersman and Nazemzadeh, 2017	X	X		X		X	X
Na et al., 2013	X						X
Ozbay et al., 2007	X					X	
Park et al., 2019		X	X	X			X
Pereira and Andraz, 2007					X	X	
Pereira and Andraz, 2012	X					X	
Portugal-Perez and Wilson, 2012	X	X	X	X			X
Pradhan and Bagchi, 2013	X	X					X
Pradhan et al., 2013	X	X					X
Pradhan, 2019		X	X				X
Tong et al. 2014	X					X	
Wessel, 2019	X	X	X	X			X
Yu et al., 2012					X	X	
Zhai, 2018					X	X	

A general overview of the quantitative methods employed by the reviewed studies is another objective of the inductive content analysis procedure. The methods

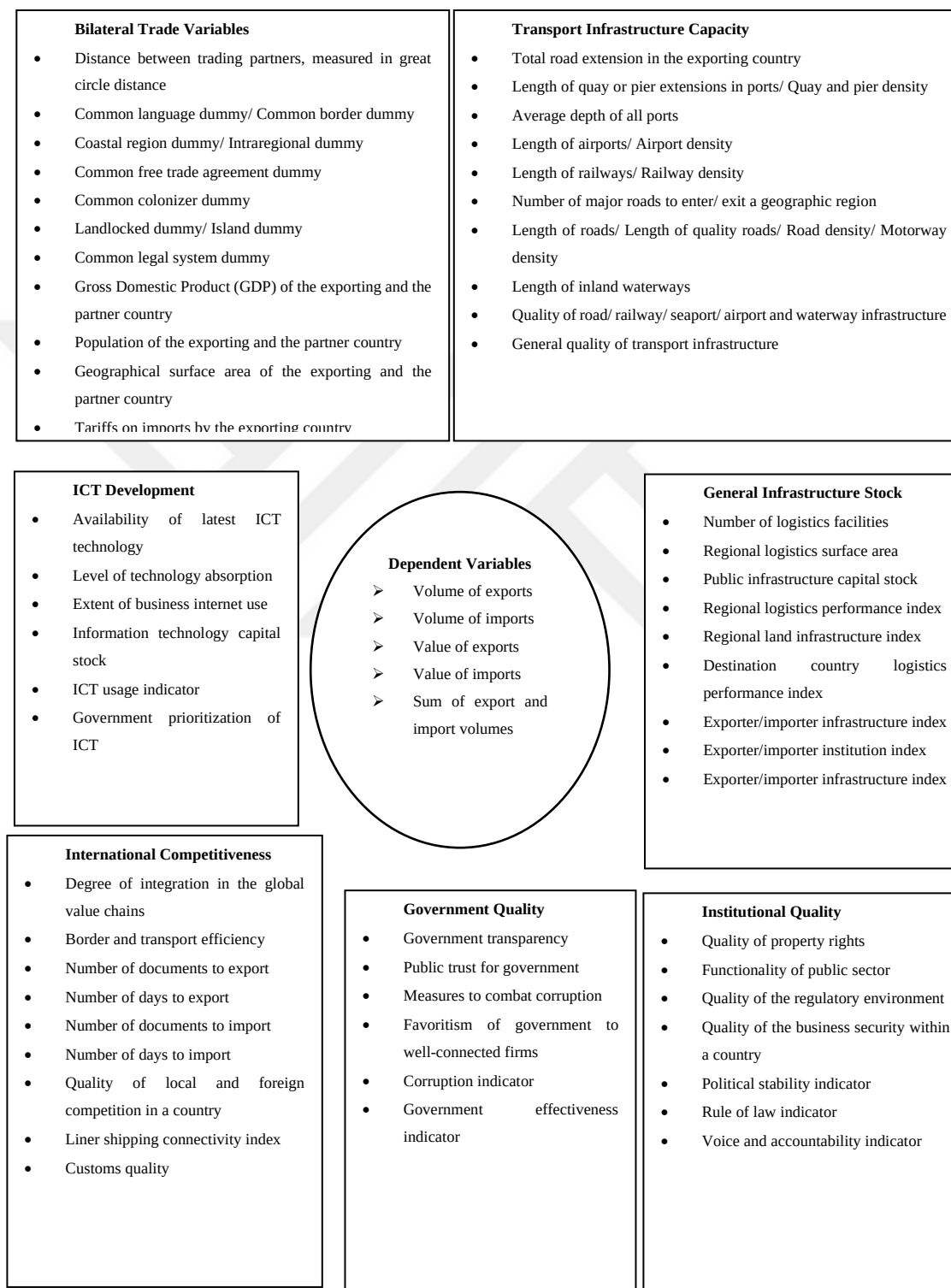
used for various research purposes are classified concerning relevant dimensions, as provided in Table 15. The analytical approaches are divided into four main groups as causality, regression, spatial and simulation methodologies based on the reason of modeling endeavors. Causality methods are incorporated in short-run causality (Granger causality) and long-run causality (VAR, ARDL, VECM) analysis. The majority of causality methods are used to search for short-run and long-run relationships between transport infrastructure and economic growth, nevertheless, a study also considers exports with a focus on trade flows under causality framework. Regression methods identify impacts of multiple factors for a phenomenon, in which time series include a single entity over time while panel regression models involve cross-sectional data. Papers with a focus on economic growth or regional development mainly use panel models to enable cross-sectional analysis based on the Cobb-Douglas production function, within different geographic coverages (municipality, province, region, country groups). Regarding studies on trade flows, 3 of them apply panel regression models for cross-sectional analysis. Spatial methods deal with spatial interactions of economic factors in regions (e.g. Spatial Durbin Model) or treat bilateral trade flows (gravity models). For simulation methods, general equilibrium modeling seeks responses of agents to shocks in the overall economy based on a set of equations, which is utilized by only 1 paper. In consideration of interest in spatial dynamics of transport infrastructure in terms of trade, this thesis uses gravity modeling which is the main tool to evaluate trade flow effects caused by transport infrastructure investment and accompanying factors.

Table 15: Analytical Methods of the Reviewed Papers

	Causality Methods				Regression Methods			Spatial Methods		Simulation Methods
	Granger Causality	VAR	ARDL	VECM	Time Series Regression	Panel Regression	Tobit/ Probit Model	Spatial Durbin Model	Gravity Model	General Equilibrium Model
Achour and Belloumi, 2016				X						
Banerjee et al., 2020						X				
Bensassi et al., 2015									X	
Berechman et al., 2006						X				
Bottasso et al., 2018									X	
Cantos et al., 2005						X				
Coşar and Demir, 2016									X	
Demurger, 2001						X				
Deng et al., 2014						X				
Donaldson, 2018						X				X
Duranton, 2015						X			X	
Elburz, 2018								X		
Farhadi, 2015						X				
Francois and Manchin, 2013							X		X	
Hong et al., 2011						X				
Jiwattanakulpaisarn et al., 2011						X				
Kuştepli and Akgüngör, 2010					X					
Li and Qi, 2016	X					X				
Lima and Venables, 2001							X		X	
Martinez-Zarzoso et al., 2003									X	
Meersman and Nazemzadeh, 2017		X		X						
Na et al., 2013						X				
Ozbay et al., 2007						X				
Park et al., 2019						X				
Pereira and Andraz, 2007		X		X						
Pereira and Andraz, 2012		X								
Portugal-Perez and Wilson, 2012									X	
Pradhan and Bagchi, 2013	X	X		X						
Pradhan et al., 2013			X							
Pradhan, 2019				X						
Tong et al. 2014		X								
Wessel, 2019									X	
Yu et al., 2012	X			X						
Zhai, 2018										X

The inductive content analysis procedure is finalized with a deduction process of the variables used in the empirical studies on transport infrastructure and trade relation under the scope of this study. As exhibited in Figure 26, the derived explanatory factors are classified into several broad dimensions and different forms of dependent variables are identified. The predictors in the reviewed papers are selected from indicators related to bilateral trade, transport infrastructure capacity, ICT development, general infrastructure stock, international competitiveness, government quality and institutional quality. Thus, in the studies reviewed, dependent variables are chosen from a narrow range of factors while the explanatory factors can be taken from a large range of aspects. This situation implies that determination of the response variables is straightforward, however careful evaluation is needed when considering explanatory factors for the phenomenon under investigation. Keeping the aforementioned multi-dimensional nature of transport infrastructure in mind, the inductive content analysis on the employed factors in the studies has informed the variable selection procedure for the quantitative modeling exercises by providing a rich and sound baseline.

Figure 26: Factors on the Transport-Trade Relation in the Content Analysis



3.2.1. A Combined Approach of Systematic Literature Review and Content Analysis on the Studies Related to Transport Infrastructure

Literature review is an inseparable part of scientific research process, that is characterized by the assessment of different sources of knowledge to detect cohesion among the literature sources and to derive inferences on the research phenomena, still, it is a common case that the audience of the research encounters with an unclear end product of this process (Seuring and Gold, 2012). The authors point out the employment of systematic and transparent techniques in performing literature reviews as a requirement for the reliability and validity of the derived conclusions from literature sources. Regarding this point, content analysis is entitled as a solid framework for a replicable, systematic and accurate way of reviewing the literature.

Content analysis is defined as a systematic and objective tool to extract justifiable inferences from verbal, visual or written data with the purpose of description and quantification of a particular issue (Downe-Wamboldt, 1992). It comprises a group of techniques for empirical studies in the field of social sciences, that are applicable within a qualitative or a quantitative approach. As the employed approach for this study, qualitative content analysis has a focus on the informational substance in written documents instead of a search for theoretical perspectives (Forman and Damschroder, 2008). The scope of content analysis covers two underlying stances of analysis. The first stance explores the manifest meanings of textual material while the second one seeks for revealing the latent content in the text through interpretation of phrases and assertions, the latter being adopted in the scope of this study.

The analytic classification and identification of dimensions for the systematic review material can be carried out in an inductive or deductive manner. Deductive approach involves categorical evaluation based on the existing theoretical background where categories are pre-defined before the review process; while, in inductive approach, the categories are deduced from the review material iteratively within cycles for category construction by constant comparison, testing and revision all along the process (Mayring, 2000). Relating to another classification perspective, Seuring and Gold (2012) suggest a

two-step method for analytic category building to combine the reliability of theoretical foundation and flexibility for tricky review material in the category building cycles. In this two-step process, essential framework and main aspects are firstly constructed based on the prevailing theory and then individual categorical classifications are assessed and refined during the coding procedure within an inductive approach. This procedure is applied in the present study through an inductive way of category building in back-and-forth cycles, but according to a pre-determined conceptual level. The pre-determined theoretical background consists of the derived arguments and constructs of the exhaustive literature review for the theories relevant to the broader economic benefits of transport infrastructure.

3.3. QUANTITATIVE METHODS EMPLOYED IN THE STUDY

The main methodological approach of this study is shaped upon empirical analysis with a quantitative approach although mixed-method research design is applied by also incorporating qualitative analysis, namely the combined approach of systematic literature review and inductive content analysis. The essential quantitative method has been initially conceived as a spatial model framework, specifically the gravity model of bilateral trade. Nevertheless, the insights from the content analysis on the methods of the reviewed papers have suggested that, before delving into the spatial analysis, a separate initial empirical analysis would strengthen the study. In that regard, causality analysis is performed following its extensive use in the reviewed papers such as Achour and Belloumi (2016), Park et al. (2019), Pereira and Andr  z (2007), Tong et al. (2014). In that way, short-run and long-run dynamics of the connection between transport infrastructure and trade development are investigated within an autoregressive distributed lag (ARDL) model for Turkey.

Consequently, two separate empirical methods are applied within the scope of this study, firstly ARDL as a preliminary analytical tool for causality, followed by the core method of the gravity model of bilateral trade flows in consideration of spatial effects. In

essence, the methodological soundness has been reinforced by employing multi-method strategy.

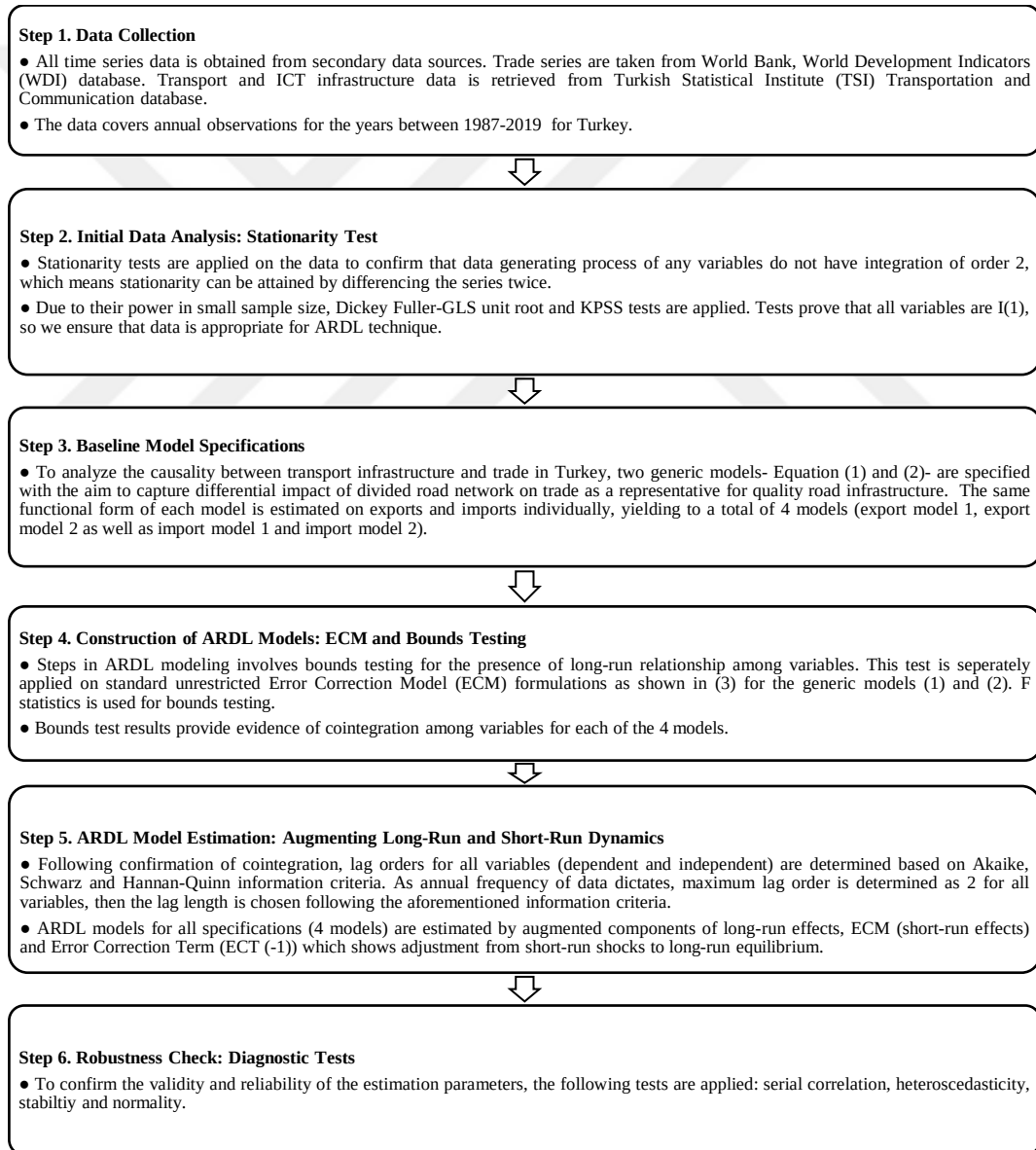
3.3.1. Causality Analysis: Autoregressive Distributed Lag (ARDL) Method⁽⁴⁾

The causality concept initiated by Wiener (1956) and later formalized for practical application by Granger (1969) is a frequently applied tool to search for the dynamic links between time series, including the relationship between transport infrastructure investment and its economic benefits. In the context of stochastic processes, causality relies on the simple idea of predictability that when past observations of X involve useful information to predict Y, it means that there is a causality relationship from X to Y. As an innovation in this cluster of methods, the ARDL approach is developed by Pesaran and Shin (1998) and Pesaran et al. (2001) by incorporating short-run and long-run relationships within a single time series model. Hence, it enables to disentangle cointegration relations (i.e. long-run relations) from short-run dynamics with an unrestricted error correction model (ECM) (Kripfganz and Schneider, 2018). This method is deliberately chosen as it is a convenient and flexible analytical tool with high estimation power for small sample size, a method referred to as the most suitable for limited number of observations (Alam et al., 2020). Moreover, the association between dependent and independent factors is examined with concurrent and also lagged values. Ahmad and Du (2017) identify other advantages as: (1) Although long-run relationships are studied under the condition of the same order of integration with stationary variables in other approaches, ARDL allows for order of integration of $I(0)$ and $I(1)$ and their mixture. Besides, stationarity is not required for estimation. (2) It provides unbiased estimates and valid test statistics even in the case of complications in statistical properties of variables, e.g., endogeneity. (3) An error correction model (ECM) can be obtained from the ARDL model with a simple transformation, showing integrated dynamics of short-run to long-run adjustment without sacrificing long-run information. Due to the advantages mentioned

⁴ This section involves slightly modified reproduction of parts from Şahan and Tuna (2021).

above, ARDL methodology is applied to disentangle the connection between transport infrastructure and trade in Turkey with annual data for the time horizon between 1987 and 2019. An explanation of the steps for the data collection procedure and analytical methodology is provided in Figure 27. All procedures are performed on Eviews 10 software.

