BRIDGING GAPS, BUILDING FUTURES: DECIPHERING THE ECONOMIC IMPACTS OF TRANSPORT INFRASTRUCTURE AND ITS INVESTMENT IN A GLOBAL CONTEXT

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DECLARATION

We hereby declare that:

(1) This undergraduate FYP is the end result of our own work and that due acknowledgement has been given in the references to ALL sources of information be they printed, electronic, or personal.

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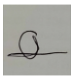
2. LOO CHUN YUAN	21ABB01669	
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ABSTRACT

This study investigates the relationship between transportation infrastructure and economic growth across 48 countries, which included 33 developed countries and 15 developing countries. Transportation infrastructure is separated specifically into different types of transportation, such as road, railway, water, and air transport. Panel data analysis was conducted by employing Full-Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) models to determine which transportation infrastructure influences economic growth within these diverse contexts. In addition, this study also includes current data on transportation infrastructure investment as a key variable for the analysis.

The results show that there is a positive relationship between transportation infrastructure across developed and developing countries. Specifically, different impacts of different transportation modes on economic growth, shedding light on their respective contributions to particular countries' RGDP. Furthermore, this study also reveals the importance of transportation infrastructure investment as a crucial promoter of economic development. This research offers important insight for researchers and policymakers who wish to maximize transportation infrastructure investment to promote sustainable economic growth as it conducted an in-depth analysis that covers both developed and developing countries. The results of this study have strategic consequences for the allocation of resources and strategic planning in the field of transportation infrastructure development. They also provide alternatives for improving economic performance and advancing equitable growth internationally.

Keywords: Transportation infrastructure (road, railway, air, and water), transportation infrastructure investment, RGDP, developing countries, developed countries, panel data analysis, FMOLS, DOLS, economic growth

CHAPTER 1: INTRODUCTION

1.0 Introduction

Chapter One starts with a deliberation of the research background on how economic miracles in Japan, Korea, and China push infrastructure development and the importance of transport infrastructure towards economic growth. The problem statement in this research emphasizes the importance of economic growth by highlighting the drawbacks of its absence like unemployment, poverty, and a reduced standard of living. Problems like whether the overall transportation infrastructure, different transportation infrastructure types, and its transportation infrastructure investment drive economic growth were discussed too.

The research objectives, questions, and hypotheses were designed around the problems stated. The significance of this study involves creating a new insight into the relationship between transport infrastructure (road, railway, water, and air) and transport infrastructure investment on economic growth. The new theoretical framework together with the variables including capital and labor as components of the Cobb-Douglas production function model can create a fresh insight into the results of different countries.

1.1 Research Background

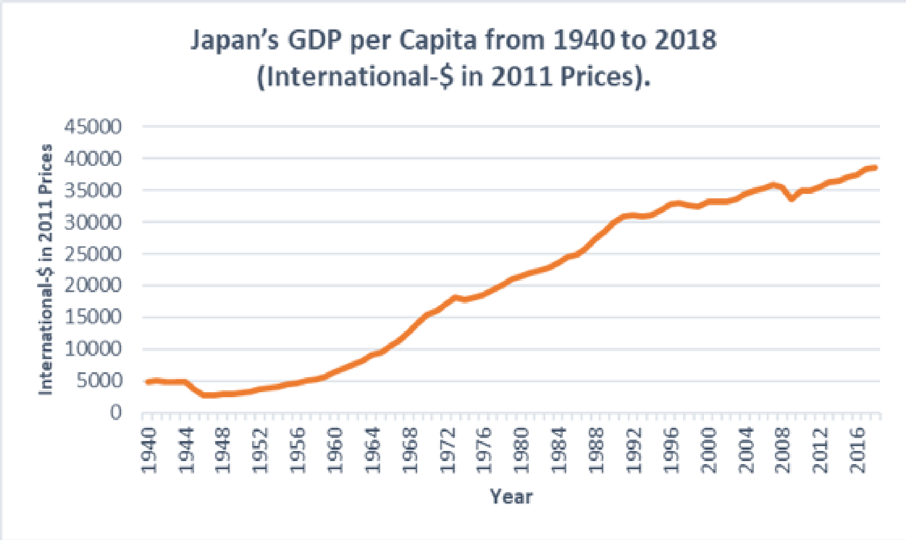
Economic growth is not only the cornerstone of a country's prosperity but also a formidable tool for improving human welfare and combating poverty. It is the basis of economies, propelling job creation, raising income levels, and expanding opportunities for individuals and enterprises (Islam et al., 2003). Every country aims for economic growth because it means a better standard of life for its citizens. However, the current global unstable economy is characterized by a concerning pattern of diminishing economic growth rates in many countries (Mccoll, 2023). To be more specific, the global economic growth rate is expected to decline from 3.1%

in 2020 to 2.1% in 2023 (World Bank Group, 2023). The desire for continuous, optimal economic expansion is still an unchanging goal for nations (Wen & Chen, 2008). This pursuit of high and long-term economic growth is often associated with an aim for an economic boom or miracle, which allows for revolutionary progress and unparalleled breakthroughs in economic development (Rayhan, 2021).

An economic miracle, also known as an economic boom, is a term used to describe an exceptionally fast and dynamic era of economic growth and development in a nation or region. These times are marked by sharp gains in important economic metrics including RGDP, income levels, industrialization, and living standards (Crawford, 2014). This is often seen after World War II when several nations transformed into mega-economic nations (Rayhan, 2021). Like, the Japanese economic miracle, which occurred from post-World War II until the late 1980s, bridged its gap with Western nations (Babones, 2021). Beckley (2018) and Takada (1999) mentioned that Japan's RGDP growth rates exceeded 10% in eight of the twelve years from 1959 to 1970, propelling it to become the world's third-largest economy by 1970. Putting the growths together, Figure 1.1 shows the impact of World War II on Japan's economy, with a RGDP per capita of 2771.37 (International $ in 2011 Prices) in 1946 and has surged impressively over 10 times to 28601 (International $ in 2011 Prices) by 1989.

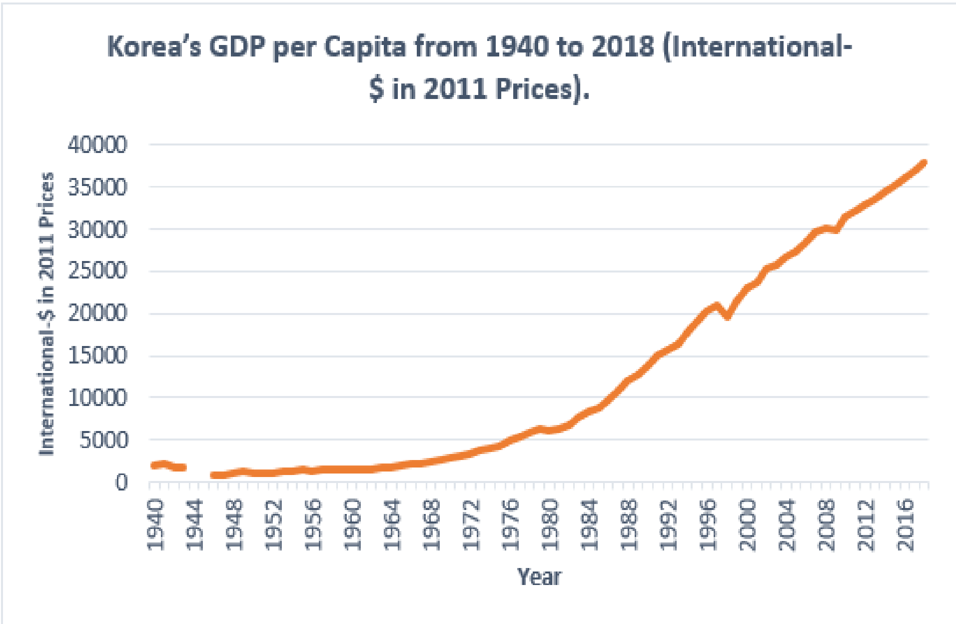
It's not just pure figures nor it was easily attainable, Takada (1999) stated that the cessation of military responsibilities resulted in roughly 4 million job losses and 13.1 million unemployed people with widespread homelessness and starvation. It was the occasion to rebuild destroyed foundations, and access the US market, followed by reform measures, including dissolving zaibatsu corporations, land redistribution, and labor democratization under the US occupation that gave Japan the chance for an economic boom (Valdés, 2003).

Figure 1.1: Japan's GDP per Capita from 1940 to 2018 (2011 International $).



Source: Created using data collected from Bolt and van Zanden (2020) under the measurement unit of International $ in 2011 prices.

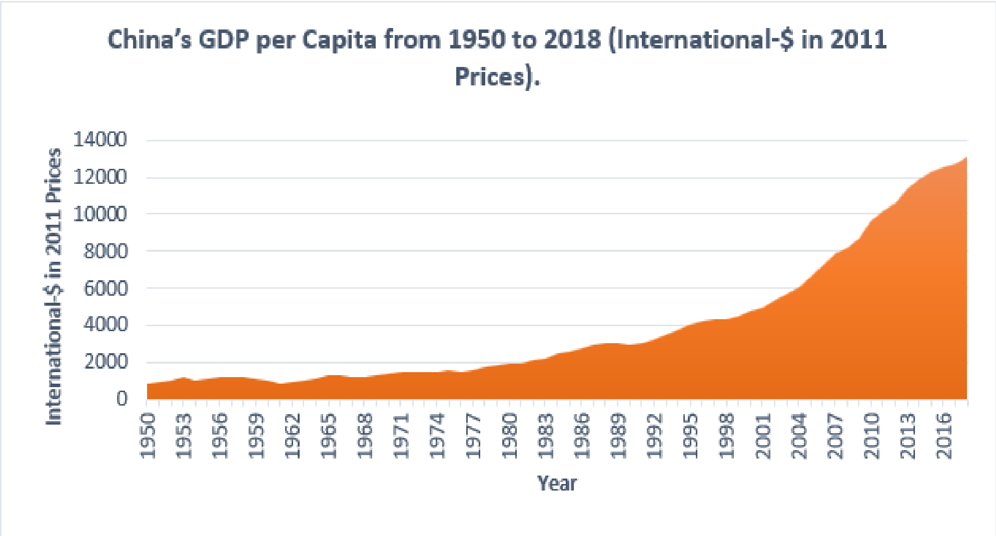
Figure 1.2: Korea's GDP Per Capita from 1940 to 2018 (2011 International $).



Source: Created using data collected from Bolt and van Zanden (2020) under the measurement unit of International $ in 2011 prices.

The key towards South Korea's "Miracle on the Han River" is somewhat similar. The 1961 military coup conducted by Park's government necessitated comprehensive economic reconstruction after the 1953 Korean War (Kim, 2013; Le et al., 2016). Park's regime prioritized planned economic development, transitioning from light to heavy industries, with notable expansions in exports such as ships and electronics by the late 1970s (Koen, 2021; Cetin & Karadas, 2018). Significant investments in education also led to an increase in tertiary enrolment rates from 16% in 1980 to 70% in 2016, aligning with its development goals (Cetin & Karadas, 2018). These led to the notable 14-fold growth in RGDP per capita from 1960 to 1999 (1547.6918 to 21540.693 International $ in 2011 Prices) as shown in Figure 1.2. Importantly, in 1962, the nation's GNP was a mere $2.3 billion (in 1980 constant prices) with a per capita income of $87, largely stemming from the agricultural sectors. The economic boom with a 7.3% average annual growth rate transformed South Korea into one of the distinguished Four Asian Tigers by the early 1990s (Cetin & Karadas, 2018).

Figure 1.3: China's GDP Per Capita from 1950 to 2018 (2011 International $).



Source: Created using data collected from Bolt and van Zanden (2020) under the measurement unit of International $ in 2011 prices.

The same goes for China which has had an economic boom since its reform in the late 1970s, transforming from a planned economy to a worldwide economic powerhouse, with an average real GDP growth rate of 9.82% from 1978 to 2008

(Sachs & Woo, 2003: Whalley & Zhao, 2013). Notably, human capital, driven by reforms in higher education since 1999, contributed to 38% of China's growth in the early 2000s (Lin & Song, 2002). Achievements like increased urbanization have somehow boosted economic productivity too (Babones, 2011). To prove its economic wealth, Figure 1.3 shows that China's RGDP per capita has increased by around 12 times from 1980 to 2010.

The fundamental question revolves around the events that occurred throughout the periods and the tactics used to obtain economic miracles. The answer to this question lies in the adoption of diverse development paradigms, which are a variety of techniques that were critical for their economic development. These paradigms included export-oriented industrialization, government-led initiatives, technological advancements, human capital investments, diversification efforts, strategic foresight, global integration, and adaptive policy frameworks (Hsu, 2015). Notably, Ko (2014) wrote that infrastructure consists of "installations that form the basis for any operation or system." Referring to this statement, does infrastructure development play a role in economic booms?

Hsu (2015) indicated that China's Western Development Strategy launched in 2000 was to target China's widening income gap between rural and urban areas through resource shifts and extensive infrastructure projects, ultimately leading to economic development. Japan on the other hand recognized its social capital gap relative to advanced nations and had strategically utilized public investment through the 1957 New Long-term Economic Plan and the 1960 National Income Doubling Plan (Yoshino & Nakahigashi, 2000; Katzner, 2001). This underscores the significance of social capital in tandem with public investment for robust infrastructure development and subsequent economic growth. Undoubtedly, this unequivocally bolstered Japan's technological progress and dominance through enhanced infrastructure, thereby amplifying the connectivity of people, goods, and energy Yoshino & Nakahigashi, 2000)

The Korean government initiated economic development plans in 1962, facilitating crucial infrastructure projects and attracting international capital through credit guarantees to private enterprises borrowing from foreign investors (Ko, 2014; Kim, 2013). These policies, which included strong private property rights, an emphasis on education, macroeconomic stability, and infrastructure investments, were critical in Korea's democratization and industrialization (Le et al., 2016). Privatization of public enterprises, particularly in the infrastructure and utilities sectors, accelerated private sector restructuring and capital inflows, in line with the 1998 comprehensive privatization policy (Le et al., 2016; Kim, 2013).

These examples, taken together, highlight the critical importance of infrastructure in driving economic booms. The synergy between soft and hard infrastructure is a driving force behind economic expansion (Skorobogatova & Kuzmina-Merlino, 2017). Over the long term, investments in education and healthcare provide the bedrock for advancement (Sahoo et al., 2010), while the presence of ample energy resources underpins sustained development (Apurv, & Uzma, 2020; German & Bustillos, 2014). Effective waste management, while not intricately linked, exerts influence on both public health and ecological equilibrium (German & Bustillos, 2014). While communication stands as a pivotal element, its significance is tempered by the fluidity of technological evolution (Del Bo & Florio, 2008; Sahin et al., 2014). However, transport infrastructure emerges as the cornerstone, providing a direct conduit to trade facilitation, improved market accessibility, and increased appeal to foreign investment, making it the most closely associated component to economic success (Del Bo & Florio, 2008; Sahoo et al., 2010; German & Bustillos, 2014; Sahin et al., 2014).

Expressively, the 2021 Suez Canal blockage, on March 23, underscored the vital role of robust transportation infrastructure. This global pivotal trade pathway connecting the Mediterranean Sea to the Red Sea via Egypt had 19,000 ship transits in 2020 and handled 13.5% of the world's freight (Gao & Lu, 2019). The Ever-Given container ship's entanglement in this trade route disrupted the flow of natural gas, cargo, and oil, halted over 400 vessels, holding up an estimated $15 to $17 billion worth of goods and causing immediate disruptions in global markets, including a $0.40 increase in gas prices (Lee & Wong, 2021). The incident underscored the vulnerability of global supply chains and the economy to transportation bottlenecks, emphasizing the critical necessity for continuous investment in transportation infrastructure and the pivotal role of maritime trade, which accounted for over 80% of international trade in 2015, highlighting the need to enhance transport networks for economic stability (Lee & Wong, 2021).

Another significant example is the COVID-19 pandemic which began in late 2019, resulting in lockdowns, travel restrictions, production closures, and an increase in demand for personal protection equipment and medical supplies (Pujawan & Bah, 2021). Pujawan and Bah (2021) even mentioned that global economies shrank by 4.9% in 2020 as worldwide shipping activity dropped dramatically. According to Ozdemir et al. (2022), supply chain disruptions caused a bullwhip impact in the manufacturing industry. Particularly in food supply systems with product shortages and panic buying (Ozdemir et al., 2022). Supply chains had to identify and tackle recovery challenges, potentially requiring long-term restructuring and the formation of new partnerships due to temporary lockdowns posing threats to firms and their supply chain partners (Paul et al., 2021). Aral et al. (2020) stated that there was a 19.8% year-on-year drop in container traffic from China's top eight ports in February 2020, and U.S. corporations lost between 8.4% and 10.3% of their Chinese suppliers. This global crisis emphasizes the crucial significance of resilient transport infrastructure that can resist and react to unforeseen obstacles to ensure the stability and resilience of supply chains and global trade.

These events have renewed the focus of governments on the importance of transport infrastructure toward economic growth. The expansion of transportation infrastructure has been adopted as a key 2025 target for China to reach its desired economic growth goal (Huld, 2022). Moreover, the introduction of the Belt and Road Initiative by China is to encourage international trade through the assistance of infrastructure development to partner countries, and it is expected to contribute to global economic growth that ranges between 0.7% to 2.9% (Ruta et al., 2019). Besides, the US government have also planned to re-increase the spending on transport infrastructure to better support its domestic economic growth needs (Boushey, 2021). Moreover, Japan has launched a 116 billion USD Quality Infrastructure initiative that targets China's Belt and Road Initiative to boost economic growth through infrastructure development in different countries (Harris, 2019). Meanwhile, the European Commission has planned to invest €6.2 billion into 107 road infrastructure projects to construct a sustainable and efficient transport network for better mobility (Directorate-General for Mobility and Transport, 2023). In addition, the Indian government is a more radical example with a plan to allocate 1.7% of RGDP on transportation infrastructure as a foundation for a US$ 5 trillion economic goal ("India's improved", 2023).

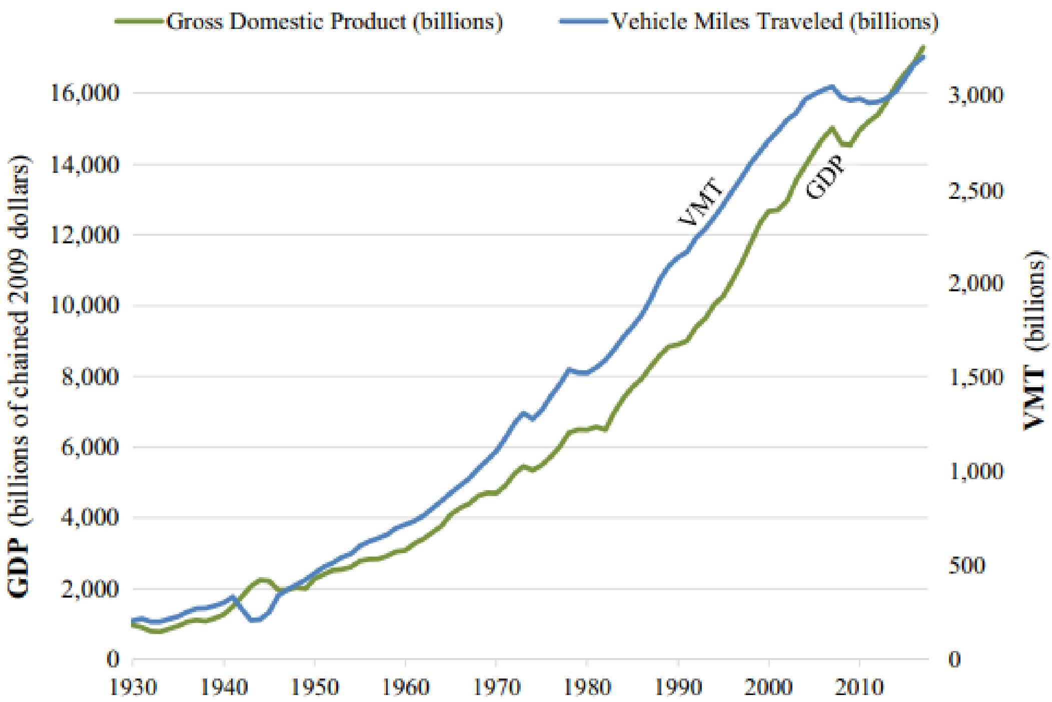
Despite that, there are controversies too, cost and schedule overruns in transportation infrastructure projects that are a global concern due to their economic implications. Research indicates that roughly 30% of road and bridge projects face schedule overruns (Love et al., 2015). For instance, Love et al. (2015) revealed that the Boston Big Dig project's cost escalated from an initial estimate of US$2.6 billion to US$14.6 billion, with a seven-year delay. Despite this, there's limited empirical evidence regarding the microeconomic importance of transport infrastructure (Holl, 2006). Hummels (2007) even revealed the unbalanced current high transport infrastructure costs and relatively low transportation revenue. Not to mention, the trillion-dollar construction industry constituting 5% to 7% of RGDP in most countries, involves intricate, non-standard activities that challenge quality assessment, like corruption (Chen et al., 2020). Numerous stakeholders, including clients, consultants, contractors, and subcontractors, are typically involved (Kenny, 2009). Corruption in construction can have dire consequences, compromising project quality, selection, and maintenance, resulting in diminished economic returns and human costs like injuries and fatalities. Chen et al. (2020) proposed that public corruption negatively impacts road quality. While governments play a crucial role in regulating and procuring construction projects, concerns persist about their capacity to fulfil these roles effectively (Kenny, 2009).

