Department of Economics and Finance

Program: Economics and Business, Major in Management

Course: Sustainable Development, Energy and Climate

"Maximizing Sri Lanka's Railway Potential: Sustainability & European Insights"

SUPERVISOR

Prof. Aldo Ravazzi Douvan

CANDIDATE

Sharique Naveed Mohin[1]

Id: 275081

[1] shariquemohin5@gmail.com

"Maximizing Sri Lanka's Railway Potential:
Sustainability & European Insights"

Abstract

Railway transport plays a crucial role in sustainability and economic mobility, yet Sri Lanka's network continues to grapple with inefficiencies, outdated infrastructure, and poor integration. This study examines the country's rail sector through a comparative lens, drawing insights from successful European models to analyze infrastructure management, public perception, digitalization, and sustainability.

The findings reveal significant underutilization and operational inefficiencies, but there are practical, cost-effective solutions. Enhancing scheduling, implementing digital ticketing, electrifying key routes, and integrating multi-modal transport could dramatically improve efficiency. Meanwhile, innovative financing strategies—such as public-private partnerships (PPPs) and Hong Kong's "Rail + Property" model—offer promising avenues for investment and long-term growth.

A data-driven modernization strategy can enhance financial stability, social inclusivity, and sustainability in Sri Lanka's rail and transport sector as a whole. Future research should delve deeper into financing mechanisms, technological advancements, and regulatory reforms to ensure lasting improvements.

Keywords: Sri Lanka Railway, Sustainable Transport, Infrastructure Modernization, Public-Private Partnerships, Electrification, Multi-Modal Transport, European Railway Models

Word count: 13,493 words

Table of Contents

Introduction

The railways have long been considered as one of the most efficient and fair mode of transportation, having a low environmental footprint, and some could even say less resource intensive than road-based transport such as private cars or busses. Across the world, the rail system has played a significant role in a nation's economic development, expansion, and in the modern context environmentally friendly, fast, and clean transportation. However, the success of the railways does not depend solely on efficiency, accessibility, and sustainability. The core challenge for a country like Sri Lanka is not expanding its railway network but maximizing the utility of the existing network to become more efficient and sustainable.

Developing Sri Lanka's rail sector is significantly associated with the broader socio-economic and environmental concept. To resolve these issues, solutions such as significant overhauls or system change cannot be a near term solution; thus, we should approach with a holistic, strategic, and data-driven approach. The approach taken should deal with the underlying issues that plague the growth of the Sri Lankan railway, and the efficiency improvements itself shall result in improvements of sustainability.

As global trends skew towards sustainable mobility, Sri Lanka should adopt policies that enhances connectivity, increases operational efficiency, and integrate railway services into multimodal transport network. Maximizing existing infrastructure is the most practical, and cost-effective approach, especially considering the economic constraints burdening the country. Instead of introducing completely new lines from scratch, optimized rail scheduling, energy efficiency, rolling stock procurement, and digitalization can significantly improve railway services.

Sustainability is the cornerstone of railway modernization. The United Nations Sustainable Development Goals (SDGs) should serve as a relevant framework for Sri Lanka's railway system. The railway sector can make substantial contributions to several SDGs, including SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

The modernization and general improvement of the railway system can not only contribute to the previously mentioned SDGs but also indirectly to SDG 8 (Decent work and Economic growth), SDG 10 (Reduced Inequalities), and even SDG 4 (Quality Education). By adopting a resource-efficient approach to modernizing railway infrastructure, Sri Lanka can reduce its carbon footprint while enhancing connectivity for millions of daily commuters.

Ultimately, railway reform should not be perceived as a temporary solution but as a long-term commitment to enhancing public transportation. A superficial approach will not provide the structural transformation necessary to create an efficient, cost-effective, and environmentally sustainable railway system. This thesis investigates the core challenges and limitations of Sri Lanka's railway sector, explore sustainable and financially viable improvements, while drawing insights from European models to formulate policy recommendations that align with UN sustainability objectives.

Through a comprehensive investigation of these themes, this research seeks to propose a roadmap for Sri Lanka's railway development that is economically feasible, socially beneficial, and environmentally responsible.

Chapter 1 Conceptual Framework

This chapter will be dedicated to the discussion of the Introduction and Conceptual Framework of the contemporary Sri Lankan Railway system. From an overview serving as the introduction, covering the historical development of Sri Lanka's Railways and the general purpose of the rail in the nation, to the significance of sustainability in transportation, while encompassing the Sustainable Development Goals that would be achieved through the advancement of the Railway.

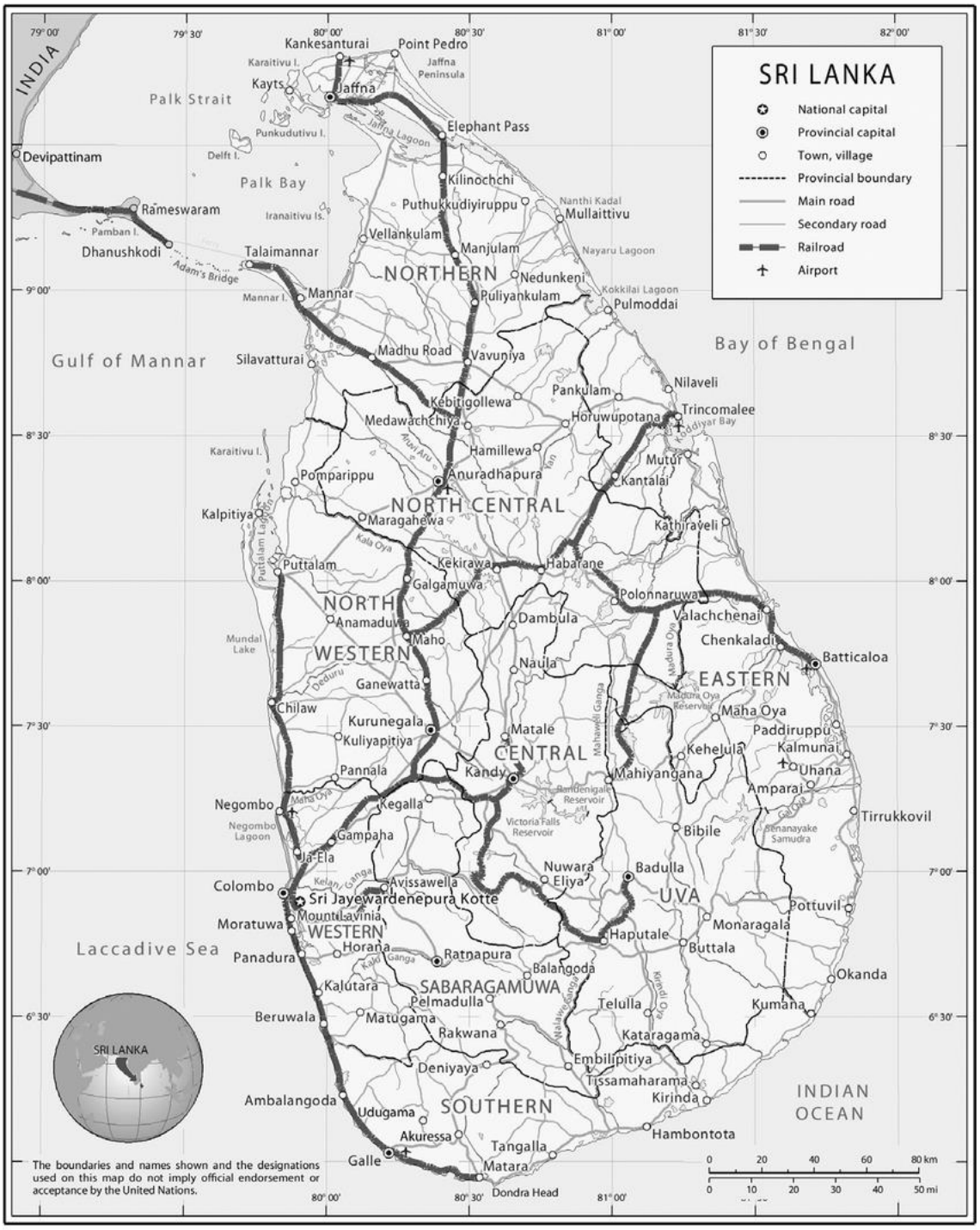

Figure 1 Map of Sri Lanka comprising of Sri Lankan transport networks (United Nations, 2008)