Figure 27: Data Collection and Analytical Steps for ARDL Model



3.3.1.1. Variable Selection Procedure and Information on the Variables

The dependent and independent variables are selected based on the transport infrastructure-trade factors used in the reviewed papers as illustrated in Figure 26. It is standard to use value of exports and imports as the response variable under investigation. The explanatory variables are taken from the ‘transport infrastructure capacity’ and ‘ICT development’ categories in Figure 26.

Exports of goods and services with constant prices (LNEXPORT) and imports of goods and services with constant prices (LNIMPORT) demonstrate the economic indicators on which the effect of infrastructure prevails. Road and railway comprise the land transport system, so total road length (LNROAD), divided road length (LNDIVIDED), railway length (LNRAIL) and mobile cellular subscription per 100 people (LNICT) are used as indicators for transport infrastructure and ICT respectively, on which details are given in Table 16. Secondary data from the World Bank database (trade variables) and Turkish Statistical Institute (infrastructure variables) are employed. All variables are log-transformed as a common procedure to obtain smoother time series data for better statistical properties. Data sources are presented in Appendix 2.

Table 16: Transport-Trade Factors in ARDL Approach

Variable	Explanation	Supporting References
LNEXPORTS	Exports of Goods and Services (constant 2010 US\$)	Coşar and Demir (2016), Bensassi et al. (2015), Bottasso et al. (2018), Portugal-Perez and Wilson (2012).
LNIMPORTS	Imports of Goods and Services (constant 2010 US\$)	Bottasso et al. (2018), Francois and Manchin (2013).
LNROAD	Total Road Length (km)	Bottasso et al. (2018), Duranton (2015), Francois and Manchin (2013), Portugal-Perez and Wilson (2012), Demurger (2001), Cantos et al. (2005).
LNDIVIDED	Divided Road Length (km)	Elburz (2018).

LNRAIL	Railway Length (km)	Bottasso et al. (2018), Portugal-Perez and Wilson (2012), Demurger (2001), Cantos et al. (2005).
LNICT	Mobile Cellular Subscriptions (per 100 people)	Francois and Manchin (2013), Wessel (2019).

3.3.1.2. Steps to Construct the ARDL Model: Stationarity Tests, Baseline Model Specifications, Bounds Testing

In time series, non-stationarity refers to a stochastic process characterized by a unit root that violates statistical assumptions necessary for estimation. These properties are constant mean, variance and autocorrelation form over time, which altogether constitute essential conditions for statistical inference. In order to prepare time series data for statistical analysis, most methods require a preliminary test for stationarity and application of necessary differencing procedures to obtain stationarized series through I(1)—first differencing and I(2)—second differencing in the case of non-stationarity. Although pre-testing and stationarization are not necessary steps in ARDL modeling, these tests are applied as suggested by Nkoro and Uko (2016) to ensure that the I(2) process does not prevail in any of the variables, which aborts application of the ARDL method.

Dickey–Fuller–GLS and KPSS tests are applied in stationarity analysis pursuant to Arltová and Fedorová (2016) due to their power in small sample sizes. Dickey–Fuller–GLS checks for unit root in time series (non-stationarity) and KPSS is a test for stationarity. The Dickey–Fuller–GLS test is a modification of ordinary Dickey–Fuller test statistics with generalized least squares (GLS) foundation, standing out as an efficient test robust to sample size and lag length selection. It is applied with a null hypothesis of non-stationarity. The Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test is based on the Lagrange multiplier (LM) test for the rationale of stationarity around a trend. It is executed for the null hypothesis of stationarity, contrary to the null of the first test.

The examination begins with the construction of an appropriate ARDL framework for the nexus between transport infrastructure and trade. A multivariate study is established on the premise that the main transport infrastructure (land network) would

have a promoting impact on international trade flows. For convenience, only a sound set of variables is considered to construct regression functions for the sake of statistical power of the study to counteract constraints by degrees of freedom and complications of time series variables (Ali et al., 2021). Upon selected criterion on the variety of factors in each equation, two model specifications are generated differing according to the set of independent variables. Each of the following models is employed for export and import series:

$$\text{TRADE}_t = \rho_0 + \rho_1 \ln \text{DIVIDED}_t + \rho_2 \ln \text{RAIL}_t + \rho_3 \ln \text{ICT}_t + \pi_t \quad (1)$$

$$\text{TRADE}_t = \lambda_0 + \lambda_1 \ln \text{ROAD}_t + \lambda_2 \ln \text{DIVIDED}_t + \lambda_3 \ln \text{RAIL}_t + \lambda_4 \ln \text{ICT}_t + \Psi_t \quad (2)$$

where TRADE_t refers to aggregate value of exports/imports at time t ; ρ_0 and λ_0 are constant terms; π_t and Ψ_t are white noise error terms in model 1 and 2, respectively. Divided road network is present in model 1; it is also included along with total road length in model 2. This parametrization attempts to decouple individual effects of different road quality levels. In a nutshell, trade is expressed as a function of divided road, railway and ICT in model 1 and total road, divided road, railway and ICT in model 2.

The ARDL modeling process entails several steps. Firstly, bounds testing technique is applied to check for cointegration for models 1 and 2. For that purpose, an unrestricted error correction model (ECM) is regressed to test the significance of lagged values of variables at different levels. Upon identification of a cointegration relationship among variables, a second step involves estimation of long-run and short-run parameters of models 1 and 2 for exports and imports by augmenting long-run and ECM (short-run) specifications.

In the formulation of ARDL models, an unrestricted ECM can be generated for model 2 as follows:

$$\Delta \ln \text{TRADE}_t = \beta_0 + \beta_1 \sum_{i=1}^p \Delta \ln \text{TRADE}_{(t-i)} + \beta_2 \sum_{j=0}^q \Delta \ln \text{ROAD}_{(t-j)} + \beta_3 \sum_{k=0}^r \Delta \ln \text{DIVIDED}_{(t-k)} + \beta_4 \sum_{s=0}^y \Delta \ln \text{RAIL}_{(t-s)} + \beta_5 \sum_{w=0}^z \Delta \ln \text{ICT}_{(t-w)} +$$

$$\alpha_1 \ln \text{TRADE}_{(t-1)} + \alpha_2 \ln \text{ROAD}_{(t-1)} + \alpha_3 \ln \text{DIVIDED}_{(t-1)} + \alpha_4 \ln \text{RAIL}_{(t-1)} + \alpha_5 \ln \text{ICT}_{(t-1)} + \delta_t \quad (3)$$

where TRADE_t refers to aggregate value of exports/imports at time t , Δ is the first difference operator, δ_t is white-noise error term, $(t-1)$ refers to the first lag of each variable, and each notation from the group of ‘p,q,r,y and z’ in summation terms denotes different lag length of each variable chosen based on statistical information criteria. In this framework, $\sum$ terms capture short-run dynamics whereas cointegrating relationships are expressed in lagged parameters at levels with coefficients α_1 to α_5 . In terms of bounds testing, an F-test is exercised to find out whether there is a long-term relationship (cointegration) between exports/imports and transport infrastructure for the following hypothesis:

$H_0: \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ (no cointegration)

$H_1: \alpha_1 \neq 0$ or $\alpha_2 \neq 0$ or $\alpha_3 \neq 0$ or $\alpha_4 \neq 0$ or $\alpha_5 \neq 0$ (presence of cointegration)

After confirmation of long-run relationships through bounds testing, estimations are realized for models 1 and 2 for exports and imports.

3.3.1.3. Robustness of the Models: Reliability and Validity

Finally, a formal testing procedure is engaged to verify inferences drawn from the estimations, for the reliability and validity of the models. Linear regression models are estimated based on several assumptions and these assumptions need to hold for valid estimation results. Therefore, after time-series regressions, it is crucial to test for the validation of the model and establish the reliability of the insights deducted from the analysis. Main properties are assumed on the error terms, hence formal post-estimation tests are applied to check for robustness of models by examining specific residual properties. The applied tests and their explanations are as follows:

1. **Serial Correlation Test:** Serial correlation (or autocorrelation) refers to the violation of the assumption that residuals are serially uncorrelated. Lagrange multiplier (LM) test is used to test for serial correlation. Particularly, Breusch-Godfrey Lagrange multiplier test has an F distribution and applies for general, high-order,

autoregressive moving average (ARMA) errors with the null hypothesis of no serial correlation.

2. Normality Test: The Jarque-Bera (JB) statistic is employed to test for normality. JB test has a χ^2 (chi-square) distribution under the null hypothesis of normally distributed error terms.
3. Heteroscedasticity Test: Another assumption of linear regression models holds that residuals have unknown but same variance, which is known as homoscedasticity. When this assumption is violated, residuals show changing variance, a case referred to as heteroscedasticity. The Breusch-Pagan-Godfrey test is a type of Lagrange multiplier test for the null hypothesis of homoscedasticity under χ^2 (chi-square) distribution.
4. Stability Test: Ramsey Reset test is implemented to check for the correctness of functional form and existence of omitted variable bias (i.e., failing to involve all related independent variables in the regression) with a test statistic following F distribution.

3.3.2. Exploration of Spatial Interactions: Gravity Model of Bilateral Trade Flows

Gravity model approach is a useful tool to investigate spatial interactions. It is developed in analogy to Newtonian gravitation and applied in a broad range of contexts involving commodity flows, migration, traffic flows and bilateral trade flows between markets.

Classical theories on trade like Ricardian comparative advantage theory and Heckscher-Ohlin's factor endowment model provide theoretical background to understand trade flows however they are not convenient for empirical studies. The use of gravity model to explain patterns of international trade flows is proposed by Tinbergen (1962), inspired by Newton's law of gravitation which postulates that attraction between any two masses occurs with a force in direct proportion to the product of their masses and inverse proportion to the squared distance between them. Comparably, bilateral trade flows from

country i to country j , Z_{ij} , is positively related to the product of countries' economic sizes, measured by GDP (Y_i and Y_j) and negatively related to the distance ($Dist_{ij}$) between countries. This flow can be represented mathematically as follows:

$$Z_{ij} = \frac{Y_i * Y_j}{Dist_{ij}} \quad (4)$$

Theoretical foundations of gravity framework are constructed by Anderson (1979) to ground the relation in Equation 4 into the field of economics, with the assumption that goods are differentiated by country of origin. Further developments on the model (Anderson and Van Wincoop, 2003; Helpman et al., 2008 etc.) have turned the initially intuitive framework based on size effect, into a structural gravity setup which considers demand and product differentiation. The structural gravity model of trade relies on sound theoretical foundations and has a focus on trade costs, a model well-suited to draw inferences on the distribution cost of commodities in a market setting with frictions (Anderson, 2011), corresponding mainly to transport costs.

Hence it has been a frequently employed robust instrument for complex spatial interaction analysis for policy research in areas like trade and transport policy. Within the scope of this study, an alternative and more robust estimation approach- Poisson pseudo-maximum likelihood (PPML) estimator- is embraced for a structural gravity model specified to investigate the relationship between transport infrastructure investment in different modes and trade expansion in Turkey. The steps followed for data collection, gravity model development, methodological approach, estimation and robustness analysis are outlined in Figure 28. All procedures are conducted on Stata 14 software.

Figure 28: Methodological Procedures in Gravity Modeling

Step 1. Data Collection

- Firstly, the partner countries are identified for the regression equations for exports and imports. Trade flows of Turkey with countries which account for %80 of total value of exports and imports in 2017 are considered. Based on this rule, bilateral trade flows between Turkey and 33 countries constitute the dependent variable for export models and flows from 28 countries to Turkey compose the dependent variable for import models.
- Data for a broad range of factors is taken from secondary sources. Export and import values for Turkey are retrieved from Turkish Statistical Institute (Turkstat) database. Gravity dataset for distance along with dummies for common border, common language and colonial relationship are retrieved from CEPII database. GDP per capita for Turkey and partner countries are sourced from World Bank. Data for investment in transport infrastructure types in Turkey is taken from OECD. Indicators for quality of transport infrastructure types are retrieved from the Global Competitiveness Index (GCI) of World Economic Forum (WEF). ICT variable for Turkey is sourced from the Telecommunication Development Sector (ITU-D). Indicators for government effectiveness, regulatory quality and control of corruption for Turkey are taken from the Worldwide Governance Indicators (WGI). Liner Shipping Connectivity Index (LSCI) for partner countries is taken from UNCTAD. Data for access to electricity for partner countries is obtained from World Bank. As for the transport sector value added for partner countries, data is sourced from OECD.
- The panel dataset covers the period between 2003-2017.



Step 2. Data Preparation

- Variables for distance, sum of GDP per capita of Turkey and partner country along with infrastructure investment are transformed into logarithmic form while the dependent variables (value of exports and imports) are required to be in levels for gravity estimation with PPML method.
- The data for transport infrastructure investment in Turkey is converted into US dollars by Euro/US Dollar exchange rate obtained from IMF for compatibility between monetary measurements as others are denominated in US dollars.



Step 3. Construction of the Extended Gravity Model

- An extended gravity equation is built to explore the effects of expansion in different transport modes on trade flows. This model setup stands as a baseline with broad range of independent variables.



Step 4. Estimation of the Gravity Model of Trade with PPML Approach and Robustness Analysis

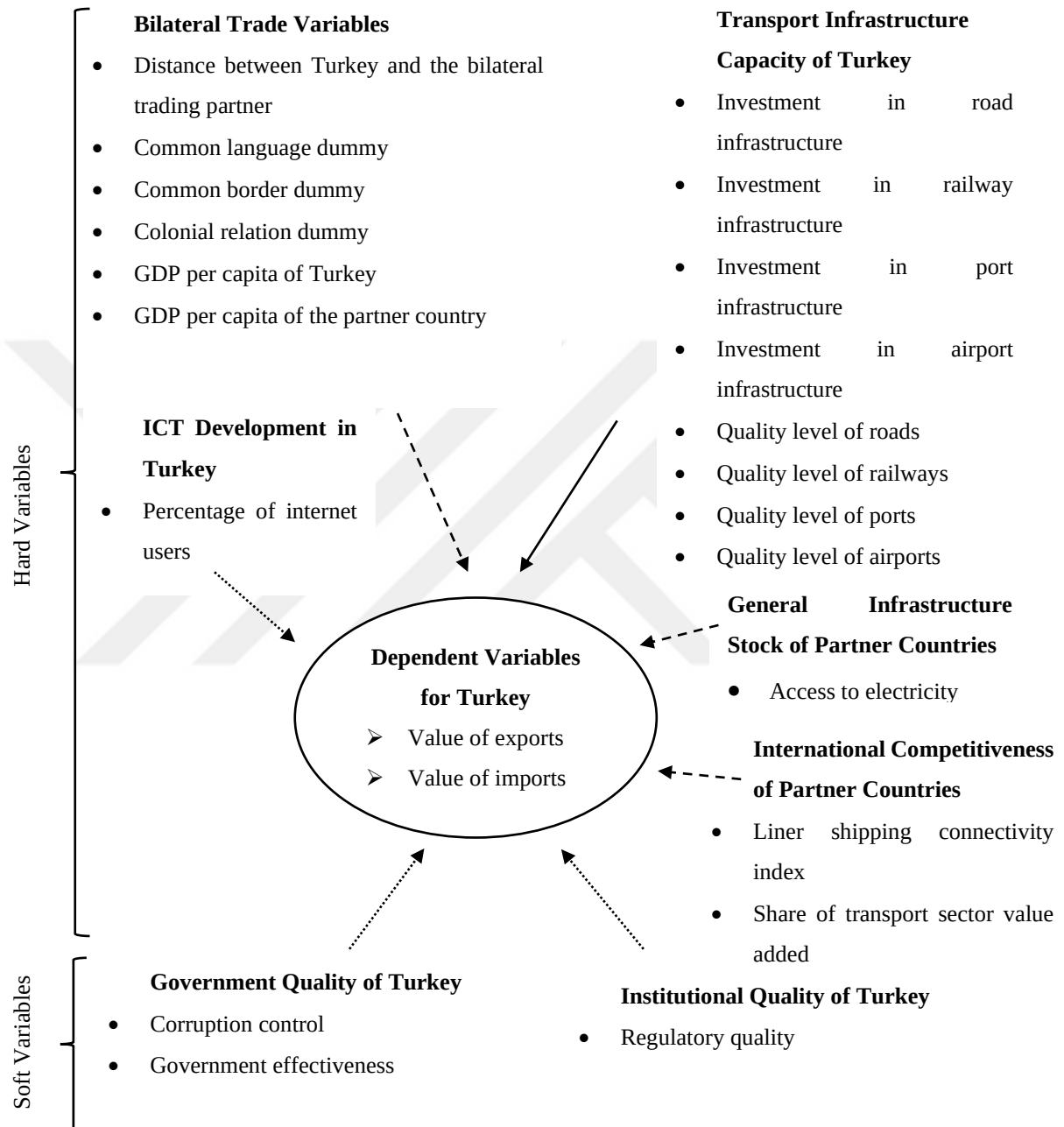
- The regressions are performed for exports and imports with different variations of the extended model to investigate various aspects as well as to check for reliability and validity by comparing consistency among specifications. As the main aim of the study centers upon the disclosure of the trade benefits of network expansions of various transport types, different equations are estimated specifically with diverse set of modes to understand individual transport type effects better. Other peculiarities are also considered, namely ICT as a complementary to a well-structured transport system along with government and institutional quality to control for the public policy dimension. The rest of the factors functions as control variables for partner countries, to disentangle particularly the effects of modes on trade expansion.
- To capture any differential impact, generic model variations are regressed for exports and imports separately, as a research strategy.
- Further explorations are carried out by using infrastructure quality of transport modes and interaction terms among them instead of infrastructure investment, as separate analysis. In this way, the analysis is strengthened and the results are compared for consistency.
- Regarding robustness of the models, PPML is used to counter the inherent heterogeneity in such datasets. To alleviate endogeneity, fixed effects for partner countries are added into regressions. Moreover, Ramsey Reset test is performed on the extended gravity model specification to check for the correctness of the multiplicative functional form.