1.2 Problem Statement

Based on the United Nations Economic Commission for Europe, transport is critical as it facilitates people's mobility, the creation and distribution of goods, and economic progress (UNECE, n.d.). The International Transport Forum (2013) also mentioned that transport infrastructure promotes economic development by facilitating private investment, generating new activities, and transforming economic geography, contributing to poverty reduction, human development, and employment generation.

Given its importance, the problem of insufficient transport infrastructure is severe, like traffic issues. The World Health Organization disclosed that around 1.3 million people lost their lives in traffic crashes, and between 20 to 50 million people encounter injuries annually (WHO, 2022). Among the figures, 70% of deaths are from developing countries while 65% of deaths involve pedestrians, which are ultimately due to insufficient and poor transport infrastructure (Kareem, 2003). This highlights the importance of transport infrastructure to attain SDGs 3 and 11, focusing on ensuring healthy lives, reducing road accident fatalities, and providing safe, affordable, accessible, and sustainable transport systems (Deka & Ranganathan, 2023).

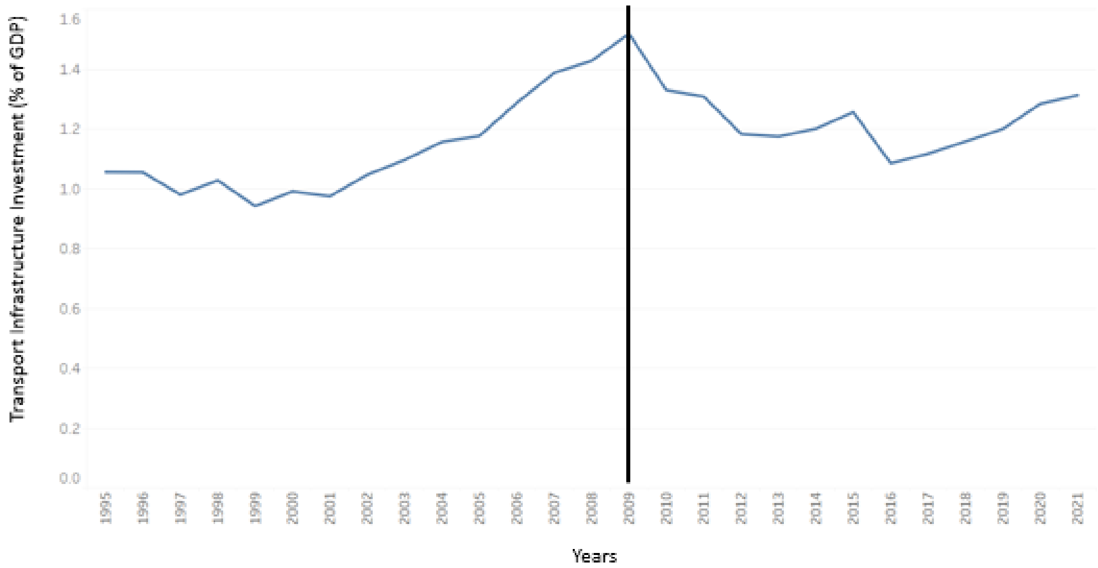
Figure 1.4: US Real GDP and Vehicle Miles Travelled (VMT) from 1929 to 2017.



Source: Marshall & Dumbaugh (2020).

Not only that, but insufficient transport infrastructure also leads to traffic congestion. Supporting Figure 1.4, Marshall and Dumbaugh (2020) indicated that traffic jams will restrict economic opportunities as vehicles travel much lesser. In urban settings, this insufficiency also causes severe traffic jams resulting in both noise and air pollution, ultimately diminishing the quality of life (Pucher et al., 2005). Notably, India's poor transport infrastructure has led to an average of 135 hours stuck in traffic per year, resulting in an accumulated $22 billion in reduced productivity and waste of fuel (Daniel, 2023; Pucher et al., 2005).

Figure 1.5: Average transport infrastructure investment in % of GDP from 1995 to 2021.



Source: Created using data collected from OECD Data (n.d.-b), The Prince of the State (2022), and The World Bank, World Development Indicators (2023b).

Notes: 48 countries included in this chart, which are: Albania, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bulgaria, Canada, China, Croatia, Czechia, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, India, Ireland, Italy, Japan, Korea, Rep., Latvia, Lithuania, Luxembourg, Moldova, Montenegro, Netherlands, New Zealand, North Macedonia, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkiye, Ukraine, United Kingdom, United States, Uzbekistan.

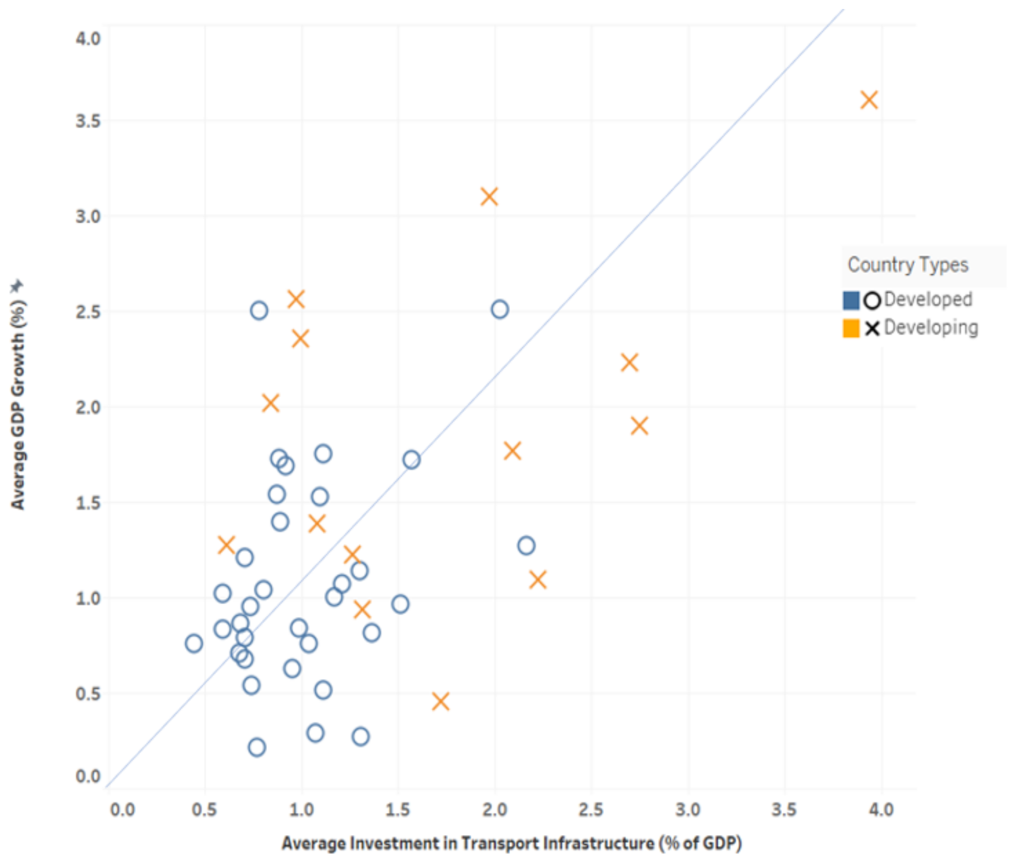
The above statements indicate the importance of transport infrastructure; however, Figure 1.5 indicates an opposing finding in the practical world. The line chart indicates that average investment in transport infrastructure had an increasing trend and reached its peak in 2009. However, a sharp decrease in transport infrastructure investment was shown since then, which is due to the Financial Crisis in 2008. Given the importance of transport infrastructure, although there has been an uprising trend since 2016, average investment has not yet reached its peak in 2009.

To emphasise the issue, the Deputy Managing Director of IMF, Tao Zhang mentioned that since the onset of the 2008 global financial crisis, the growth in public transport investment has been too low for too long and benefitted too few with economic opportunities (Zhang, 2016).

This is highly due to the consensus regarding the need for more investment in transport infrastructure as its relationship towards economic growth is uncertain which can be shown from the steady decrease in transport investment from over 6 per cent of GDP in the late 1960s to an overall not exceeding 1.6 per cent in Figure 1.5. The existence of opposing findings like the positive impact of infrastructure on regional growth in Europe tends to diminish a few years after implementation (Crescenzi & Rodriguez-Pose, 2008; Crescenzi et al., 2016); also, the no immediate impact on motorway investments in the U.S. states creates doubt on the effect of transport infrastructure towards economic growth (Leduc & Wilson, 2012). In particular, given the scarce resources available, too much spending on transport infrastructure can be costly, with critics labelled such as unproductive, often termed as "bridges to nowhere," with limited economic benefits, substantial cost overruns, and inefficient resource use. Not to mention, cost overruns and delays are persistent issues that can turn seemingly viable transport infrastructure projects into "white elephants".

Also, in the context of the Cobb-Douglas production function, which relates economic growth (GDP) to capital (K) and labour (L), it is anticipated that transportation can bolster economic growth by facilitating production (Wang et al., 2020; Agbigbe, 2016). However, there is an ongoing debate on whether capital (K) and labour (L) increments alone can drive GDP growth independently without transportation infrastructure. Thus, the current gap revolves around the need for transport infrastructure and whether it brings economic growth.

<u>Figure 1.6: The scatter plot of 48 countries' average transport infrastructure investment in % of GDP and average GDP growth (%).</u>



Source: Created using data collected from OECD Data (n.d.-b), The Prince of the State (2022), and The World Bank, World Development Indicators (2023b).

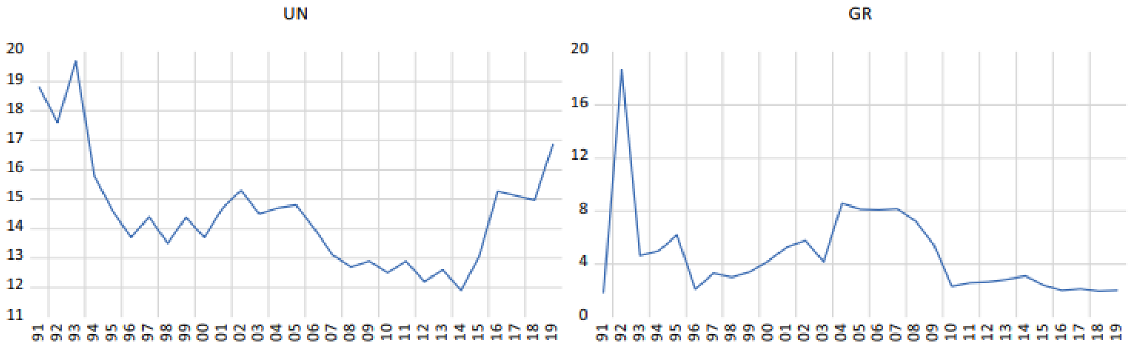
Notes: The calculations are based on data spanning from 1995 to 2021 with 48 countries with the blue line indicating the best-fit-line. The developed countries are Austria, Belgium, Canada, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Rep., Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States, Uzbekistan. Developing countries included are Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Georgia, Moldova, North Macedonia, Russian Federation, Turkiye, China, Montenegro, India, Ukraine, and Serbia.

Moving on, Figure 1.6 shows the relationship between the average transport infrastructure investment and the average RGDP growth of 48 countries. It is observed that most scattered dots are outside the trend line, showing uncertainties towards the effectiveness of transport infrastructure towards economic growth. Adding on, as anticipated, developed countries exhibit lower economic growth compared to developing nations. Interestingly, developed countries also demonstrate a lower overall investment in transport infrastructure. This can be explained by the need and the sufficiency of transport infrastructure according to the development stage of different countries. In particular, the need for infrastructure in developed countries is compelling as the increase in the current sufficiency level might not bring effectiveness towards better economies. On the other hand, public infrastructure investment has been exceptionally strong in Asia's emerging and developing regions, averaging approximately 8% of RGDP since 2008 (Zhang, 2016). Nonetheless, as developed countries did experience the high demand and impact of transport infrastructure development on economic opportunities during their developing stage, the effectiveness of transport infrastructure towards economic growth in developed and developing countries presents a striking research gap.

Back to basics, why economic growth?

Hoshi and Kashyap (2004) proposed that economic stagnation or the absence of economic growth leads to deflation and disarray in the financial system. Ultimately resulting in unemployment as the manufacturing sector is affected when demand falls and costs rise during stagnation. The relatively stable cost of consumption goods during this period may further reduce real wages and further increase unemployment, forming a negative loop. In particular, Hjazeen et al. (2021) stated that economic stagnation in Jordan has hindered job opportunities for university graduates in the labor market. Figure 1.7 shows the high correlation between economic growth and the unemployment rate, in which the unemployment rate will rise when economic growth drops.

Figure 1.7: The unemployment rate (UN) and GDP growth rate (GR) in Jordan from 1991 to 2019.



Source: Hjazeen et al. (2021)

To address the uncertainties stated above, this research aims to understand the relationship between transport infrastructure towards economic growth by using a set of different transport infrastructure types to effectively measure the integration of transportation modes. As the sufficiency and initiatives in transport infrastructure differ according to countries and their economic development stage, 48 countries are chosen based on data availability, containing 33 developed and 15 developing countries. This also aims to provide a clearer understanding of regional differences in outcomes based on varying country settings.

1.3 Research Objectives

1.3.1 General Objectives

The significance of economic growth with the eagerness of every nation to achieve it raises questions about whether transport infrastructure still plays a vital role in driving economic growth, as it did during past economic miracle periods in certain countries. This study aims to understand the relationship between transport infrastructure, transport infrastructure investment and different transport infrastructure types on economic growth. The research employs panel data analysis on 48 countries from 1995 to 2021.

1.3.2 Specific Objectives

To fulfil the general objective, this research will concentrate on 3 key objectives:

1) To study the impact of transport infrastructure on economic growth in developed and developing countries.

2) To study the significance of transport infrastructure investment towards economic growth in developed and developing countries.

3) To study the impact magnitude of different transport infrastructure types towards economic growth in developed and developing countries.

1.4 Research Questions

To offer clarity, the following research questions have been formulated.

1) Is there a significant relationship between transport infrastructure and economic growth in developed and developing countries?
2) Is there a significant relationship between transportation infrastructure investment and economic growth in developed and developing countries?
3) To what extent do different types of transportation infrastructure influence economic growth in developed and developing countries?

1.5 Hypotheses of the Study

H1: There is a significant relationship between transport infrastructure and economic growth in developed and developing countries.

H2: There is a significant relationship between transport infrastructure investment and economic growth in developed and developing countries.

H3: The influence of different types of transportation infrastructure on economic growth varies depending on the different economic development status of countries.

1.6 Significance of Study

To begin with, this study investigates the effect of transport infrastructure and transport infrastructure investment towards economic growth with panel data using 33 developed and 15 developing countries from 1995 to 2021. Furthermore, this research incorporates road, railway, water, and air infrastructure variables to represent transport infrastructure. It also integrates capital and labour as components to align with the Cobb-Douglas production function model. This study employs a new theoretical framework encompassing Cobb-Douglas Production Function, New Economic Geography Theory, Infrastructure-Led Industrialization Theory, and Crowding-In Effect to examine the relationships among the variables. By employing this enhancing framework, researchers may unlock fresh perspectives on the interplay between transport infrastructure and economic growth. Such insights have the potential to inform the design of more targeted interventions aimed at enhancing economic outcomes.

Additionally, this study enhances the understanding of various stakeholders, including economists, investors, and government entities, regarding how transport infrastructure and its investment influence economic growth in both developed and developing countries. This research contributes to policymakers' understanding of the current transport infrastructure level of their countries and the need to carry on investment in this sector. The sufficiency of different types of transport infrastructure and their return on investment may serve as a reference for national budget allocation and transport infrastructure development plans in the 48 selected countries included in this study.

1.7 Chapter Layout

The study is structured into five key sections. Chapter 1 introduces the research, presenting its background, problem statement, objectives, research questions, hypotheses, and significance. In Chapter 2, a comprehensive literature review explores the underlying theories and previous research findings concerning the relationship between corruption and various control variables. Chapter 3 outlines the proposed methodology, detailing aspects like data collection, the study's scope, and research design. Moving on to Chapter 4, the focus shifts to data analysis, encompassing result interpretation and a discussion of the study's major findings. Finally, Chapter 5 encapsulates the study with conclusions, policy implications, insights into limitations, and recommendations for future researchers.

1.8 Conclusion

The multinational issue regarding economic stagnation has led to severe drawbacks like unemployment, poverty, and a reduced standard of living. Following the gaps on the need and effectiveness of transport infrastructure investment and transport infrastructure towards economic growth, this study aims to study whether transport infrastructure influences economic growth. The same goes for investment in transport infrastructure as it shapes a country's development and budget allocation. Specifically, this study examines the influence of various transportation infrastructure types (including roads, railways, air, and water) on economic growth. To address uncertainties related to general assumptions, the analysis focuses on 48 countries which are generally chosen based on data availability. This approach provides a clearer understanding of regional differences in outcomes based on varying geographical contexts.

CHAPTER 2: REVIEW OF LITERATURE

2.0 Introduction

According to multiple scholars, economic growth is a continuous increase in the country's production of goods and services, which is commonly gauged by RGDP. It represents development and prosperity, which result in higher living standards, more employment possibilities, and better services. As a result of improvements in resource allocation, efficiency, and technology, it also includes increased access to healthcare and education. The idea is complicated and has many facets, with different viewpoints taking economic, social, environmental, and cultural considerations into account.

According to past research, the literature on the impact of transport infrastructure and infrastructure investments on economic growth has identified several economic and non-economic cases. Due to its benefits for connections, cost-savings, trade, and productivity, transportation infrastructure is a key factor in economic growth. A well-developed infrastructure not only promotes regional growth, reducing inequities, and generating jobs, but it also draws foreign investment and makes it easier to trade internationally. However, the results of this empirical research are typically inconclusive. It is crucial to take into account the financial difficulties and social and environmental repercussions connected with infrastructure development to ensure long-term sustainability and evenly distributed economic growth.

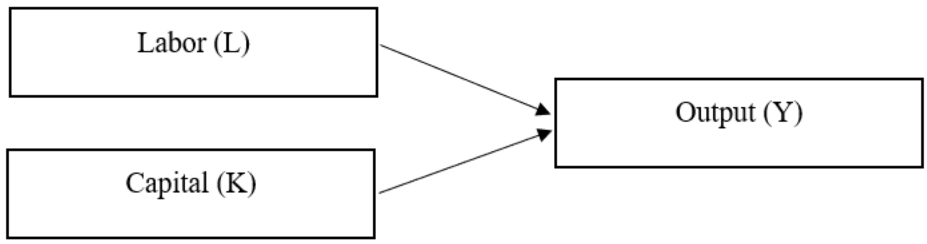
This chapter explores the theoretical framework of this research to create a solid conceptual basis of investigation. Then, it will also conduct an in-depth review of the available literature and provide a detailed analysis of earlier studies and intellectual contributions in the area. The conceptual framework supporting the study will next be developed and explained in section 3, after which the hypotheses that will direct the empirical investigation will be formulated and presented in section 4. This organized strategy will guarantee a methodical and thorough evaluation of the research issue, which helps to significantly advance the body of knowledge in this field.