1.1 Overview of Rail Transportation in Sri Lanka

The Sri Lankan Railway or then called the Ceylon Railways was inaugurated on the 27th of December 1864, marking its 160th year of operation at the time of writing this thesis. It started off to serve the freight needs of the burgeoning British colonial empire. It started as a mode of transportation of coffee from the uplands to the port city of Colombo, this sector can be seen in Figure 1 starting from the Central areas namely Kandy traversing towards the South West of the island. While returning from Colombo it furnished the highlands with labor, machinery, and other essential items to continue the agricultural operations. As time progressed, many of the coffee plantations were hit with blight, a plant disease which is caused of fungal nature. This pushed the corporate management to switch to crops such as tea, which flourished and rapidly increased demand for rail, pushing the British to expand the tracks by another 100 miles. However, this increase in demand was met with more labor requirements in the central highlands, which in part made the railway to expand its passenger operations. As the British sought to exploit further agricultural developments, they increased the railway to the Northwest, West, and Southwest parts of the island, while there was further expansion to the central highland areas. The presence of a natural harbor in the northeastern city of Trincomalee compelled the British to extend their railway network towards it, even though the region was a dry zone with limited agricultural activity (Kesavan, et al., 2015)

At the turn of the 1940's the focus on road development took a central role in the nation's transport infrastructure, opening a golden era of road-based transport. This however, started to have a negative effect on the nation's railway transport, as seen below in Figure 2, the extensions, and additions of the railway system took a brief gap of expansions from 1956 to 1990, and instead only modernization efforts were conducted (Kesavan, et al., 2015).

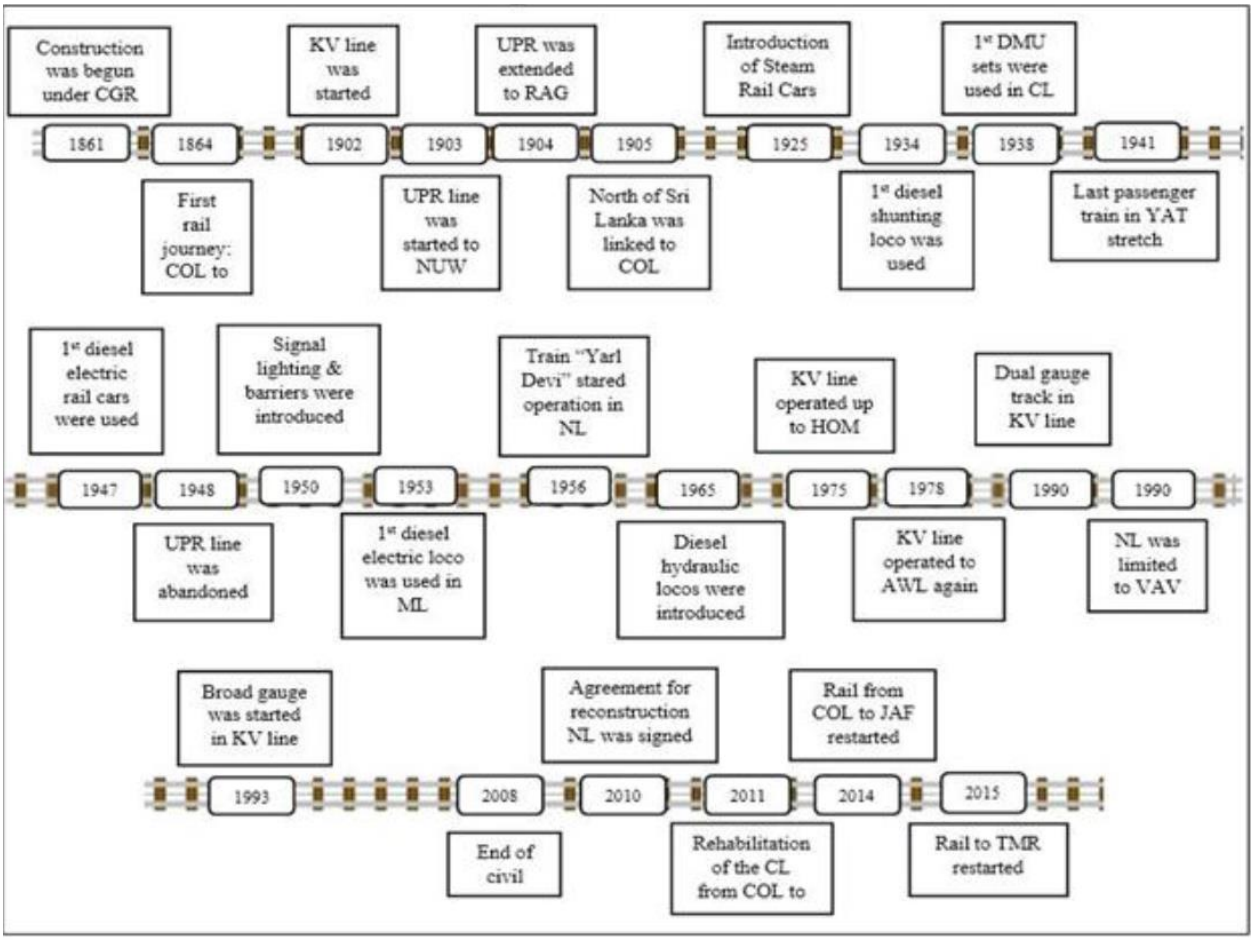

Figure 2: This timeline presents key milestones in the development of Sri Lanka's railway network from 1861 to 2015. It highlights major expansions, technological advancements, and reconstruction efforts. Notable abbreviations: KV – Kelani Valley Line, UPR – Upcountry Railway, NL – Northern Line, CL – Coastal Line, AWL – Avissawella, HOM – Homagama, VAV – Vavuniya, YAT – Yatiyantota, RAG – Ragama, TMR – Trincomalee, COL – Colombo. Adapted from (Kesavan, et al., 2015)

Upon further examination of the timeline and observation of changes in the Sri Lankan railway, a leapfrog effect emerges from the gap between revenue collection and operational expenditure. In other words, farebox recovery declined, delaying essential modernization efforts. Furthermore, while revenue collection stagnated, the organization encountered increasing political interventions and trade unionization, which progressively hindered any potential upgrades. Eventually, upgrades and modernization efforts regressed due to the civil war from 1983 to 2009. However, the post-war period witnessed a surge of reconstruction and modernization efforts (Kesavan et al., 2015). The immediate post-war railway construction efforts reflected the political will to ensure the continued development of railway infrastructure. Once the railway lines were fully constructed with the assistance of the Government of India, the line became a popular mode of transportation

between the South and North. The line reached its capacity, necessitating the implementation of special weekend services (Thalpawila, 2016)

Year	2017	2018	2019	2020	2021	2022
No of Diesel Electric Loco	95	56	59	103	103	103
Number of Diesel Hydraulic Locos	42	28	30	42	42	41
No of Diesel Multiple Units	102	149	75	106	106	133
No of Carriages	583	825	590	1,418	1,480	710
No of Cargo Wagons	234	787	737	1,999	1,994	335
No of Oil Tankers	228	228	258	273	278	220
No of Operable Steam Locomotives	3	3	3	4	3	3

Figure 3 The yearly count of rolling stock. Data from (Government of Sri Lanka, 2025)

This brings us to the present day, where, according to the most recent data available in 2022, as presented in Figure 6, the share of diesel electric locomotives and diesel multiple units has increased, while the number of carriages has decreased. This indicates a general increase in passenger numbers, but passenger hauling capacity has decreased. In terms of freight capacity, the number of cargo wagons and oil tankers has also experienced a year-on-year decrease, which could be a sign of a slowdown due to Covid-19 or the economic downturn. (Government of Sri Lanka, 2025)

Year	2017	2018	2019	2020	2021	2022
Total trips operated (Both passenger and goods trains)	120,311	117,189	115,232	86,251	69,036	110,916
No. of Passengers Carried (in millions)	-	-	-	-	-	281,458
Number of trains a day	370	375	-	-	-	-
Number of Passenger trains per day	330	274	316	223	174	289
Number of goods trains per day	19	23	18	-	-	-
Number of passengers carried a day	374,419	367,000	352,000	178,301	98,527	281,458
Number of Goods carried a day (MT)	5,473	6,845	4,931	4,939	5,027	4,778
Freight Traffic Density per year (Ton Km Mn)	144.79	119.78	120.85	114.37	161.56	138.68*
Number of freight trains per day	18	36	18	13	15	15
Passenger Traffic Density per year (Passenger Kms)	7,495	7,709	7,309	3,905	2,158	6,602