3.3.2.1. Variable Selection Procedure and Information on the Variables

To construct a solid gravity framework, selection of independent variables is of particular importance to capture real-world mechanisms in a mathematical setup to get reliable insights. The independent variables comprise of the key factors under investigation – transport infrastructure investments as explanatory variables as well as the control variables which are included in the models to get the actual impact of transport infrastructure without interference by other trade cost interactions.

The dependent and independent variables are determined mainly upon the transport infrastructure-trade factors used in the reviewed papers, which are shown in Figure 26, as well as contemplating indicators utilized for broader economic benefits of transport infrastructure in line with the research question and aims of this study. The selection of dependent variables is straightforward, the value of exports and imports are chosen as the response variables to investigate trade benefits of different transport modes. As for independent variables, a diverse range of factors corresponding to each category in Figure 26 are used in the analysis. As shown in Figure 29, the adopted factors for this study to investigate the mode-specific effects of transport investments on trade flows are classified under the categories developed in Figure 26. Different categories of causal relationships have been represented with different types of arrows. The solid arrow implies the focal investigation point of causal relation, namely trade benefits of transport infrastructure capacity in Turkey. The dotted arrows refer to a subordinate interest in the trade effects of variables that are interacting with transport capacity, as outlined by the relevant theories in Figure 2. Among these, government and institutional quality variables are involved as control variables as well. The dashed arrows represent the control variables for partner country, that are involved to treat omitted variable bias (the case of not considering all relevant variables) and to detach the actual impact of expansions in transport modes on trade facilitation from the influence of inter-related factors.

Figure 29: Selected Variables in the Spatial Analysis



Aligned with Portugal-Perez and Wilson (2012), the gravity equation setup involves both hard and soft components within the set of independent variables, the dependent variables belonging to hard dimension by nature. The inclusion of tangible (hard) and intangible (soft) elements serves as enriching and reinforcing the analytical power and soundness of inferences of the study.

As stated, the independent variable set is built according to the latent content on the selection of variables, derived from the reviewed papers. Table 17 shows a brief explanation and the supporting references for the inclusion of such factors. Dependent variables (export and import values) and gravity variables (distance, dummies and GDPPC) are selected among typical factors in gravity setup. Hence, careful consideration is directed to the selection of explanatory and to a larger extent, of control variables. Investment values in transport infrastructure types in Turkey are taken as the main explanatory variables to understand trade benefits of resource allocation in different transport types, departing from the general inclination for physical capacity measures (i.e., length in km) or less frequently for capital value of transport infrastructure. As another point to investigate, the interactions among transport types are also evaluated to understand the effect of modal competition and substitution on trade development in Turkey. Moreover, following the inferences from the systematic review, indicators measuring the quality of infrastructure types for Turkey are also considered. The rationale for quality considerations relates to two aspects. Firstly, the effect of quality of the transport system is explored to get insights on the potential trade benefits of upgrades in the logistics system. Secondly, the reliability and validity of the study can be scrutinized by comparing separate regressions with investment data and with quality data, albeit representing diverse aspects of transport infrastructure. ICT stands out as a core infrastructure to complement a strong transport network, thus variable for the percentage of internet users to the population in Turkey is taken as a proxy for ICT infrastructure in Turkey. Setting off from the idea that benefits of transport investments can be realized with fine-tuned development policies and supporting regulations (Chatman and Noland, 2011), indicators for government effectiveness and control of corruption for Turkey are added as representatives of the government's pivotal role in transport decisions and planning (Hasselgren, 2013; Crescenzi et al., 2016). Moreover, these factors function as control variables to get the true mechanism of the impact of transport infrastructure on trade development and to avoid omitted variable bias. In addition, regulatory quality of Turkey is also considered as a proxy to quality of institutional setting for promoting private sector progress (Kyriacou et al., 2019). This factor is added to understand the

potential enabler role of favorable institutional environment in receiving returns from transport investment. Besides, it serves as another control variable to ensure robust regressions. Regarding control variables for the partner countries, rigorous attention has been paid to find proxy variables which are not related to transport connectivity of Turkey to avoid likely statistical problems such as multicollinearity, which distorts estimation procedures. Accordingly, indicators such as logistics performance index (LPI) are not considered due to the possible interaction with transport infrastructure information of Turkey. With this perspective, a measurement of access to electricity is taken to account for general infrastructure condition in the partner country while transport value added is included to consider the development of transport sector, liner shipping connectivity index is also included representing both aspects. Data sources and further explanations on the variables are provided in Appendix 3.

Table 17: Information on the Gravity Model Variables

Variable	Explanation	References
Exports	Value in thousand US dollars.	Coşar and Demir (2016), Bensassi et al. (2015), Bottasso et al. (2018), Portugal-Perez and Wilson (2012).
Imports	Value in thousand US dollars.	Bottasso et al. (2018), Francois and Manchin (2013).
Distance	Distance between capitals of Turkey and a partner country, km.	Lima and Venables (2001), Portugal-Perez and Wilson (2012), Bensassi et al. (2015), Bottasso et al. (2018).
Common Border	Dummy = 1 if Turkey and a partner country share a border.	Portugal-Perez and Wilson (2012), Bensassi et al. (2015), Bottasso et al. (2018).
Common Language	Dummy = 1 if Turkey and a partner country share a common language.	Portugal-Perez and Wilson (2012).
Colonial Relationship	Dummy = 1 if there is/was a colonial relationship between Turkey and a partner country.	Portugal-Perez and Wilson (2012).
GDPPC	GDP per capita, in US dollars.	Lima and Venables (2001), Wessel (2019), Bottasso et al. (2018).
Road Investment	Road infrastructure investment, in Euros.	Cantos et al. (2005), Ozbay et al. (2007), Yu et al. (2012), Bottasso et al. (2018).
Rail Investment	Rail infrastructure investment, in Euros.	Cantos et al. (2005), Yu et al. (2012).
Airport Investment	Airport infrastructure investment, in Euros.	Cantos et al. (2005), Yu et al. (2012).

Port Investment	Port infrastructure investment, in Euros.	Cantos et al. (2005), Meersman and Nazemzadeh (2017), Yu et al. (2012).
Road Quality	Ranges between 1 and 7.	Portugal-Perez and Wilson (2012), Wessel (2019), Coşar and Demir (2016).
Rail Quality	Ranges between 1 and 7.	Portugal-Perez and Wilson (2012), Wessel (2019).
Airport Quality	Ranges between 1 and 7.	Portugal-Perez and Wilson (2012), Wessel (2019).
Port Quality	Ranges between 1 and 7.	Portugal-Perez and Wilson (2012), Wessel (2019).
ICT	Internet users (% of population).	Portugal-Perez and Wilson (2012), Francois and Manchin (2013).
Government Effectiveness	Indicator on capacity for policy formulation and implementation, ranging between -2.5 and 2.5.	Portugal-Perez and Wilson (2012), Francois and Manchin (2013).
Corruption Control	Level of corruption, ranging between -2.5 and 2.5.	Portugal-Perez and Wilson (2012).
Regulatory Quality	Indicator for an effective regulatory environment to reinforce private sector development, ranging between -2.5 and 2.5.	Portugal-Perez and Wilson (2012), Francois and Manchin (2013).
Liner Shipping Connectivity Index (LSCI)	Level of connectivity to GVCs, score calculated through benchmarking.	Wessel (2019).
Electricity Access	Percentage of population with access to electricity, %.	Wessel (2019).
Transport Value Added	Transport sector value added as a share of GDP, %.	Bensassi et al. (2015).

3.3.2.2. Gravity Modeling and Robustness of the Models

The usefulness of PPML approach for gravity-type equations is proposed by Santos Silva and Tenreyro (2006), based on the argument that multiplicative form estimation is the appropriate technique for gravity equation. Although ordinary least squares (OLS) regression is the traditional estimation method with a log-linearized specification, the authors show that PPML technique generates robust estimations to various heteroscedasticity types in contrast to severely biased estimates obtained by OLS, through Monte Carlo simulations. Another issue in gravity modeling is the tackling of zeros in trade flow data, which prevails as an intrinsic property of trade flows. Zero values are all dropped out of the equation with OLS method as logarithm of zero is not defined,

therefore PPML comes forward as a convenient alternative to involve zero trade flows and incorporate that information in the analysis as the dependent variable is defined in levels instead of logarithmic form. Egger and Staub (2016) confirm reliability of PPML estimations in both small and large samples as well as in case of various stochastic processes. Furthermore, they emphasize general inconsistency of parameter estimates in OLS setting even if the log-linear equation is the correct model.

Numerous empirical studies on trade flows are conducted in the framework of exponential-family generalized linear models (GLM), among which PPML is being applied most frequently (Egger and Staub, 2016). Also, in the gravity model studies reviewed for the content analysis, shown in Table 15, PPML estimator is employed for instance by Coşar and Demir (2016), Wessel (2019), Bottasso et al. (2018), Portugal-Perez and Wilson (2012). Aligning with the general approach in the literature as well as inspired by the reviewed papers, this study follows PPML approach in gravity modeling to explain the effects of logistics infrastructure expansion in different modes on trade development. In Figure 28, procedures followed for data collection, model building, estimation and robustness check are presented briefly. As outlined, PPML estimations are carried out with a panel dataset composed of explanatory variables and control variables for the time period between 2003-2017. Following Bottasso et al. (2018), analysis is performed by trade flows with the countries which cover 80% of the total value of exports/imports of Turkey in 2017. The dependent variables are established on trade flows towards 33 partner countries for export models and trade flows from 28 partner countries for import models.

Within the framework of this thesis, the extended gravity model is defined with the following equation:

$$\begin{aligned} Trade_{flows_{ijt}} = \exp [& B_0 + B_1 \ln(Distance) + B_2 Common\ Border + \\ & B_3 Common\ Language + B_4 Colonial\ Relationship + B_5 \ln(GDP_{PC_{it}} + GDP_{PC_{jt}}) + \\ & B_6 \ln(Road\ Investment_{it}) + B_7 \ln(Rail\ Investment_{it}) + B_8 \ln(Airport\ Investment_{it}) + \\ & B_9 \ln(Port\ Investment_{it}) + B_{10} ICT_{it} + B_{11} Government\ Effectiveness_{it} + \\ & B_{12} Corruption\ Control_{it} + B_{13} Regulatory\ Quality_{it} + B_{14} Electricity\ Access_{jt} + \\ & B_{15} Transport\ Value\ Added_{jt} + B_{16} LSCI_{jt}] \varepsilon_{ijt} \quad (5) \end{aligned}$$

where Trades_{ijt} represents exports/imports of Turkey to/from a partner country j in year t ; i and j stand for Turkey and a partner country, respectively; GDPPC_{it} and GDPPC_{jt} stand for GDP per capita of Turkey and GDP per capita of partner country j in year t , respectively; ICT_{it} stands for rate of internet users in Turkey; LSCI_{jt} refers to liner shipping connectivity index for partner country j ; ε_{ijt} is error-term.

There are several issues on reliability and validity to be handled during the gravity modeling process. To begin with, the gravity model is established on a panel data framework, in which it is an integral process to decide whether to include fixed effects (FE) or random effects (RE). However, the assumptions of RE model do not hold in the setting of this study with a research focus on the impact of transport infrastructure expansion through trade flows between Turkey and its prominent trade partners, indicating that FE model is the appropriate framework (Ülengin et al., 2015). In addition to control variables among independent factors, the incorporation of dummy variables for partner countries (both for export and import regressions) capture their individual effects (Head and Mayer, 2014), controlling for unobserved heterogeneity as a methodological strategy to tackle endogeneity and simultaneity problems in gravity models (Bottasso et al., 2018). The addition of partner country fixed effects into regressions isolates any unobserved causes of trade and enables to detect individual trade effects of transport infrastructure types, leaving only change in infrastructure development over time. Another aspect in gravity modeling involves the inclusion of multilateral resistance terms to account for trade barriers a country encounters with all its trading partners (not just bilateral trade barriers) for accurate estimations. In the case of this study, it is not a concern as gravity models account for these terms when the estimation approach is adopted as PPML estimator with fixed effects, as shown by Fally (2015). Furthermore, statistical significance of estimated coefficients is evaluated based on robust standard errors clustered at Turkey-trading partner levels, which reinforces reliability.

All the modeling procedures of gravity analysis consist of fragmented treatment for reliability and validity, specific to the applied analytical step, from variable selection to estimation. Yet, further robustness exercises are performed by estimating different variations of Equation 5 for exports and imports with several combinations of the

explanatory factors in focus. Moreover, Equation 5 is re-estimated by inclusion of interaction terms among modes and also quality data for each transport type instead of investment data to scrutinize effects of transport infrastructure in different dimensions as well as to check for the consistency of results with that of gravity models. Besides, the multiplicative functional form assumed under PPML is inspected by RESET tests on the extended model for export and import regressions with the null hypothesis of ‘there is no model misspecification’ to verify methodological reliability.



CHAPTER FOUR

TRANSPORTATION INFRASTRUCTURE AND TRADE DEVELOPMENT

4.1. ARDL MODEL ANALYSIS: RESULTS, ROBUSTNESS AND DISCUSSION

(5)

The quantitative analysis of this study starts with a preliminary evaluation of short-run and long-run dynamics between trade and transport infrastructure in Turkey within ARDL approach.

4.1.1. Pre-Evaluation Before ARDL Modeling

As an initial step, stationarity tests are conducted to ensure that variables have lower integration order than 2, which is a necessary condition to apply ARDL modeling. The results of stationarity tests are presented in Table 18. According to the Dickey–Fuller test, the null hypothesis of nonstationarity is rejected for the first differenced series with 95% confidence level, implying that they are I(1) stationary. Regarding KPSS test results, the null of stationarity for the first differenced data is failed to be rejected with 95% confidence level, pointing out that variables are I(1) stationary. Overall, the preliminary statistical investigation reveals that series have a homogenous order of integration with I(1) process, which shows the compatibility of assumptions for the ARDL approach, as it is not possible to implement it in case of higher orders than I(0) and I(1).

Table 18: Stationarity Test Results

	DF-GLS		KPSS	
	Null: Series Has a Unit Root		Null: Series is Stationary	
	Level	First Difference	Level	First Difference
LNEXPORT	−1.6865	−5.6323 ***	0.1972 **	0.0604
LNIMPORT	−2.2527	−7.3678 ***	0.1849 **	0.0617
LNROAD	−1.1621	−5.5187 ***	0.4160 **	0.2241
LNDIVIDED	−0.2804	−2.8005 ***	0.6533 **	0.2910
LNRAIL	−1.6491	−4.9582 ***	0.1793 **	0.0859
LNICT	−1.2288	−3.0855 *	0.2000 **	0.0890

⁵ This section involves slightly modified reproduction of parts from Şahan and Tuna (2021).

Note: ***, ** and * indicate level of significance at the 1%, 5% and 10% levels, respectively.

After stationarity tests, bounds testing is applied to check for the existence of cointegration relationship between transport infrastructure and exports/imports. Table 19 shows the results of the bounds testing process. F statistics show evidence of cointegration with the calculated F scores exceeding critical values at 1% for all models. So an integral long-term link between trade volume and transport infrastructure stock exists in Turkey. This confirms the common verdict put forward by different theories, such as network theory and transport geography, that improvements in transport infrastructure have a reducing effect on transaction and transportation costs, stimulating international trade interactions.

Table 19: Bounds Test Results

	F Statistics	Critical Bound Values (10%)	Critical Bound Values (5%)	Critical Bound Values (1%)
Export-Transport Infrastructure Model 1	13.5253 ***	2.67–3.58	3.27–4.30	4.61–5.96
Export-Transport Infrastructure Model 2	5.4622 **	2.52–3.56	3.05–4.22	4.28–5.84
Import-Transport Infrastructure Model 1	7.5996 ***	2.67–3.58	3.27–4.30	4.61–5.96
Import-Transport Infrastructure Model 2	7.1512 ***	2.2–3.09	2.56–3.49	3.29–4.37

Note: *** and ** indicate level of significance at the 1% and 5% levels, respectively.

4.1.2. Analysis of Short-Run and Long-Run Dynamics in a Single Framework

After confirming cointegration in the series with bounds test, short-run and long-run relationships between transport infrastructure and trade are estimated using ARDL approach. The imposition of maximum lag length is of crucial importance in time series analysis as it determines the power of the test statistics considerably. In Wooldridge (2012: 642), it is stated that maximum lag length is primarily mandated by the frequency and sample size of the data, asserting that lag length of 1 or 2 is sufficient for annual frequency. Following this, due to annual frequency of data, maximum lag length is set to 2 for both

trade and explanatory variables and optimal lag length is selected based on different modeling measures, namely Akaike, Schwarz and Hannan–Quinn information criteria. In Table 20 and Table 21, the model results for exports and imports are demonstrated.