2.1 Theoretical Framework

The following theories were utilized by previous studies to explain how economic growth is affected by its determinants, which are transport infrastructure and infrastructure investment. The theories we have used in this research are the Cobb-Douglas Production Function, New Economic Geography, Infrastructure-Led Industrialization theory, and Crowding-In Effect theory.

2.1.1 The Cobb-Douglas Production Function

Figure 2.1: The Cobb-Douglas Production Function



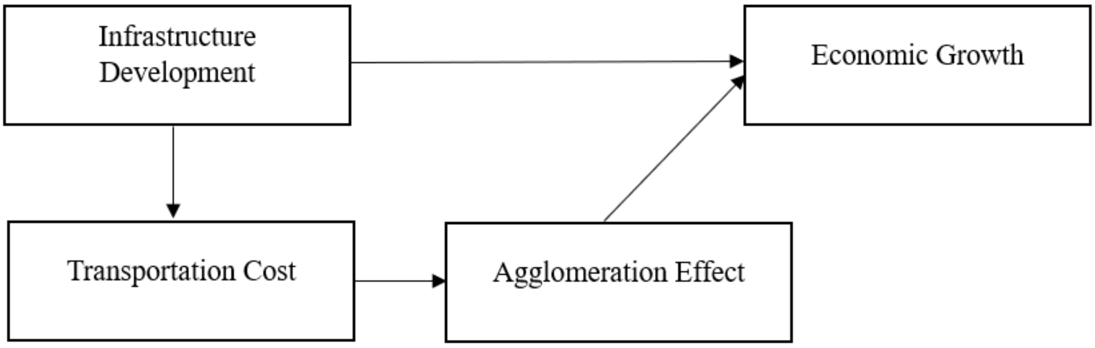
Source: Cobb & Douglas (1928)

The Cobb-Douglas production function is a mathematical model of production that illustrates how labor (L) and capital (K) inputs affect an economy's output (Cobb & Douglas, 1928). There is a formula, $Q = AL^{\alpha}K^{\beta}$, where A is the total factor productivity, α and β are positive constants representing the output elasticities of labor and capital respectively, while L and K represent the quantities of labor and capital inputs (Douglas, 1976). The function, which exhibits consistent returns to scale, is used to examine how changes in labor and capital affect production and growth in the economy (Hassani, 2012). According to Balk (2022), economic expansion can be viewed as the outcome of rising labor and capital inputs as well as technical developments that boost total factor productivity (represented by the constant

"A" in the function) in the context of the Cobb-Douglas function. This theory defines labor and capital as two factors that are essential predictors of an economy's or a firm's production (Hajkova & Hurnik, 2007). However, it's vital to keep in mind that the correlations, in reality, might be more complicated than the Cobb-Douglas function predicts and that externalities, institutions, and other factors may also have a big impact on economic growth (Labini, 1995).

2.1.2 The New Economic Geography Theory

Figure 2.2: New Economic Geography

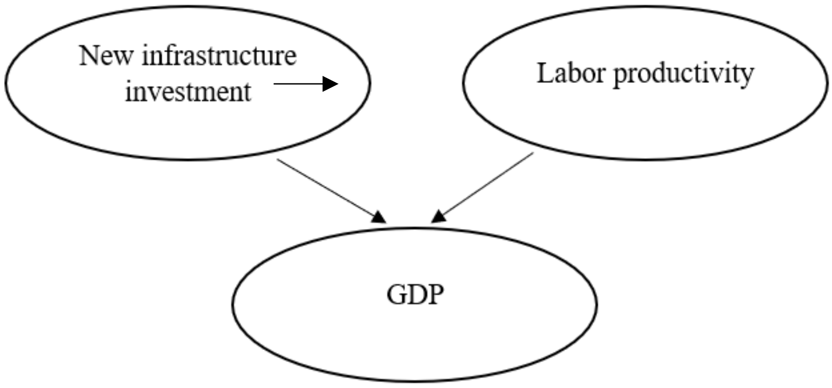


Source: Fujita and Krugman (2003)

This theory explores how infrastructure affects agglomeration dynamics, which in turn affects economic growth patterns (Schmutzler, 1999). Hassink and Gong (2019) pointed out that economic geography is significantly shaped by infrastructure, particularly by transportation networks. Infrastructure fundamentally affects transportation costs, which in turn affects where businesses choose to locate. Due to high transportation costs, businesses may relocate closer to markets to reduce costs. However, as infrastructure advances and transportation costs come down, the narrative changes (Krugman, 2010). Increased connection causes agglomeration effects that encourage businesses to group for a variety of reasons, including supply chain efficiencies, knowledge dissemination, and labor availability (Krugman, 1998). Fujita and Krugman (2003) also stated that regional economies can benefit from their comparative advantages due to effective trade cost reduction provided by modern transportation and communication networks. Thus, regions are then allowed to concentrate on their comparative advantages with this reduction, which promotes economic development (Ottaviano & Puga, 1998). As a result, infrastructure development encourages effective resource allocation and specialization, which serves as a driver for economic growth (Chandra, 2021).

2.1.3 The Infrastructure-Led Industrialization Theory

Figure 2.3: Infrastructure-Led Industrialization

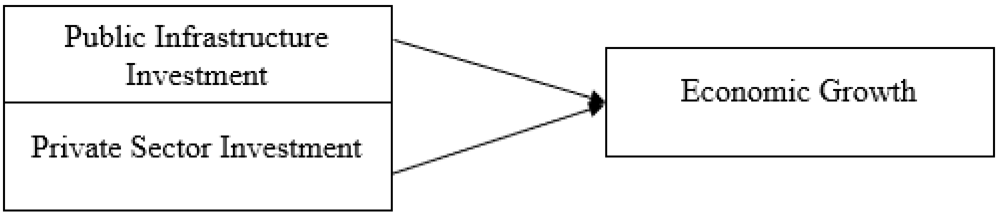


Source: Agénor (2010)

According to the infrastructure-led industrialization theory, encouraging industrial expansion through strategic infrastructure investments is essential for boosting economic growth (Agénor, 2010). Nnyanzi et al. (2022) highlighted the necessity for countries to support infrastructure development as an overall indicator in order to enable the manufacturing sector's contribution to total production and economic development. An environment that is suitable for industrial activity is created by well-developed infrastructure, which includes transportation networks, energy supplies, and communication systems (Schindler & Kanai, 2019). For instance, Yoshino (2008) discovered that sub-Saharan Africa's exports are negatively impacted by the region's weak public infrastructure, as indicated by the average number of days per year that businesses endure power outages. Younis (2014) also states that private investment and public infrastructure investment have a favorable and considerable long-term influence on economic growth. Moreover, Agénor's (2010) study pointed out that public infrastructure could result in significant nonconvex characteristics in the economy's production technology due to the impact of network effects. This phenomenon has significant consequences for the relationship between public investment and economic expansion. However, the national savings rate and the rate of private investment indicate an adverse impact on growth (Ansar et al., 2016).

2.1.4 Crowding-In Effect

Figure 2.4: Crowding-In Effect



Source: Hatano (2010)

Crowding-In Effect is an economic concept that relates to the connection between private sector investment and governmental infrastructure investment, which in turn affects economic growth (Damrich et al., 2022). The interaction between public and private investment's effects on economic growth and sociocultural circumstances have been long discussed and recognized (Hussein and Benhin, 2015). According to Bahal et al. (2018), economic activity is stimulated when governments invest in public infrastructure projects like constructing roads, bridges, or utilities. Investments in public infrastructure may have beneficial externalities or spillover effects that boost competitiveness and productivity while promoting economic growth (Hatano, 2010). As public infrastructure advances, a favorable climate for private-sector investment is created. By lowering operational costs, risks, and uncertainties, the improved infrastructure creates an environment that is conducive to private sector engagement (Matvejevs & Tkacevs, 2023). Yu and Vulov (2021) also stated that a more efficient and competitive economy supports long-term sustainable economic growth through improved infrastructure. In short, the Crowding-In Effect highlights how public infrastructure investment may stimulate private-sector investment and economic growth (Pamba, 2022).

2.2 Review of Literature

According to Acemoglu (2012), economic growth is a steady rise in a country's output of goods and services over time. The growth of a country is commonly measured by using Gross Domestic Product (GDP) which represents the total value of all completed products and services produced within its borders in a specific time period, typically a year or a quarter (Lewis, 2013). Glaeser et al. (1995) view it as a sign of a nation's progress, leading to higher living standards, more jobs, better infrastructure, and improved public services. Rodrik (2012) sees it as an enhancement in the standard of living, encompassing higher incomes and improved access to services like healthcare and education. North (1959) defines it as increased productivity due to resource allocation, efficiency, and technological advances. Urbano et al. (2018) consider it as the steady rise in average income per person, reflecting improved economic prospects. In short, various perspectives on economic growth exist and it is multifaceted.

Li & Li (2022) propose the Solow-Swan model as a fundamental framework for comprehending economic growth, emphasizing capital accumulation, population growth, and technological advancement as primary drivers (Li et al., 1998). Conversely, Howitt (2010) advocates for Endogenous Growth theories, highlighting internal forces' role in fostering growth, particularly through their impact on technological progress, as opposed to external factors (Pack, 1994). Despite some researchers suggesting alternative models, it is essential to emphasize that the Cobb-Douglas production function remains the classic. Notably, the widely used Cobb-

Douglas production function is a cornerstone model in economic research, asserting that labor and capital influence productivity, thus affecting a country's economic growth (Felipe & Adams, 2005).

Numerous studies have explored the critical roles of labor and capital in driving economic growth. Labor, encompassing both workforce quantity and quality, is a vital input in the production process, with research highlighting its positive impact on output, particularly in developing economies, and its connection to human capital development and innovation (Auziņa-Emsiņa, 2014; Durlauf et al., 2001; Barro, 1999; Wijaya et al., 2021). Conversely, the relationship between economic growth and capital investment is equally substantial. Both human and physical capital investments drive innovation, technical progress, and increased production. Solow's neoclassical growth model, as explained by Durlauf et al. (2001), underscores capital's pivotal role in fostering long-term economic growth. Romer's (1990) research highlights capital's contribution to technological advancements that sustain economic growth, and Pelinescu (2015) confirms its importance by demonstrating its positive association with real GDP in panel models.

Therefore, building upon the theories and previous research mentioned above, this study focuses on the externalities of the expansion of transportation infrastructure on economic growth and treats it as a component of production.

2.2.1 Road Transport Infrastructure

Modern travel has significantly improved in convenience thanks to a variety of transportation alternatives as society makes rapid economic progress. Although there are many ways to get about, automobile and rail transportation are still very common (Sun et al., 2018). Ng et al. (2019) indicate that road infrastructure underscores how important it is for enabling effective mobility for people and commodities, which in turn supports economic growth.

Previous research exploring the impact of road transportation infrastructure on economic growth produced a mixed bag of findings. According to Kveiborg and Fosgerau (2007), utilizing larger vehicles, boosting truckloads, and lowering empty loads can all have a positive impact on economic growth. Similarly, Li et al. (2014) highlighted the importance of things like road length, highway passenger turnover, highway quality ratings, and the percentage of cement roadways connecting regional communities for future attention. Their studies emphasized the connection between the rate of economic expansion and the development of road transport infrastructure. Additionally, it was noted that an increase in road length per thousand people would support export growth (Ng et al., 2019). The World Bank's Research Group also found that expanding the availability of high-density roads might draw a larger proportion of users and thereby support economic growth ("How Far Do Roads", 2020). According to The World Bank, a higher road density typically translates into improved connectivity and accessibility, which might lead to higher investment and economic activity by facilitating more efficient movement of people and products ("How Far Do Roads", 2020).

However, despite historical findings indicating more wealthy countries frequently have stronger road networks, supporting a variety of economic activity, recent research has produced conflicting findings (Sun et al., 2018). Recent studies imply that the impact of road transport development on economic growth may not be as large as previously believed. Ng et al. (2019) found that if other socioeconomic factors like education, exports, physical capital, and urbanization aren't taken into account, the favorable impact of road transport expansion on economic growth declines. For instance, Locatelli et al.'s (2017) research revealed that massive road transportation infrastructure projects tend to be expensive and fall short of delivering the benefits they were expected to. Results from static and dynamic panel data regressions conducted by Crescenzi and Rodríguez-Pose (2012) also show that the influence of road infrastructure on economic growth is relatively small. Moreover, Maparu and Mazumder (2017) found that road infrastructure development only affects significantly in the long run but has no impact in the short run due to the high price and limited benefits.

Zhang et al. (2021) and Zhang & Cheng (2023) found that there exist a few huge gaps between road transport and economic growth. Firstly, the proxies for transport infrastructure employed in this study did not include air and water transportation due to the availability of data (Zhang & Cheng, 2023). Secondly, the relationships between these variables are linear in this study due to the application of VECM and cannot identify thresholds. Depending on the degree of infrastructure, the impact of transportation on economic growth may vary in some circumstances. For example, for developing countries with inadequate transportation infrastructure, the marginal contribution may be considerable (Zhang et al., 2021). The last one would be the imbalance of transportation infrastructure development that did not meet the regional economic integration's requirements. This is because different regions have their own strengths and weaknesses (Zhang et al., 2021).

Earlier research looked into the connection between road infrastructure development and economic growth using a variety of statistical methodologies. First of all, researchers like Zhang & Cheng (2023) and Maparu (2017) most frequently employ the Vector Error Correction Model (VECM) to investigate both long-run and short-run effects of road transport development toward economic growth. Next, Sun et al. (2018) employed the Lotka-Volterra model to examine the competitive interactions between highway transport, railroad transport, and the local economy of Xinjiang. In addition, the Spatial Econometric model and Time-Lagged model are used by Zhang et al. (2021) when conducting this study. Last but not least, the Multi-Period Difference-in-Difference (DID) model was also applied by Sui et al. (2022) during research.

In short, the literature on the relationship between road transport infrastructure and economic growth presents inconsistent findings. These disparities are attributed to variations in statistical methods used, including VECM, Lotka-Volterra, and multi-period DID models, as well as differences in geographic regions studied. To address this issue, it is essential to promote regional economic integration through the development of well-balanced transportation infrastructure.

2.2.2 Railway Transport Infrastructure

Wu et al. (2021) stated that transportation infrastructure has a variety of effects on long-term economic growth, and the railway's contribution to economic development has long been debatable. According to Shi (2018), most traditional economists highlight those railways, with their enormous capacity, have a huge economic impact by reducing transportation costs, expanding markets, and promoting the expansion of sectors like coal mining, iron production, and machinery manufacturing.

Previous studies investigating the effect of railway infrastructure on economic growth came up with a mixed bag of results. The construction of railway infrastructure acts as a stimulant to promote economic expansion (Tornabene & Nilsson, 2021). According to Bouraima et al. (2020), The Economic Community of West African States had established an effective and interoperable rail transportation system, and this plan was intended to help promote interconnectivity and boost trade and economic growth in West Africa. Additionally, according to the report done by Dwiatmoko et al. (2020), a 1 billion IDR investment in the railway subsector increases economic output by 1.633767 billion IDR, increases the income of society members by 362.507 million IDR, and generates 9,556 new job possibilities. This demonstrates the need for the government budget (APBN) to be redirected in order to place a priority on the overall growth of railway transportation for both goods and passengers. Dwiatmoko et al. (2020) also highlighted that increased railway density implies expanded capacity and network coverage, facilitating more effective transportation of both passengers and freight. This effectiveness can result in cost reductions for customers as well as businesses, and then foster economic growth.

However, according to Williamson (1965), Fogel (1964) and other researchers diminish the significance of railways, with Fogel demonstrating that their economic impact when compared to water transport, is minimal in terms of GNP growth. This suggests that water transport may take the place of railways and that railways are not necessary for economic expansion. Chen and Haynes (2015) also stated that transit impacts are negligible compared to the impacts from public railways despite considering a positive spillover effect. Furthermore, the study's findings, which covered the years 1977 to 2009, conducted by Kayode et al. (2013) showed that the influence of railway transportation on Nigeria's economic development was minimal. The outcome specifically shows that there is an insignificant relationship between the rise of railway transportation investment and Nigeria's RGDP growth rate. Thus, Crescenzi et al. (2016) concluded that the impact of railway transportation infrastructure on economic growth was unclear, negligible, or even adverse.

Since there are different results found in the relationship between railway transport infrastructure to economic growth, the statistical methods and samples used in the studies are examined.

It is clear that the disparate statistical methods used have influenced the conflicting results about the effect of railway infrastructure on economic growth. First of all, Dynamic Spatial Modeling was used most frequently in the previous studies (Wu et al., 2021; Chen and Haynes, 2015; Wang et al., 2020). Next, the Input-Output Model was applied by Dwiatmoko et al. (2020). Thirdly, the Vector Error Correction Model was used by Pradhan and Bagchi (2013) to find the two-way causal relationship between railway transport and economic expansion.

In summary, the impact of railway transport development on economic growth yields diverse results in the existing research. Some studies have reported no significant connection between railway infrastructure and economic development, while a substantial body of literature suggests a meaningful association. To delve deeper into this, the research introduced a weighted treatment for different types of railways, creating a weighted railway index to better assess the density of railway infrastructure. This approach also calculated the railway density for each province. Consequently, it is recommended that the government allocate a larger portion of the national budget (APBN) towards enhancing rail transportation, encompassing both cargo and passenger services, in order to foster economic growth (Dwiatmoko et al., 2020).

2.2.3 Air Transport Infrastructure

According to Bourguignon and Darpeix (2016), air transport infrastructure is a stimulus for progress as well as the reflection of development. As a catalyst, it promotes domestic and international connectedness by facilitating effective mobility in geographically vast or infrastructure-challenged locations. By linking its size with economic activity and demographic wealth, it simultaneously reflects development (Bugayko & Shevchenko, 2020).

Mixed results were found in the previous studies examining the influence of air transport infrastructure on economic growth. From previous studies, it was found that air transport infrastructure is an important driver of economic growth (Kumar & Patel, 2023). According to Aschauer (1989), with significant output elasticity estimates of 0.24, he demonstrated how the "core" infrastructure fosters economic growth. Based on contemporary endogenous growth theory, Barro (1990) observed that air infrastructure may overestimate the pace of long-term economic growth. Moreover, Lai (2020) stated that air transports are known for their effectiveness in moving heavy loads across countries. The amount of cargo carried by air is a useful indicator of the volume of trade as well as the need for quick delivery of valuable or urgent goods such as consumables, electronics, and medicinal products. Increased air freight volumes indicate heightened commerce activity and strengthen export-oriented industries by broadening corporate access to markets and fostering economic growth. To give play to the function of market scale in determining economic growth performance, Huang and Li (2006) advocated for extending the market scale by further enhancing the air transport infrastructure of provinces and cities in the mainland.

However, some of the studies also identified that air transport infrastructure is not significant in affecting economic growth in both developed and developing countries. Zhang and Graham (2020) found that although there is a contribution by air transport to job creation and the service sector, it only has less causal significance toward the economic growth of a particular country. For instance, research on developed economies shows that while air transportation infrastructure does improve connectivity and accessibility, its direct impact on overall economic growth is still very small (Budd & Ison, 2020). This is illustrated by instances where areas with significant air infrastructure growth do not always experience commensurate increases in economic output. In these situations, the causal significance of air transportation infrastructure appears to be diminished as a result of factors like technical development, education, and institutional frameworks having a more significant impact on economic growth (Zhang & Graham, 2020).

Since there are different results found in the relationship between air transport infrastructure to economic growth, the statistical methods and samples used in the studies are examined.

A number of statistical methods have been conducted in previous studies to examine the relationship between air transport infrastructure and economic growth. First of all, the Error Correction Model (ECM) was employed by Bourguignon & Darpeix (2016) to identify the relationship between these two variables. Next, the Vector Autoregressive Model (VAR) was used by Y. Zhang & Cheng (2023), and the Non-linear Autoregressive Distributed Lag Model (NARDL) was applied by Kumar & Patel (2023).

In summary, the literature on the connection between air transport infrastructure and economic growth presents two opposing outcomes. Most studies affirm a significant relationship, while a minority argue for insignificance. These disparities arise from research gaps, including consideration of sectoral feedback effects, implications of airport expansion and agglomeration, and network spillovers in air transport. These gaps contribute to the divergence in research findings.