Figure 4 Operational Overview of the Railway. Data from (Government of Sri Lanka, 2025)

While looking at from an operational standpoint of view and considering that the most recent data is still till 2022, we see passenger traffic remains above 350,000 people per day till 2019, the last year before Covid-19 lockdowns. As global trends recover back to pre-pandemic levels, we can assume the ridership has started returning at least close to pre covid levels. (Government of Sri Lanka, 2025)

1.2 Sustainable Development Goals (SDGs) & the 2030 Agenda

The UN Sustainable Development Goals, i.e. SDGs, are central to the 2030 agenda for sustainable development. It is an outline adopted by all UN member states, that are to be taken for global peace and prosperity for the environment and people of Earth, it calls for all countries of all income categories to work together in tackling critical humanitarian issues at hand, while simultaneously taking steps to protect our natural environment. Among the 17 SDG's, railway development aligns closely with SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action). Additionally, an indirect case of improving the railway infrastructure will support SDG 8 (Decent Work and Economic Growth), SDG 10 (Reduced Inequalities), and SDG 4 (Quality Education). (United Nations, 2015)

The Sustainable Development Goals (SDGs) are the culmination of decades of global efforts toward sustainability, beginning with the 1992 Earth Summit in Brazil, where 178 countries adopted Agenda 21, a comprehensive plan for sustainable development. The first concrete goals emerged from the 2000 Millennium Summit at the UN headquarters in New York, leading to the Millennium Development Goals (MDGs), which successfully aimed to reduce global poverty by 2015. As the MDGs era neared its end, discussions for a successor framework began at the Rio+20 conference in 2012, where mandates for further sustainability measures were established. This led to the formation of a 30-member Open Working Group, which developed the SDGs through negotiations with the UN General Assembly. In January 2015, these discussions culminated in proposing the adoption of the 2030 Agenda for Sustainable Development which was approved in September of that year. Today, the SDGs continue to be reviewed and advanced through an annual global forum. (United Nations, 2015)

Counting global trends since the inception of the 2030 Agenda, the progress presented has been uneven. According to the UN SDG Progress report of 2024, only 17% of SDG targets are currently on track, while 35% of the goals has witnessed points of no progress, or even worse, regression. This highlights the urgent need for enhanced policy implementation, especially in infrastructure, climate resilience, and sustainable urban development. As illustrated by Figure 5, we can see the progress levels, i.e. the percentage of completions: this further highlights the lack of progress by

humanity. As we delve deeper into the SDGs progress report, we come across Figure 3, where we can see the progress of each goal, and as discussed before the goals most concerning about the railway development is SDG, SDG9, SDG11, and SDG13, has only made on average moderate or marginal progress, representing a lack of achievement as of now. This would underscore the importance of policies such as railway modernization and improvement, further the other indirect goals as we described them as before, SDG4, SDG8, and SDG10 have also shown disappointing results (UN General Assembly Economic and Social Council, 2024).

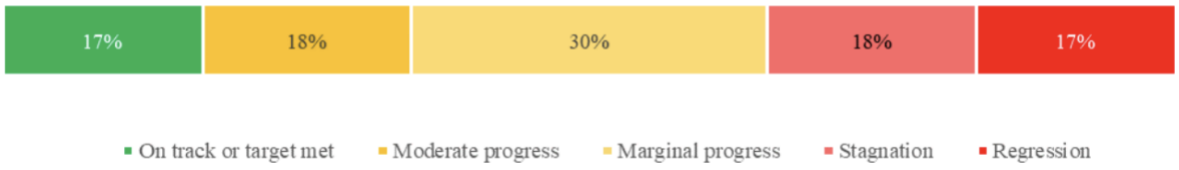

Figure 5 Overall progress assessment across targets with trend data, 2024 (UN General Assembly Economic and Social Council, 2024)

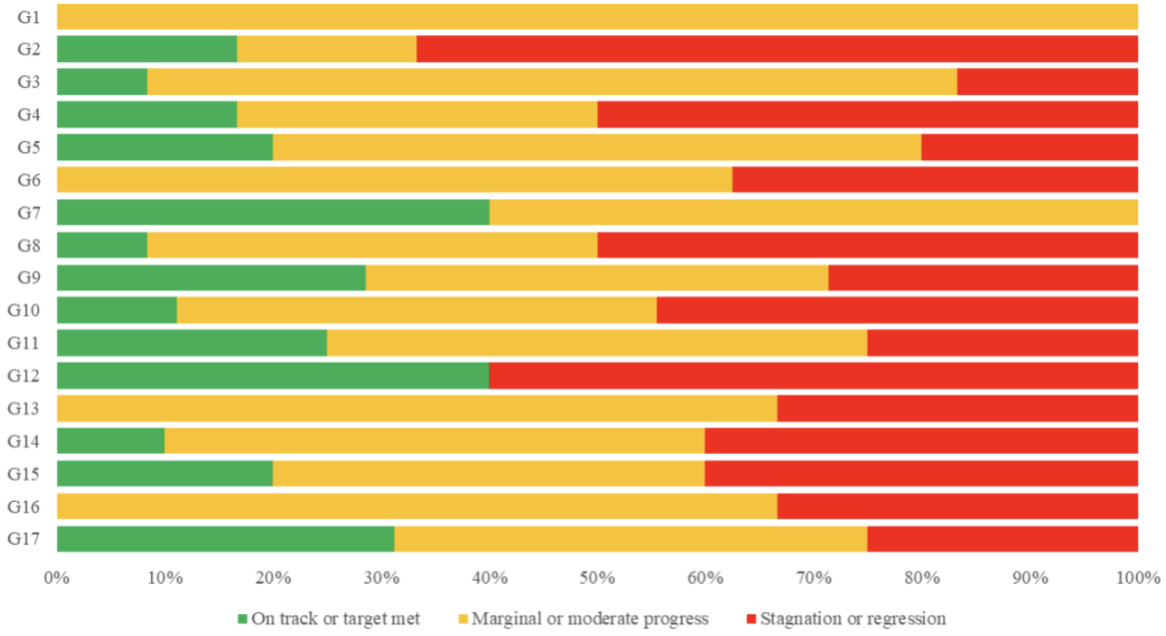

Figure 6 Progress assessment for the 17 Goals based on assessed targets with trend data, by Goal (UN General Assembly Economic and Social Council, 2024)

As we continue scrutinizing the relevant SDG goals individually, we can see where the improvement or regression is coming from, but as we would not be able to individually assess all the factors, we can focus on factors that could be considered generally imperative to the areas we need to focus on for the goals of this thesis. When considering the main goals outlined previously, SDG9 has seen a positive reduction of CO2 emissions from 2015 to 2021 of a rate of 11.5%, however we would also need to consider that during this period there was a significant slowdown in many activities due to the Covid 19 pandemic. For SDG11, according to the SDG progress report, "In 2022, 24.8% of the urban population lived in slums or slum-like conditions, slightly lower than 25% in 2015, but higher than 24.2% in 2020. The total number of slum dwellers was 1.12 billion in 2022, 130 million more than in 2015": this could be a result of the pandemic economic slowdowns as well, but there still is a general increase in the amount of people living in squalid conditions, which highlights the need for effective policy implementation. Further, global sprawling has increased at a rate of 5.6% annually, compared to the 1.5% densification: this puts immense pressure on the valuable natural land that exists, and could negatively affect the natural habitat. It might be possible to alleviate the level of damage done to natural lands by encouraging densification by making public transport more accessible, namely the railways which brings more high-capacity arrivals of passengers into one area. Continuing to SDG13, the climate actions of countries, as seen in the graph as well is meager and this pattern of achievements is reflected by the Earth's average temperature increasing above 1.45 degrees Celsius in 2023 compared to 1850, the closest it has got to the 1.5-degree lower threshold of the Paris Climate Agreement. (UN General Assembly Economic and Social Council, 2024)

Lastly, when we bring attention to the indirect contributions, we see how a well-developed railway could aid in reducing socio-economic inequalities (SDG 10) by providing affordable transportation options for marginalized communities. Furthermore, efficient rail connectivity enhances access to employment opportunities (SDG 8) and facilitates student mobility, thereby improving education accessibility (SDG 4). As Sri Lanka modernizes its railway network, integrating sustainability principles, digitalization, and resource efficiency will be key to ensuring that its transport sector aligns with the global sustainability agenda. The subsequent chapters of

this thesis will explore how policy interventions, technological advancements, and optimized infrastructure utilization can drive Sri Lanka's rail sector toward achieving these goals.