Table 20: ARDL Models for Exports

		Export-Transport Infrastructure Model 1	Export-Transport Infrastructure Model 2
Variables		Coefficient	Coefficient
Adjustment	ECT (−1)	−0.4424 *** (0.050)	−0.7658 *** (0.120)
Long Run	LNROAD		−0.2764 ** (0.121)
	LNDIVIDED	0.3203 ** (0.129)	0.3593 *** (0.081)
	LNRAIL	2.2492 *** (0.864)	1.1297 (0.744)
	LNICT	0.1035 *** (0.025)	0.1100 *** (0.0150)
			0.3784 *** (0.118)
Short Run	Δ(LNEXPORT (−1))		0.5812 *** (0.176)
	Δ(LNDIVIDED)		−0.5702 *** (0.211)
	Δ(LNDIVIDED (−1))		−1.4770 ** (0.622)
	Δ(LNRAIL)	−1.4597 ** (0.6965)	
	Constant	1.9576 (6.911)	15.2174 ** (7.083)

Notes: *** and ** indicate level of significance at the 1% and 5% levels, respectively. Standard errors are in parenthesis.

Table 21: ARDL Models for Imports

		Import-Transport Infrastructure Model 1	Import-Transport Infrastructure Model 2
Variables		Coefficient	Coefficient
Adjustment	ECT (−1)	−1.0979 *** (0.164)	−1.2515 *** (0.173)
Long Run	LNROAD		−0.2293 * (0.131)
	LNDIVIDED	0.6591 *** (0.105)	0.6445 *** (0.090)
	LNRAIL	0.4393 (0.758)	−0.1899 (0.722)
	LNICT	0.0627 *** (0.018)	0.0699 *** (0.016)

Short Run	$\Delta(\text{LNDIVIDED})$	1.5584 *** (0.255)	1.5126 *** (0.237)
	$\Delta(\text{LNRAIL})$	-3.5874 *** (1.243)	-4.3059 *** (1.214)
	$\Delta(\text{LNICT})$	0.3020 *** (0.061)	0.3149 *** (0.058)
	Constant	15.3161 ** (6.216)	24.1040 *** (7.092)

Notes: ***, ** and * indicate level of significance at the 1%, 5% and 10% levels, respectively. Standard errors are in parenthesis.

Firstly, ECT (-1) denotes an error correction term and it corresponds to a feedback effect showing how much of a deviation caused by a positive or negative shock in the previous period is corrected within a year. It is negative as expected, because it incorporates the speed of adjustment to long-run balance. For exports, the models reveal a 44% and 76% convergence to the long-run steady state export level per year in case of a shock. For imports, on the other hand, going back to equilibrium takes less than a year with respective values of -1.09 and -1.25. This is a striking insight as it demonstrates the case that development of transport infrastructure promotes sustainable facilitation of imports rather than exports, considering speed of adjustment. This might be associated with export promotion, requiring other logistics-related reinforcements in support of a better transport system. For example, formation of logistics villages, expansion of the number of industrial zones, enforcement of policy measures to enable doing business more easily and promotion of R&D activities to enhance productivity backed by technological improvements can be integrated into the quality of a logistics system to benefit from agglomeration and network effects.

The presence of short-run dynamics between trade and infrastructure variables is evident for both imports and exports, despite stemming from different factors. To begin with exports, railway infrastructure is significant at 5% in both models and divided road length, lagged value of exports along with lagged divided road length are highly significant at 1% in model 2. When we consider the sparsely distributed geographic locations of production centers and topographic difficulties of the landscape in Turkey, enhancements in divided roads can boost exports by speed and connectivity advantages. The road transport mode requires less capital investment, making it a more convenient

measure in transport policy. Besides, it allows for door-to-door service, access to rural areas and more flexible transport options with economies of scale advantages. The significance of divided road infrastructure rather than total road stock points to a demand for higher speed in the national transport system to compete within global value chains. So, we can say that divided road as a better-quality road transport infrastructure provides transport cost reduction, higher market accessibility and productivity, ultimately upgrading export performance, in support of the conclusions drawn in studies such as Duranton et al. (2014), Datta (2012) and Volpe Martincus et al. (2017). As for railways, rail networks are expected to connect different provinces with each other in the country and make further connections to the rest of the world, developing both national and international trade environment as shown by Donaldson (2018). However, the significant negative signs for imports and exports in the short run suggest that it is not the case for Turkey to be realized in a short time window. For the most part, this could be a result of rail network development for freight transport being a recent dimension in transport policy of the country, with an emphasis of intermodality and interconnectivity. However, results show that it will take time to realize the benefits from railway investments under some conditions. Efficiency of railways in trade formation can be realized with an extensive railway connection to gateways and hubs in a cost-advantageous fashion. More policies for rail connectivity and intermodality should be developed to cultivate the contribution of rail connection in welfare generation through trade. The high significance of railway stock in long-run export performance justifies our explanations that rail connection should be handled with a perspective of long-term transport policy and planning. Imports are interrelated with all infrastructure variables with high significance in the short run. The role of divided roads is greater for imports than exports. Similarly, the negative signs on railways with stronger parameters suggest that once trade benefits of railway development are realized, imports will potentially increase to a higher extent than exports in the short run. These two remarkable points create an understanding that land transport systems are especially beneficial for imports growth for Turkey. Significant causation from ICT reveals that information extracted from big data in operations, digital communication tools

and development of intelligent transport systems result in increases in imports through transport efficiency and safety benefits in the short term.

Long-run effects show causality from divided roads, railway and ICT to exports as well as from divided roads and ICT infrastructure to imports; any effect is distorted by the significant but negative coefficient of total road infrastructure. In the long run, ICT provides a greater contribution in export development whereas divided road stock favors imports more.

4.1.3. Reliability and Validity: Model Diagnostic Tests

After time-series regressions, it is crucial to test for specific properties to validate the model and establish the reliability of the insights deducted from the analysis. Thus, diagnostic tests are conducted to verify robustness of the models for the reliability and validity of the inferences drawn.

The power and reliability of the models are tested with results presented in Table 22. All models satisfy necessary conditions for valid and unbiased results, leading to reliable estimates. The residuals are serially uncorrelated (LM test) with normal distribution (Jarque–Bera test) and homoscedastic variances (Breusch–Pagan–Godfrey), proving that the models are well-specified. Besides, the Ramsey Reset test confirms stability of models in time, eliminating misspecification or nonlinearity bias.

Table 22: Robustness of ARDL Models

	Export- Transport Infrastructure Model 1	Export- Transport Infrastructure Model 2	Import- Transport Infrastructure Model 1	Import- Transport Infrastructure Model 2
Serial Correlation	0.11 (0.89)	0.17 (0.84)	0.63 (0.54)	1.20 (0.31)
Heteroscedasticity	1.61 (0.19)	1.58 (0.18)	1.00 (0.45)	1.00 (0.45)
Stability	0.15 (0.85)	0.84 (0.44)	0.85 (0.44)	0.98 (0.39)
Normality	1.09 (0.57)	1.85 (0.39)	0.28 (0.86)	0.26 (0.87)

Note: *p* values are in parenthesis.

4.2. AUGMENTED GRAVITY MODEL ANALYSIS: RESULTS, ROBUSTNESS AND DISCUSSION

As highlighted previously, the core analytical approach of this study involves gravity model methodology developed for bilateral trade flows as this study concerns with the spatial effects of transport infrastructure under the research perspective proposed by the theory of new economic geography. The gravity models are estimated with PPML approach and robustness assessments are performed with various techniques for export and import estimation models. The findings are discussed in light of theoretical framework constructed for the research objectives of this study, displayed in Figure 2.

4.2.1. Augmented Gravity Model Analysis for Exports

The main analytical procedure begins with an inquiry into the effects of transport infrastructure expansion on export development in an attempt to quest the transport-led export growth hypothesis.

4.2.1.1. Gravity Model Results for Exports

Firstly, the extended model in Equation 5 is estimated and then its different variations are regressed for in-depth inferences for 33 export partners of Turkey for the period between 2003-2017. The results of gravity regression for exports are presented in Table 23. In the first column, the results of the extended model are shown as a baseline specification, upon which various models are estimated. As the notion of gravitation suggests, the total economic size, namely sum of GDP per capita of Turkey and partner country, has a significant positive impact on exports of Turkey in all specifications, the only bilateral trade flow variable which is not dropped out of regressions during the analysis. A detailed discussion is necessary for divergent impacts of investment in different transport types across models. Firstly, investments for all transport types significantly affect trade according to the baseline estimation of Export Model 1.

However, there is a remarkable result that rail investment seems to have a negative effect on trade whereas investments in other transport types seem to contribute to trade development with significant positive coefficients. This can be associated with several unique characteristics of the transportation system in Turkey. The primary motivation behind railway construction has been establishment of regional connectivity with a traditional view, which remained as a core policy for a prolonged period. Thus, the provisions on railway connectivity are a recent phenomenon in Turkey, gaining momentum especially after 2003 (MoTI, 2019), which might leave railway transport with inadequate service levels for freight transportation. Relatedly, the share of railway in freight transport keeps at 1% within the last two decades (Turkstat, 2021b), implying that railway is not preferred frequently by stakeholders of logistics sector. This case is likely to happen because of the failure to provide cost-effectiveness as a natural outcome of inadequate network not only in terms of railway alone but also network for intermodality. Overall, railway infrastructure is neglected for a long time and recent efforts to improve its connectivity can bring results with time lags as an inherent attribute of government infrastructure investments. Moreover, a possible inefficiency in railway infrastructure investments consistently prevails in all models with high significance levels, further pinpointing the need to implement a comprehensive transport planning and policy.

Another noteworthy point is the negative sign of road infrastructure investment when road is the only transport type (in Export Model 2) and only land transportation investment is considered (in Export Model 3) as well as when road and port investment are the factors under investigation (in Export Model 5). This is a surprising result as a part of Turkish exports depends on road transport particularly with border countries. This result can be explained with the dominance of road transport in domestic freight transport rather than international commodity flows as the share of road transport in exported products falls from around 45% to 28% within the last two decades (Turkstat, 2021b). Besides, Turkey has a well-connected road transport network and additions to the existing stock might be inefficient in trade formation, caused by the nonlinear relationship between road infrastructure and export expansion, which exhibits diminishing rate of returns, as noted by Deng et al. (2014).

Regarding air and maritime transportation modes, airport and port investments generally come out as drivers for export expansion (with only insignificant exception for port investment in Export Model 5). This reflects the actual state of modal distribution of international freight transportation in Turkey, shipping being the prominent mode in export transportation with over 60% share and air transport accounting for around 11-14% of export shipment for the last twenty years (Turkstat, 2021b).

The control variables for Turkey have been included into the regressions in order to ensure robustness as well as to get insights on ICT development and some soft factors which are related to both transport and trade policy. However, changing significance and signs make any inference invalid. As for the control variables of partner countries, electricity access and LSCI are significantly positive in all modes, implying that the infrastructure development along with connectivity level (putting in a different way, openness level) of the partner countries are other determinants of export facilitation for Turkey.

Table 23: Gravity Regression Results for Exports

Variables	Export Model 1	Export Model 2	Export Model 3	Export Model 4	Export Model 5	Export Model 6	Export Model 7
Ln(GDPPC i + GDPPC j)	1.552*** (0.337)	1.473*** (0.252)	1.483*** (0.257)	1.369*** (0.275)	1.457*** (0.265)	1.435*** (0.269)	1.693*** (0.310)
Ln(Road Investment i)	0.558*** (0.164)	-0.172*** (0.0465)	-0.148*** (0.0563)	0.477*** (0.156)	-0.127*** (0.0248)		
Ln(Rail Investment i)	-0.332*** (0.0757)		-0.0414** (0.0201)	-0.289*** (0.0690)		-0.111*** (0.0150)	-0.0849*** (0.0185)
Ln(Airport Investment i)	0.100** (0.0443)						0.0960** (0.0428)
Ln(Port Investment i)	0.247*** (0.0715)			0.227*** (0.0704)	0.0209 (0.0266)	0.0736*** (0.0246)	
ICT i	-0.0189** (0.00815)	0.00748** (0.00307)	0.00874*** (0.00298)	-0.0122* (0.00720)	0.00486 (0.00408)	0.00295 (0.00325)	0.00182 (0.00383)
Government Effectiveness i	0.866** (0.426)	-0.454** (0.195)	-0.499** (0.201)	0.519 (0.428)	-0.336 (0.293)	-0.150 (0.264)	-0.297 (0.200)
Corruption Control i	-1.581*** (0.530)	-0.160 (0.101)	-0.0626 (0.130)	-1.478*** (0.529)	-0.343 (0.309)	-0.560** (0.274)	0.0452 (0.0978)
Regulatory Quality i	-0.0936 (0.234)	0.413** (0.184)	0.461** (0.186)	0.0555 (0.240)	0.349* (0.208)	0.383** (0.195)	0.231 (0.183)
Electricity Access j	0.0440** (0.0197)	0.0397* (0.0235)	0.0439** (0.0223)	0.0449** (0.0196)	0.0375* (0.0216)	0.0410* (0.0214)	0.0501** (0.0244)
Transport Value Added j	0.0669 (0.0667)	0.0542 (0.0715)	0.0526 (0.0711)	0.0552 (0.0722)	0.0553 (0.0726)	0.0532 (0.0712)	0.0641 (0.0670)
LSCI j	0.00589* (0.00342)	0.00829** (0.00377)	0.00821** (0.00373)	0.00723** (0.00362)	0.00824** (0.00377)	0.00788** (0.00371)	0.00702* (0.00364)
Observations	172	172	172	172	172	172	172
Cluster FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald Test	6698	2020	2668	5774	2247	2404	3158

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations. Regressions for some combination of modes have not converged (failing to provide estimations), so they are not considered.

Another research area involves interaction among variables which occurs when the joint impact on the output is different from the main effects of each factor. Gravity modeling forms a convenient framework to search for interactions among different elements by adding relevant terms to search for whether factors are integrated in effect, as

applied by Duranton (2015), Bensassi et al. (2015), Portugal-Perez and Wilson (2012). Considering complementarity and competition concept between transport modes, understanding the nature of interplay among modes can provide valuable insights for promotion of exports. Thus, another line of regressions is performed with interaction terms for investments in different transport types as main infrastructure factors and the results are demonstrated in Table 24. To begin with the interaction between road and rail transport, the negative sign suggests substitutability between these two land transportation investments reinforced by the implication of decreasing marginal effect of these transport types on exports. Moreover, the insignificant interaction between road and airport investment as well as railway and airport investment might indicate inadequate land connectivity for air transportation. Besides, there might be a tendency to take investment decisions in air transport infrastructure detached from consideration of other modes. As for the interaction between rail and port investment, the insignificant term can be explained by the inefficiency in railway investment and the scarcity of existing railway networks. The strongly significant interaction between airport and port investment supports scholarly discussions on the complementarity between air and sea transport, the former specializing in high-valued freight and the latter for low-valued products such as raw materials (Ducruet et al., 2011a). Estimates for control variables do not show significant deviations from that of gravity models presented in Table 23. Generally, interaction terms reveal consistent results with gravity estimations in Table 23, strengthening reliability and validity of the analysis.

Table 24: Gravity Regression Results for Modal Interaction in Exports

Variables	Interaction Model 1	Interaction Model 2	Interaction Model 3	Interaction Model 4	Interaction Model 5	Interaction Model 6
Ln(GDPPC i + GDPPC j)	1.502*** (0.247)	1.561*** (0.297)	1.524*** (0.254)	1.453*** (0.259)	1.483*** (0.252)	1.540*** (0.238)
Ln(Road Investment i)* Ln(Rail Investment i)	-0.0744*** (0.00979)					
Ln(Road Investment i)* Ln(Airport Investment i)		0.0279 (0.0341)				
Ln(Rail Investment i)* Ln(Airport Investment i)			0.0113			

Investment i)*			(0.0153)			
Ln(Airport						
Investment i)						
Ln(Road						
Investment i)*				0.0528*		
Ln(Port				(0.0299)		
Investment i)						
Ln(Rail						
Investment i)*					0.0166	
Ln(Port					(0.0153)	
Investment i)						
Ln(Airport						
Investment i)*						0.0549***
Ln(Port						(0.0158)
Investment i)						
ICT i	0.00825***	0.000624	0.00172	-0.00219	0.000927	-0.00369
	(0.00292)	(0.00441)	(0.00359)	(0.00430)	(0.00349)	(0.00391)
Government						
Effectiveness i	-0.545***	-0.408**	-0.439**	-0.171	-0.365	0.00564
	(0.190)	(0.200)	(0.199)	(0.306)	(0.253)	(0.252)
Corruption Control						
i	0.0311	-0.112	-0.139	-0.594*	-0.304	-0.647***
	(0.0910)	(0.0970)	(0.109)	(0.334)	(0.240)	(0.219)
Regulatory Quality						
i	0.425**	0.110	0.146	0.0993	0.146	0.106
	(0.188)	(0.195)	(0.194)	(0.215)	(0.207)	(0.197)
Electricity Access j	0.0496**	0.0475**	0.0460*	0.0390*	0.0427**	0.0343
	(0.0245)	(0.0234)	(0.0249)	(0.0204)	(0.0208)	(0.0236)
Transport Value						
Added j	0.0521	0.0602	0.0583	0.0585	0.0576	0.0644
	(0.0707)	(0.0697)	(0.0720)	(0.0747)	(0.0745)	(0.0727)
LSCI j	0.00819**	0.00808**	0.00829**	0.00823**	0.00838**	0.00752**
	(0.00370)	(0.00373)	(0.00376)	(0.00381)	(0.00381)	(0.00380)
Observations	172	172	172	172	172	172
Cluster FE	Yes	Yes	Yes	Yes	Yes	Yes
Wald Test	1838	1887	2734	1940	2308	1826

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations. Regressions for some combination of modes have not converged (failing to provide estimations), so they are not considered.