2.2.4 Water Transport Infrastructure

One of the core sectors of the blue economy is maritime transport, which promotes tourism, produces the production and use of renewable energy, and offers food and other resources (Frățilă et al., 2021). According to Munim and Schramm (2018), over 80% of trade is carried by the sea today. There is a significant association between trade and RGDP, as seen by the moderate 2.3% expansion in global goods trade volumes in 2014, which followed a 2.5% increase in the global gross domestic product (RGDP) ("Review of Maritime Transport 2015," 2015).

In previous studies, the majority of earlier scholars estimated the impacts of seaport investment infrastructure on economic growth using a production function technique and found that there is a significant correlation between these two variables (Jouili & Allouche, 2016). Additionally, Bottasso et al. (2014) discovered that every 10% increase in port capacity can result in an increase of 6-20% in regional RGDP in Europe. Furthermore, Chang et al. (2014) found that in the South African context, a single unit shortage in port activity might result in a 17% economic loss, while Shan et al. (2014) showed that in China, a 1% increase in port cargo throughput corresponds to a 7.6% gain in RGDP per capita growth. Thus, this indicates that increased bulk commodity production, commerce, and consumption are indicated by higher maritime freight volumes, which support economic growth. Besides, according to Jouili and Allouche (2016), the existence of seaports and waterways infrastructure is crucial to economic expansion. Song and Van Geenhuizen (2014) came to the unique conclusion that seaport investment in

China boosts regional economic growth, although there are clear discrepancies between the regional and provincial effects.

However, some researchers discovered that maritime transportation had a greater influence on economic growth than air and land transportation, which can occasionally have no impact or even negatively harm economic growth, particularly in developing countries (Park et al., 2019). According to Aritua et al. (2021), improved transportation conditions are necessary for economic development, but they may not be enough to spur it on by themselves. In addition, Mudronja et al. (2020) found that investments in road and rail infrastructure tended to generate more significant economic gains than waterway infrastructure development when analyzing transportation modes and their effects on RGDP growth in numerous nations. The result from the study conducted by Fosu and Twumasi (2022) also shows that the effect of waterways transport and government spending on transportation is insignificant in boosting US economic growth.

Since there are different results found in the relationship between railway transport infrastructure to economic growth, the statistical methods and samples used in the studies are examined.

A number of statistical methods have been conducted in previous studies to examine the relationship between water transport infrastructure and economic growth. The panel regression model was most frequently used by researchers like Jiang et al. (2011) and Frățilă et al. (2021) to measure the multi-dimensions of transportation infrastructure and investigate the relationship between water transport infrastructure and regional economic growth. Other than that, Munim and Schramm (2018) give empirical evidence using a structural equation model (SEM) of the key economic effects of port infrastructure quality and logistics performance. Furthermore, Park et al. (2019) employed the panel two-stage least squares approach to parameter estimation for economic growth and supply and demand functions, while Lean et al. (2014) applied a dynamic structural model to estimate accurately the relationship's changes over time.

In short, the literature underscores the intricate link between water transportation infrastructure development and economic growth. While studies generally suggest a positive relationship between seaport investment and economic growth, regional variations exist (Jiang et al., 2011). Case studies from Europe and China highlight the significant economic benefits of expanding port capacity. However, disparities arise as economic growth isn't solely dependent on maritime transportation; roads and railways often yield greater gains. These discrepancies stem from various research methods, including panel regression, structural equation modeling, and dynamic structural models. Hence, further research is essential, considering diverse contexts, approaches, and global economic dynamics.

2.2.5 Transportation Infrastructure Investment

According to Du et al. (2022), one of the main issues for economists has been the contribution of infrastructure investment to economic growth. Numerous studies conducted over the last century have attempted to comprehend the complex interactions between these two elements in light of the fact that infrastructure development can serve as an engine for economic growth (Du et al., 2022). The backbone of contemporary economies is infrastructure, which includes industries like transportation, communication, energy, and technology and allows for effective resource allocation, production, and commerce (Zhang et al., 2021). Thus, investigating the complex relationships between infrastructure investment and economic development becomes essential as nations strive for sustained growth and development.

Mixed results were found in the previous studies examining the influence of transport infrastructure investment on economic growth. From previous studies, it was found that rapid transport infrastructure investment precedes economic expansion (Ibahimov et al., 2023). According to Wylie (1996), the output elasticities are similar to those that Munnell (1992) estimated for the

United States and may even be stronger, indicating that infrastructure may play a more significant role in Canada's economy than it does in the United States. Furthermore, Zhang et al. (2021) also found that different forms of public infrastructure have unique spatial effects on local economic expansion. Notably, with favourable direct and indirect effects, energy infrastructure exhibits the most significant overall effect on economic growth. In short, investment in public investment is strongly associated with economic growth across different state development levels. Somik (1999) emphasized that while regional economic growth depends on public investment, the composition of investments is equally important. Future research should take scale, spatial considerations, model definition, and conceptual links into account for a thorough understanding of infrastructure productivity.

However, some of the studies also identified that transport infrastructure investment is not significant in affecting economic growth. According to Ansar (2016), an in-depth investigation built on a wealth of data disproves the popular belief that infrastructure investment promotes economic value and that China excels in this area. Contrary to expectations, the majority of infrastructure expenditures do not produce positive risk-adjusted returns, which calls into question their function as growth drivers. Furthermore, China's track record of delivering infrastructure is comparable to that of wealthy democracies, refuting assertions of a distinct edge (Ansar, 2016). Moreover, few studies show the insignificant impact of public investment on economic growth in Pakistan, especially in the short run (Younis, 2014). It's because pricey large-scale transportation infrastructure projects frequently fall short of providing the promised benefits in the short term (Zhang & Cheng, 2023).

Since there are different results found in the relationship between transport infrastructure investment to economic growth, the statistical methods and samples used in the studies are examined.

In earlier studies, a variety of statistical techniques were used to investigate the relationship between infrastructure investment and economic growth.

First of all, the Vector Error Correction Model (VECM) is the most commonly used among researchers, such as Zhang & Cheng (2023) and Heintz (2010). Secondly, the Dynamic Multi-Sector Model is applied by Dinlersoz and Fu (2022). In addition, Heintz (2010) also employed the Error Correction Model to discover evidence of an interconnected relationship, demonstrating the existence of a long-run relationship between the productivity of the US private capital stock and the public capital stock in a dynamic formulation of an empirical model that incorporates public infrastructure as a component of production.

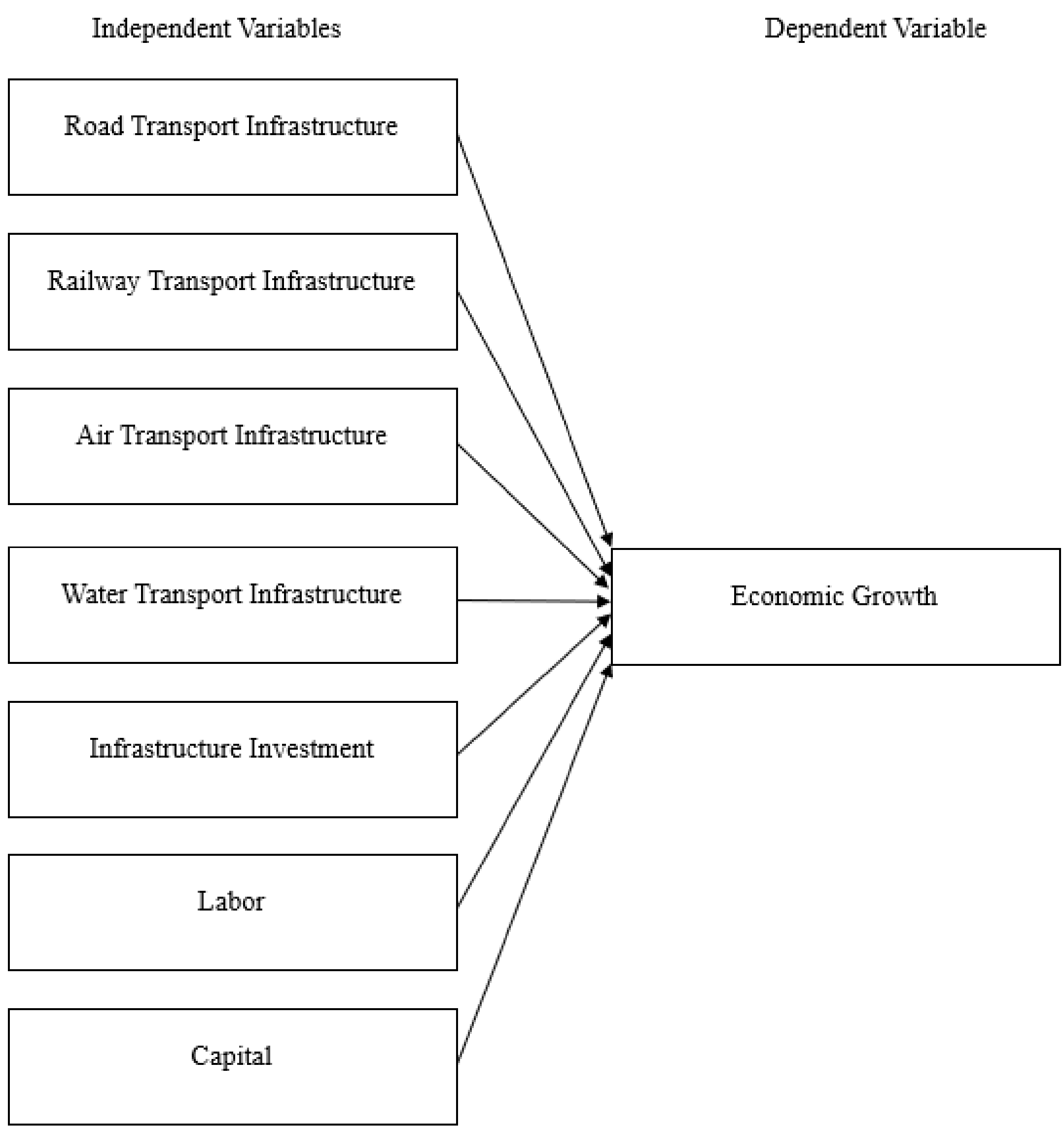
It is evident that the varied statistical techniques employed have contributed to the contradictory findings on the impact of infrastructure investment on economic growth. For example, studies by Munnell (1992), Ibahimov et al. (2023), Heintz (2010), and Zhang et al. (2021) examined the impact of infrastructure investment on economic growth. Nevertheless, Heintz (2010), who employed the Error Correction Model discovered a strong positive relationship between these two variables, however, VECM was utilized by Zhang & Cheng (2023) had found an inadequate connection.

In a nutshell, the literature presents contrasting findings regarding the link between transport infrastructure investment and economic growth. Most studies support a significant relationship, while a minority find insignificance. These disparities are attributed to variations in statistical methods like VECM, Dynamic Multi-Sector Model, and ECM, as well as the diverse range of countries studied, including the UK, Pakistan, the US, Canada, and others. These methodological and geographical differences account for the varying research outcomes.

Overall, this thorough analysis of the literature investigates the complex relationship between transport infrastructure and transport infrastructure investment towards economic growth across a variety of types of transportation, including land, rail, air, and water transport. The review emphasizes that the results produce contradictory findings that are influenced by various statistical techniques and varying geographic situations. Thus, it is crucial to take statistical techniques, geographical differences, and other circumstances into account when determining how transport infrastructure and infrastructure investment affect economic growth.

2.3 Conceptual Framework

Figure 2.5: Conceptual Framework



According to the previous theoretical framework model that was used in the preceding section, we created a conceptual framework to study economic growth.

The impact of transport infrastructure will be determined by the joint effect of the 4 transport infrastructure types, namely road, rail, water and air. Thus, in this conceptual framework, 7 independent variables, which are road transport infrastructure, railway transport infrastructure, air transport infrastructure, water transport infrastructure, infrastructure investment, labor, and capital have been incorporated into the conceptual framework.

These independent variables will greatly influence economic growth, according to the studies mentioned above. The assumptions' validity will therefore be discussed using the conceptual framework. The following part will discuss the hypotheses in light of this framework.

2.4 Hypotheses Development

2.4.1 Transport Infrastructure Towards Economic Growth

According to research conducted by Mohmand et al. (2016), the development and expansion of a country’s economy are positively impacted by transportation infrastructure directly and indirectly. The advantages of transportation infrastructure for trade, productivity, cost-savings, and connections make it a vital component of economic growth. In addition to encouraging regional prosperity, lowering inequality, and creating jobs, a well-developed infrastructure also attracts foreign investment and facilitates cross-border trade (Kauzen et al., 2020). Rodrigue and Notteboom (2024) also underscored that transport infrastructure is important especially true in the current global economy, where economic prospects are closely linked to the movement of people and goods, as well as the use of ICTs. In addition, they support social inclusion, urbanization, and innovation, enhancing living standards and encouraging sustainable development (Zhang & Cheng, 2023). Thus, the first hypothesis development for this study is:

H1: There is a significant relationship between transportation infrastructure and economic growth.

2.4.2 Transport Infrastructure Investment Towards Economic Growth

Drawing on the theory of infrastructure-led industrialization and the crowding-in theory, earlier research underscores the precedence of swift infrastructure investment in driving economic expansion (Ibahimov et al., 2023). Wylie (1996) suggests that output elasticities resembling those estimated by Munnell (1992) for the United States, and potentially even stronger, imply a heightened role of infrastructure in Canada's economy compared to the United States. Moreover, Zhang et al. (2021) reveal distinct spatial impacts of various public infrastructure types on local economic growth, with energy infrastructure notably displaying the most substantial overall effect due to favorable direct and indirect consequences. In essence, public investment exhibits a robust association with economic growth across varying levels of state development. Somik (1999) stresses the significance of both the level and composition of public investments for regional economic expansion. To comprehensively grasp infrastructure productivity, forthcoming research should consider factors such as scale, spatial dynamics, model definitions, and conceptual linkages. Thus, the second hypothesis development for this study is:

H2: There is a significant relationship between transport infrastructure investment and economic growth.

2.4.3 Different Magnitudes of Transport Infrastructure Types Towards Economic Growth

Proceeding the hypothesis of study, hypothesis 3 stated that the influence of different types of transportation infrastructure on economic growth varies depending on their economic development stage. Thus, further subhypotheses are developed based on different types of transport infrastructure, which are, road, railway, water and air transport infrastructure.

2.4.3.1 Road Transport Infrastructure Towards Economic Growth

It has been demonstrated by Ng et al. (2019) and Li et al. (2014) that road transport infrastructure development and economic growth are positively correlated. According to Kveiborg and Fosgerau (2007), utilizing larger vehicles, boosting truckloads, and lowering empty loads can all have a positive impact on economic growth. Similarly, Li et al. (2014) highlighted the importance of things like road length, highway passenger turnover, highway quality ratings, and the percentage of cement roadways connecting regional communities for future attention. Additionally, it was noted that an increase in road length per thousand people would support export growth (Ng et al., 2019). These studies recommend linking the development of road transport infrastructure with socioeconomic and urban growth policies to promote sustainable economic growth. According to Schmutzler (1999), the New Economic Geography theory investigates how infrastructure influences agglomeration dynamics and economic trends. Thus, the third hypothesis development for this study is:

H3: There is a significant relationship between road transport infrastructure and economic growth.

2.4.3.2 Railway Transport Infrastructure Towards Economic Growth

Railway transport infrastructure has a positive significant relationship with economic growth. It has been demonstrated that the construction of railway lines promotes economic growth (Tornabene & Nilsson, 2021). In order to improve interconnectivity and trade in the region, Bouraima et al. (2020) highlight the Economic Community of West African States' attempts to build a productive rail network. According to Dwiatmoko et al. (2020), a 1 billion

IDR investment in railways generates significant economic benefits, such as higher output, individual income, and job prospects. This emphasizes the value of giving railroad expansion financial priority in the government. According to Wu et al. (2021), investments in railways promote sustainable economic development both directly through multipliers and indirectly through the attraction of private tourism, which boosts economic growth. Dwiatmoko et al. (2020) also highlighted that increased railway density implies expanded capacity and network coverage, facilitating more effective transportation of both passengers and freight. Thus, the fourth hypothesis development for this study is:

H4: There is a significant relationship between railway transport infrastructure and economic growth.

2.4.3.3 Air Transport Infrastructure Towards Economic Growth

According to earlier research, the infrastructure of air transportation has a significant role in the expansion of the economy (Kumar & Patel, 2023). Aschauer (1989) proved how the "core" infrastructure promotes economic growth, with strong output elasticity estimates of 0.24. Barro (1990) observed that air infrastructure may overestimate the rate of long-term economic growth based on current endogenous growth theory. For instance, some Chinese research articles focus on how the nation's transportation infrastructure affects economic development (Lai, 2020). Huang and Li (2006) argued for expanding the market size by further improving the air transportation infrastructure of provinces and cities on the mainland in order to give play to the role of market scale in influencing economic growth performance. In short, according to research by Wang and Wang from 2007, air infrastructure is essential for economic growth. Thus, the fifth hypothesis development for this study is:

H5: There is a significant relationship between air transport infrastructure toward economic growth.

2.4.3.4 Water Transport Infrastructure Towards Economic Growth

Earlier research predominantly employed production function techniques to evaluate the impact of seaport infrastructure investment on economic growth, consistently finding a significant positive correlation between these factors (Jouili & Allouche, 2016). Bottasso et al. (2014) revealed that a 10% increase in port capacity can lead to a 6-20% rise in regional RGDP across Europe. In the South African context, Chang et al. (2014) demonstrated that even a minor port activity shortage could result in a substantial 17% economic loss. Meanwhile, in China, Shan et al. (2014) identified a noteworthy linkage, where a 1% increase in port cargo throughput corresponds to a robust 7.6% increase in RGDP per capita growth. While Song and Van Geenhuizen (2014) reported that seaport investments fostered regional economic growth in China, disparities between regional and provincial effects were evident. Jouili and Allouche (2016) underline the critical role of seaports and waterways infrastructure in facilitating economic expansion. Thus, the sixth hypothesis development for this study is:

H6: There is a significant relationship between water transport infrastructure toward economic growth.

2.5 Conclusion

Chapter 2 explores the fundamentals of this study, providing a thorough examination of both the theoretical and empirical layers. To give readers an understanding of the various theoretical frames through which researchers have viewed the complex relationship between infrastructure and economic growth, this chapter starts by illuminating the theoretical framework that has guided past inquiries in this field. Building on this theoretical framework, the chapter next reviews the literature on the relevant independent variables, such as infrastructure investment, labor, capital, and the transportation types that are relevant (road, rail, air, and water). This critical review summarizes prior research, demonstrating the complexity of these factors and their diverse effects on economic growth in various circumstances. It also points out research gaps related to methodological differences and the different stages of economic development in different nations. These gaps highlight the necessity for complex studies that take many settings into account. Moreover, this chapter also developed a conceptual framework, which clarifies the research questions and hypotheses that will direct the empirical investigation. It acts as a strong and thorough foundation, drawing on the wealth of literature to guide the analytical framework and research goals, ultimately leading to a better understanding of the complex relationships between infrastructure and economic growth.

CHAPTER 3: RESEARCH METHODOLOGY

3.0 Introduction

This chapter aims to propose a model to evaluate the relationship between transport infrastructure and economic growth that fits into the research topic. This methodology is designed to create a feasible model to analyze the data to generate results for this research. Panel data with selected variables and countries containing sufficient data are adapted in this study to examine the relationship between variables. An empirical model will be derived from the Cobb-Douglas production function and extended with variables with the support of the theoretical framework reviewed in Chapter 2. Dynamic Ordinary Least Square (DOLS) and Fully Modified Ordinary Least Square estimation models will be employed to quantify the relationship between the dependent variable of economic growth and the independent variable of transport infrastructure and infrastructure investment.

3.1 Data processing

Step 1: Review current journals on the relevant topic to develop an understanding of the topic and select variables to be discovered.

Step 2: Collect data from reliable sources such as World Bank Data, UNECE Transport Division Database, OECD Data, and government websites.

Step 3: Compute panel data by arranging different data sources into an Excel table following year and country.

Step 4: Run the data in EViews to analyse the relationship between variables.

Step 5: Interpret the result generated by EViews.

3.2 Theoretical Model

This paper aims to evaluate the relationship between economic growth and independent variables of types of transport infrastructure and transportation infrastructure investment. Cobb-Douglas is adapted as a basic model in this paper. Cobb-Douglas's function is to measure economic growth by examining the production in a country. It can measure the production elasticity and the economic return of infrastructure can be included in it as a production function (Charlot & Schmitt, 1999). Transport infrastructure is debated to be an important production factor that parallels together with Labour and capital (Elburz & Cubukcu, 2020).