1.3 Importance of Cost-Effective Sustainable Development

As Sri Lanka emerges from the Covid 19 triggered economic crisis, an economy already weakened by the Easter bombings, a series of terrorist attacks staged across Sri Lanka in 2019, the finances and resources available for the country was minute. This combined with the fact that Sri Lanka, imported a significant amount of its essential items, put a strain on the foreign exchange reserves, which meant any import had to be of high importance to be imported. As the country emerges from the economic crisis, the government must be extremely careful in using its limited resources, thus cost-effective measures remain imperative to fund sustainable development (Weerasinghe, et al., 2023). Furthermore, when talking about topics such as sustainable development, policy makers tend to fall for a phenomenon known as double costing, because when considering the improvement of a certain SDG goal, whereas when there is a plan to improve a certain area of the economy, there is a disregard of how it could positively affect other areas. To conceptualize this, we can look at the World Bank paper (Vorisek & Shu, 2020), "For example, improvements in water and sanitation infrastructure can reduce child mortality. Improvements in health indicators can reduce poverty, and vice-versa". This indicates that investment into one area might affect another, and the synergy between the two areas, as stated by (Vorisek & Shu, 2020), from the IMF to the WHO has either been miscalculated or not calculated at all. This builds the situation in which the economic effects of investing into one economic area such as the railways, which as described earlier should only be affecting SDG9, SDG11, and SDG13, but would indirectly improve progress of SDG8, SDG10, and SDG4.

An example of cost-effective policies that can be taken for railway modernization could be the electrification of the railway. It cannot be done to the whole network immediately and thus must be done methodically and progressively. The investment to most railways is usually not a for-profit venture, but this does not amount to efficiency being disregarded, financial resources are being used to keep the organization afloat, and policies such as electrification could alleviate the burden placed on the State. Electrification could introduce economic value by reducing the need to

purchase diesel, and if the energy mix is replenished with more renewables, the emissions would fall, while if the energy mix was filled with more polluting fuels, it would be more harmful to the environment, and only mitigating point of consumption emissions. However, as discussed before it may help for the case of Sri Lanka's import dependent economy, and the transport synergy would be aided as there would not be a need to invest as much in roads and other vehicles. However, it would not make sense to electrify low density routes immediately, rather it would hold more significance in introducing electrified sections to high density sectors, thus remaining cost effective. (Siyambalapitiya, 2021). A similar phenomenon could be observed in Germany, whereas of 2019, 40% of tracks have not been electrified, and as the German government's "Bundesverkherswegeplan", or "Plan for Federal Traffic Routes", several tracks that are currently not electrified are to be electrified. But as in Sri Lanka, all of them cannot be electrified simultaneously. For a sustainable plan, cost benefit analysis must be conducted, but instead of the previous paper mentioned, where the highest passenger density sections are electrified, the German railway company, Deutsche Bahn, would electrify a track of more where than 1350 tons are transported per hour, or in the cases of high-speed corridors, 800 tons per hour and one operation per hour. This case highlights that although the environmental will would remain high, it does not always make economic sense, to immediately electrify, thus holding advantages of the diesel-powered trainsets. Moreover, following the rule of thumb, the costs of electrifying a kilometer of track is around one million Euros, a similar saving must be received for the investment to deem it worthy of investment. (Müller, Gürster, Schmidt, Obrenovic, & Bierlaire, 2019)

1.4 Research Objectives & Scope

This research endeavors to explore sustainable strategies for maximizing the utility of Sri Lanka's existing infrastructure. Sustainable policy implementations should remain cost-effective and address the environmental and social challenges currently impacting the system. The study investigates the limitations of Sri Lanka's national railways, including outdated infrastructure, inefficient scheduling, lack of multimodal integration, and inadequate digitization. This investigation aims to identify the fundamental issues that must be addressed at the core of the

railway system. By comparing Sri Lanka's railway development strategies with successful European models, this research seeks to identify adaptable policies and solutions tailored to the Sri Lankan context while ensuring financial viability. Additionally, the study explores potential financing mechanisms, such as public-private partnerships, to support sustainable railway expansion without imposing excessive fiscal burdens. The primary focus of this research is on Sri Lanka's existing railway infrastructure, its operational inefficiencies, and feasible modernization strategies. Drawing insights from global railway systems, the study seeks to formulate comprehensive policy recommendations that enhance railway efficiency, support national economic objectives, and contribute to long-term sustainability efforts.

Chapter 2 Methodology

2.1 Research Approach

This qualitative research study examines the comparative challenges and best practices of railway systems in Sri Lanka and Europe. Railway infrastructure, governance, and financing mechanisms are inherently complex, necessitating an in-depth understanding of technical, economic, and policy-based components. To address this complexity, thematic analysis was employed to identify patterns and key issues across various domains, including safety, accessibility, multi-modal transport, and cost-effective infrastructure strategies. The research primarily relies on secondary data sources, such as government reports, policy papers, academic journals, and industry publications. Given data limitations and inconsistencies in official Sri Lankan sources, the study emphasizes qualitative analysis, supplemented by descriptive statistics where applicable.

2.2 Data Collection Methods

Data for this study was gathered from various sources. Government and institutional reports, such as those from the Sri Lankan Ministry of Transport, Sri Lanka Railways (SLR), and the World Bank, and were thoroughly analyzed. These documents provided valuable insights into policy directions, existing challenges, and proposed solutions. Due to logistical and resource constraints,

fieldwork was not conducted, limiting the ability to collect primary data directly for this thesis. In addition, due to the lack of transparency in some Sri Lankan government reports, additional verification was required through cross-referencing with global sources, news articles, and expert opinions. Journals, railway industry white papers, and European Union policy documents were also used to compare Sri Lankan railway inefficiencies with best practices in Europe. Special attention was given to studies on public-private partnerships (PPPs), digitalization, safety protocols, and multi-modal transport integration.

To gain a deeper understanding of the topic, YouTube mini documentaries were utilized to provide deeper visual insights into global transit models. These documentaries offered valuable perspectives on operational practices, passenger experiences, and infrastructure design. Through fact-checking against academic and institutional sources, the reliability of these videos was maintained. Their visual content enhanced the practical application of theoretical concepts. Additionally, personal experiences in major European cities provided firsthand exposure to European railway systems. This experiential learning helped direct the research focus towards the most pressing issues.

2.3 Data analysis strategy

The collected data was analyzed using a thematic analysis approach. The findings were categorized into four primary areas: safety, accessibility, infrastructure efficiency, and financing mechanisms. Patterns were drawn by comparing Sri Lanka's railway inefficiencies with European best practices, particularly in Germany, Sweden, and the UK. A detailed comparison was conducted in each key area, focusing on multi-modal integration, regulatory frameworks, and investment strategies. European railway models served as benchmarks to assess the feasibility of implementing similar policies in Sri Lanka. However, certain issues, such as rolling stock incompatibility, lacked extensive academic research, making it challenging to conduct a fully quantitative assessment. Additionally, government reports often omitted detailed breakdowns of operational failures, necessitating interpretative analysis based on available secondary sources.

In some cases, the data presented in official reports lacked mathematical consistency. For instance, when analyzing the share of different modes of transport, the official data released sometimes added up to more than 100%, indicating errors or inconsistencies in the reporting process. Furthermore, some data was poorly organized, lacking basic formatting that would have facilitated easier interpretation and analysis. These issues highlighted the need for scrutiny and cross-verification of data to ensure reliability and accuracy in the findings.

2.4 Research limitations

Despite its comprehensive nature, the study encountered several limitations. Many Sri Lankan government and institutional reports provided only vague explanations of railway inefficiencies, complicating efforts to extract detailed insights. This limitation required additional interpretative efforts and reliance on global railway case studies to infer potential causes of inefficiencies. While some sources referenced issues with newer Chinese and Indian train fleets, there was a dearth of detailed technical studies analyzing the mechanical, operational, and economic impact of these incompatibilities. Due to data constraints, the study leaned heavily towards qualitative thematic analysis rather than a fully quantitative model. Future research could benefit from detailed operational data, passenger surveys, and cost-benefit assessments to provide a stronger empirical foundation.

Chapter 3 Challenges in Sri Lanka’s Railway System

3.1 Limited Rail Coverage & Punctuality

The railways play a pivotal role in public transport across Sri Lanka; however, it continues to be lagging with persistent issues related to its coverage and punctuality. As rail remains an affordable and a relatively safe mode of travel, especially in the situation of long-distance commuters,

inefficiencies in scheduling, inadequate and incompatible infrastructure, and outdated operational practices has continuously contributed to delays, and underutilization of track capacity.