The quality of transport infrastructure network together with infrastructure expansion is another aspect investigated by the reviewed papers involving Coşar and Demir (2016), Hong et al. (2011), Wessel (2019), Portugal-Perez and Wilson (2012), Limao and Venables (2001) along with Francois and Manchin (2013). The quality of transport modes can be decisive for the extent to which a country can realize wider economic impacts from transport infrastructure expansion. In this context, another set of gravity equations are estimated by replacing investment variables with quality variables for each transport type in Equation 5 and the results are shown in Table 25. According to the Quality Model 1 adopted from the extended gravity specification, quality of road and

airport seems to have no significant impact on trade expansion, when individual quality levels of each mode are involved. As a primary infrastructure type, the presence of roads might be the necessary condition for export growth rather than its quality level. As for airport quality, this result can be associated with the positioning of the sector prominently in passenger transportation with an allocated total fleet share of 95% (DGCA, 2020). These inferences are drawn on the relative situation of transport modes within the logistics system for the model which evaluates quality of all transport types. The negative impact of rail quality on exports might occur as an outcome of the immature network establishment with an ongoing process of railway network development. Moreover, in line with the results for the extended gravity regression in Table 23, this can arise from the inefficient allocation of resources in railway projects. As another explanation, quality of transport infrastructure might be a triggering factor only when transport network is established to a certain level, leading to inefficiency the other way around. As an ultimate and most important insight, port quality has a significant and strong impact on export growth, in confirmation with the results in Table 23, demonstrating its leading position in international trade movement. As the last significant point, it is worthwhile to comment on the positive effect of airport quality when it is the sole infrastructure factor under interest. High-value products such as computer components, health products, jewelry require unique services of speed, reliability, safety and security which can be provided by air transportation. Thus, when the effect of air transport on export promotion is detached from other transport types, its unique attributes become prominent. Despite giving somewhat controversial results with changing signs and significance, the quality regressions verify the importance of infrastructure improvements in air and maritime transport types with land transportation kept in a subordinating position, in line with the gravity results in Table 23.

Table 25: Gravity Regression Results with Modal Quality for Exports

Variables	Quality Model 1	Quality Model 2	Quality Model 3	Quality Model 4
Ln(GDPPC i + GDPPC j)	2.001*** (0.562)	1.711*** (0.306)	1.736*** (0.268)	1.766*** (0.507)
Road Quality i	-0.100 (0.492)	0.00208 (0.0710)		0.0809 (0.113)
Rail Quality i	-0.705*** (0.169)			0.0521 (0.142)
Airport Quality i	-0.458 (0.452)		0.116** (0.0512)	
Port Quality i	1.376*** (0.453)			
ICT i	0.000980 (0.00915)	0.00374 (0.00411)	0.00119 (0.00295)	0.00516 (0.00626)
Government Effectiveness i	-0.436 (0.285)	-0.427* (0.239)	-0.441* (0.241)	-0.397 (0.316)
Corruption Control i	0.817*** (0.308)	-0.0578 (0.0924)	-0.138 (0.0985)	-0.00606 (0.0788)
Regulatory Quality i	-0.121 (0.281)	0.0902 (0.200)	-0.00779 (0.201)	0.0178 (0.219)
Electricity Access j	0.0255 (0.0279)	0.0384 (0.0264)	0.0366 (0.0250)	0.0212 (0.0298)
Transport Value Added j	-0.0442 (0.0844)	0.0562 (0.0706)	0.0610 (0.0736)	-0.0648 (0.0957)
LSCI j	0.00569 (0.00485)	0.00923** (0.00361)	0.00936** (0.00370)	0.00677 (0.00503)
Observations	132	160	160	132
Cluster FE	Yes	Yes	Yes	Yes
Wald Test	3961	2160	2558	3341

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations. Regressions for some combination of modes have not converged (failing to provide estimations), so they are not considered.

4.2.1.2. Further Investigation of Reliability and Validity

All in all, the results are somewhat consistent for gravity, interaction and quality regressions except for sign and significance reversals for road infrastructure which is attributed to its complex, multi-type and policy instrument nature. Although this study has probed into the reliability and validity of the analysis on exports all along the research process, some issues are further monitored. To begin with, as a main issue, endogeneity, i.e. reverse causality, refers to the case where there is a bi-directional feedback relationship in which export growth is driven by transport infrastructure and in turn the causation

works in the other way around. Endogeneity is a major concern in panel data structure as it violates main statistical assumptions, however in terms of this study, the causality runs probably from transport infrastructure to exports with a direct mechanism of impact instead of infrastructure expansion pulled by export growth, as argued by Portugal-Perez and Wilson (2012) as well as Francois and Manchin (2013). Nevertheless, as discussed earlier, the inclusion of fixed effects has been the main methodological strategy to remedy possible endogeneity concerns in the models. Specifically, the partner country fixed effects, i.e. cluster fixed effects, are supposed to control for unobserved causes of exports in Turkey. As the focus of this study concentrates on Turkish exports, leading to single country-trading partner pairs, it is not reasonable to consider other fixed effects like exporting country dummy, year dummy etc., as in Bottasso et al. (2018). Furthermore, RESET test is applied to control for the accuracy of model specification in PPML framework which assumes a multiplicative functional form. RESET test has given evidence for accurate model specification as the null hypothesis of ‘correct functional form’ is failed to be rejected at all confidence levels for the extended model under the PPML method, reassuring robustness of the baseline model specification.

4.2.2. Augmented Gravity Model Analysis for Imports

Although export-led growth has led to a large pile of research in infrastructure and growth nexus through export expansion, scholarly interest has remained limited for the effect of transport infrastructure on import growth. This study entails the effects of transport infrastructure expansion on import development along with export expansion for an overall evaluation of trade generation.

4.2.2.1. Gravity Model Results for Imports

The extended model in Equation 5 has also been the baseline model for the investigation of imports with a panel dataset comprising 28 import partners of Turkey for the period between 2003-2017. Different modifications of the extended model have been

estimated to understand the influence of investment in different modes, interaction among transport types and modal quality of infrastructure on import expansion. The estimation results have been shown in Table 26. The gravity variable for sum of GDP per capita of Turkey and partner country is significant in all model specifications, showing the relevance of economic magnitude for import flows like in the case of exports. To begin with the extended model of Import Model 1 in Table 26, road infrastructure investment appears to have a negative and significant effect on imports. This may occur as a result of geographic distribution of the import partners in remote territories and also constantly declining employment of road transport for imported goods with a share of around 15% in 2019 (Turkstat, 2021b). Moreover, road investment might have become inefficient after a saturation point, displaying a nonlinear relationship as proposed by Deng et al. (2014). When modes are considered altogether, airport and port investment seem to have no significant influence on imports. As far as railway investment is concerned, the coefficients are strongly significant with the highest values when compared to other modes. Railway shows up as a consistent contributor for import expansion in all models. This is a plausible insight that railway offers promising benefits for import expansion when its prevailing 1% share in import transportation is enhanced through investments. Going back to the results of the extended model, air and sea transportation components might be overridden by the potential of railway transport investment. The effect of individual modes is explored in Import Model 2 to Import Model 5. The individual effect of road transport is similar to that in the extended model as well as in Import Model 6 with road and airport infrastructure. This pattern accompanied with its insignificance in some of the estimated models, strengthens the explanations by its limited use for imports. Regarding airport investment, it is insignificant in most models however it is identified with negative coefficients when combined with road-port and rail-port transport types. It can be derived from the lack of consistent estimates for air transport that this transport infrastructure type is not an important factor in fostering imports. As for maritime transport, port infrastructure investment is a determinant factor for import growth in all models with only exception of the extended model. The positive causation from port infrastructure to imports suggests that availability of maritime transport infrastructure is

also important for import expansion, following railway infrastructure. Land transportation types are not among major factors for export growth however railway infrastructure becomes prominent for import expansion. As for ICT, this infrastructure type stands as a triggering factor for import expansion with its significance in most models, signaling as a complementary when import flows are concerned. Considering the control variables for Turkey, government effectiveness drives import development as a soft variable, apparently influential through policies supporting trade openness and free markets. Control variables for partner countries do not affect imports unlike the case for exports, still they are involved in the models to mitigate the possible disturbance by unobserved effects.

Table 26: Gravity Regression Results for Imports

Variables	Import Model 1	Import Model 2	Import Model 3	Import Model 4	Import Model 5	Import Model 6	Import Model 7	Import Model 8	Import Model 9	Import Model 10	Import Model 11
Ln(GDPPC i + GDPPC j)	0.697*** (0.199)	0.812*** (0.170)	0.904*** (0.144)	0.913*** (0.164)	0.568*** (0.162)	0.831*** (0.179)	0.568*** (0.161)	0.911*** (0.149)	0.621*** (0.158)	0.595*** (0.171)	0.633*** (0.171)
Ln(Road Investment i)	-0.239** (0.112)	-0.141*** (0.0426)				-0.142*** (0.0420)	0.0168 (0.0405)			0.0746 (0.0576)	
Ln(Rail Investment i)	0.196*** (0.0577)		0.137*** (0.0202)					0.137*** (0.0202)	0.0950*** (0.0243)		0.0739*** (0.0267)
Ln(Airport Investment i)	-0.0508 (0.0532)			-0.0143 (0.0266)		-0.0210 (0.0265)		-0.00727 (0.0259)		-0.162*** (0.0355)	-0.128*** (0.0311)
Ln(Port Investment i)	0.0288 (0.0452)				0.0824*** (0.0160)		0.0852*** (0.0171)		0.0704*** (0.0176)	0.125*** (0.0252)	0.0975*** (0.0205)
ICT i	0.00356 (0.00264)	0.00675*** (0.00224)	0.0141*** (0.00218)	0.0101*** (0.00308)	0.0116*** (0.00196)	0.00490* (0.00293)	0.0121*** (0.00246)	0.0135*** (0.00294)	0.0135*** (0.00208)	0.000374 (0.00258)	0.00232 (0.00261)
Government Effectiveness i	0.867** (0.369)	0.754** (0.359)	0.177 (0.351)	0.390 (0.314)	0.800*** (0.291)	0.763** (0.363)	0.770** (0.353)	0.179 (0.353)	0.596* (0.341)	0.854** (0.371)	0.790** (0.363)
Corruption Control i	0.0314 (0.123)	0.349*** (0.0904)	0.0500 (0.0818)	0.259*** (0.0904)	-0.0366 (0.101)	0.357*** (0.0910)	-0.0578 (0.101)	0.0526 (0.0830)	-0.138 (0.0861)	-0.190* (0.103)	-0.164* (0.0836)
Regulatory Quality i	-0.676** (0.342)	-0.226 (0.321)	0.0796 (0.284)	0.00732 (0.312)	-0.266 (0.262)	-0.304 (0.344)	-0.244 (0.308)	0.0541 (0.302)	-0.204 (0.276)	-0.856*** (0.322)	-0.763** (0.338)
Electricity Access j	-0.0130 (0.00830)	-0.0286*** (0.00887)	-0.00180 (0.00869)	-0.0199** (0.00862)	-0.0164** (0.00830)	-0.0300*** (0.00886)	-0.0151 (0.00973)	-0.00228 (0.00862)	-0.00483 (0.00920)	-0.0200* (0.0103)	-0.0146 (0.00925)
Transport Value Added j	-0.0309 (0.0455)	-0.0446 (0.0419)	-0.0239 (0.0433)	-0.0347 (0.0438)	-0.0649 (0.0496)	-0.0409 (0.0432)	-0.0650 (0.0498)	-0.0226 (0.0454)	-0.0514 (0.0496)	-0.0458 (0.0537)	-0.0392 (0.0524)
LSCI j	0.110 (0.718)	0.412 (0.688)	0.543 (0.698)	0.572 (0.672)	0.254 (0.748)	0.400 (0.673)	0.263 (0.754)	0.540 (0.697)	0.279 (0.740)	0.0967 (0.727)	0.116 (0.736)
Observations	157	157	157	157	157	157	157	157	157	157	157
Cluster FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald Test	2528	1515	2270	1787	2219	1564	2295	2548	3111	2685	2801

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations. Regressions for some combination of modes have not converged (failing to provide estimations), so they are not considered.

To account for modal complementarity and rivalry, gravity regressions are re-run with interaction terms of infrastructure investments in different transport types. According to the regression results with interaction terms presented in Table 27, interaction among all involved combinations of modes indicate complementarity except for road and airport infrastructure pair which shows a substitution relationship. At this point, it is necessary to clarify the background of this substitution relationship between road and air transport which can be related to modal shift. Motivations for a modal shift can come from comparative advantages in cost, flexibility, reliability and speed with a switch towards more flexible, faster and cost-efficient modes, particularly road and air transport for freight transport (Rodrigue, 2021b). Thus, new requirements in global supply chains open new competition areas for transport types. As another noteworthy interaction, the substitution relationship between road and rail for exports has turned to a connection of complementarity for imports. Considering the distribution of imported products in the country territories, companies can be indifferent between these two land transport options for the domestic short haulage transportation service where road transport is inevitable for the final leg of delivery. Actually, the complementarity of land components for air and maritime transport is evident by the strongly significant interaction terms in Table 27, except for the substitution between road and air. This result is expected by the predominance of maritime and air freight transport in imports, inclined by the share of 63% and 14% in 2019, respectively (Turkstat, 2021b). Moreover, the differentiated service levels of air and maritime transport for products with distinct attributes show up as a significant positive interaction, displaying complementarity between these modes, as in exports. Overall, there is strong evidence to infer that modal complementarity is an important catalyst in fostering imports. Another noteworthy result involves the higher magnitude of ICT when transport types are in interaction, implying the capacity of ICT infrastructure especially for the facilitation of intermodality.

Table 27: Gravity Regression Results for Modal Interaction in Imports

Variables	Interaction Model 1	Interaction Model 2	Interaction Model 3	Interaction Model 4	Interaction Model 5	Interaction Model 6	Interaction Model 7	Interaction Model 8	Interaction Model 9
Ln(GDPPC i + GDPPC j)	0.924*** (0.157)	0.920*** (0.163)	0.830*** (0.139)	0.586*** (0.152)	0.597*** (0.144)	0.637*** (0.159)	0.674*** (0.137)	0.892*** (0.150)	0.655*** (0.135)
Ln(Road Investment i)* Ln(Rail Investment i)	0.0383*** (0.0140)								
Ln(Road Investment i)* Ln(Airport Investment i)		-0.0632*** (0.0191)							
Ln(Rail Investment i)* Ln(Airport Investment i)			0.0763*** (0.0137)						
Ln(Road Investment i)* Ln(Port Investment i)				0.0919*** (0.0181)					
Ln(Rail Investment i)* Ln(Port Investment i)					0.0761*** (0.0126)				
Ln(Airport Investment i)* Ln(Port Investment i)						0.0527*** (0.0123)			
Ln(Road Investment i)* Ln(Rail Investment i)* Ln(Airport Investment i)* Ln(Port Investment i)							0.0521*** (0.00930)		
Ln(Road Investment i)* Ln(Rail Investment i)* Ln(Airport Investment i)								0.0255** (0.0111)	
Ln(Road Investment i)* Ln(Rail Investment i)* Ln(Port Investment i)									0.0726*** (0.0124)
ICT i	0.0133*** (0.00216)	0.00389 (0.00277)	0.0193*** (0.00259)	0.0145*** (0.00226)	0.0131*** (0.00210)	0.0159*** (0.00252)	0.0186*** (0.00269)	0.0148*** (0.00249)	0.0153*** (0.00231)
Government Effectiveness i	0.228 (0.364)	0.564 (0.347)	0.255 (0.329)	0.608** (0.284)	0.653** (0.285)	0.640** (0.292)	0.423 (0.299)	0.276 (0.354)	0.452 (0.300)
Corruption Control i	0.172** (0.0862)	0.316*** (0.0900)	0.117 (0.0921)	-0.132 (0.106)	-0.130 (0.0933)	0.0528 (0.101)	-0.0587 (0.0951)	0.191** (0.0895)	-0.160* (0.0890)
Regulatory Quality i	0.141 (0.312)	-0.292 (0.350)	0.339 (0.316)	-0.121 (0.258)	-0.229 (0.251)	0.0358 (0.267)	0.148 (0.277)	0.203 (0.339)	-0.0722 (0.258)
Electricity Access j	-0.0116 (0.00860)	-0.0273*** (0.00892)	-0.00470 (0.00799)	-0.00978 (0.00835)	-0.00701 (0.00838)	-0.0140* (0.00826)	-0.00399 (0.00835)	-0.0125 (0.00841)	-0.00261 (0.00869)
Transport Value Added j	-0.0317 (0.0425)	-0.0290 (0.0423)	-0.0439 (0.0437)	-0.0632 (0.0499)	-0.0552 (0.0486)	-0.0646 (0.0483)	-0.0564 (0.0474)	-0.0383 (0.0428)	-0.0506 (0.0481)
LSCI j	0.615 (0.701)	0.472 (0.661)	0.599 (0.702)	0.327 (0.738)	0.261 (0.728)	0.398 (0.745)	0.450 (0.721)	0.617 (0.700)	0.363 (0.716)
Observations	157	157	157	157	157	157	157	157	157
Cluster FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald Test	1445	1239	2490	2422	2597	2030	2442	1812	2696

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations.