The basic framework of the Cobb-Douglas production function studies the relationship variable of Labour (L) and Capital (K) and an output of real gross domestic production (Y) (Kayode et al., 2013). To compute a model that meets the research objective we have extended the New-classical growth model by including variables of Transport Infrastructure of Various types (T) and transport infrastructure investment (INV) as a new production function. The framework of Equation (1) adopted the research of Bosede et al. (2013), Sahoo et al. (2010), and Rietveld and Nijkamp (1992).

$$Y = f(K, L, T, INV) \qquad (1)$$

Equation (2) of the extended Cobb-Douglas production function could be drawn as below:

$$Y_{it} = AK_{it}{}^{\alpha} L_{it}{}^{\gamma} T_{it}{}^{\delta} INV_{it}{}^{\tau} \varepsilon_{it} \qquad (2)$$

Where K, L, T, and INV illustrate the economic output, capital, labor, and transport infrastructure investment respectively, while A, α, γ, δ and τ denote constant and ε is the error term. The application of i denotes time and t denotes country categories. The A denotes other factors like technology that affect the production output to be constant and irrelevant to the time effect (Saidi, 2018). By having his constant term, the relationship between variables can be better captured (Cantos et al., 2005). This gives a direct indication of the effect of variables towards economic growth with the appearance of decreasing or constant return to scale (Barro, 1990). Moreover, the Cobb-Douglas production function can capture the relationship between variables efficiently in a steady state (Cockburn et al., 2013). An extended Cobb-Douglas production function can capture other variables into the model under assumptions of constant return to scale across independent variables (Kayode et al., 2013). According to Martins et al. (2012), the simple linearized of the extended Cobb-Douglas production function with the application of logarithm has made it an effective model in predicting the relationship of economic growth with different production variables.

3.3 Empirical Model

The empirical model refers to the development of a statistical model based on real-world data observation and theoretical assumptions. An empirical model can help to better observe the relationship between transport infrastructure and economic growth by providing statistical support (Mohmand et al., 2016). The model in this research will review the relationship between transportation infrastructure and economic growth in a variety of countries.

According to Gherghina et al. (2018), countries have different focuses on the development of transport infrastructure types, separating the type of transport infrastructure can better capture the economic contribution of respective transport infrastructure. Moreover, different types of transport infrastructure will have a strong relationship with different sub-industries which leads to a different effect on economic growth (Alam et al., 2021). To better capture the contribution of different types of transport infrastructure affect under the variable of transport infrastructure (T) we split into 4 variables based on the types of transport infrastructure which are Rail Transport Infrastructure (Rail), Road Transport Infrastructure (Road), Air Transport Infrastructure (Air) and Water Transport Infrastructure (Water) in Equation (3).

$$Y = f(K, L, Road, Rail, Air, Water, INV) \qquad (3)$$

Equation (4) drawn below is the extended Cobb-Douglas production with all the variables included multiplicatively. The expression of Cobb-Douglas adapted from the research of (Alam et al., 2021), Boopen (2006), Elburz and Cubukcu (2020).

$$Y_{it} = A_{it}K_{it}^{\beta_1}L_{it}^{\beta_2}Road_{it}^{\beta_3}Rail_{it}^{\beta_4}Air_{it}^{\beta_5}Water_{it}^{\beta_6}INV_{it}^{\beta_7}\varepsilon_{it} \quad (4)$$

3.4 Model Specification

Real Gross Domestic Production = f (Labour, Capital, Road Transportation Infrastructure, Rail Transportation Infrastructure, Air Transportation Infrastructure, Water Transportation Infrastructure, Inland Transportation Investment)

To examine the relationship of the variable with the dependent variable, the model is expressed in natural logarithm terms as illustrated below. According to Pradhan & Bagchi (2013), the combination of different types of transport infrastructure is statistically feasible, and by including all variables logarithmically the proliferative effect over time can be captured. Besides, analysis with natural logarithm of variables can examine the relationship between different types of transport infrastructure (Njoh, 2009). Moreover, the error term is entered in the model multiplicatively, to make equation (5) feasible.

$$RGDP_{it} = A + \beta_1 LnL_{it} + \beta_2 LnK_{it} + \beta_4 LnRoad_{it} + \beta_3 LnRail_{it} + \beta_5 LnAir_{it} + \beta_6 LnWater_{it} + \beta_7 LnINV_{it} + \varepsilon_{it} \quad (5)$$

Whereby,

$RGDP_{it}$ = Real Gross Domestic Production for country category i at time t

L_{it} = Labour for country category i at time t

K_{it} = Capital for country category i at time t

$Road_{it}$ = Road Transport Infrastructure for country category i at time t

$Rail_{it}$ = Rail Transport Infrastructure for country category i at time t

Air_{it} = Air Transport Infrastructure for country category i at time t
$Water_{it}$ = Water Transport Infrastructure for country category i at time t
INV_{it} = Inland Transportation Investment for country category i at time t
i = All Sample Countries, Developed Countries, Developing Countries
t = 1, 2, 3, 4, …, 27 (1995- 2021)
ε_{it} = Error Term

3.5 Data Collecting

This research focuses on evaluating the significance of transportation infrastructure and its investment towards economic development. To better understand the role of transportation infrastructure toward economic growth among various countries, a panel of selected countries with a period from 1995 to 2021 is chosen for this research. Cobb Douglas's Production function is the basic model for this study. In Cobb Douglas production, GDP and capital are measured using constant prices from a benchmark year, while L can be measured with available labour supply for a given year (Luo et al., 2010). Data from the World Bank and Penn World are popularly used as variable measurements for the Cobb-Douglas production function (Ng et al., 2019). This study utilized data from the World Bank as the variable measurement for the Cobb Douglas Production function, aligning with the study by Saidi et al. (2018) and Kabaklarlı et al. (2018). World Bank data is chosen for this study as its data is more up-to-date (until 2021) as compared to Penn World data which is limited to 2019.

The variable measurement data for Transport Infrastructure and Transport Infrastructure Investment are gathered from secondary sources, including The World Bank, OECD Statistics, and the UNECE Transport Division Database. Moreover, data from respective country websites such as the National Bureau of Statistics of China and the Japan Ministry of Land, Infrastructure, Transport and Tourism are used as complementary sources to complete the panel data. By including more countries, this study can obtain an accurate result by having a sufficient sample size. Additionally, as most countries do not have a complete yearly record of all the variables chosen, unbalanced panel data from 1995 to 2021 is applied. This allows us to better control the omitted variables and intra-country differences to reduce biases in the analysis (Hsiao, 2007).

3.6 Data Description

Table 3.1: Variable Measurement

Variables	Indicator Name	Variable Description	Source
Real Gross Domestic Production	RGDP	The sum of gross value added by all resident producers at a constant 2015 price in USD	World Bank Data
Labor	L	People aged above 15 who supply labor for the production	World Bank Data
Capital	K	Gross capital formation at a constant 2015 price in USD	World Bank Data
Road Transport Infrastructure	ROAD	Density of motor vehicle roadway (total road length per square km)	UNECE Transport Division Database
Rail Transport Infrastructure	RAIL	The density of railway available for service divided at a specific period (total rail length per square km)	World Bank Data
Water Transport Infrastructure	WATER	Coastal freight volume (20-foot equivalent unit × KM travelled)	OECD Data
Air Transport Infrastructure	AIR	Air freight volume (Metric Tons × KM travelled)	World Bank Data

Inland Transportation Investment	INV	Total Spending on new and improvement of inland transport infrastructure (% GDP)	OECD Data

Table 3.2: Country area measurement

Variables	Variable Description	Source
Land Area	A country's total land area (sq. km)	World Bank Data

**For other data sources, refer to Appendix 5*

Table 3.3: Categorization of countries

Developing Countries	Developed Counties
Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Georgia, Moldova, North Macedonia, Russian Federation, Turkiye, China, Montenegro, India, Ukraine, Serbia	Austria, Belgium, Canada, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Korea, Rep., Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States, Japan, New Zealand, Uzbekistan

Real Gross Domestic Production

This variable is to measure the economic growth over the observed period. Gross domestic production with a constant 2015 price in USD can better capture real economic growth by eliminating inflation and providing cross-country comparison with unified currency. This measurement can better examine the relationship between specific transport infrastructure towards the economy (Kabaklarlı et al., 2018; Shoukat & Ahmad, 2021)

Labor

This variable is adapted from the Cobb-Douglas production function as a control variable. The total labour force allows the measurement of the total availability of labor as input of production (Khatun & Afroze, 2016). Using this variable is to include labour of different education levels (Adame et al., 2017). Moreover, the data from World Bank Data can ensure data accuracy with dedicated research conducted in emerging economies (Worku, 2011).

Capital

This variable is adapted from the Cobb-Douglas production function as a control variable. Gross capital formation at a constant 2015 price in USD indicates the value of capital available for production activity over time eliminating inflation and providing cross-country comparison with unified currency. Using gross capital formation can include the effect of private and public investment to generate a more assessable result (Kabaklarlı et al., 2018) and it can better capture the effect of transportation infrastructure in facilitating production (Fosu & Twumasi, 2022).

Road Transport Infrastructure

This variable is to measure the density of Road transportation in a country. The sum of different roads including e-roads also called as electric roads, is added up to represent the total length of road transportation infrastructure (Cigu et al., 2018). The adaption of road density can better evaluate the improvements of road transportation networks and capture its trade effects (Ghosh and Dinda, 2021).

Rail Transport Infrastructure

This variable is to measure the density of rail transportation in a country. Railway density can represent the extension of the network over a country (Maparu & Mazumder, 2017; Wang et al., 2020). It can better evaluate the coverage and accessibility of the railway network that better links to economic activities.

Air Transport Infrastructure

This variable is to measure the freight transport with the use of air transportation. Air freight transport is adapted as an important freight transportation media, it is adapted to the measurement because it has bigger economic contributions compared to passengers and can quantity the application of air transportation infrastructure (Park et al., 2019).

Water Transport Infrastructure

This variable is to measure the freight transport with the use of water transportation. Water transport infrastructure supports shipment activity which is crucial to the economy by moving large volumes of cargo. 20-foot equivalent unit (TEU) as a standardised measurement in the shipping industry can be used as a quantitative measurement to evaluate the application of water transportation (Park et al., 2019).

Inland Transportation Infrastructure Investment

This variable is to measure the total investment made to upgrade and construct new transport infrastructure. Inland transport infrastructure investments can indicate the total gross investment made by a country on various types of transport infrastructure (Hayaloğlu, 2015). Adapting investment as a percentage of GDP in the respective country can eliminate the inflation effect and provide a cross-country comparison.

3.7 Model estimation

Performing time series data solely on model utilization Cobb-Douglas production function often faces non-stationary problems among variables (Kayode et al., 2013). Therefore, Panel data analysis is adopted in this study to better capture the complex relationship between transportation infrastructure and economic growth among different country categories. Panel unit-root test and panel cointegration analysis will be performed as preliminary checking on the panel data. Then, applying advanced data econometrics approaches such as Dynamic Ordinary Least Square (DOLS) and Fully Modified Least Square (FMOLS) to deal with the non-stationary and serial cointegration problems in panel data (Danish et al., 2019). A Wald test will be performed subsequently to evaluate the joint effect of transportation infrastructure.

3.7.1 Panel unit-root test

Panel unit root test is to evaluate the stationarity among variables and to determine the degree of integration between variables. Unit root tests can help detect the existence of unit roots to prevent biased results through the adaption of non-stationary data with a stochastic trend in a time series. Besides, Benerjee, et al. (1986) argued that the result of the time series test cannot be universally applied to cross-sectional groups. Moreover, the unit root test will lose its power when time series data is lacking in observations (Ramirez, 2007). Therefore, the panel unit root test should be adapted for the preliminary test of panel data. Panel unit root test like the Levin-Lin-Chu (2002) (LLC), and Im-Pesaran-Shin (2003) (IPS) enhances the power of the test by considering cross-sectional data (Philips & Ouliaris, 1990). LLC and IPS are simple methods to check data stationarity before selecting the suitable estimation (Chen et al., 2015). As compared to LLC, IPS is more powerful in panel data with short time dimension through better combination with cross-sectional dimension (Bornhorst & Baum, 2001).

Besides, the study of Badalyan et al. (2014) reported that different unit root tests might have different results. According to Breitung (2000), panel root tests like LLC and IPS will lose accuracy if the result contains bias in having over correlation and removes local means. Therefore, the Fisher-PP test is adapted to minimize the effects of possible serial correlation and heteroscedasticity in the error terms (Phillips & Perron, 1988). Maddala and Wu (1999) recommended the Fisher test, which improves the unit root test by allowing tests on each cross-section to fit the length difference. Due to this, different unit root tests would have different emphases and could produce different results (Barbieri, 2006). Therefore, this study will perform LLC, IPS and Fisher-PP unit root tests simultaneously for cross-comparisons.

Hypothesis testing:

H0 = there is a unit root among the variable and variables are not stationary

H1 = there is no unit root among the variables and variables are stationary

This research will perform LLC, IPS and Fisher-PP test unit root tests with the program embedded in EViews 12. The decision-making will be based on the result p-value, the null hypothesis will be rejected if the result p-value is lower than the significant level of (1%,5%,10%).

3.7.2 Panel Cointegration Analysis

Cointegration is an econometric approach that accesses the pertain of the long-term relationship between time series variables which allows the researcher to estimate their short-term dynamics relationship (Perman, 1991). The principle of the cointegration test is to examine the significance of the relationship between variables and find the existence of the long-term relationship between variables' short-term disturbances (Abadir & Taylor, 1999). We can perform a panel cointegration test when there is a unit root in the panel data. Therefore, if the panel data is stationary with no unit root possess a penal cointegration test is not required. In this study, the panel cointegration test of Kao (1999b) and Johansen Fisher test is proposed to test the cointegration between variables.

According to Batool and Akbar (2023) cointegration test by Kao (1999b) is feasible because as compared to the cointegration test by Pedroni (2004), it incorporates two-step procedures that enforce homogeneity across panel members which helps address common relationships. Besides, Kao's cointegration test includes common unit-root tests like Dickey-Fuller and provides a simplified method to estimate a common connection among variables across countries. This cointegration test applies to the panel model with different intercepts across cross-sectionals and generates results based on spurious regression within the panel data (Kao, 1999a).

On the other hand, regarding the controversy over quantitative proof of the Fisher equation, MacDonald and Murphy (1989) proposed that a cointegration test specified based on the Fisher equation should be implemented. Johansen developed a cointegration framework that considers stochastic and deterministic trends to provide a cointegration analysis that fits various panel data (Perron & Campbell, 1993). Johansen's cointegration analysis adapted the likelihood method in the vector autoregressive model as a based approach for a systematic approach in cointegration analysis (Johansen, 1991). Moreover, Johansen's cointegration analysis can provide asymptotically results of different levels of cointegration with other variables, this makes it more feasible for this study as compared to the Penroni cointegration test that assumes cointegration among all variables. Furthermore, this study will perform the Johansen Fisher Panel Cointegration test and perform estimation of DOLS and FMOLS, this is believed to overcome the test problem of short constant parameter and non-stationary data as stated in Johansen (2009). According to Maddala and Wu (1999), the p-value from Johansen maximum likelihood cointegration test statistics is more feasible as it comprises bootstrap-based critical values and can provide more reliable results than other tests such as Im-Pesaran-Shin (IPS) tests by overcoming common issues in panel analysis.

Hypothesis testing:
H0 = There is no cointegration among the variables
H1 = There is cointegration among the variables

This research will perform the Kao panel cointegration test and Johansen Fisher cointegration test with the program embedded in EViews 12. The decision-making will be based on the result p-value, the null hypothesis will be rejected if the result p-value is lower than the significance level of (1%,5%,10%).

3.7.3 Dynamic Ordinary Least Square (DOLS) and Fully Modified Ordinary Least Square (FMOLS) Estimations

Many economic studies especially for macroeconomic issues will adapt panel cointegration data and perform suitable model estimation to prove their model and determine the regression coefficient (Baltagi & Kao, 2004). Kao and Chiang (2004) suggested that the OLS model is still systematically biased in estimating cointegrated data despite increasing a large sample size. According to Chen et al. (1999) when this problem occurs having a bias-corrected OLS estimator will not resolve the problem and it still could not generate accurate results. They suggested that DOLS and FMOLS estimation can help to estimate an effective cointegration model. This study applies the Dynamic Ordinary Least Squares (DOLS) method developed by Engle and Granger (1987) and the Fully Modified Ordinary Least Squares (FMOLS) method by Philips and Hansen (1990). DOLS and FMOLS are chosen because they can be performed to check the cointegration relationship even with the issue of serial correlation and missing variables in the model (Rehman et al., 2023). Moreover, DOLS and FMOLS can be performed when the data is stationary at the origin, or when the data is stationary after differenced once (Yorucu & Bahramian, 2015).

When dealing with a serial correlation problem, FMOLS as a non-parametric method can be more effective at considering the potential correlation between the error term and the first difference of the regression (Maeso-Fernandez et al., 2004). FMOLS adapted Bartlett Kernal's long-run variance which allows the constant estimators of long-term variance and is robust in meeting model assumptions (Tong and Yu, 2018). Furthermore, FMOLS has an advantage against endogenous bias which is the problem of missing variables (Özcan, 2013). Therefore, FMOLS can help this research to better evaluate the relationship between transportation infrastructure and economic growth without having a lengthy variable. Besides, DOLS is another alternative estimation that addresses the lag and leads to the estimation (Shameem, 2022). Although causing a decrease in the degree of freedom, like lead, lags, and contemporaneous values of the regressors in first differences, nevertheless it still makes DOLS an unbiased estimator for the long-run parameter (Maeso-Fernandez et al., 2006). DOLS can also provide an asymptotically efficient estimate and it can minimize feedback problems by allowing short-term dynamics to be modelled separately (Ji et al., 2023).

3.7.4 Wald Test

Wald (1943) proposed a test to examine whether a combination of variables will have an effect towards another variable to determine whether a typical force is accountable in the study. Wald test is similar to the LM test, it asymptotically follows the $\chi 2$ distribution with data stationary at the first difference and assesses the significance of the model parameter (Buse, 1982; Satorra, 1989). Wald test can better fit in general models unlike Lagrange Multiplier test requires more model restriction (Hayashi et al., 2011). Wald test suites an exploratory methodology as it can be used to find alternative parameters that fit the model and reduce constraints (Chou & Bentler, 2002). Moreover, when the sample size is sufficient, the Wald test can generate a reliable result and can easily be interpreted with standard error distribution resemblance to z-test (Vittinghoff et al., 2011). Several studies employed the Wald test to determine the significance of transportation infrastructure towards economic growth; Maparu and Mazumder (2017), Wang et al. (2019), and Batool and Goldmann (2021) employed the Wald test to determine the importance of transportation infrastructure in the short run after performing VAR test; Wang et al. (2020), Saidi et al. (2018), Balsalobre-Lorente et al. (2020) and Saidi et al. (2018) performs Wald test to determine the importance of transportation infrastructure towards economic growth by cooperation with other variables in various model estimators such as SEM, ARDL and GGM. Meanwhile, the methodology in the studies by Tong and Yu (2018), Badalyan et al. (2014), and Liu and Hao (2018) are synchronized with this study by performing the Wald test together with the FMOLS & DOLS estimator to determine the relationship between variables and enhancing research finding.

Wald test can provide a re-estimation of the model by excluding other variables to capture the joint significance that is not shown in standard output

(Makutėnienė et al., 2022). Therefore, it is employed in this study after the performance of FMOLS and DOLS estimator. The existence of long-run relationships among variables can be evaluated with the significance of F-statistics and Chi-square outcome (Okoye et al., 2021). This will enhance this study by quantifying the uncertainty from individual parameter estimates and improve model significance This study employs the Wald restrictions program embedded in EViews 12, with coefficient restriction on all types of transportation RAIL, ROAD, WATER and AIR to examine the relationship between transportation infrastructure and economic growth. The decision-making will be based on the result of the F-statistic, with the null hypothesis of no relationship between transportation infrastructure (joint parameter of RAIL, ROAD, WATER and AIR) and economic growth will be rejected if the result p-value is lower than the significance level of (1%,5%,10%).