According to the 2021 Administration Report (Sri Lanka Railways, 2021) by the Sri Lankan railways the network length had a total of 1,607km of track, a slight increase from the 1,593km stated in the 2019 administration report (Sri Lanka Railways, 2019). However, this underscores the lack of expansion in recent years, further limiting the railway's effectiveness. This stagnation possibly indicates railway project delays, or potentially the railway being deprioritized by the government.

Further, a 2012 Transport Sector Policy note had already identified the underutilization of existing track capacity as a major issue. This exact issue was also identified in the 2019 and 2021 administration reports, especially a lack of utilization of the areas outside of the Colombo Metropolitan region, meaning a significant chunk of the railways outside of the capital area is not being utilized to its maximum potential, demonstrating the lack of progress occurring in the railway sector, further preventing railway network optimization. This underutilization could possibly be due to the bottle neck in the capital Colombo's Maradana-Fort Sector highlighted in the 2012 Note, where it demonstrated that the urban railways operating inside the metropolitan area hindered the passage of other national railway corridors, moreover this issue is still pertinent according to the 2019 administration report. (Sri Lanka Railways, 2021) (Sri Lanka Railways, 2019) (Kumarage, Sri Lanka Transport Sector Policy Note, 2012)

in terms of punctuality: an integral part of reliability and customer experience; however, the Sri Lankan railways has been continuously struggling in this area - In Sri Lanka, on-time arrivals, defined as arrivals with delays of less than 5 minutes: have historically fluctuated - The percentage of on-time arrivals dropped to 44% in 2019 from 49% in 2018; and delays (tardiness of above 10 minutes) increased from 26% to 40% during this period - However: there were some improvements in 2021; when on-time trains increased to 57% and delays of over 10 minutes reduced to 31% - Although the recent figures show improvement, Sri Lankan railways still has over a third of trains arriving late (Sri Lanka Railways, 2019) (Sri Lanka Railways, 2021) (Kumarage, Sri Lanka Transport Sector Policy Note, 2012). Nonetheless, these figures cannot be deemed realistic: as this

period faced lockdowns limiting people's movements; and allowing trains to operate without being hindered by excessive passenger loads. As we delve deeper into the administration reports: we see that the primary causes of train delays remain unchanged; locomotive failures, track defects, failure of signaling equipment, speed restrictions due to weak track conditions, and non-availability of locomotives and power sets. These lingering issues represents a lack of amendments to implement substantial measures to resolve underlying operational inefficiencies - Although there have not been any substantial changes reported: the 2019 report indicated that at year end that there was about a 1.7% decrease in passenger trains; and a 2.7% decrease in the freight sector compared to year end 2018. It is reasonable to assume that the improvement in punctuality is due to reduced train operations: allowing more manageable train scheduling. Moreover, if we look at Figure 4, we see more than a halving of the trains operated, thus confirming that this reduction was indeed a factor of the lockdown which possibly allowed more on-time arrivals. The slight improvement in punctuality could thus be considered a temporary operational adjustment rather than long-term infrastructure development: such as double-tracking major routes, including those to Katunayake and Negombo; preventing any increase in service frequency without compromising reliability. These underlying issues must be resolved: as has been emphasized since 2012 by the Transport Sector Note by Dr. Kumarage of the World Bank.

3.2 Insufficient Infrastructure & Customer Satisfaction

As one of Asia's oldest railway networks, Sri Lanka Railways has struggled to maintain its infrastructure and uphold service standards, leading to inefficiencies in both transport operations and customer experience. Although, the railways play their crucial role in public transportation, their aging infrastructure, bureaucratic inefficiencies, and financial limitations continue to hinder their development and optimization. (Perera & Shaja, 2023). As we have told before, there has been little to no progress resolving core issues, but the state of the railways get worse as we explore the path of customer satisfaction, as the stations lack facilities, track maintenance is lacking, and ticketing systems remain antiquated. (Danthanarayana & Kumarage, 2021).

The railway infrastructure has remained largely unchanged, despite calls for modernization being echoed over the years. According to the 2023 paper by Shaja & Perera, the amount of track stood

at 1492km, main stations at 181, and sub-stations at 162, many of the lines are still dependent on outdated signaling systems and single-track operations. (Perera & Shaja, 2023). As discussed before this leads to frequent delays, congestions, and bottlenecks forming. In addition, if we look at Figure 6, the statistics provided by the government, which is only available till 2022, we see the statistics are in flux, they have a sideways growth pattern, possibly indicating that infrastructure is going offline for such a long period that even when the reporting period is over, they have remained offline, prolonging delays, and in some areas forcing trains to take a heavily restricted speed to continue safe operations.

Year	2017	2018	2019	2020	2021	2022
Total Length of the track (Km)	1568	1465	1492	1648	1607	1611
No. of Main Railway Stations	179	177	181	182	182	182
No. of Sub Railway Stations	164	162	162	163	163	163
Train Halts	61	71	71	71	71	71

Figure 7 Overview of static infrastructure (Government of Sri Lanka, 2025)

The structure of the Sri Lanka Railways (SLR) is a major contributor to inefficiency. The organization lacks operational flexibility and is heavily dependent on government subsidies for its survival (Kesavan, et al., 2015). Further restricting the survival of the utilization of funding, as seen in the 2019 and 2021 reports, the funding for railway reports remained allocated, but remained underutilized due to slow decision-making and administrative disorganization (Danthanarayana & Kumarage, 2021). Similar situations have been alleviated in other regional countries of the region such as Malaysia, and India, through the implementation of partial privatization or independent railway authorities; these policies have seen a considerable amount of success as it has seen increased infrastructure investment and service quality in their respective countries (Abeysekara, 2021). However, privatization comes with its downsides, and a major resistance would be from the employees as any privatization effort would see a major attempt to cut down on employees.

In addition to the internal struggles in improving existing infrastructure, another source of contention comes from the encroachments existing around the track. In just a small sector of the main line of the Sri Lankan Railway, namely the Maradana to Rambukkana sector, there exists 749 encroachments, which would require further resources to be relocated before upgrading any tracks (Ministry of Transport, 2025). This shows that is not only disorganized management, but lack of

legal enforcement in railway property issues. Further, if there are any plans to improve the existing infrastructure, they would be hampered due to the additional resources that need to be displaced to clear out railway property encroachments. For instance, on the previously declared sector, there are 101 curves, of which 32 have curves with a radius less than 620 meters. However, the minimum radius of a curve must be greater than 620 meters to accommodate speeds of 100 kilometers per hour. Therefore, any modernization efforts, including land acquisition costs, would necessitate the expenditure of resources on clearing encroachments. Furthermore, the addition of higher-speed rail would necessitate further land acquisition, even from encroachers, which poses a significant challenge to any modernization efforts and, consequently, imposes a speed limitation (Ministry of Transport, 2025).

Another significant challenge in the railway sector is the low customer satisfaction in the Sri Lankan Railway. Contributing to this poor rating is the condition of stations, and onboard facilities. The customer satisfaction study by Perera, Nazeer, and De Alwis assessed passenger satisfaction using the RII metric. The RII metric is the Relative Importance Index, calculated using a quantitative survey, to consequently calculate the percentage of satisfaction. In the framework of the RII, a rating below 50% would be considered low, when 50%<RII< 70% it would be deemed medium, and above 70% is high. As we look at the satisfaction levels below in Figure 7, the lowest is on canteen facilities; safety locker facilities, WIFI facilities and toilet facilities were some of the lowest rated facilities at stations (Perera, Nazeer, & Alwis, 2023). These fixes are usually low-cost fixes that could significantly improve the experience of commuters, encouraging use of the railways.

Services and Facilities in Railway Stations	RII	Percentage of RII (%)	Satisfaction Level
Seat reservation and ticketing services	0.67	67	Medium
Season ticketing services	0.62	62	Medium
Providing information (customer information screens)	0.5	50	Medium
Waiting room facility	0.47	47	Low
Toilet facilities (separate and common toilets)	0.46	46	Low
Seating facilities in stations	0.5	50	Medium
Retaining room facilities	0.525	52.5	Medium
Canteen facilities	0.354	35.4	Low
Safety lockers facilities	0.28	28	Low
Wi-Fi facilities	0.314	31.4	Low
Disability access to railway stations	0.56	56	Medium

Figure 8 Customer satisfaction level on service and facilities in station. Data adapted from (Perera, Nazeer, & Alwis, 2023)

3.3 Integrated Ticketing System & Multi-Modal Transport Barriers

The Sri Lankan Railway has long struggled without the introduction of an integrated tariff system, limiting the possibility of a multimodal transport system from becoming a convenient alternative, and holding back commuters from maximizing the utility of the existing infrastructure system. As seen before, the administration reports from 2019 and 2021 have both underscored the lack of integration between the rail and bus systems, despite previous policy recommendations. In contrast, as we look at the Italian integrated tariff system (ITS), there has been an increase in public transport usage since its inception, and a considerable improvement for commuter convenience. (Abrate, M., & D, 2008). This system has been further improved in cities across Europe, where transport providers allow riders to tap their bank card while entering urban transport networks. Additionally, recent studies concerning digitizing Sri Lanka's ticketing system through IoT[2], including RFID e-ticketing[3], GPS[4] tracking, and real-time passenger counting (Balasingham, et al., 2025).