To investigate the effect of infrastructure quality of different transport modes on imports, gravity regressions with infrastructure quality variables for transport types are estimated by the baseline model of Equation 5 and its relevant variations. The results of quality regressions for imports are presented in Table 28. To begin with Quality Model 1,

as a derivation of extended gravity specification, quality of road infrastructure seems to have a negative impact on import facilitation when individual quality of all modes are considered simultaneously. This is consistent with the gravity regression results for imports which fail to manifest significant evidence for the impact of road infrastructure investment in pushing import growth in Table 26. Road quality appears as a trivial factor in import development, a situation attributable to road transport being non-essential and being used in lower frequency for import transport. As for rail quality, Quality Model 1 exhibits inefficacy of rail quality in import development whereas quality of other modes influence imports positively, when all modes are considered simultaneously. This is a controversial result as the positive effect of rail infrastructure investment on imports has been demonstrated persistently by gravity regression results in Table 26, indicating the predominance of railway transport for import development. A possible interpretation for this result can be the inadequacy of railway connectivity, implying that quality becomes important once after availability of necessary infrastructure is provided. Relatedly, Vickerman et al. (1999) argue that realization of the benefits of transport infrastructure depends on the condition that it can rule out bottlenecks substantially. To progress into a stage of eliminating bottlenecks, a level of infrastructure network is required, then quality turns out to be essential. As far as airport quality is considered, the results show significant contribution in import growth despite the findings for uninfluential airport infrastructure investment on imports by the gravity models in Table 26. This is consistent with the interpretation that after a certain level of infrastructure is established for a transport type, its quality becomes effective in trade generation even the transport type is not a reliable driving force. Regarding port quality, it comes out as an important impetus for imports when all modes are considered, with its large infrastructure stock. When port quality is evaluated alone, it is insignificant conceivably because of high level of modal complementarity for imports. As a complementary infrastructure to transport, results show that ICT has a steering role in import expansion.

Table 28: Gravity Regression Results with Modal Quality for Imports

Variables	Quality Model 1	Quality Model 2	Quality Model 3	Quality Model 4	Quality Model 5	Quality Model 6
Ln(GDPPC i + GDPPC j)	0.686*** (0.221)	0.923*** (0.180)	0.746*** (0.182)	0.971*** (0.166)	0.819*** (0.203)	0.675*** (0.215)
Road Quality i	-1.473* (0.765)	0.0344 (0.0575)				0.594*** (0.102)
Rail Quality i	-0.311 (0.208)		-0.291*** (0.0685)			-0.432*** (0.115)
Airport Quality i	1.591** (0.706)			0.327*** (0.0587)		
Port Quality i	0.646** (0.326)				-0.109 (0.0974)	
ICT i	0.0266*** (0.00865)	0.00978*** (0.00324)	0.0293*** (0.00461)	0.00400* (0.00205)	0.0161*** (0.00498)	0.0160*** (0.00423)
Government Effectiveness i	0.0230 (0.503)	0.390 (0.313)	0.480* (0.263)	0.366 (0.321)	0.415 (0.312)	0.787*** (0.276)
Corruption Control i	-0.0681 (0.288)	0.236** (0.0919)	0.516*** (0.118)	0.00644 (0.0877)	0.274*** (0.0865)	0.337*** (0.113)
Regulatory Quality i	0.356 (0.354)	0.00283 (0.294)	0.618** (0.246)	-0.243 (0.284)	0.237 (0.280)	0.150 (0.261)
Electricity Access j	-0.0209** (0.00909)	-0.0201** (0.00889)	-0.0276*** (0.00902)	-0.0254*** (0.00835)	-0.0183** (0.00880)	- (0.00905)
Transport Value Added j	-0.0745* (0.0433)	-0.0338 (0.0438)	-0.0980*** (0.0342)	-0.0165 (0.0444)	-0.0462 (0.0443)	-0.0756* (0.0400)
LSCI j	-0.444 (0.713)	0.558 (0.663)	-0.147 (0.727)	0.382 (0.681)	0.618 (0.672)	-0.405 (0.643)
Observations	129	157	129	157	157	129
Cluster FE	Yes	Yes	Yes	Yes	Yes	Yes
Wald Test	20720	2437	5101	1503	2446	15344

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations.

4.2.2.2. Further Investigation of Reliability and Validity

All along the analytical process, the consistency of gravity, interaction and quality regressions are observed. As expected with the inclusion of factors representing different dimensions of transport infrastructure, the results are consistent to some extent, in reflection of the development of logistics system in Turkey with fragmented transport

policy implementations. Moreover, the results do not contradict with the main notions of theory of new economic geography and the main premises of the knowledge on wider economic benefits of transport infrastructure. In terms of methodological robustness, partner country fixed effects are added to alleviate possible complications by endogeneity which poses a major issue in gravity models although the stimulation is expected to proceed from transport infrastructure to import development with one-directional causation (Portugal-Perez and Wilson, 2012; Francois and Manchin, 2013). Moreover, the reliability of PPML estimation is assessed with RESET test for the accuracy of functional form. The null hypothesis of ‘correct functional form’ is failed to be rejected at all levels of significance, which validates the use of a multiplicative (nonlinear) functional form for robust results.

CONCLUSION

General Discussion and Theoretical Contribution

For a developing country, a well-established logistics system enables integration and capacity to compete in global supply chains, which is feasible with transport infrastructure investments. Turkey, as a developing country, is located at the crossroads linking East-West along with North-South transport corridors for international freight transportation. Moreover, the country functions as an interconnecting point between Europe, the Middle East, Black Sea, Mediterranean and Central Asia due to its geographic standing. To obtain potential trade benefits from this advantageous position, Turkey has been implementing substantial investments in transport infrastructure for nearly two decades, to increase accessibility and connectivity. In that way, welfare gains are to be received through agglomeration, specialization, factor productivity and overall supply chain efficiency provided by the enhanced logistics system (Banister and Berechman, 2001; Chatman and Noland, 2011). Turkey aims to attain competitive advantage in international trade with declining transport costs and improved opportunities for multimodal and intermodal transport by logistics network extensions. Considering this influential position of transport infrastructure, Turkey has been pursuing a strategic policy in the form of continuous investments for all transportation types since 2003, at the same time developing transport policy instruments in counterpart for a well-established, cost-efficient and reliable logistics system for trade flows (MCT, 2011). According to PSB (2019), Turkey aims to reach economic targets, specifically a GDP level of \$2.14 trillion, \$226.6 billion of exports, \$293.5 billion of imports in 2023. Moreover, in terms of logistics and transportation sector, it is aimed to upgrade the LPI ranking of 47 in 2018 to 25 in 2023. In the path to reach these goals, transport plays a key role, occupying a significant share in infrastructure investment projects in Turkey. Specifically, transport investment receives a share of 30-35% of government budget (Bodur Gümüş, 2018), thus the effect of this investment on trade generation offers an important research area in evaluating the efficacy of such a policy. In this context, this study aims to explore the

relationship between transport infrastructure improvements and trade development in Turkey. The research question of the study is described on the grounds for the measurement of export and import stimulating effects of transport infrastructure investment in Turkey.

As far as the complementarity of transport modes is concerned within the whole logistics system, transport networks are established by connectivity among road, rail, air and maritime transport types. However, research on the broader economic benefits of transport infrastructure has focused predominantly on land transportation, especially on highways and roads (e.g., Ozbay et al., 2007; Fan and Chan-Kang, 2005; Crescenzi and Rodriguez-Pose, 2012), then on railways (e.g., Chen and Haynes, 2017; Liang et al., 2020; Diao, 2018) or on land transport system as a whole with road and rail transport together (e.g., Wang et al., 2020). Simultaneous inclusion of all types of infrastructure in a comprehensive way lacks in scholarly knowledge on the topic, leaving a research gap (Park et al., 2019). This research tendency also prevails in studies for Turkey as Coşar and Demir (2016) take road investment to investigate accessibility benefits to international markets, Kuştepelı et al. (2012) conduct causality analysis between highway infrastructure and exports, Ülengin et al. (2013) evaluate investments in road projects. Thus, the limited line of studies for Turkey has investigated the economic benefits of transport infrastructure by considering road only, discarding other transport types. Moreover, the papers use a narrow time range which might isolate long-run effects by excluding lagged effects identified among the main premises in the content analysis procedure. Also, the geographical scope involves regional analysis for Turkey which might hinder the true relationship as marginal effect of transport diminishes when scale gets smaller (Berechman et al., 2006; Cantos et al., 2005). Hence, this thesis aims to analyze the trade outcomes of Turkey's transport infrastructure investment in road, rail, air and maritime transport types for policy implications involving all modes, in aggregate terms for the whole country to capture the overall magnitude and with a large time horizon to consider lagged effects.

Regarding theoretical foundations, logistics research has outgrown from other disciplines of marketing, management and engineering as a multidisciplinary area in the

last century, thus scarcity in the developed theories in this establishing area has led to a common practice to borrow theories from a wide range of fields such as marketing, economics, sociology, management, political science and engineering (Stock, 1997; Swanson et al., 2017). In this context, theories from several disciplines have been used as a foundation to examine the connection between transport infrastructure and trade development following the focus of this thesis. The theoretical framework has been constructed in Chapter 2, involving broad and specific theories. The broad theories consist of location theory and trade theory. Specific theories are stratified in scope by a hierarchical approach in the order of macro-level decision making, spatial effects and micro-level impacts. After discussing the theories, an a priori theoretical model on the transport infrastructure-trade development nexus is proposed as ‘Transport Network-Oriented Trade Development’, on which main arguments of the literature are tested corresponding to the research question and objectives of this study. The a priori model is revised based on the findings of the quantitative analysis by embracing a qualitative research approach in addition to the main quantitative research orientation of the study, within an abductive reasoning framework. The output of theory-building efforts forms the main theoretical contribution of the study.

In terms of the research design formulation of this thesis, a novel mixed method strategy is identified as ‘sequential transformative research design’, which involves a research approach with theoretical orientation, consisting of two phases, one providing information for the other. Upon the constructs of the extensive theories and generation of the a priori theoretical model, a line of research procedures are identified in the investigation of transport infrastructure-trade relation in Turkey. The rich theoretical background of the topic has enabled building a research strategy involving multiple methods as well as deductive and inductive systems of scientific reasoning to reinforce the insights provided as the findings of this study. Albeit being designed on a quantitative basis, this study employs qualitative methods in the specific phases to address the research objectives in the overall design of the study. After establishing the a priori theoretical model with a qualitative approach, mainly empirical research pile on the economic effects of transport infrastructure is surveyed through a combination of systematic literature

review and inductive content analysis to derive guidance for the quantitative models in the subsequent research phase. The content analysis has provided information on descriptive attributes such as main theme, study type, research approach as well as empirical details for sampling units, geographical coverage, included transport modes and employed analytical methods of the reviewed papers. Gravity model of trade flows as a spatial model framework has been determined as the core analytical method of this study. However, the frequent application of causality analysis in the reviewed papers, has pinpointed that the inclusion of this methodology as a separate initial analysis would enrich the strength of analytical structure of the study. In this regard, short and long-run relationship between trade and transport infrastructure are initially analyzed with ARDL model estimations as a preliminary examination by incorporating only land transport types and ICT infrastructure for the period between 1987-2019 for exports and imports. Then, the core analytical methodology is applied by gravity model estimations for export and import flows to encompass the spatial dimension of the relationship between transport infrastructure and trade.

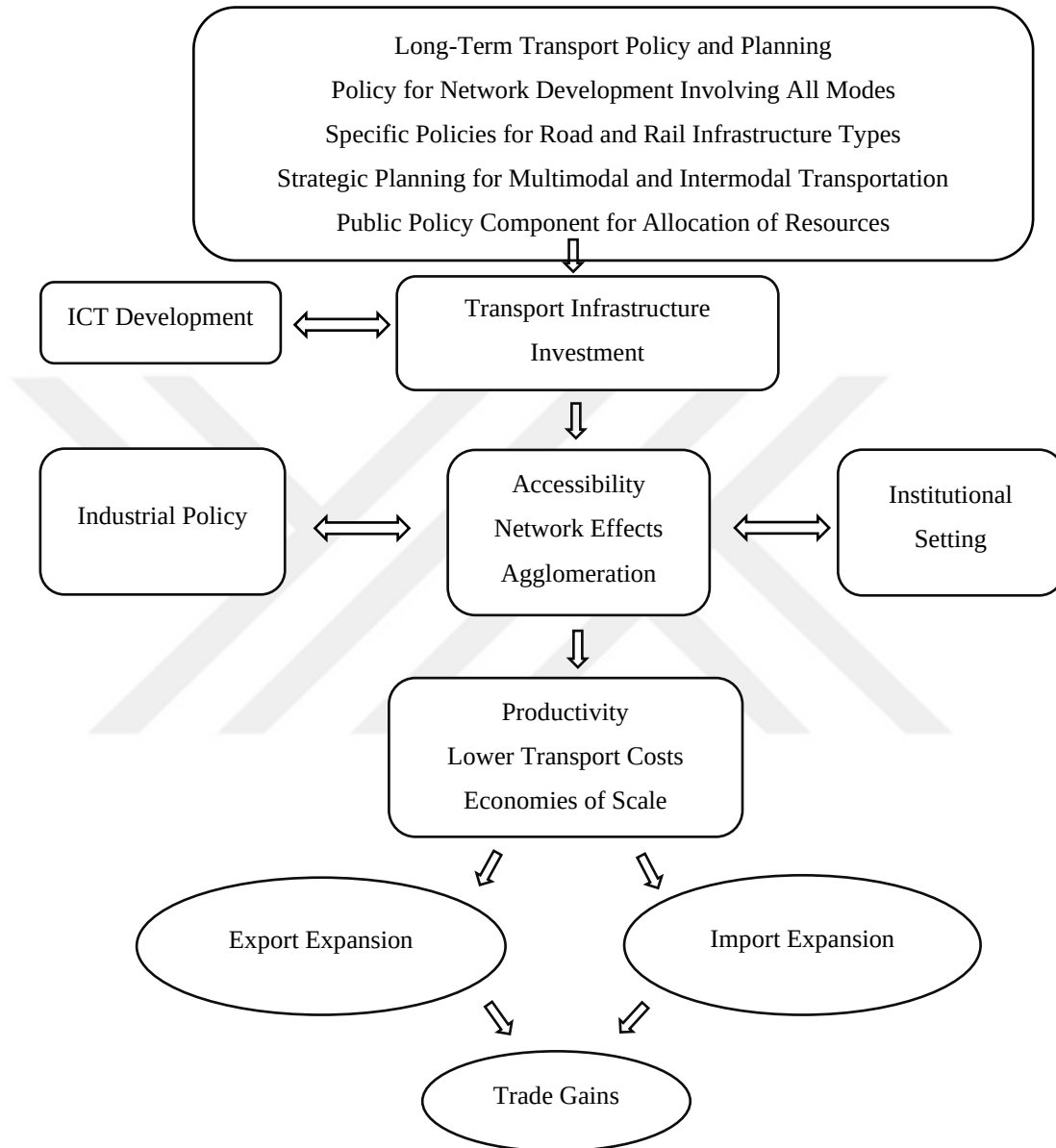
To begin with the initial quantitative model, several procedures are applied in the formulation of ARDL models. Upon presenting brief information on the variables, stationarity tests are carried out as initial analysis. As a next step, two divergent models are specified as the fundamental representations for ARDL approach. Bounds tests are performed to check for the presence of cointegration relationship among the variables with the unrestricted error correction model (ECM). After confirmation of the long-run connection with the results of bounds testing, ARDL regressions are estimated to examine the causality from physical extensions of land transport infrastructure as well as ICT development to trade growth for exports and imports separately. Lastly, reliability and validity of the estimated models are confirmed with conventional diagnostic tests by verifying the robustness of the models.

In terms of the major analytical framework, the methodological procedure for gravity model of trade involves several steps. Regarding the dataset used in the regressions, gravity models are estimated with a panel dataset with the response variables for bilateral trade flows between Turkey and 33 partner countries for exports and between

Turkey and 28 partner countries for imports, spanning the period between 2003 and 2017. Concerning independent variables, a wide range of factors are involved in the models, namely transport infrastructure investment variables for each mode as the main explanatory variables; bilateral trade variables of distance, the sum of GDPPC of Turkey and partner country along with dummies for common border, common language and colonial relationship. Moreover, a factor for ICT development is also added along with control variables for government effectiveness, corruption control and regulatory quality for Turkey; electricity access, transport value added and LSCI for partner countries to obtain robust estimates. To enrich the inferences drawn as well as to strengthen the reliability and validity of the models, the interaction among investments in different transport types and quality level of transport infrastructure for each mode is also considered as the main explanatory factors for exports and imports. In terms of reliability and validity, the variables are rigorously selected among the factors which are drawn from the reviewed papers on the trade-transport relation in the content analysis procedure. In that way, it is aimed to include relevant factors to capture the true nature of the relationship and to avoid omitted variable bias. Methodologically, a recently developed approach, namely PPML, has been employed in the regression procedures as it gives robust and reliable estimates for various forms of stochastic processes, in the presence of heteroscedasticity and for both small and large sample sizes (Santos Silva and Tenreyro, 2006; Egger and Staub, 2016). Finally, the appropriateness of the functional form is evaluated with RESET test which has validated the model specification.