3.8 Conclusion

In this chapter, the extended Cobb-Douglas production function is employed as the theoretical model to construct an empirical model that meets the study's objectives to evaluate the relationship between economic growth and transport infrastructure and infrastructure investment. Based on the literature review above, we have selected suitable measurements to quantity selected variables to enable the performance of the quantitative analysis. The panel unit-root tests and panel cointegration tests are executed to ensure the model estimations of Dynamic Ordinary Least Square and Fully Modified Least Square are appropriate to be performed. A Wald test is also used to determine the joint effect of 4 types of transport infrastructure.

CHAPTER 4: FINDINGS

4.0 Introduction

This chapter discusses the results of the findings beginning with a preliminary analysis which showcases the summary of data among 48 countries from 1995 to 2021. This is followed by the panel unit root test to examine the stationarity of the data collected. The panel data analysis under DOLS and FMOLS estimations will determine the long-run relationship between the dependent variable - economic growth and independent variables - transport infrastructures and transport infrastructure investment. Lastly, robustness checks are conducted to determine the robustness of the key findings under various assumptions.

4.1 Preliminary Analysis

This section is to better understand the data set before entering the tests ‘results. To better showcase the data set of 48 countries (33 developed and 15 developing countries) spanning from 1995 to 2021, charts and graphs will be provided for better visuals.

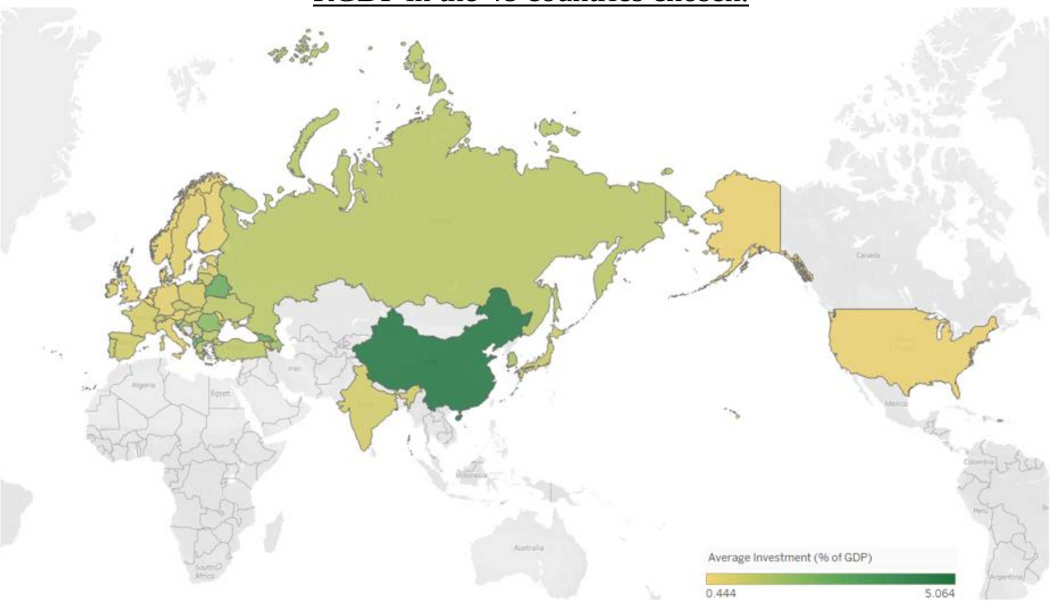
Table 4.1 shows the descriptive statistics based on the sample data, as the comparisons of the minimum and maximum indicate the spread of the data and the outliers, the findings indicate that water, labour, capital, and RGDP have very high spread. Also, as the mean of all variables have greater values than their median, these indicate that all variables have positive skewness. Not only that, Air Road, Rail and Investment variables, have more symmetrical distributions as the mean and median have a smaller difference gap. However, for a better understanding of the data, especially on the differences between data collected for developed and developing countries, graphs are drawn out for better and clearer presentations.

Table 4.1: Descriptive statistics results of panel data with 48 countries from 1995 to 2021.

Variables	Obs.	Mean	Median	Min.	Max.	Std. Dev
RGDP (Constant 2015 US$ Billions)	751	1141.49	215.64	3.86	19481.97	2847.91
Capital (Constant 2015 US$ Billions)	751	278.10	50.43	0.70	6053.28	748.62
Labour (Millions)	751	328.12	45.32	1.89	7807.10	1076.06
Road Density (Per KM Square)	751	0.38	0.31	0.01	1.00	0.24
Rail Density (Per KM Square)	751	1.97	1.50	0.01	10.19	1.71
Water (TEU Thousand)	751	4411.13	16.17	0.00	243560.00	23214.80
Air (TEU Thousand)	751	2.57	0.19	0.00	42.99	6.30
Investment (% GDP)	751	1.14	0.91	0.17	7.72	0.82

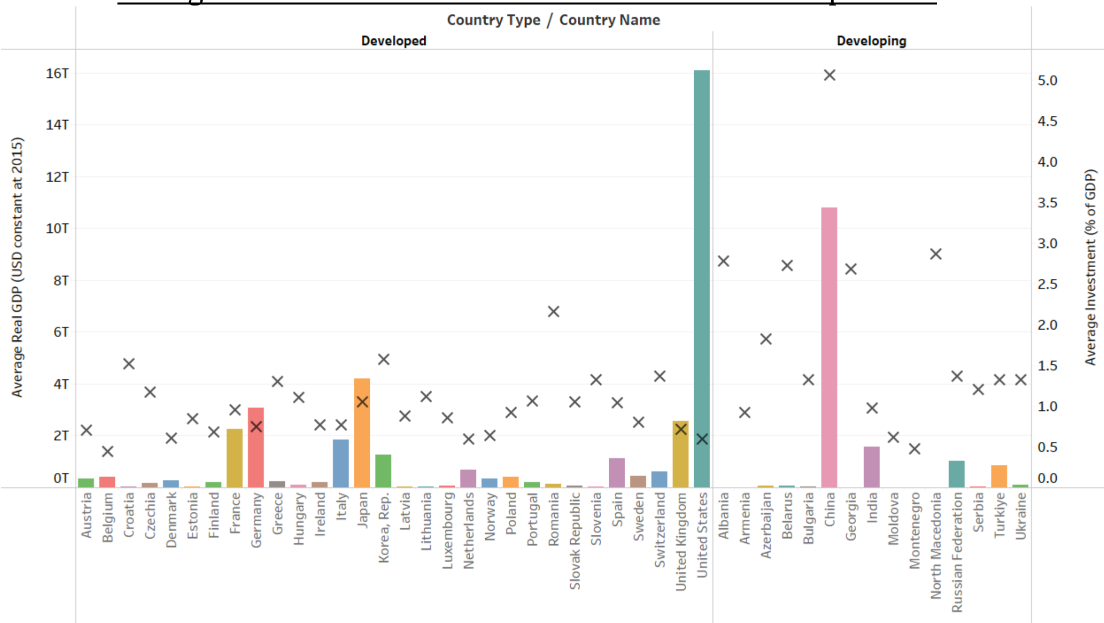
Notes: RGDP is Real GDP, Labour and Capital denote the labour and capital variables, Road Density denotes road transport infrastructure, Rail Density denotes rail transport infrastructure, Water denotes water transport infrastructure, Air denotes air transport infrastructure, and Investment denotes transport infrastructure investment.

Figure 4.1: Average transportation infrastructure investment in the percentage of RGDP in the 48 countries chosen.



Source: Created using the panel data of the study.

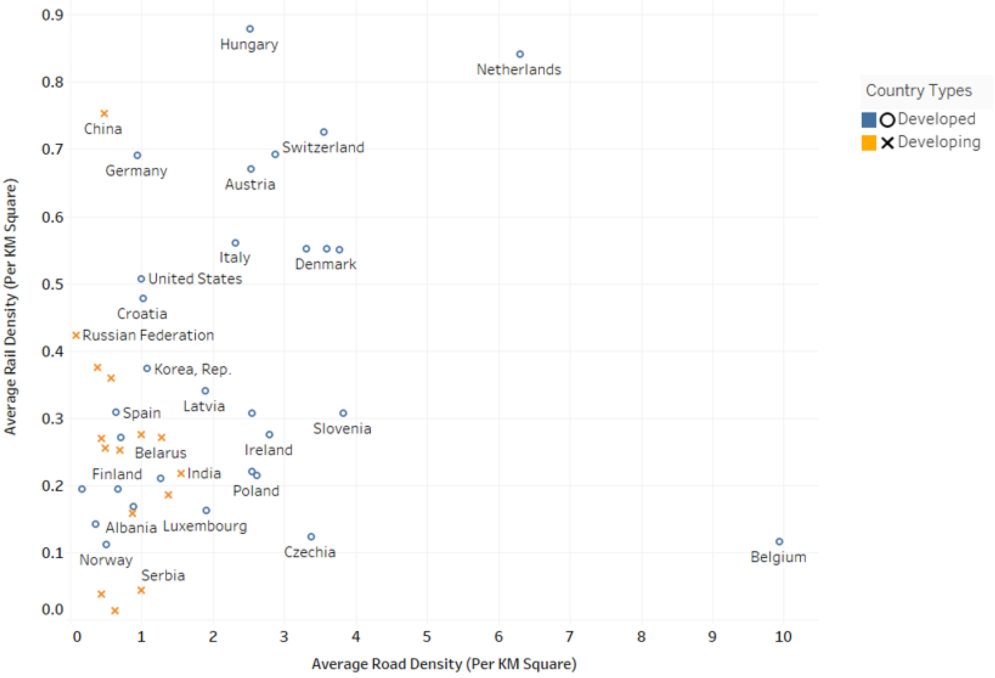
Figure 4.2: Average transportation infrastructure investment (% of GDP) and average real GDP of the 48 countries chosen in the sample data.



Source: Created using the panel data of the study.

To begin with, Figure 4.1 illustrates the average transportation infrastructure investment in the percentage of RGDP in the 48 countries chosen in a map chart, with China having the highest percentage of investment among all. To have a better comparison between developed and developing countries, Figure 4.2 is drawn out with Real GDP added in to better illustrate the data. Given that the investment variable has a measuring unit of percentage of RGDP, Real GDP added in will give a comprehensive understanding of how much investment is poured in by these countries. The results show that developing countries have an overall higher percentage of investment compared to developed countries, especially China which is putting 5.064% of its nearly 11 trillion USD RGDP into transportation infrastructure investment. Notably, although the US has less than 1% of its RGDP in transport infrastructure investment, the amount after converted into USD is still astonishingly higher than most countries due to its incredibly high real GDP.

Figure 4.3: Average Road density and rail density of the countries chosen in the sample data.



Source: Created using the panel data of the study.

Figure 4.3 combines the average road density and average rail density to indicate the land transport development of the sample countries. The distribution of countries in road density shows a clearer comparison with developed countries having an overall higher road density than developing countries. Apart from that, the distribution of countries in rail density is scattered with no obvious differences between the 2 country categories. On the whole, developed countries do have better road transport infrastructure development, indicating a more complete connection of domestic networks than developing countries.

Concluding this section, the sample data of the research shows interesting interactions between variables in individual countries and even when grouped according to country type – developed and developing countries. Given that, there are remarkable differences between developed and developing countries shown in terms of transport infrastructure and transport infrastructure investment too. Therefore, the following sections aim to determine the differences between these relationships in both developed and developing countries.

4.2 Unit Root Test

To scrutinize the stationarity of the variables, Levin, Lin, and Chu (LLC), Im, Pesaran, and Shin (IPS), and Fisher PP unit root tests are used. Table 4.2 shows the panel unit roots results for the 48 sample countries spanning from 1995 to 2021. The results suggest that all variables are stationary at the first difference, I (1). The result holds when the tests are conducted for developed (Table 4.3) and developing countries (Table 4.4).

As the unit root tests show stationary results, the panel cointegration tests mentioned in the methodology, which are the Kao panel cointegration test and Johansen Fisher cointegration test will be ignored.

Table 4.2: Unit Root Tests for the Overall Sample

Variables	LLC Intercept without trend		LLC Intercept with trend		IPS Intercept without trend		IPS Intercept with trend		Fisher PP Intercept without trend		Fisher PP Intercept with trend	
Level												
log(RGDP)	-7.1688	***	-1.6066	*	-0.7966		0.2389		171.6780	***	69.5982	
log(Capital)	-7.7143	***	-7.2589	***	-3.3962	***	-4.8459	***	147.3680	***	204.1580	***
log(Labour)	2.9360	***	2.5779		2.9598		0.6642		103.1340		64.2752	
log(Rail_Density)	-3.2749	***	-15.4270	***	-2.9432	***	-9.7401	***	151.8460	***	235.7180	***
log(Road_Density)	6.5962		10.3923		-4.3495	***	-6.6828	***	238.1220	***	228.7850	***
log(Water+1)	-8.0323	***	-32.9169	***	-3.8693	***	-10.1871	***	117.8090	***	359.2900	***
log(Air+1)	-21.2422	***	-31.3763	***	-8.7362	***	-7.6832	***	158.6190	***	140.2390	***
log(Investment)	-5.4248	***	7.4373		-4.7949	***	-1.3464	*	148.9260	***	121.3020	**
1st Difference												
log(RGDP)	-21.5240	***	-19.6569	***	-21.0817	***	-18.6988	***	574.5380	***	570.2590	***
log(Capital)	-21.4096	***	-18.7530	***	-21.6249	***	-18.0672	***	657.5660	***	1110.1100	***
log(Labour)	-11.2620	***	-15.9842	***	-16.4506	***	-17.4402	***	516.7520	***	477.3550	***
log(Rail_Density)	-38.9473	***	-41.5248	***	-32.2249	***	-27.0290	***	904.3550	***	2728.1800	***
log(Road_Density)	-248.3140	***	-47.7465	***	-63.9891	***	-20.4107	***	988.9860	***	1393.3700	***
log(Water+1)	-91.6234	***	-77.2817	***	-32.6769	***	-28.5168	***	592.2750	***	1221.3500	***
log(Air+1)	-404.0150	***	-657.9530	***	-72.6726	***	-74.0186	***	832.5360	***	1131.9300	***
log(Investment)	-21.8263	***	-15.9830	***	-21.6605	***	-15.3667	***	699.2310	***	958.0320	***

Notes: log(RGDP) is Log Real GDP, log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment., **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*

Table 4.3: Unit Root Tests for the Developed Sample Countries.

Variables	LLC Intercept without trend		LLC Intercept with trend		IPS Intercept without trend		IPS Intercept with trend		Fisher PP Intercept without trend		Fisher PP Intercept with trend	
Level												
log(RGDP)	-7.3417	***	-3.7297	***	-2.2303	**	-1.2688		154.1870	***	53.0405	
log(Capital)	-3.1392	***	-3.0343	***	-0.0362		-3.8236	***	72.0369		84.5872	**
log(Labour)	-3.6802	***	-1.7467	**	2.054		-2.2778	**	60.666		48.5377	
log(Rail_Density)	-1.4374	*	-9.4014	***	-1.4420	*	-1.9439	**	95.7185	***	182.0020	***
log(Road_Density)	12.4826		15.8058		-4.2270	***	-8.8509	***	183.2030	***	174.5730	***
log(Water+1)	-7.5498	***	-32.6208	***	-4.3026	***	-11.6073	***	91.7550	***	323.0540	***
log(Air+1)	0.4757		-1.9930	**	-0.4822		-2.3014	**	91.2850	**	94.8979	**
log(Investment)	-3.0764	***	212.5260		-3.2118	***	-1.2881	*	97.9981	***	86.8728	**
1st Difference												
log(RGDP)	-18.4878	***	-16.9856	***	-17.6252	***	-15.7600	***	412.5080	***	430.0060	***
log(Capital)	-18.4003	***	-16.0641	***	-18.8552	***	-15.5329	***	495.8010	***	965.3370	***
log(Labour)	-13.4017	***	-12.1428	***	-14.3367	***	-12.9255	***	347.1380	***	291.79	***
log(Rail_Density)	-29.5176	***	-37.5800	***	-27.3933	***	-24.1559	***	627.1400	***	1971.1500	***
log(Road_Density)	-250.8640	***	-43.5684	***	-73.5972	***	-22.8969	***	554.3300	***	982.9110	***
log(Water+1)	-91.8801	***	-79.7347	***	-33.9520	***	-28.3848	***	445.0950	***	875.2730	***
log(Air+1)	-23.5093	***	-21.3535	***	-23.3818	***	-17.0305	***	599.1500	***	559.4910	***
log(Investment)	-17.4804	***	-13.0714	***	-17.0840	***	-13.7246	***	455.9200	***	738.2320	***

Notes: log(RGDP) is Log Real GDP, log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment., **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*

Table 4.4: Unit Root Tests for the Developing Sample Countries.

Variables	LLC				IPS				Fisher PP			
	Intercept without trend		Intercept with trend		Intercept without trend		Intercept with trend		Intercept without trend		Intercept with trend	
Level												
log(RGDP)	-3.0056	***	2.1219		1.9140		2.3296		17.4906		16.5576	
log(Capital)	-6.1413	***	-6.6875	***	-6.2226	***	-3.0110	***	75.3314	***	119.5700	***
log(Labour)	0.9239		6.518		2.2436		4.106		42.4677	*	15.7375	
log(Rail_Density)	-3.3824	***	-12.0710	***	-3.0704	***	-7.6976	***	56.1272	***	53.7163	***
log(Road_Density)	-3.9471	***	-3.0874	***	-1.6509	**	-0.9959		54.9190	***	54.2111	***
log(Water+1)	-2.4813	***	-1.4504	*	-0.4011		-1.1944		26.0542		36.2361	**
log(Air+1)	-16.4576	***	-32.9706	***	-14.6896	***	-10.0974	***	67.3340	***	45.3409	**
log(Investment)	-4.7823	***	-1.9156	**	-3.7417	***	-0.5630		50.9283	***	34.4290	
1st Difference												
log(RGDP)	-11.3305	***	-10.2748	***	-11.5678	***	-10.0677	***	175.6180	***	140.2530	***
log(Capital)	-11.1509	***	-9.6949	***	-10.6439	***	-9.2438	***	161.7660	***	144.7780	***
log(Labour)	-2.2599	**	-10.2712	***	-8.1815	***	-12.0328	***	169.6130	***	185.5650	***
log(Rail_Density)	-26.1337	***	-18.8603	***	-17.0517	***	-12.3336	***	277.2140	***	757.0300	***
log(Road_Density)	-6.4230	***	-18.0339	***	-9.7475	***	-6.4908	***	434.6560	***	410.4580	***
log(Water+1)	-5.7962	***	-11.5029	***	-7.2664	***	-9.3871	***	147.1790	***	346.0750	***
log(Air+1)	-401.7720	***	-643.8830	***	-93.2194	***	-97.4217	***	233.3860	***	572.4410	***
log(Investment)	-13.4877	***	-9.5109	***	-13.3380	***	-7.7165	***	243.3110	***	219.8000	***

Notes: log(RGDP) is Log Real GDP, log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment., **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*

4.3 Panel Data Analysis

Table 4.5: FMOLS and DOLS Results for the Overall Sample

	Panel Data Result					
Variables	**ALL**		**Developed**		**Developing**	
	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS
LOG(CAPITAL)	0.648*** (0.025)	0.590*** (0.082)	0.622*** (0.021)	0.530*** (0.087)	0.494** (0.188)	1.017* (0.551)
LOG(LABOUR)	0.284*** (0.095)	0.486* (0.263)	0.306*** (0.077)	0.613** (0.251)	-0.327 (1.626)	-1.678 (5.550)
LOG(RAIL_DENSITY)	0.007 (0.018)	0.221 (0.153)	0.025 (0.016)	0.297** (0.135)	-0.064 (0.071)	-0.948 (1.147)
LOG(ROAD_DENSITY)	0.021 (0.015)	0.009 (0.031)	0.018 (0.012)	0.0003 (0.025)	0.816** (0.339)	0.697* (0.334)
LOG(WATER+1)	0.013*** (0.004)	0.002 (0.012)	0.014*** (0.003)	0.003 (0.010)	0.111 (0.106)	-0.103 (0.109)
LOG(AIR+1)	-0.004 (0.017)	-0.066 (0.045)	-0.003 (0.015)	-0.098** (0.048)	-0.175 (0.134)	-0.220 (0.164)
LOG(INVESTMENT)	-0.051*** (0.019)	-0.044 (0.053)	-0.048*** (0.016)	0.026 (0.066)	0.057 (0.097)	-0.022 (0.099)
Wald Test						
F-Stat	2.797**	1.091	4.869***	2.069*	2.077*	2.723*

*Notes: log(RGDP) is Log Real GDP, log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment. * Denotes significant at 0.10 level, ** denotes significant at 0.05 level, *** denotes significant at 0.01 level. The lag and lead selection method for the DOLS estimator is based on the Akaike information criterion, the comparison with the Schwarz information criterion is attached as Appendix 1.*

As the panel unit root tests' results support the stationarity of all series at level, the 2 different estimation methods, which are Full Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) are conducted to examine the long-term relationship between different transportation infrastructure types, investment in transportation infrastructure and economic development.