The key issues remain quite simple and persistent. In terms of multi modalism, public transport terminals from across the country do not have a multi modal connections. For instance, as per the

[2] IoT- Refers to Internet of Things, small devices that are connected to the internet
[3] RFID- Radio Frequency Identification
[4] GPS- Global Positioning System, compromised of a series of satellites used to triangulate locations precisely

review of Sri Lanka transport sector conducted by Dr Kumarage of the World Bank, the public transport terminals fall short of other terminals. The report was produced in 2010, but remains true 15 years later, the public transport terminals to the airport falls short of the airport. If one were to take a bus, it would be possible to get close to the airport, but the bus would still fall short of about 200m inconveniencing travelers with luggage, elder people and children. The Bastian Mawatha Bus terminal was said to be the answer to connect the lack of a multi modal terminal across the country, but it has never come to fruition (Kumarage, 2010). Looking for confirmation of the terminal being built, there exists many attempts to restart the project envisioned by the Review of the Sri Lankan transport sector note of 2010, majorly the $250 million project offered by the Maju group of Malaysia on a pro bono basis, to create a new transport hub system, including an e-ticketing system for the urban and suburban trains, intra-city busses, and taxis, but this did not come to fruition (Sirimanna, 2014). Overall, while discussing the introduction of multi-modal systems, we must address the underlying issues hindering their implementation, particularly in the capital city. Further plans were introduced in 2019, and this was to build multi-modal transport hubs, particularly in Jaffna, Galle, and Katunayake, the city of the main airport, to facilitate seamless transfer between the bus and train system, however by 2024 these projects have not been initiated (Perera & Shaja, 2023).

In terms of the integrated tariff system, Sri Lanka does not have one to date. The ticketing system also remains outdated, with manual checks still in use at most stations. While other regional railway networks of the Asian region have transitioned to smart cards, QR-code based ticketing, and mobile app integration, the Sri Lankan Railway continue to be mainly dependent on paper tickets that can only be purchased at station counters, increasing congestion and making fare collection inefficient (Danthanarayana & Kumarage, 2021). As proposed by the Maju group project in 2014, works must be done to introduce Sri Lanka into digitized processes into all modes of transport. A report by the Chicago Metropolitan Agency for planning, underscored how travelers get disincentivized if they would have to pay twice, or thrice to use the most efficient path, and an incentive to make these commuters to take more efficient paths and reducing congestion would be an integrated fare system across public and private transit agencies. However, these come with hurdles, as transit agencies would have to coordinate with each other, and this may prove difficult, as some agencies taking more profitable routes may be disincentivized to take this path. (Chicago

Metropolitan Agency for Planning, 2023). Similar cases certainly do exist in Sri Lanka, where there exists a big market share between private and public busses, and proper coordination could improve overall customer experience, while simultaneously a hub integrated to railway infrastructure could lead to better utilization of existing infrastructure.

Chapter 4 Environmental & Climate Considerations in Rail Development

4.1 Rail's Role in Reducing Carbon Emissions

The transport sector in general is a major source of global emissions, but after a deeper analysis we find that 75% of total emissions is emitted by road transport, while accounting for nearly 40% of global oil consumption (BloombergNEF, 2020). However, the railways tend to emit a relatively lower amount of CO2 per distance travelled. Between the car, rail, bus, and planes, the railways have the lowest emission of CO2 at a mean rate of 22g per passenger km, while the highest was an average medium car at 148g per passenger km (IEA, 2022). This combined with the increasing congestion suggested by all the previous transport sector notes, suggest that per passenger that leaves the rail for car transport will experience a seven-fold increase in emissions.

As we localize the data to Sri Lanka, we see severe congestion due to the high number of container trucks, which inherently would cause more fuel consumption, delays, and excessive CO2 emissions. A case study suggested that if just four of the export processing zones container shipments are shifted from road to rail there would be a 50% reduction in CO2 emissions. (Jayatilaka, et al., 2012). This reduction in road-based transport would lead to decreased congestion, indirectly reducing CO2 emissions from vehicle idling, decrease road maintenance costs, and improve logistical efficiency benefitting businesses. This study further shows, how in terms of freight, all major commercial and industrial lants are connected by railway and is consequently a suitable alternative to road-based transport. However, rail usage is extremely underutilized in terms of freight, with only a small percentage of freight being transported via rail.

Sri Lanka, classified as a Low Middle-income country (LMIC) by the World Bank; faces unique challenges in its decarbonization of its transport sector, due to limited rail infrastructure and reliance on fossil fuels. A COP 28[5] report comprising of a group of LMIC countries, Sri Lanka was not included, emphasized that if LMIC's matched the rail's best performing countries it could result in the reduction of CO2 by up to 1.8 gigatons (Gt), and further help countries decouple their economic growth from emissions growth, enabling a sustainable development strategy. (Blumenfeld, Townsend, Brechemier, Plummer, & Chebl, 2023).

4.2 Environmental Impact Assessment (EIA): Sri Lanka vs. EU Procedures

The Environmental Impact Assessment (EIA) is a pivotal regulatory tool used to globally evaluate the environmental consequences of proposed development projects. It plays an essential role in ensure infrastructure projects ensure minimal damage to the environment, thus prompting sustainable development. (Glasson, Therivel, & Chadwick, 2005). While Sri Lanka and the EU both have an established EIA framework, their effectiveness, and implementation differ significantly. The EU's EIA process is more structure, transparent, and legally binding, however the Sri Lankan framework is often obstructed by poor enforcement, political intervention, and inadequate public participation. (Gamalath, Perera, & Bandara, 2014)

Sri Lanka's EIA framework was introduced through the publication of the National Environmental Act (NEA) No.47 of 1980, where subsequent amendments were introduced in 1988 and 2000 (Gamalath, Perera, & Bandara, 2014). The introduced framework mandates that all major infrastructure projects, including railway expansions and transport hubs, undergo environmental assessment before approval. Although, the framework seems to have the rigid and stringent markers, its effectiveness is usually questionable due to several key shortcomings.

A major weakness impeding the EIA process in Sri Lanka is its level of enforcement. The EIA reports are treated more as a sort of formality, rather than a key decision-making tool suggests that major changes would not occur if the report revealed something negative. The process is usually

[5] Conference of Parties of the UNFCCC, the organization in charge of the framework convention on climate change, while 28 denotes the conference that took place in Dubai.

influenced by high level governmental figures and financial interests, this leads to frequent environmental damage, despite reported risks. In addition, although the law allocates public participation in the results of the EIA, communities involved in the report do not participate during the 30-day feedback period, for lack of access, and understanding of their rights. Sri Lanka also tends to fail in considering the culminative effects of multiple projects, and only focus on each project individually, which means the effects of other projects going on in a region is not considered while studying the EIA. Finally, a major issue of the Sri Lankan environmental framework is the weak post approval monitoring, which is caused by lack of legally binding post implementation audits, consequently enabling developers to avoid upkeeping their environmental responsibilities afterwards (Gamalath, Perera, & Bandara, 2014).