The results show that transport infrastructure is more effective for import expansion than export promotion. The inefficacy of road and rail transport types especially in supporting export growth signal for complications in policy development and implementation in transport infrastructure extensions. Transport infrastructure investment decisions should be given by considering all transport types for the overall network and accessibility prospects, anchored to a long-term transport policy and planning along with public policy.

Figure 30: Transport Network-Oriented Trade Development Policy



Source: Author's Own Construction Based on Lakshmanan (2011), Banister and Berechman, (2001), Meersman and Nazemzadeh (2017).

As outlined in the methodological approach, the a priori theoretical model is revised based on the insights obtained from the quantitative analysis, with an abductive approach. The revised model is presented in Figure 30 in which some transport policy and public policy elements are involved as requirements before transport infrastructure investment. Besides, ICT development is not taken as an external factor but a policy

instrument in connection with transport infrastructure investments. The integration of industrial policy and institutional setting are other aspects added to the model, showing conditions to benefit more from accessibility, network and agglomeration outcomes of transport infrastructure expansion.

Practical Implications

Some practical inferences can be drawn from the results of the gravity models which is the main analytical tool of this study involving spatial characteristics for the economic effects of network expansion of transport types. First of all, the gravity regression results show that road infrastructure investment is not a reliable tool in export promotion when considered alone. However a 1% increase in road infrastructure investment results in a rise of 5.58 US dollars in the aggregate value of exports when all modes are involved, and a rise of 4.77 US dollars when road, rail and port investments are considered together, with unusually large impacts. When pairwise investments are taken into account, a 1% investment in road infrastructure causes a decline between 1.27-1.72 US dollars in total exports. These results can be explained by the network property of transport infrastructure that potential economic effects of additional expansions depend on the total accumulated stock of that infrastructure type (Deng et al., 2014), exhibiting nonlinearity. As Turkey has an established road transport network, further improvements can be a distorting factor for export promotion due to the inefficient allocation of resources for redundant investments. But when there is an overall shift in logistics infrastructure, road investment acts as a catalyzer in export promotion. As for railway investment, a 1% rise would result in a fall between 0.41-3.32 US dollars in export value. Railway infrastructure has been forsaken for a long time and recent developments, especially infrastructure expansions in electrified lines have been undertaken with a focus mainly on passenger transportation, retaining the inadequate network of railway for freight transportation. Further inefficiencies can be encountered in the management of rail lines as well, for instance, some international rail lines are suspended after starting operation, leading to accumulation of idle infrastructure stock. All in all, railway transport has not

been upgraded to a cost-advantageous position for transporting exports. The promising transport types for export promotion come to the forefront as air and maritime transportation. When an additional amount of 1% is invested in air transport infrastructure, value of exports goes up by around 1 US dollar. The return of investing 1% more in maritime infrastructure ranges between 0.73-2.47 US dollars in exports. As a final inference, ICT infrastructure does not function as a complement in export promotion, opposing the outlooks about its supporting role for transport infrastructure in trade growth.

Considering interaction models for exports, complementary and competition relation between modes is observed to a limited extent. The negative sign for road-rail interaction term signals for a substitution effect between these modes. The positive estimates for road and port as well as airport and port suggest complementary relation between road and maritime along with air and maritime transport types. The complementary role of road for maritime transport emphasizes the shortage of railway network development in Turkey where rail connectivity to ports is essential to gain comparative advantage in trade for a country. The interaction regression results support that air and maritime transport types are natural complements to each other with differentiated service and price levels for distinct product types. As far as quality of transport modes are concerned, a 1-unit upgrade of index scale in port quality leads to a surge in 13.76 US dollars when all modes are considered, indicating a large impact. Regarding air transport quality, when it is improved by 1 unit of index scale, exports are expected to increase by 1.16 US dollars when air transport is the only transport mode under examination. Quality regressions corroborate the inefficiency of transport infrastructure developments in fostering exports for land transportation elements, namely road and rail, which coincides with the findings of gravity regressions for exports.

According to the gravity models for imports, road and air transport infrastructures come out as trivial elements for import growth. Nevertheless, rail infrastructure reveals persistently a pivotal role in boosting imports. When amounts allocated to rail infrastructure are increased by 1%, a rise in imports ranging between 0.74-1.96 US dollars takes place. As for maritime infrastructure, when port investment is expanded by 1%, the value of imports goes up by 0.70-1.25 US dollars. For transportation of imported products,

port and rail transport types are prominent factors in line with the common case that ports act as engines for welfare gains (Park et al., 2019) coupled with the complementary support of railways. So, investment in railway infrastructure especially serves as a driver for import rather than export generation. Moreover, ICT has a contributing effect on import growth in contrast to the case of exports.

When interaction among transport types is examined, a high level of complementarity takes place among transport modes. There exists complementary relationship between road and rail, rail and air, road and maritime, rail and maritime, air and maritime infrastructure pairs. The rivalry between road and railway infrastructure for exports turns into a complementary relationship for imports. Road has a substitution relationship with air transport infrastructure, implying rivalry between the modes. This remarkable situation can come from the modal shift for flexible, reliable and speedy transport types to fulfill the requirements of global supply chains (Rodrigue, 2021b). Also, it can be derived that land transport components have a complementary role for air and maritime transportation for imports. In terms of quality effects of transport modes for imports, road and rail quality do not exhibit a well-grounded impact. However, quality improvements in air transport infrastructure by 1 unit of index scale result in a rise in import value between 3.27-15.91 US dollars. Bearing the overall logistics system quality, a 1-unit quality upgrade of index scale in maritime infrastructure pays off with a rise of 6.46 US dollars in value of imports.

Overall, transport infrastructure investment has a triggering effect on imports rather than exports in Turkey. If Turkey aims to benefit from the considerable investments in transport infrastructure for export promotion to achieve export-led growth ultimately, issues about land transport should be addressed carefully. To be more specific, extensions to already well-founded road infrastructure can be made to areas offering high trade potential with an insufficient road network. A systematic investment plan based on pre-evaluations can be followed starting from the projects with the highest potential in trade generation per investment. Moreover, railway connectivity should be accelerated starting from the key ports, then gradually being formed for the rest to provide sound, reliable and well-connected networks for majority of ports. Paying special attention on road and rail

transport particularly for export promotion, investment and transport network decisions should be made by considering all modes simultaneously instead of addressing them separately due to system characteristics of transport networks. Such a policy approach would enhance exports and imports further when coupled with supporting industrial policies to benefit better from accessibility, network effects and agglomeration economies and with establishing the necessary institutional setting to enable persistence of policy implementation, inclusive decision making by consultation to various stakeholders, cooperation with private sector. Besides, ICT infrastructure should be integrated into transportation business to realize its potential in export promotion. This integration would also serve as a driver for import expansion to a higher extent. ICT stands as an essential instrument in offering differentiated transport services such as traceability and visibility and also increasing efficiency by implementation of technology with automated solutions in transport processes and decreasing total transport costs with rising productivity. For import transportation, multimodal and intermodal transportation is used, as inferred from the high level of complementarity among modes, however application of such business practices lacks for exports as suggested by the limited modal interaction. Thus, infrastructure planning should be handled in a way that multimodal and intermodal transportation become a common business practice as a result of long-term efforts to enhance connectivity and integration of modes.

Limitations and Directions for Further Research

This study involves several limitations which also offer new directions for future research. A major limitation of this study lies in the potential endogeneity problem which might be inherent in the structure of gravity model equation built to analyze transport infrastructure and trade relationship within a spatial setting. There is no formal and straightforward way to detect endogeneity in a regression analysis, so measures are taken to capture unobserved effects on exports and imports, namely incorporation of partner country fixed effects and control variables for Turkey as well as for partner countries to minimize possibility of endogeneity. As another limitation which is related to

methodological aspects, although the panel dataset of gravity models is strongly balanced, missing data is dropped out of regression analysis in PPML approach, leading to a loss in number of observations. As a final limitation concerning the implications from quantitative methods, ARDL model and gravity regressions are quite diverse in terms of the set of independent variables, time frame and functional specification (former linear and the latter nonlinear), so the results are separately evaluated.

As a future research direction, mixed methods can be applied with comparable quantitative techniques by using the same variables for the same time-horizon. This study investigates the benefits of transport infrastructure investment on trade promotion in a developing country perspective for Turkey. As a future research idea, the examination can be exercised on a set of developing countries to get insights about country-specific differences for the cultivation of trade benefits of transport infrastructure.

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APPENDICES

APPENDIX 1: List of Cargo Ports

Port Name	Cargo Type/Transportation Method Details	Port Operator	Province
Akçansa Çanakkale Port	Drybulk, General Cargo	Akçansa Çimento Sanayi ve Tic. A.Ş.	Çanakkale
Akçansa Ambarlı Port	Drybulk, General Cargo, Ro-Ro, Chemical, Asphalt	Akçansa Çimento Sanayi ve Tic. A.Ş.	Istanbul
Marmaris Port	Cruise, General Cargo	Marmaris Liman İşletmeleri A.Ş.	Muğla
Diler Port Facility	Drybulk, General Cargo	Diler Demirçelik Endüstri ve Tic. A.Ş.	Kocaeli
Gisaş Tuzla Pier	Drybulk, General Cargo	Gisaş Gemi İnşa Sanayi A.Ş.	Istanbul
Solventaş Port	Fuel, Chemical, Drybulk	Solventaş Teknik Depolama A.Ş.	Kocaeli
Yazıcı Pier	Drybulk, General Cargo, Ro-Ro, Container	Yazıcı Demir Çelik San. ve Tur. Tic. A.Ş.	Hatay
Kroman Port	Drybulk, General Cargo	Kroman Çelik A.Ş.	Kocaeli
Ford Otosan Yeniköy Pier	Ro-Ro, General Cargo, Drybulk	Ford Otomotiv Sanayi A.Ş.	Kocaeli
Aksa Pier	Chemical, Drybulk, General Cargo	Aksa Akrilik Kimya sanayi A.Ş.	Yalova
Aslan Çimento Port	Drybulk, General Cargo	Oyak Çimento Fabrikaları A.Ş.	Kocaeli
Ulusoy Çeşme Port	Cruise, Ro-Ro	Ulusoy Çeşme Liman İşletmesi A.Ş.	Izmir
Tüpraş İzmit Refinery	Fuel, LPG, Chemical, Drybulk, General Cargo	Türkiye Petrol Rafinerileri A.Ş.	Kocaeli
Aygaz Samsun Terminal	LPG	Aygaz A.Ş.	Samsun
Opet Mersin Terminal	Fuel	Opet Petrolcülük A.Ş.	Mersin
Sasa Terminal	Chemical	Sasa Polyester San. A.Ş.	Hatay
Petgaz LPG Pier	LPG	Petgaz A.Ş.	Hatay
Aygaz Dörtyol Terminal	LPG	Aygaz A.Ş.	Hatay
Aygaz Ambarlı Terminal	LPG	Aygaz A.Ş.	Istanbul
Alpet Mersin Pier	Fuel	Altınbaş Petrol ve Ticaret A.Ş.	Mersin
Marport Container Terminal	General Cargo, Drybulk, Container	Marport Liman İşletmeleri Ticaret ve Sanayi A.Ş.	Istanbul
Kumport	Drybulk, General Cargo, Ro-Ro, Container	Kumport Liman Hizmetleri ve Lojistik Sanayi ve Ticaret A.Ş.	Istanbul
Ambarlı Mardaş Pier	Drybulk, General Cargo	Mardaş Marmara Deniz İşletmeciliği A.Ş.	Istanbul
Port Akdeniz	Cruise, Ro-Ro, General Cargo, Drybulk, Container, Asphalt, Chemical	Ortadoğu Antalya Liman İşletmeleri A.Ş.	Antalya
Zeyport	Cruise, General Cargo, Drybulk, Ro-Ro, Ferry	Zeyport Zeytinburnu Liman İşletmeleri San. ve Tic. A.Ş.	Istanbul
Martaş Port	Drybulk, General Cargo, Ro-Ro, Chemical, Container	Martaş Marmara Ereğlisi Liman İşletmeleri A.Ş.	Tekirdağ
Ege Çelik Port	Drybulk, General Cargo	Liman İşletmeleri ve Nakliyecilik Sanayi ve Ticaret A.Ş.	Izmir
Shell Derince Terminal	Fuel, Chemical	The Shell Company of Turkey Ltd.	Kocaeli
Ataş Mersin Terminal	Fuel	Ataş Anadolu Tasfiyehanesi A.Ş.	Mersin
Mks Marmara Port	Chemical	Mks Marmara Entegre Kimya Sanayi A.Ş.	Bursa
Çekisan Antalya Terminal	Fuel	Çekisan Depolama Hizmetleri Ltd. Şti.	Antalya
Shellturcas Antalya Terminal	Fuel	Shell & Turcas Petrol A.Ş.	Antalya
Borusan Port	Drybulk, General Cargo, Container, Ro-Ro	Borusan Lojistik Dağıtım ve Depolama Taşımacılık ve Tic. A.Ş.	Bursa
Gemport	Drybulk, General Cargo, Container, Ro-Ro, Liquified Gas	Gemport Gemlik Liman ve Depolama İşletmeleri A.Ş.	Bursa

Çayırova Cam Sanayi Pier	Drybulk, General Cargo	Çayırova Cam Sanayi A.Ş.	Kocaeli
Batlıman Port	Drybulk, General Cargo	Batlıman Liman İşletmeleri A.Ş.	Izmir
Dikili Liman	Cruise, Drybulk, General Cargo, Ro-Ro, Chemical	Dikili Liman ve Turizm İşletmeleri Ticaret A.Ş.	Izmir
İdç Nemrut Port	Drybulk, General Cargo	İdç Liman İşletmeleri A.Ş.	Izmir
Altıntel Port	Chemical, Fuel	Altıntel Liman ve Terminal İşletmeleri A.Ş.	Kocaeli
Gübretaş Yarımcı Port	Drybulk, Chemical	Gübretaş Gübre Fabrikaları T.A.Ş.	Kocaeli
Ak-Taş Terminal	Chemical	Ak-Taş Dış Ticaret A.Ş.	Kocaeli
İçdaş-1 Port	Drybulk, General Cargo, Container	İçdaş Çelik Enerji Tersane ve Ulaşım Sanayi A.Ş.	Çanakkale
Petline Terminal	Fuel	Petline Petrol Ürünleri Ticaret A.Ş.	Kocaeli
Ünye Port	Drybulk, General Cargo	Ordu Büyükşehir Belediyesi Başkanlığı	Ordu
Çolakoğlu Pier	Drybulk, General Cargo	Çolakoğlu Metalurji A.Ş.	Kocaeli
BP Gemlik Terminal	Fuel, Chemical	BP Petrolleri A.Ş.	Bursa
Koruma Klor Terminal	Drybulk, Chemical, General Cargo	Koruma Klor Alkali Sanayi ve Ticaret A.Ş.	Kocaeli
Güzel Enerji Dolfen Terminal	Fuel	Güzel Enerji Akaryakıt A.Ş.	Kocaeli
Bütangaz Terminal	LPG	Butangaz A.Ş.	Tekirdağ
Evyapport	Drybulk, Chemical, General Cargo, Container, Ro-Ro	Evyap Deniz İşletmeciliği Lojistik ve İnş. A.Ş.	Kocaeli
Poliport	Drybulk, Chemical, General Cargo, Fuel	Poliport Kimya Sanayi ve Ticaret A.Ş.	Kocaeli
Tüpraş Aliğa Terminal	Fuel, Chemical, LPG	Türkiye Petrol Rafinerileri A.Ş.	Izmir
Ege Gübre Terminal	Drybulk, Fuel, Chemical, LNG/LPG, General Cargo	Ege Gübre Sanayi A.Ş.	Izmir
Habaş Nemrut Port	Drybulk, General Cargo	Habaş Sanai ve Tıbbi Gazlar İst. End. A.Ş.	Izmir
Gübretaş Iskenderun Port	Drybulk, General Cargo Chemical, Fuel	Gübretaş Gübre Fabrikaları T.A.Ş.	Hatay
Botaş Ceyhan Terminal	Fuel	Botaş Boru Hatları İle Petrol Taşıma A.Ş.	Adana
Botaş Dörtüol Port	Fuel, LNG	Botaş Boru Hatları İle Petrol Taşıma A.Ş.	Hatay
Botaş LNG Terminal	LNG	Botaş Boru Hatları İle Petrol Taşıma A.Ş.	Tekirdağ
Nuh Çimento Pier	Drybulk, General Cargo	Nuh Çimento Sanayi A.Ş.	Kocaeli
Rota Port	Drybulk, General Cargo	Rota Liman Hizmetleri Sanayi A.Ş.	Kocaeli
Hopa Port	Drybulk, General Cargo, Fuel, LPG, Ro-Ro, Container	Park Denizcilik ve Hopa Liman İşletmeleri A.Ş.	Artvin
Limaş Port	Drybulk, General Cargo, Chemical, Fuel, Koteşner	Limaş Liman İşletmeciliği A.Ş.	Kocaeli
Çelebi Bandırma Port	Cruise, Drybulk, General Cargo, Ro-Ro, Container, Chemical	Çelebi Bandırma Uluslararası Liman İşletmeciliği A. Ş.	Balıkesir
Haydarpaşa Port	Drybulk, General Cargo, Container	TCDD	Istanbul
Alsancak Port	Cruise, Drybulk, General Cargo, Container, Chemical	TCDD	Izmir
Samsunport	Cruise, Drybulk, General Cargo, Fuel, Chemical, Ro-Ro	Samsun Uluslararası Liman İşletmeciliği	Samsun
Safi Derince Port	Drybulk, General Cargo, Container, Ro-Ro, Chemical, Special Purpose Cargo	Safi Derince Uluslararası Liman İşletmeciliği A.Ş.	Kocaeli
Limak Iskenderun Port	Drybulk, General Cargo, Container, Ro-Ro	Limak Iskenderun Uluslararası Liman İşletmeciliği A.Ş.	Hatay
M.I.P. Mersin Port	Drybulk, General Cargo, Container, Ro-Ro, Cruise, Ferry, Fuel, Chemical	Mersin Uluslararası Liman İşletmeciliği A.Ş.	Mersin
Ceyport Tekirdağ Port	Ferry, Cruise, Drybulk, General Cargo, Container, Chemical	Ceyport Tekirdağ Uluslararası Liman İşl. A.Ş.	Tekirdağ
Karabiga Port	Drybulk, General Cargo	Karabiga Belediyesi Başkanlığı	Çanakkale