According to Yahyaoui and Bouchoucha (2021), the residuals' potential autocorrelation and heteroscedasticity phenomena, as well as the disturbance factors, are taken into consideration by the FMOLS. It also corrected the endogeneity of the independent variables (Liddle, 2012). In addition, DOLS can be used in modelling the time series data. It also allows for the inclusion of lagged terms, capturing the dynamic effects of past values on the current results (Yahyaoui & Bouchoucha, 2021). Thus, this study employed FMOLS and DOLS as estimators since they are particularly useful in economic applications that contain time-series data and have long-term relationships. However, FMOLS is more suitable for examining long-term data and more efficient when dealing with highly correlated variables. Thus, FMOLS is preferable in this study.

Table 4.5 shows the result of FMOLS and DOLS estimations across 3 different country categories: developed countries, developing countries, and the overall countries sample. Among the variables examined, capital exhibits a significant relationship in the overall sample. However, labour does not show statistical significance in developing countries. This is because most developing countries are labour-intensive countries (Niebel, 2018). Thus, labour's marginal contribution towards economic growth may be limited in these countries due to the relative quantity of labor and lower levels of human capital, which makes labor seems insignificant in empirical studies when compared to capital (Dua & Garg, 2019).

To examine the magnitude of different transportation infrastructure types towards economic growth, this study also carried out tests for every type of transport infrastructure. The findings reveal a highly significant relationship between water transport and economic growth across the sample countries, especially in developed countries, supported by the FMOLS model, highlighting the pivotal role that maritime infrastructure plays in promoting economic growth. This suggests the high dependence of more developed economies on this type of infrastructure. As we know, developing and maintaining water transport infrastructure, such as ports, navigable rivers, etc requires a high level of investment. In contrast, many developing countries do not have sufficient financial resources to invest in such transport infrastructure. Interestingly, on the other side, the road is more crucial in emerging countries based on the table above. This result emphasizes how crucial it is to spend money on road infrastructure in developing countries to improve connectivity, ease trade, and boost economic activity. However, the model shows insignificant results for railway and air transport across the overall sample. In the context of the countries under study, it implies that the development of railway and air transport are not equally crucial for economic growth compared to the construction of other types of transport infrastructure, such as water and road transportation infrastructure.

Furthermore, while FMOLS highlights significant transport infrastructure investment in the developed countries and the overall sample, the results show negatively effects on economic growth. This highlights the complex nature of the relationship between infrastructure investment and economic growth. As evidence for the negative relationship, according to Sachs and Woo (2003), China's intense drive to develop its infrastructure was emphasized by hurried projects that ultimately caused bridges and roads to collapse in 1998 and 1999. This example highlights quality, maintenance and governance of the rushed transportation infrastructure projects might be very poor and may lead to negative outcomes. It also draws attention to the dangers of weak fiscal policy and inefficient use of public funds. These results underscore the necessity of customized policy responses to accommodate the different dynamics and demands found in different national contexts.

In order to examine the relationship between transport infrastructure and economic growth, the Wald test is conducted by the joint tests of the significance of all types of transport infrastructure, namely water, road, railway, and air transport. The Wald test result from both models found that transport infrastructure investments and transport infrastructure have a substantial correlation with economic growth across the overall sample. These results suggest that, when considering both the developed and developing countries together, transportation infrastructure plays a statistically significant role in boosting economic growth. These results highlight the potential advantages of planned and comprehensive developments in transportation infrastructure, particularly can enhance competitiveness, efficiency, and connection and eventually promote sustainable overall economic growth. In short, despite the individual tests for various types of transportation infrastructure showing varied results, the overall findings found that transportation infrastructure is still an important catalyst in promoting economic growth.

In short, this study provides a clearer picture of how transport infrastructure affects economic growth. Similar to the puzzle game, each piece allows us to see a wider image and identify more effective strategies for promoting economies.

4.4 Robustness Tests

To ensure the reliability and validity of the key findings when assumptions change, this study carried out several robustness checks. These tests are aimed at confirming the consistency and reliability of the relationship between transport infrastructure and economic growth after certain procedures or variables are adjusted. This part included 2 types of robustness checks to test the findings under different circumstances, which are:

1. Robustness checks with a smaller sub-sample of 41 countries
2. Robustness checks using Real GDP per Capita as an alternative indicator of economic growth.

Note: Each of the two robustness tests is conducted individually and does not have any interrelation with the others.

4.4.1 Robustness Check with a Smaller Sample of 41 Counties.

To begin with, a robustness check was conducted on a smaller sub-sample data set which contains 41 countries, including 30 developed and 11 developing countries. This adjustment aims to address the bias possibility raised by obtaining data from multiple sources to increase the richness of the countries available. Therefore, 7 countries with data obtained from other sources are removed due to the data unavailability on the major sources.

The result in Robust Table 4.6 illustrates the result of FMOLS and DOLS estimator using the subsample data set. By comparing with the panel data result, no coefficient flip occurs between the result of the two sample groups and the relationship between variables remains, indicating that the relationship between variables is present regarding the sample size. Besides, Wald statistic values in the two results are similar with slight changes in developing countries, and the relationship between transportation infrastructure and economic growth remains constant. A constant result is presented in transport infrastructure. These consistent results conclude that the estimation result is robust and effective.

Table 4.6: Robustness Check Table: Sub-Sample Data Set with 41 Countries

Variables	**ALL**		**Developed**		**Developing**	
	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS
LOG(CAPITAL)	0.639***	0.590***	0.621***	0.530***	0.505*	1.017*
	(0.025)	(0.082)	(0.021)	(0.087)	(0.240)	(0.551)
LOG(LABOUR)	0.289***	0.486*	0.306***	0.613**	-4.029	-1.678
	(0.095)	(0.263)	(0.077)	(0.251)	(3.445)	(5.550)
LOG(RAIL_DENSITY)	0.022	0.221	0.025	0.297**	0.194	-0.948
	(0.020)	(0.153)	(0.016)	(0.135)	(1.633)	(1.147)
LOG(ROAD_DENSITY)	0.02	0.009	0.018	0.0003	0.551	0.697*
	(0.015)	(0.031)	(0.012)	(0.025)	(0.487)	(0.334)
LOG(WATER+1)	0.014***	0.002	0.014***	0.003	0.149	-0.103
	(0.004)	(0.012)	(0.003)	(0.010)	(0.138)	(0.109)
LOG(AIR+1)	-0.005	-0.066	-0.003	-0.098**	-0.032	-0.22
	(0.017)	(0.045)	(0.015)	(0.048)	(0.187)	(0.164)
LOG(INVESTMENT)	-0.051***	-0.044	-0.048***	0.026	0.005	-0.022
	(0.019)	(0.053)	(0.016)	(0.066)	(0.124)	(0.099)
Wald Test F-Stat	3.166***	1.091	4.894***	2.069*	0.848***	2.723*

*Notes: log(RGDP) is Log Real GDP, log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment. * Denotes significant at 0.10 level, ** denotes significant at 0.05 level, *** denotes significant at 0.01 level. The lag and lead* *selection method for the DOLS estimator is based on the Akaike information criterion, the comparison with the Schwarz information criterion is attached as Appendix 2. Countries adapted are listed in Appendix 4. The unit root test on the sub-Sample Data set is in Appendix 6-8.*

4.4.2 Robustness Check Using Real GDP per Capita as an Alternative Indicator of Economic Growth

The relationship between transport infrastructure and transport infrastructure investment towards economic growth is multifaceted and can be influenced by other factors. Therefore, a robustness check using Real GDP Per Capital (at constant 2015 US$) as an alternative economic growth measurement is adopted. This is because Real GDP Per Capita captures things that may be deemed important to overall well-being like economic health and growth (Callen, 2022). This enhances the research by evaluating the effectiveness of transportation infrastructure and its investments in supporting economic growth relative to the population size. Furthermore, adapting new measurements of economic growth can reduce the potential risk of endogeneity and obtain a more reliable relationship estimator.

Results from the Robustness Table 4.7 shows that the relationship between transportation infrastructure and economic growth remains robust with evidence of the Wald test, while 4 types of transportation infrastructure show a continued relationship with economic growth. Besides, transportation infrastructure investment continued the negative relationship with economic growth with the population effect removed. This result supports a strong relationship between transportation infrastructure and economic development despite the measurement of economic growth having a distinct relationship with other variables. This reinforces the effectiveness of the analysis in capturing the multifaceted dynamics between transportation infrastructure and economic growth.

Table 4.7: Robustness Check Table: RGDP per capita as Economic Growth's Measurement.

Variables	**ALL**		**Developed**		**Developing**	
	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS
LOG(CAPITAL)	0.666***	0.656***	0.639***	0.571***	0.507**	1.167
	(0.026)	(0.093)	(0.024)	(0.094)	(0.195)	(0.657)
LOG(LABOUR)	-0.431***	-0.265	-0.402***	-0.102	-1.354	-1.978
	(0.102)	(0.298)	(0.089)	(0.271)	(0.000)	(6.624)
LOG(RAIL_DENSITY)	0.02	0.146	0.035*	0.236	-0.035	-1.231
	(0.020)	(0.173)	(0.019)	(0.145)	(0.073)	(1.369)
LOG(ROAD_DENSITY)	0.027	0.017	0.023	0.005	0.841**	0.858*
	(0.017)	(0.035)	(0.014)	(0.027)	(0.351)	(0.398)
LOG(WATER+1)	0.014***	-0.001	0.014***	0.0003	0.144	-0.127
	(0.004)	(0.013)	(0.004)	(0.010)	(0.110)	(0.130)
LOG(AIR+1)	0.0004	-0.068	-0.001	-0.106**	-0.173	-0.298
	(0.018)	(0.051)	(0.017)	(0.052)	(0.138)	(0.196)
LOG(INVESTMENT)	-0.044**	-0.063	-0.038**	0.022	0.028	-0.031
	(0.020)	(0.060)	(0.018)	(0.071)	(0.100)	(0.118)
Wald Test F-Stat	3.034***	0.637***	4.453***	1.495***	2.007***	2.92***

*Notes: log(RGDP) is Log Real GDP, log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment. * Denotes significant at 0.10 level, ** denotes significant at 0.05 level, *** denotes significant at 0.01 level. The lag and lead selection method for the DOLS estimator is based on the Akaike information criterion, a comparison with the Schwarz information criterion is attached as Appendix 3. The unit root test on the sub-sample data set is in Appendix 9.*

4.5 Conclusion

This study employed panel unit root tests (LLC, IPS and Fisher PP) which all showed significant or stationary results under the first difference. Panel estimations of FMOLS are used to achieve the three objectives of this study. To align with the impact of transport infrastructure on economic growth, Wald Test indicated a positive significant relationship between transport infrastructure and economic growth in all 3 country categories.

Other than that, to study the significance of transport infrastructure investment towards economic growth, this study revealed a marginally negative relationship with economic growth, which was especially noticeable in the developed sample countries and the overall sample. Ultimately, interesting new information was gleaned from the research on the differing effects of different types of transportation infrastructure on economic growth. Water transport infrastructure is found beneficial for economic growth in the overall and developed county categories. Road transport infrastructure is found to boost economic growth in developing countries. However, rail and air transport infrastructures do not show any relationship towards economic growth.

Notably, the robustness checks using the smaller sub-sample and Real GDP per Capita data sets also indicated the same results, further strengthening the report's findings with evidence.

CHAPTER 5: CONCLUSION

5.0 Introduction

This chapter focuses on providing a clear summary of the thesis. The results of this study are not solid unless the discussion shifts to future developments while focusing on future developments and the implications for transportation infrastructure and its investment. To do this, this study will go through the objectives, questions, and reasoning behind the research once more before summarising the results. The summary of the findings is arranged based on the research objectives in order to give a logical synopsis of the thesis and facilitate discussion of the study's implications. The study's contributions, limitations and recommendations will also be provided in line with the discussed implications.

5.1 Recapitalisation of Findings

The continuous argument over the relationship between transport infrastructure and economic growth explores the role it plays in promoting economic growth, especially during an era of prosperity. Based on empirical data and thorough analysis, it is clear that transportation infrastructure is a major factor in development. Moreover, noteworthy examples like China's strategic development plans and Japan's technological achievements highlight the strong association between economic growth and investments in transportation infrastructure. Similarly, the industrialization and democratization of Korea have been greatly aided by its coordinated efforts to expand its infrastructure.

Despite its importance, some scholars and academics still question the efficiency of infrastructure development, argue for alternative approaches to foster growth, or highlight the necessity of a thorough examination of particular situations and circumstances. These academic discussions enhance academic discourse and provide insight into policy-making processes by fostering a greater understanding of the multifaceted connection between infrastructure and economic growth.

Arising from such, this study aims:

1. To study the relationship between transport infrastructure and economic growth
2. To study the relationship between transportation infrastructure investment and economic growth
3. To study the magnitude of different transport infrastructure types towards economic growth

To achieve these objectives, this study employed panel data analysis, which consists of unit root tests and FMOLS estimation. In the process, the data covered the years ranging from 1995 to 2021 and 48 countries around the world. The results of the unit root suggest that all of the variables are stationary at first difference. Thus, cointegration tests are not applicable since the variables do not exhibit trends or systematic patterns over time.

5.1.1 To Study the Relationship between Transport Infrastructure and Economic Growth

This study discusses the overall effects of transport infrastructure on economic growth, with the result from Chapter 4 providing clarification. Throughout history, a multitude of academic investigations attempted to figure out the complex relationship between infrastructure development and its function as a booster of economic growth (Du et al., 2022). According to Zhang et al. (2021), infrastructure is the backbone of today's economies, supporting effective resource allocation, production, and commercial activity. It includes industries like transportation, communication, energy, and technology.

The Wald test result from the model found that infrastructure investments and transport infrastructure have a substantial correlation with economic growth in all countries and developed countries. This emphasizes how these factors are vital in promoting economic development through promoting investment, improving connectivity, and facilitating commerce. Despite the individual tests for various types of transportation infrastructure showing varied results, the overall findings found that transportation infrastructure is still an important catalyst in promoting economic growth. This result highlights the potential advantages of planned and comprehensive developments in transportation infrastructure, particularly can enhance competitiveness, efficiency, and connection and eventually promote sustainable overall economic growth.

This suggests to policymakers that maintaining investment in transportation infrastructure is essential to economic development plans, with a focus on closing gaps and clearing bottlenecks in the system. It also highlights the possibility of international cooperation and knowledge exchange in infrastructure planning and development, enabling nations to benefit from one another's experiences and best practices. However, to maximize infrastructure investments' effects on economic growth and advance equitable development for all, it is still imperative to make sure they are backed by efficient governance, upkeep, and complementary policies.

5.1.2 To Study the Relationship between Transport Infrastructure Investment and Economic Growth

This study finds that transport infrastructure investment has significant effects in the developed countries and the overall sample, contrasting, is its insignificance in developing countries. This result highlights the complex nature of the relationship between infrastructure investment and economic growth. In line with the results, Zhang et al. (2021) and Ibahimov et al. (2023) found that investment in public infrastructure is strongly associated with economic growth across different state development levels. Different forms of public infrastructure have unique spatial effects on local economic expansion. Furthermore, as Somik (1999) pointed out, different types of public infrastructure have different spatial effects on regional economic growth. Somik also stressed the importance of the mix of infrastructure investments. Consequently, to fully explain infrastructure efficiency, future research should incorporate size, geographic dynamics, model specifications, and conceptual relationships.

On the other hand, several studies have shown that investing in infrastructure might not be the most effective way to stimulate economic growth. Based on a thorough review of data, Ansar (2016) argues that the accepted view that infrastructure investment fosters economic value, especially in China, may not be true. Surprisingly, a large fraction of infrastructure investments do not produce positive risk-adjusted returns, which calls into question their viability as development boosters. Furthermore, China's track record of providing infrastructure is almost identical to that of wealthy democracies, indicating that it does not possess a clear advantage (Ansar, 2016). Additionally, research from Younis (2014) shows that public investment has very little effect on Pakistan's economic growth, especially in the short run. This is sometimes ascribed to the inability of pricey, expansive transportation infrastructure improvements to produce the anticipated advantages quickly (Zhang & Cheng, 2023). All of these results point to the possibility that infrastructure investment may not be a very effective way to boost economic growth in developing countries.

5.1.3 To Study the Magnitude of Different Transport Infrastructures Toward Economic Growth

Through the application of the model to various forms of transport infrastructure, the analysis shows a strong positive correlation between water transport and economic growth in developed countries, underscoring the critical role that maritime infrastructure plays in fostering economic growth. This suggests the high dependence of more developed economies on these types of infrastructure. Based on the research by Fosu and Twumasi (2022), this is because developing and maintaining water transport infrastructure, such as ports, navigable rivers, etc requires a high level of investment. This result is supported by the research from Munim and Schramm (2018), who indicate that over 80% of trade is carried by sea today. According to Bottasso et al. (2014), the regional RGDP of Europe can rise by 6-20% for every 10% increase in port capacity. Cullinane and Wang (2006) also found that the provision of international logistics services has evolved into a key component of port operations beyond only cargo handling.

Interestingly, road transport is solely significant with a positive relationship in developing countries. Notably, research by Li et al. (2014) and Kveiborg and Fosgerau (2007) highlights several variables that support economic growth, including the use of bigger cars, more truckloads, and better roads. Li et al. (2014) also emphasizes the crucial role that road infrastructure development plays by highlighting the significance of indicators like road length, highway passenger turnover, and the quality of roadways connecting regional communities. Furthermore, Ng et al. (2019) show a clear correlation between the growth of exports and the length of roads per capita, highlighting the critical role that roads play in promoting trade and commerce in developing countries. In conjunction, these results highlight the need for policies that prioritize road infrastructure in addition to more comprehensive socioeconomic initiatives to promote sustainable economic growth in developing countries.

However, the findings show that railway transport tested to be insignificant across the sample. This implies that the development of railway transport may be not equally crucial for economic growth as the construction of other types of transport infrastructure. This result is supported by the study conducted by Kayode et al. (2013) who stated that there is an insignificant relationship between the rise of railway transportation investment and Nigeria's RGDP growth rate. Chen and Haynes (2015) also stated that transit impacts are negligible compared to the impacts from public railways despite considering a positive spillover effect. In addition, Crescenzi et al. (2016) also discovered that the impact of railway transportation infrastructure on economic growth was unclear, negligible, or even adverse.

Although research indicates that air transport infrastructure has a favourable impact on economic growth and the creation of jobs in the service sector, the results still show that it is insignificant in every country category (Zhang and Graham, 2020). As evidence of increasing air infrastructure does not significantly correspond with growth in economic production, the direct influence of air infrastructure on economic growth is still rather small, even with improved connectivity (Budd & Ison, 2020). Thus, to comprehend the complex relationship between the infrastructure of air transportation and economic growth, it is crucial to examine statistical methods and sample sizes.

5.2 Implication of Study

This study investigates the relationship between transport infrastructure and economic growth in 3 country categories, which are developed countries, developing countries, and the overall sample. This research adds to the body of knowledge on theoretical discussions concerning the relationship between economic growth and transportation infrastructure. It offers empirical support for the theory known as "infrastructure-led growth," which suggests that strategic infrastructure investments are crucial for promoting economic growth by encouraging industrial expansion (Agénor, 2010). Nnyanzi et al. (2022) also emphasize the importance of supporting infrastructure development to enable the manufacturing sector's contribution to overall production and economic development. Furthermore, the results underscore the crucial of considering the multifaceted implications of different transportation infrastructures in different country categories, encompassing its influence on regional growth, productivity, and competitiveness.