In contrast the EU's EIA process emphasizes the public to pay a role in its EIA process. Unlike Sri Lanka's single 30-day feedback period the public is given the opportunity to get their issues addressed, leading to a multi round stakeholder consultation. Further, all risks to the environment must be addressed, and if the project developers are unable to come up with an option without significantly damaging the environment, they must be ready to accept a no project option (Glasson, Therivel, & Chadwick, 2005). However, in Sri Lanka, the option of "no project" is not required, nor are any alternative options that are enshrined in the EU, thus projects with poor site locations might go ahead leading to excess resource wastages, namely environmental, but possibly financial as well. The EU also maintains a stronger post approval monitoring system, especially with legal weight, where failure to comply often leads to penalties or suspension (Glasson, Therivel, & Chadwick, 2005). However, it's crucial to emphasize that this does not imply the EU is entirely indifferent to the lack of enforcement. Instead, the frequency of such cases is lower. For instance, in Italy, it was recently discovered that organized criminal groups have for years been. involved in extensive illegal dumping and burning, causing years of damage to the environment and human health. Although damage was significant, the enforcement of the law by the European Court of Human Rights (ECHR) underscored the importance of judicial enforcement (Machado, 2025)

4.3 Electrification & Renewable Energy Integration

As global trends inch towards accomplishing decarbonization, countries such as Sri Lanka should also be looking towards exploring the options it has available. The Sri Lankan railway removed steam engines from use at the period of dieselization but has not been able to shift towards an electrified network as rapidly because the additional infrastructure needed for electrified lines (Kesavan, et al., 2015). This high usage of diesel units contributes to high CO2 emissions, and lack of efficiency. The Sri Lankan Railway should be exploring viable options to achieve a sustainable framework to power its railway network. Sri Lanka can utilize many global models to modernize its system, but one of the best models with the most data could possibly deem as the European railway network.

To begin with, as Sri Lanka lacks significant electrified infrastructure, a country like its situation must be explored, and this role model could be the Latvian electrification model. Latvia, at 14% electrification is one of the least electrified railway networks in Europe, substantially lower than the 55% EU average. However, the shift away from diesel is marked by immense benefits, where a study showed emissions reducing by 80% by 2050, if a complete switch occurs in Latvia. In addition, electric trains consume less energy per passenger-km and tone-km, leading to tremendous energy savings as well. As the efficiency of electric trains are higher as well, the savings would be transferred to the consumers and businesses, while the economy will also improve by reduced fuel import dependency (Rozentale, et al., 2020). Sri Lanka, with zero electrification in place stands to benefit immensely with such an electrification strategy, leading to substantial economic and environmental benefits. However, the capital required for electrification and the limitation of the national grid remains a major challenge for development of the railway.

An alternative to electrification could be the use of hydrogen to replace older units. While full electrification is generally considered the most ideal solution, some networks lack the capacity to even consider it, making hydrogen a viable alternative, especially for rural low-density areas. A study in Southern Italy examines the potential of hydrogen in non-electrified mountainous regions where electrification would be economically unfeasible. The study's key benefits include reduced emissions, energy efficiency improvements, and flexible deployment. Hydrogen-powered systems

generate zero emissions at the point of use, minimizing harm to sensitive environmental areas. Hydrogen power sets typically achieve 47-50% efficiency, making them more competitive with electric trains compared to their diesel counterparts. In terms of deployment, hydrogen does not require additional infrastructure like overhead catenary or third rail, reducing costs and enabling operations across most networks (Fragiacomo & Piraino, 2019). This presents the case for Sri Lanka using hydrogen as an alternative to the current diesel units in service, however, the introduction of hydrogen rail sets, brings in a new set of challenges, such as carriage compatibility, and availability of hydrogen train sets in Sri Lanka's wide gauge tracks. Nonetheless, hydrogen powertrains bring a vast number of benefits that may fit the needs of the SLR.

Another focus area of the electrification and renewable integration to the SLR, should be the consideration of hydrogen refueling infrastructure, and cost considerations. As direct research on the SLR exists, an adaptation of European models is needed again. Hydrogen-powered trains require the additional infrastructure to refuel them, and an investigation into their refueling structure highlighted key factors on transitioning to hydrogen. Firstly, green hydrogen production would be technically and economically viable through usage of solar or wind, while making it more sustainable due to Sri Lanka's foreign exchange crisis reducing import dependency. A hydrogen refueling station serving 20 trains will require an electrolyser with at least a 3.5MW capacity and at a cost of €50/MWh (Guerra, et al., 2021). However, it's important to note that the price of electricity in Sri Lanka has been fluctuating recently, although it's generally lower compared to more developed countries. While reduced labor costs may make the initial cost of constructing facilities more feasible, the hydrogen fuel cell approach is a significant change that could revolutionize low-density routes. It has the potential to be a cost-effective and sustainable fuel source for the Sri Lankan Railway. Furthermore, the fluctuating demand in the national grid could further enhance the viability of this approach by providing stabilization measures for energy sources that cannot provide flexible energy output.

While electrification is a key player in achieving sustainable development it is not enough. The electricity used must come from renewable sources. The Latvian Electrification study emphasizes the need to integrate renewable. Energy sources such as solar and wind power into railway electrification projects to maximize the environmental benefits received. Adopting energy

solutions such as batteries and grid stabilizers, is also key in achieving a balanced source of sustainable energy production. The use of smart grids is also recommended to ensure a safe balance for the delivery of energy to rail and national operation, preventing overloads and inefficiencies (Rozentale, et al., 2020). Sri Lanka is abundant in solar, wind and hydro, thus allowing the simple integration of renewable energy into the railway, which could in turn significantly reduce operating costs, while promoting sustainability. However, the Sri Lankan grid is also sensitive, recently, the whole nation experienced a power outage due to monkeys tampering a single component of the grid, while historically the power grid has been prone to rolling black outs, making electrification less reliable (Wright, 2025). An unreliable power source could make delays more frequent, and thus backup power such as onboard diesel generators, or independent railway generators would be required to ensure adequate redundancies exist to continue smooth operations.

Although the grid raises concerns, electrification remains crucial in achieving a sustainable transport system. Electrification continuously reduces reliance on fossil fuels and enables regenerative braking, a technology that captures kinetic energy during deceleration and converts it back to usable energy in the grid. This not only reduces brake wear but also acts as a braking system. A study on the SLR developed a model to assess energy savings when transitioning from Diesel Multiple Units (DMUs) to Electric Multiple Units (EMUs). The simulation, conducted between Colombo Fort and Veyangoda railway stations, revealed that 28.7% of the energy required for acceleration can be recovered through regenerative braking, and 23.9% of the energy otherwise lost through frictional braking is also recovered. These energy savings amount to 458Kwh per trip, significantly improving efficiency. The study also considered potential challenges faced by EMUs and concluded that regenerative braking recovered between 15-35% of the energy used, which aligns with international standards (Gunatillake & Samaliarachchi, 2022). The previously mentioned Latvian study also mentioned the incorporation of regenerative braking to substantiate significant economic and environmental benefits (Rozentale, et al., 2020). Integrating such braking systems into any electrification plan would lead to long term cost reduction and sustainability improvements. However, the effectiveness of such solutions depends on the ability for the grid to absorb excess generated energy and effectively redistribute it. A proposed solution to prevent any overload is the incorporation of “trackside energy storage systems”, such systems include batteries and flywheel technology, to store excess regenerated power and optimize its utilization during non-

peak hours (Gunatillake & Samaliarachchi, 2022). The implementation of these systems may not be far-fetched, considering that most of the Sri Lankan Railways rolling stock are converted electric locomotives and multiple units. Consequently, existing units can be easily converted back with minimal financial capital if electrification is implemented.

4.4 Negative Environmental Impacts of Railways (Biodiversity, Landscape, Noise)

While remains one of the most sustainable and environmentally friendly mode of transportation, it still influences the environment. Its development could cause significant damage to the environment around it, and the damage could take forms of biodiversity loss, habitat fragmentation, landscape alteration, and noise pollution (Milewicz, Mokrzan, & M. Symanski, 2023). These issues are particularly relevant in Sri Lanka, where the railway network goes through ecologically sensitive areas.