Sadaş Samsun Terminal	Fuel	Samsun Akaryakıt Depolama A.Ş.	Samsun
İpragaz Terminal	LPG	İpragaz A.Ş.	Hatay
Habaş Pier	LPG, Fuel	Habaş Sınai ve Tıbbi Gazlar İstihsal Endüstrisi A.Ş.	Kocaeli
Petkim Port	Chemical, LPG, General Cargo, Drybulk, Fuel	Petkim Petrokimya Holding A.Ş.	Izmir
Poaş Antalya Terminal	Fuel	Petrol Ofisi A.Ş.	Antalya
Petrol Ofisi	Fuel	Petrol Ofisi A.Ş.	Hatay
İskenderun Terminal	Fuel	Petrol Ofisi A.Ş.	Samsun
Poaş Samsun Terminal	Fuel	Socar Turkey Akaryakıt Depolama A.Ş.	Izmir
Socar Terminal	Fuel	Petrol Ofisi A.Ş.	İstanbul
Poaş Haramidere Terminal	Fuel	Petrol Ofisi A.Ş.	Trabzon
Poaş Trabzon Terminal	Fuel	Petrol Ofisi A.Ş.	Kocaeli
Petrol Ofisi A.Ş.	Fuel	İskenderun Demir ve Çelik A.Ş.	Hatay
Derince Terminal	Drybulk, General Cargo, Fuel, Chemical	Güzel Enerji Akaryakıt A.Ş.	Izmir
İsdemir Port	Fuel, LPG	Trabzon Liman İşletmeciliği A.Ş.	Trabzon
Güzel Enerji Aliağa Terminal	Drybulk, General Cargo, Ro-Ro, Chemical, Container, Fuel, Special Purpose	Rubis Terminal Petrol Ticaret ve Sanayi A.Ş.	Hatay
Trabzon Port	Fuel	Mesbaş-Mersin Serbest Bölge Kurucu ve İşleticisi A.Ş.	Mersin
Rubis Petrol Terminal	Drybulk, General Cargo, Fuel, Chemical, LPG	Bagfaş Bandırma Gübre Fabrikaları A.Ş.	Balıkesir
Mesbaş Pier	Drybulk, General Cargo, Chemical, LPG, Container	Ekmar Denizcilik ve Gemi Acentalığı A.Ş.	Hatay
Bagfaş Bandırma Port	Drybulk, General Cargo	Efesan Demir Sanayi ve Ticaret A.Ş.	Kocaeli
Orhan İkinci Pier	Drybulk, General Cargo, Ro-Ro, Asphalt, Water	Toros Tarım Sanayi ve Ticaret A.Ş.	Adana
Efesanport	Drybulk, General Cargo, Ro-Ro, Fuel, Chemical	İskenderun Enerji Üretim ve Ticaret A.Ş.	Adana
Toros Tarım Ceyhan Terminal	Drybulk	İstanbul Gübre Sanayi A.Ş.	Kocaeli
Sugözü Port	Drybulk, General Cargo, Chemical, LPG	TP Petrol Dağıtım A.Ş. ve İzgin Depolama San. Tic. Ltd. Şti.	Kocaeli
İgşaş Port	Fuel, Chemical	Bartın Belediyesi Başkanlığı	Bartın
TP Petrol İzgin Terminal	Cruise, Drybulk, General Cargo, Fuel	Ordu Büyükşehir Belediyesi Başkanlığı	Ordu
Bartın Port	Drybulk, General Cargo	TDİ A.Ş.	Mersin
Fatsa Port	Cruise, Hızlı-Kargo Gemisi, Drybulk, General Cargo	Giresunport Liman İşletmeciliği A.Ş.	Giresun
TDİ Taşucu Port	Cruise, Drybulk, General Cargo, Chemical, Container	Riport Rize Liman İşletmesi Yatırım A.Ş.	Rize
Giresun Port	Drybulk, General Cargo, Ro-Ro, Cruise, Container	Ayvalık Belediyesi Başkanlığı	Balıkesir
Riport	Cruise, Drybulk, General Cargo, Ro-Ro	TTK Genel Müdürlüğü (TTK Liman ve Demiryolu İşletme Müdürlüğü)	Zonguldak
Ayvalık Port	Drybulk, General Cargo, Ro-Ro, Cruise	Milangaz Lpg Dağıtım Tic. ve San. A.Ş. (Likitgaz Dağıtım ve Endüstri A.Ş.)	Hatay
TTK Zonguldak Port	LPG	Milangaz Lpg Dağıtım Tic. ve San. A.Ş. (Likitgaz Dağıtım ve Endüstri A.Ş.)	Kocaeli
Milangaz Dörtyol Terminal	LPG	Ereğli Demir ve Çelik Fabrikaları T.A.Ş.	Zonguldak
Milangaz Kocaeli Terminal	Drybulk, General Cargo, Fuel, Chemical, Ferry	Balıkesir Büyükşehir Belediye Başkanlığı	Balıkesir
Erdemir Port	Drybulk, General Cargo	Etibakır A.Ş.	Kastamonu
Saraylar Port	Drybulk, General Cargo, Chemical, Ro-Ro, Container	Kdz. Ereğli Belediye Başkanlığı	Zonguldak
İnebolu Port	General Cargo		
Karadeniz Ereğli Bozhane Port			

Enerji Mersin Terminal	Fuel	Enerji Petrol Ürünleri Pazarlama A.Ş.	Mersin
Toros Tarım Samsun Port	Drybulk, General Cargo, Chemical, LNG/LPG	Toros Tarım Sanayi ve Ticaret A.Ş.	Samsun
TMO Tekirdağ Pier	Drybulk	TMO Genel Müdürlüğü Tekirdağ Şube Müdürlüğü	Tekirdağ
DFDS Pendik Port	Ro-Ro	DFDS Denizcilik ve Taşımacılık A.Ş.	İstanbul
Akpet Mersin Terminal	Fuel	Akpet Akaryakıt Dağıtım A.Ş.	Mersin
Çanakkale Kepez Port	Cruise,Ro-Ro, Drybulk, General Cargo, Container, Fuel, Chemical	Çanakkale Liman İşletmesi A.Ş.	Çanakkale
Nergis Mersin Terminal	Fuel	Nergis Petrol Mad. San. ve Tic. Ltd. Şti.	Mersin
Milangaz Samsun Terminal	LPG	Milangaz Lpg Dağıtım Tic. ve San. A.Ş.	Samsun
BTC Terminal	Fuel	Botaş International Ltd.	Adana
Yeşilyurt Port	Drybulk, General Cargo, Container	Yeşilyurt Demir Çelik Endüstrisi ve Liman İşletmeleri Ltd. Şti.	Samsun
Yeniyurt Petrol Terminal	Fuel, LNG	Yeniyurt Petrol Terminal A.Ş.	Hatay
Karadeniz LPG Terminal	LPG	Karadeniz Lpg Depolama ve Deniz Terminali Ticaret A.Ş.	Giresun
Opet Marmara Ereğlisi Terminal	Fuel	Opet Petrolcülük A.Ş.	Tekirdağ
Alpet Terminal	Fuel	Altınbaş Petrol ve Ticaret A.Ş.	Samsun
Yeni Güllük Port	Drybulk, General Cargo	Güllük Mandalya Turizm ve Liman Hiz. A.Ş.	Muğla
Ege Gaz LNG Terminal	LNG	Ege Gaz A.Ş.	İzmir
Alpet Aliağa Terminal	Fuel	Altınbaş Petrol ve Ticaret A.Ş.	İzmir
Opet Giresun Espiye Terminal	Fuel	Opet Petrolcülük A.Ş.	Giresun
Roda Port	Drybulk, General Cargo, Container	Roda Liman Depolama ve Lojistik İşletmeleri A.Ş.	Bursa
Yılport Terminal	Fuel, Chemical, Drybulk, General Cargo, Container	Yılport Container Terminali ve Liman İşletmeleri A.Ş.	Kocaeli
Marmara Terminal	Fuel	Marmara Depoculuk Hizmetleri A.Ş.	Tekirdağ
Autoport	Ro-Ro, General Cargo, Container	Autoport Liman İşletmeleri A.Ş.	Kocaeli
Op-Ay Terminal	Fuel	Opay Akaryakıt Ticaret Ltd. Şti	Kocaeli
Nemport	Drybulk, General Cargo, Container	Nemport Liman İşl. ve Özel Antrepo Nakliye Tic.A.Ş.	İzmir
Argaz LPG Terminal	LPG	Argaz Lpg Dolum ve Tevzii İnş. San. ve Tic. A.Ş.	Tekirdağ
Akpet Samsun Terminal	Fuel, LPG	Akpet Akaryakıt Dağıtım A.Ş.	Samsun
Euroil Terminal	Fuel	Modüler Petrol Sanayi ve Tic. A.Ş.	Mersin
Savka Mersin Terminal	Fuel, Chemical	Savka Plat. ve Boru Hat. İnş. İşl. Nak. Akaryakıt İç ve Dış Tic. A.Ş.	Mersin
MMK Pier	Ro-Ro, Drybulk, General Cargo	MMK Metalurji San. Tic. ve Lim. İşl. A.Ş.	Hatay
Eren Port	General Cargo, Drybulk	Eren Enerji Elektrik Üretim A.Ş.	Zonguldak
Assan Port	Container, Ro-Ro, Drybulk, General Cargo	Assan Liman İşletme A. Ş.	Hatay
Akdeniz Terminal	Fuel	Akdeniz Akaryakıt Depolama Nakliyat ve Tic. Aş.	Antalya
THY Opet Yeşilköy Terminal	Fuel	THY Opet Havacılık Yakıtları A.Ş.	İstanbul
İçdaş-2 Port	Drybulk	İçdaş Çelik Enerji Tersane ve Ulaşım Sanayi A.Ş.	Çanakkale
Aytemiz Trabzon Terminal	Fuel, LPG	Aytemiz Akaryakıt Dağıtım A.Ş.	Trabzon
Tuna Madencilik Terminal	General Cargo, Drybulk	Tuna Madencilik Nakliyat Otomotiv Tic.Ltd.Şti.	Balıkesir
Nemrut Terminal	LPG	Milangaz Lpg Dağıtım Tic. ve Sanayi A.Ş.	İzmir

Sanko Port	General Cargo, Drybulk	Sanko Petrokimya Mam. San. ve Tic. A.Ş.	Adana
Yeşilovacık Port	General Cargo, Drybulk	Yeşilovacık Liman İşletmeleri A.Ş.	Mersin
Asyaport	Container, Drybulk, General Cargo, Ro-Ro	Asyaport Liman A.Ş.	Tekirdağ
ERS Port	General Cargo, Drybulk	ERS İnşaat Müh. Asfalt Beton Taşımacılık San. ve Tic. Ltd. Şti.	Balıkesir
Dp World Yarımca Container Terminal	Container	Dp World Yarımca Liman İşletmeleri A.Ş.	Kocaeli
Cenal Karabiga Pier	General Cargo, Drybulk	Cenal Elektrik Üretim A.Ş.	Çanakkale
TP Ambarlı Terminal	Fuel	TP Petrol Dağıtım A.Ş.	İstanbul
Socar Container Terminal	Container, General Cargo, Drybulk	Socar Aliaga Liman İşletmeciliği A.Ş.	İzmir
Aytemiz Alanya Terminal	Fuel, LPG	Aytemiz Akaryakıt Dağıtım A.Ş.	Antalya
Etki Port	LNG	Etki Liman İşletmeleri Doğalgaz İthalat İhracat ve Ticaret A.Ş.	İzmir
Karasu Port	Cruise, General Cargo, Drybulk, Ro-Ro, Container	İc İctaş Sakarya Karasu Limanı Yatırım ve İşletme A.Ş.	Sakarya
Sinop Port	General Cargo, Drybulk, Cruise, Ro-Ro	Siport Liman İşletmesi A.Ş.	Sinop
ASBAŞ Port	Drybulk, General Cargo, Container	Asbaş Serbest Bölge Kurucusu ve İşleticisi A.Ş.	Antalya
Yalova Ro-Ro Terminal	Ro-Ro	Yalova Ro-Ro Terminali A.Ş.	Yalova
Belde Port	Drybulk, Container	Med Lojistik A.Ş.	Kocaeli
Sönmez Çimento Pier	Drybulk, General Cargo	Sönmez Çimento Yapı ve Madencilik San. Tic. A.Ş.	Adana
Atakaş Port	Drybulk, General Cargo, Container	Atakaş Liman İşletmeciliği ve Tic. A.Ş.	Hatay
Star Refinery Port	Fuel, LPG	Star Rafineri A.Ş.	İzmir
Tosyalı Port	General Cargo, Drybulk	Tosyalı Demir Çelik Sanayi A.Ş.	Hatay
KGM Tavşancıl Port Facility	Asphalt	Karayolları Genel Müdürlüğü	Kocaeli
Kumcular Port	General Cargo, Drybulk, Ro-Ro	S.S. İstanbul Anadolu Yakası Kumcular Üretim ve Pazarlama Kooperatifi	İstanbul
Akkuyu Cargo Terminal	General Cargo, Drybulk	Akkuyu Nükleer A.Ş.	Mersin
Oyak Port	Ro-Ro	Oyak NYK Ro-Ro Liman İşletmeleri A.Ş.	Kocaeli

Source: Author's Own Compilation from DTO (2020), MoTI (2020b), turklim.org and searates.com.

APPENDIX 2: ARDL Model Data Explanation and Sources

Variable	Explanation	Data Sources
LNEXPORTS	Exports of Goods and Services (constant 2010 US\$)	WDI (World Bank)
LNIMPORTS	Imports of Goods and Services (constant 2010 US\$)	WDI (World Bank)
LNROAD	Total Road Length (km)	(TSI) Transportation and Communication Database
LNDIVIDED	Divided Road Length (km)	(TSI) Transportation and Communication Database
LNRAIL	Railway Length (km)	(TSI) Transportation and Communication Database
LNICT	Mobile Cellular Subscriptions (per 100 people)	(TSI) Transportation and Communication Database

APPENDIX 3: Gravity Model Data Explanation and Sources

Variable	Explanation	Data Sources
Exports	Export value of goods, in thousand US dollars.	TSI
Imports	Import value of goods, in thousand US dollars.	TSI
Distance	Bilateral distance between capitals of Turkey and a partner country, measured in km.	CEPII
Common Border	Dummy variable for contiguity between Turkey and a partner country.	CEPII
Common Language	Dummy variable for a common language between Turkey and a partner country (spoken by a minimum of 9% of the population).	CEPII
Colonial Relationship	Dummy variable for a colonial relationship between Turkey and a partner country.	CEPII
GDPPC	GDP per Capita, in current US dollars.	World Bank
Road Investment	Road infrastructure investment, in current Euros.	OECD
Rail Investment	Rail infrastructure investment, in current Euros.	OECD
Airport Investment	Airport infrastructure investment, in current Euros.	OECD
Port Investment	Port infrastructure investment, in current Euros.	OECD
Road Quality	Indicator for road infrastructure quality, ranging between 1 and 7.	GCI (WEF)
Rail Quality	Indicator for rail infrastructure quality, ranging between 1 and 7.	GCI (WEF)
Airport Quality	Indicator for airport infrastructure quality, ranging between 1 and 7.	GCI (WEF)
Port Quality	Indicator for port infrastructure quality, ranging between 1 and 7.	GCI (WEF)
ICT	Percentage of population using the internet.	ITU-D
Government Effectiveness	Indicator of government's ability for quality policy formulation and implementation, ranging between -2.5 and 2.5 from lowest to highest score.	WGI
Corruption Control	Indicator on the degree of abuse of public power to gain private interest, ranging between -2.5 and 2.5 from lowest to highest score.	WGI
Regulatory Quality	Indicator of government's ability for an effective regulatory environment formulation and implementation to reinforce private sector development, ranging between -2.5 and 2.5 from lowest to highest score.	WGI
Liner Shipping Connectivity Index (LSCI)	Index of a country's integration into global markets, measured by benchmarking according to the value of 100 for the highest connected country in the first quarter of 2006.	UNCTAD
Electricity Access	Variable indicating the percentage of population with access to electricity, %.	World Bank
Transport Value Added	Value added by transport sector as a share of GDP.	OECD