The results highlight how important transportation infrastructure is for promoting development and economic growth. Based on the findings from Chapter 4, the strong correlation between water transport and economic growth highlights how important maritime infrastructure is for promoting economic growth in developed countries. This is due to its cost-effectiveness as its capacity to carry commodities at a cheaper cost than other modes of transportation, especially for bulk cargo and long-distance trips (Navata, 2022). Ships can transport huge amounts of cargo in a single journey, they can take advantage of economies of scale that lower the cost of transportation per unit. Ports and terminals, which are part of the water transport infrastructure, can also effectively accommodate huge vessels, which further improves cost-effectiveness by reducing loading and unloading times (Jurkovič et al., 2021). Thus, to take full advantage of the potential of water transportation infrastructure for promoting growth, especially in coastal regions and areas with large river networks, policymakers need to give priority to investing in this infrastructure. Through the optimization of waterborne transportation infrastructures' efficiency and capacity, governments can open up new trade, investment, and economic development prospects.

The positive significant result of road transport solely in developing countries is that poor infrastructure is a major problem for developing countries, especially in rural areas where road networks are necessary to connect rural areas to cities and make it easier for people to access markets, healthcare, and education ("Detail of a Publication", n.d.). Furthermore, road transportation is often more accessible and flexible than other forms of transportation, like rail or air, which makes it a popular option for both individuals and companies, particularly in areas with few other transportation options ("How Far Do Roads", 2020). In addition, road transportation is essential to the development of primary sectors that are common in developing nations, especially agriculture. Road infrastructure development may boost production, efficiency, and connectivity, which promotes economic growth (Ng et al., 2019). As a result, road transport development is crucial to promote economic growth strengthening connectivity and facilitating access to markets and basic services in developing countries.

Meanwhile, in the overall sample, railway transport has an insignificant relationship with economic growth. There are a number of factors, such as inefficient resource allocation, competition from other forms of transportation, operational and technological difficulties, regulatory limitations, and problems with spatial connectedness, limit the influence of railway infrastructure on economic growth (Crescenzi et al., 2016). Railways' role in propelling economic progress is further undermined by supply and demand mismatches, foreign market dynamics, and macroeconomic changes (Wu et al., 2021). To optimize railway infrastructure's efficiency and effectiveness and maximize its potential as a driver for sustainable economic development, addressing these complex challenges necessitates focused policy interventions, strategic investment planning, and concerted efforts from all stakeholders (Wu et al., 2021).

For the last types of transportation modes, air transport shows insignificant results in the overall sample. The high costs of air travel, both for passengers and freights, might be the first reason why it is insignificant. It is found to be not so accessible or affordable for some people or enterprises, especially those in lower-income areas. Furthermore, the economic benefits of air transport may be more obvious in international trading or tourism compared to a country's RGDP. Along the same line, Khanal et al. (2022) found that air transport development might have a positive but insignificant effect on economic growth. Besides, air transport is also highly dependent on external factors, such as the condition of the global economy, fuel prices, geographical areas, etc. Economic downturns, political unrest, or disruptions in the fuel supply can harm the demand for and profitability of air travel, limiting the potential economic benefits of air travel (Baltacı & Akbulut, 2015). Thus, we suggest that the government should focus on the development of a balanced transportation infrastructure to decrease reliance on a single factor and improve overall efficiency.

However, while FMOLS highlights significant transport infrastructure investment in developed countries, it shows negative effects on economic growth. In line with the results, Zhang et al. (2021) and Ibahimov et al. (2023) found that investment in public infrastructure is strongly associated with economic growth across different state development levels. However, studies like Ansar (2016) and Younis (2014) question transport infrastructure's importance in driving growth in developing countries like China and Pakistan. They draw attention to flaws in large-scale initiatives, suggesting a negligible or less noticeable effect in certain situations. Based on the finding of Sachs and Woo (2003), which certifying that rushed infrastructure project of China caused negative outcomes, highlights the importance of careful preparation, maintenance, and oversight mechanisms in order to minimize risks and optimize the long-term advantages of investing in transportation infrastructure. To make sure that funds are distributed wisely and in line with more general development goals, policymakers must carefully evaluate the applicability, effectiveness, and quality of infrastructure projects.

The measurements for different variables in this study are not the same. The measurements for railway and road are railway density and road density (length/ km^2) respectively, while both air transport and water transport are using TEU (20-foot equivalent units). As we know, road density or railway density represents the measure of transportation availability rather than economic performance. Although a high density of roads and railroads may suggest improved accessibility to transportation, hence promoting trade and economic activities, their impact on RGDP is subject to several channels. TEU is a measure of volume in units of 20-foot-long containers that can be transported ("Flexport Glossary Term", n.d.). It can affect RGDP directly since it facilitates the movement of goods and services, which supports economic activity. As TEU volumes rise, it indicates a higher level of trading, export-import transactions, and output level, which contribute directly to the RGDP of the country. An increase in TEU volumes is a sign of increasing exports, wider market access, and company competitiveness, all of which contribute to higher RGDP and wealth.

5.3 Key Highlights of the Literature

While numerous studies have explored the relationship between transportation infrastructure and economic growth, few have comprehensively examined various types of transport infrastructure within a single study. This study implies 4 types of transport infrastructure which are road, rail, water, and air. Not to mention, transport infrastructure investment is also included in this study to represent current initiatives for transport infrastructure. This study even advances beyond a regional focus by analysing on a panel-data global scale across 48 countries from 1995 to 2021. Further categorising these into developed countries and developing countries. Enabling comparative analyses between country groups, enriching the understanding of these relationships.

Next, the research also met all 3 research objectives. In detail, the findings indicate that transport infrastructure has a long-run effect towards economic growth, in the overall, developed and developing countries. On the other hand, in the overall context and developed countries, transportation infrastructure investment has a negative relationship towards economic growth. Last but not least, for individual transport infrastructure variables, the findings found that different transport infrastructures have different effects and magnitudes towards economic growth.

5.4 Limitations and Recommendations

Due to data availability issues, the data period spanning from 1995 to 2021 is the maximum period the research can achieve for panel data with 48 countries. It may seem short, but it is good enough in this study to achieve the objectives. Just that, with a longer period, it will be more interesting as it can fully capture the historical development and long-term impacts of transport infrastructure on economic growth, specifically during the intense post-World War II development period. As some unique measurement data sources are only available in the OECD, the incompleteness of data with limited countries' participation constrained us from carrying out bigger research. Therefore, future research should better emphasise collecting data which have more reliable sources and are easily accessed as they are vital in the review of policies. Also, time series analysis will be fine, as it will provide more in-depth results across the timeline.

Although this study segmented transport infrastructure into different types, with data availability constraints, each variable was restricted to a single measurement unit only. This limitation hinders the depth of analysis, particularly in examining subsectors within each transportation type and its investment. This study recommends future studies to add more variables to explore alternative proxies which can enhance the depth and breadth of the study. Like, examining subsectors within investment for each transportation type could yield nuanced insights into their respective impacts on economic growth, making policies easier to formulate.

5.5 Summary

This study has successfully achieved all research objectives. This study used the FMOLS estimation model to determine the relationship between transportation infrastructure and economic growth. This study suggested that transportation infrastructure is a crucial booster of economic growth, especially in the long run. Specifically, water transport is found to be important in developed countries while road has a significant positive impact on developing countries' economic growth. On the other hand, railway and air transport were found to be not as crucial as water and road transport toward economic growth mainly due to their high costs. In a similar vein, transportation infrastructure investment tends to negatively affect economic growth, especially in developed countries.

The influence of transportation infrastructure on economic growth has been affirmed in prior research. However, this study delves deeper into various types of transportation, presenting novel insights beyond previous findings. The findings of the relationship between transportation infrastructure and transportation infrastructure investment towards economic growth should be drawn to attention by policymakers and researchers to carry out strategic fund allocation and planned transportation infrastructure development. This study also recommends future studies to add more variables to explore alternative proxies to enhance the depth and breadth of the study.

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Appendices

Appendix 1

Comparison of DOLS Lag & Lead selection method on Panel Data Result.

	ALL		**Developed**		**Developing**	
Information Criterion	Akaike	Schwarz	Akaike	Schwarz	Akaike	Schwarz
LOG(CAPITAL)	0.590***	0.590***	0.530***	0.530***	1.017**	1.017*
	(0.082)	(0.082)	(0.087)	(0.087)	(0.551)	(0.551)
LOG(LABOUR)	0.486***	0.486*	0.613***	0.613**	-1.678	-1.678
	(0.263)	(0.263)	(0.251)	(0.251)	(5.550)	(5.550)
LOG(RAIL_DENSITY)	0.221	0.221	0.297	0.297**	-0.948	-0.948
	(0.153)	(0.153)	(0.135)	(0.135)	(1.147)	(1.147)
LOG(ROAD_DENSITY)	0.009	0.009	0.0004	0.0004	0.697**	0.697*
	(0.031)	(0.031)	(0.025)	(0.025)	(0.334)	(0.334)
LOG(WATER+1)	0.002***	0.002	0.003***	0.003	-0.103	-0.103
	(0.012)	(0.012)	(0.010)	(0.010)	(0.109)	(0.109)
LOG(AIR+1)	-0.066	-0.066	-0.098	-0.098**	-0.220	-0.220
	(0.045)	(0.045)	(0.048)	(0.048)	(0.164)	(0.164)
LOG(INVESTMENT)	-0.044***	-0.044	0.026***	0.026	-0.022	-0.022
	(0.053)	(0.053)	(0.066)	(0.066)	(0.099)	(0.099)
Wald Test F-Stat	1.091	1.091	2.069*	2.069*	2.723*	2.723*

Notes: log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment., **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*

Appendix 2

Comparison of DOLS Lag & Lead selection method of sub-sample with 41countries.

Variables Information Criterion	ALL Akaike	 Schwarz	Developed Akaike	 Schwarz	Developing Akaike	 Schwarz
LOG(CAPITAL)	0.590***	0.590***	0.530***	0.530***	1.017**	1.017*
	(0.082)	(0.082)	(0.087)	(0.087)	(0.551)	(0.551)
LOG(LABOUR)	0.486***	0.486*	0.613***	0.613**	-1.678	-1.678
	(0.263)	(0.263)	(0.251)	(0.251)	(5.550)	(5.550)
LOG(RAIL_DENSITY)	0.221	0.221	0.297	0.297**	-0.948	-0.948
	(0.153)	(0.153)	(0.135)	(0.135)	(1.147)	(1.147)
LOG(ROAD_DENSITY)	0.009	0.009	0.0004	0.0004	0.697**	0.697*
	(0.031)	(0.031)	(0.025)	(0.025)	(0.334)	(0.334)
LOG(WATER+1)	0.002***	0.002	0.003***	0.003	-0.103	-0.103
	(0.012)	(0.012)	(0.010)	(0.010)	(0.109)	(0.109)
LOG(AIR+1)	-0.066	-0.066	-0.098	-0.098**	-0.220	-0.220
	(0.045)	(0.045)	(0.048)	(0.048)	(0.164)	(0.164)
LOG(INVESTMENT)	-0.044***	-0.044	0.026***	0.026	-0.022	-0.022
	(0.053)	(0.053)	(0.066)	(0.066)	(0.099)	(0.099)
Wald Test F-Stat	1.091	1.091	2.069	2.069	2.723*	2.723*

Notes: log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment., **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*

Appendix 3

Comparison of DOLS Lag & Lead selection method on estimator using GDP Per Capital as economic growth measurement.

Variables	**ALL**		**Developed**		**Developing**	
Information Criterion	Akaike	Schwarz	Akaike	Schwarz	Akaike	Schwarz
LOG(CAPITAL)	0.656***	0.656***	0.571***	0.571***	1.167	1.167
	(0.093)	(0.093)	(0.094)	(0.094)	(0.657)	(0.657)
LOG(LABOUR)	-0.265	-0.265	-0.102	-0.102	-1.978	-1.978
	(0.298)	(0.298)	(0.271)	(0.271)	(6.624)	(6.624)
LOG(RAIL_DENSITY)	0.146	0.146	0.236	0.236	-1.231	-1.231
	(0.173)	(0.173)	(0.145)	(0.145)	(1.369)	(1.369)
LOG(ROAD_DENSITY)	0.017	0.017	0.005	0.005	0.858*	0.858*
	(0.035)	(0.035)	(0.027)	(0.027)	(0.398)	(0.398)
LOG(WATER+1)	-0.001	-0.001	0.0003	0	-0.127	-0.127
	(0.013)	(0.013)	(0.010)	(0.010)	(0.130)	(0.130)
LOG(AIR+1)	-0.068	-0.068	-0.106**	-0.106**	-0.298	-0.298
	(0.051)	(0.051)	(0.052)	(0.052)	(0.196)	(0.196)
LOG(INVESTMENT)	-0.063	-0.063	0.022	0.022	-0.031	-0.031
	(0.060)	(0.060)	(0.071)	(0.071)	(0.118)	(0.118)
Wald Test F-Stat	0.637***	0.637***	1.495***	1.495***	2.92***	2.92***

Notes: log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment., **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*

Appendix 4

Countries of smaller sub-sample data set.

Developing Countries	Developed Counties
Albania, Armeni, Georgia, Azerbaijan, Belarus, Moldova, Bulgaria, North, Macedonia, Russian Federation, Turkiye, Serbia	Austria, Belgium, Canada, Croation, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Korea, Rep., Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States

Appendix 5

Country data collect from complementary source.

Country	Indicator Name	Data Source
China	ROAD	National Bureau of Statistics of China
China	WATER	World Bank Data
India	ROAD	India Ministry of Road Transportation & Highway
Japan	ROAD	Japan Ministry of Land, Infrastructure, Transport and Tourism
Montenegro	WATER	World Bank Data
New Zealand	ROAD DENSITY	Nation Master
Ukraine	INVESTMENT	The Price of States, Case Ukraine

Appendix 6

Unit Root Tests Result for Overall Sub-Sample Data Set with 41 Countries.

	LLC		IPS		Fisher PP	
Variables	Intercept	Intercept with trend	Intercept	Intercept with trend	Intercept	Intercept with trend
Level						
log(GDP)	-8.787***	-2.073**	-1.524*	0.433	166.112***	59.023
log(Capital)	-9.000***	-8.246***	-3.533***	-5.755***	136.252***	198.367***
log(Labour)	-1.756**	2.998	2.908	0.099	145.853	58.621
log(Rail_Density)	-3.374***	-15.276***	-2.985***	-9.493***	72.869***	224.838***
log(Road_Density)	7.698	12.370	-5.150***	-7.481***	231.634***	204.455***
log(Water+1)	-7.645***	-32.681***	-4.241***	-12.427***	99.139***	329.178***
log(Air+1)	0.789	-3.178***	-0.417	-3.058***	98.464	111.424**
log(Investment)	-4.763***	-2.904***	-4.411***	-1.842**	127.64***	96.745
1st Difference						
log(GDP)	-20.395***	-18.678***	-19.958***	-18.099***	508.128***	511.941***
log(Capital)	-20.102***	-17.487***	-20.512***	-17.203***	591.361***	1058.99***
log(Labour)	-10.814***	-15.381***	-15.874***	-15.504***	451.142***	394.243***
log(Rail_Density)	-37.336***	-41.007***	-31.005***	-26.741***	795.350***	2161.97***
log(Road_Density)	-246.988***	-46.880***	-68.772***	-23.378***	895.622***	1306.25***
log(Water+1)	-92.116***	-76.357***	-35.076***	-33.206***	504.914***	904.661***
log(Air+1)	-26.720***	-24.995***	-26.100***	-19.599***	730.961***	861.340***
log(Investment)	-19.642***	-13.625***	-20.027***	-13.813***	603.395***	872.163***

*Notes: log(RGDP) is Log Real GDP, log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment. *, **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*

Appendix 7

Unit Root Tests Result for Developed Countries in Sub-Sample Data Set with 41 Countries.

	LLC		IPS		Fisher PP	
Variables	Intercept	Intercept with trend	Intercept	Intercept with trend	Intercept	Intercept with trend
Level						
log(GDP)	-8.560***	-3.332***	-2.662***	-0.504	152.173***	47.105
log(Capital)	-3.286***	-3.272***	-0.201	-4.038***	69.774	82.333**
log(Labour)	-2.868***	-1.742**	2.234	-2.100**	53.509	47.671
log(Rail_Density)	-1.437*	-9.401***	-1.442*	-6.648***	95.719***	182.002***
log(Road_Density)	14.455	17.843	-4.724***	-8.74***	178.161***	166.852***
log(Water+1)	-7.496***	-32.613***	-4.714***	-13.548***	89.041***	319.837***
log(Air+1)	0.816	-2.035**	-0.011	-2.447***	80.094**	89.109***
log(Investment)	-2.804***	-2.053**	-2.816***	-1.145	87.264**	66.997
1st Difference						
log(GDP)	-18.211***	-16.728***	-17.319***	-15.809***	378.760***	406.702***
log(Capital)	-17.492***	-15.244***	-18.160***	-14.936***	467.503***	943.7***
log(Labour)	-13.992***	-13.037***	-14.300***	-13.005***	331.623***	279.803***
log(Rail_Density)	-29.518***	-37.580***	-27.393***	-24.156***	627.140***	197.15***
log(Road_Density)	-250.091***	-42.571***	-76.793***	-25.024***	503.542***	933.463***
log(Water+1)	-91.698***	-79.608***	-34.745***	-32.068***	421.899***	837.217***
log(Air+1)	-22.955***	-20.742***	-22.818***	-16.348***	561.078***	527.445***
log(Investment)	-16.310***	-11.873***	-16.481***	-13.239***	424.096***	706.936***

Notes: log(RGDP) is Log Real GDP, log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment., **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*

Appendix 8

Unit Root Tests Result for Developing Countries in Sub-Sample Data Set with 41 Countries.

	LLC		**IPS**		**Fisher PP**	
Variables	Intercept	Intercept with trend	Intercept	Intercept with trend	Intercept	Intercept with trend
Level						
log(GDP)	-3.240***	1.008	1.477	1.671	13.939	11.918
log(Capital)	-9.726***	-8.517***	-6.969***	-4.600***	66.478***	116.034***
log(Labour)	2.015	7.523	1.922	3.669	19.360	10.949
log(Rail_Density)	-3.506***	-11.803	-3.173***	-7.483***	50.691***	44.073***
log(Road_Density)	-6.398***	-3.538***	-2.196**	-1.069	53.473***	37.603**
log(Water+1)	-1.343*	0.349	0.085	-0.297	10.098	9.341
log(Air+1)	0.504	-2.131**	-0.786	-1.915**	18.370	22.315
log(Investment)	-4.773***	-2.279**	-3.780***	-1.525*	40.376***	29.748
1st Difference						
log(GDP)	-9.405***	-8.552***	-9.925***	-8.826***	129.368***	105.239***
log(Capital)	-10.353***	-8.930***	-9.542***	-8.545***	123.858***	115.290***
log(Labour)	-1.052**	-8.366***	-7.058***	-8.456***	119.519***	114.439***
log(Rail_Density)	-24.277***	-18.528***	-15.039***	-11.922***	183.447***	202.263***
log(Road_Density)	-6.215***	-17.933***	-9.977***	-7.645***	392.079***	372.790***
log(Water+1)	-7.919***	-6.597***	-8.430***	-10.184***	83.016***	67.444***
log(Air+1)	-13.933***	-14.568***	-12.691***	-11.157***	169.883***	333.895***
log(Investment)	-11.133***	-6.746***	-11.394***	-5.736***	179.299***	165.227***

*Notes: log(RGDP) is Log Real GDP, log(Capital) is Log Capital, log(Labour)is Log Labour, log(Rail_Density) is Log Rail Transport Infrastructure, log(Road_Density) is Log Road Density, log(Water+1) is Log Water Transport Infrastructure, log(Air+1) is Log Air Transport Infrastructure, and log(Investment)is Log Transport Infrastructure Investment. *, **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*

Appendix 9

Unit Root Tests Result for RGDP per Capita.

	LLC		**IPS**		**Fisher PP**	
Variables	Intercept	Intercept with trend	Intercept	Intercept with trend	Intercept	Intercept with trend
Overall						
Level	-6.556***	-1.587*	-1.433*	0.018	185.863***	70.851
1st Difference	-21.407***	-19.357***	-21.334***	-18.824***	579.033***	562.541***
Developed						
Level	-6.579***	-3.149***	-3.053***	-0.662	164.099***	51.678
1st Difference	-18.411***	-16.59***	-17.965***	-15.891***	404.067***	421.059***
Developing						
Level	-3.030***	1.371	1.989	0.995	21.764	19.174
1st Difference	-11.237***	-10.291***	-11.516***	-10.098***	174.966***	141.482***

*Notes: *, **, and *** denotes significant at 0.10 level, 0.05 level and 0.01 level respectively.*