The railway infrastructure can often pose as a barrier of movement, thus restricting the movement of wildlife, causing fragmentation of their habitat leading to the reduced genetic diversity in animal populations. Another critical threat to be considered is the possibility of wildlife train collision, which results in the fatalities of many species. Research conducted in North America shows that the second highest cause of mortality in the bears and deers are rail collisions, only after poaching (Milewicz, Mokrzan, & M. Symanski, 2023). Like North America, we can see in table 5, that all accidents with animals lead to their fatalities, rate which is slightly better in humans, however, the accidents caused at level crossings is concerning, demonstrating a lack of barriers protecting humans and animals. However, although access to the below table gives credence that the railway affects wildlife, there is not any comprehensive datasets compiling the species that are affected by the railway. A way to mitigate collisions and damage to wildlife is to implement fencing along tracks, combined with other early warning systems alerting wildlife of approaching trains (Milewicz, Mokrzan, & M. Symanski, 2023)

Accident Type	No. of Accidents	No. of Deaths	No. of Casualties
Level Crossing Accidents	94	18	45
De-Railments	117	-	-
Run over by Train	451	175	276
Accidents due to animal hits	44	44	-
Other (specify)	-	-	*
Total	706	193	321

Figure 9 Overall Accidents of the Sri Lankan Railways in 2022. Adapted from (Government of Sri Lanka, 2025)

In terms of railway development, there is an immense need for land clearing, excavation and infrastructure construction, all of which that leads to changes in the landscape. These changes are particularly visible in the wetlands and forest regions, where rail expansion leads to deforestation, soil erosion, and consequently landslides. A major landscape issue associated with the railways is hydrological disruption. The tracks being imbedded in the network can cause alterations to the natural drainage patterns leading to flooding in some areas, and water scarcity in others (Gunaruwan & Dilrukshi, 2022). This is particularly problematic in Sri Lanka, where seasonal monsoons require water flow management, if not these factors would cause landslides and further soil degradation, harming fauna and flora, while simultaneously also affecting the people around it. Some embankments and cuttings lead to increase sedimentation in rivers, leading to the loss of aquatic habitats, and reduced biodiversity (Milewicz, Mokrzan, & M. Symanski, 2023). The environmental systems, in and around the island is covered with particularly sensitive ecosystems, and these damages could cause long term damage, that may be impossible to reverse.

Finally, while taking all the factors into account it is important to also consider the noise pollution. Train noise often exceeds 100dB, making it one of the loudest modes of transports, especially in urban and residential areas. These noises have been correlated with sleep disturbances, stress, and cardiovascular diseases (Milewicz, Mokrzan, & M. Symanski, 2023). While taking this into account, we can deduce a strong correlation with increased health risks and reduced quality of life for those living in densely populated areas such as Colombo or Kandy.

While these disturbances are detrimental to humans, it has an even larger impact on the ecosystem. For the wildlife surrounding the railways, the noise emitted by the trains could interfere with animal communication. Many species depend on vocal signals for mating, marking territory and navigation. Consequently, if the noise goes unregulated the animals living in the vicinity could start to exhibit strange behavior, and possible abandonment of habitats, this may cause ecosystem collapse. A possible mitigation of railway noise is the use of acoustic barriers, and dense foliage acting as noise absorbing material (Milewicz, Mokrzan, & M. Symanski, 2023).

Chapter 5 Comparative Analysis: European & Sri Lankan Rail Models

5.1 Public Perception of Public Transport: Lessons from Europe

Public perception plays a key role in understanding ways of improving utilization of public transport and would guide to key markers of improving railway usage as well. As we have seen in Chapter 3.2, the state of railway transport does not meet commuters' expectations and plays a big role in disincentivizing commuters from utilizing it to the fullest. The perception of public transport varies across regions due to differences in infrastructure, cultural attitudes, and government policies. Examining challenges, successes, and key differences may provide key insights into improving public transport systems in Sri Lanka, while the European models could be a source of best practices.

Firstly, as seen in Chapter 3.2, the railways are seen as unsatisfactory forms of transport, often underperforming in many metrics. The same study (Perera, Nazeer, & Alwis, 2023) that referred to the failures in railway station also highlighted overcrowdings, delays, and outdated infrastructure remaining as major deterrents for Sri Lankan commuters. These issues become more pronounced during peak hours, leading to dissatisfaction among users. The lack of timely investments in modernizing the system exacerbates these problems, making daily commutes inconvenient and stressful.

In Sri Lanka, public transportation is frequently stigmatized as a “last resort” for individuals who lack the financial means to afford private vehicles. Despite escalating fuel costs and economic difficulties, middle- and upper-class citizens generally avoid utilizing buses or trains due to concerns regarding comfort, safety, and social standing (Gunatillake & Samaliarachchi, 2022). This negative perception persists despite the affordability and relative safety of public transportation, thereby reinforcing the reliance on private vehicles and exacerbating traffic congestion. The Sri Lankan Railways have met the public discontent by bringing in modernization policies, however the reactions elicited remain varied. An instance of a negative reaction, is when Sri Lankan railways started renovation efforts that would build clean bathroom facilities, however, these facilities were later demarcated as foreigners only toilets, and these were to be locked, and only unlocked upon request of the station master by a non-Sri Lankan national (Warakapitiya, 2017). This presents not only an ethical dilemma, but also recounts the extreme measures taken by the railways to attract foreign tourist travelers as well, briefly discussed in chapter 3.3. The actions of the railways, where the facilities for locals aren’t maintained underscores that even the government views the railway as being a transportation of lower social standing.

However, while we switch to Europe, the public perception of public transportation changes drastically. In contrast to Sri Lanka, public transport in Europe is usually seen as a practical, efficient, and environmentally friendly mode of travel (European Commision, 2021). Professionals, students, retires, and other demographic groups all rely on public transport for their daily commutes, reflecting lack of status for the usage of public transport. The societal outlook of public transport is positive, and rather normal, instead of the negative stigma posed in Sri Lanka. Further, Europe in recent decades has become more environmentally conscious, viewing public transport as an essential tool to curtail their carbon output (European Environment Agency, 2020). This shift in taste and societal norms are reflected in the usage of public transport by choice, instead of Sri Lankans viewing it as a method of last resort.

5.2 Safety, Accessibility & Multi-Modal Transport

Railway safety is of paramount importance in both European and Sri Lankan railways, but the extent to which they achieve it varies greatly. The European railway system is governed by stringent regulations, such as the European Safety Directive (Matsika, Rici, Mortimer, Georgiev, & O'Neill, 2012), which mandates mandatory risk assessments, incident reporting mechanisms, and substantial infrastructure investments. European rail networks mandate strict crashworthiness through regulations like EN 12663 and EN 15227, which defines structural requirements for rail vehicle bodies and define crash impact scenarios. Furthermore, Europe has embraced modern accident investigation methodologies, including Fault Tree Analysis (FTA) and the Swiss Cheese Model, to identify and mitigate system failures.

However, in Sri Lanka, railway safety infrastructure itself is significantly less developed. The country constantly faces accidents at level crossings, which is usually the case, as there exists a lack of proper signaling and protective barriers, or sometimes the mechanisms used for signaling are no longer produced and no spare parts are produced for the existing systems to be maintained. In 2011 alone, 82 crashes occurred at railway crossings itself, while when we look at the most recent data on Table 5, in 2022 there was 94 accidents, marking a deterioration of safety. A further analysis of Table 5 shows the significant amount of people who are run over by trains, and as the accidents aren’t always at level crossings, this could indicate either high degree of trespassing, possible lack of barriers at railway stations, or even possible suicides with trains being used to execute it (European Union Agency for Railways, 2024)

However, in terms of accessibility, in which the railways in general play a major role in inclusivity and user satisfaction must be analyzed. In Sri Lanka, railway infrastructure remains largely inaccessible to individuals with mobility issues, this is caused by the lack of elevators, ramps, and tactile paths for those who are visually impaired. A 2012 World Bank Report (Kumarage, Sri Lanka Transport Sector Policy Note, 2012, p. 35) stated that only about 15% of stations comply with global design standards. Furthermore, the absence of real-time information systems and manual ticketing processes further exacerbates accessibility challenges, particularly for foreign visitors

and passengers unfamiliar with railway operations (Kumara & Bandara, 2021). The chaotic nature provided would make the railway less appealing to newer users, dissuading proper adoption. On the other hand, Europe has embraced new ideas and technology, upholding global safety and design standards. The accessibility is consequently upheld for all users of the railway, for example, in Sweden, all stations built after 2010 must include step free access, tactile guide paths, and audio announcements to aid individuals with visual and physical impairments (European Union, 2020). Countries like Spain and the Netherlands have implemented mobile apps that provide real-time accessibility information to passengers. These apps allow passengers to check elevator functionality, platform changes, and ticketing details before arriving at the station. Sri Lanka has conducted limited pilot projects to improve accessibility, especially in tourist hotspots like Kandy and Ella, however, nationwide accessibility enhancements is yet to be implemented (Sri Lanka Ministry of Transport , 2023)

The implementation of multi modal transport integration remains an integral process to Sri Lankan Railway modernization, and the aim of integration would allow efficient transfer between modes of transport, enhancing commuter convenience and system efficiency. The current state of the public transport network remains fragmented, with rail and bus services running as independent competitors rather than complementing each other. Additionally, the services remain running on independent schedules and ticketing systems, leading to multi modal commutes being disincentivized whenever possible. Further fragmentation occurs with the public/private bus divide, leading to excessive competition killing of any possibility of cohesive integration (Kumara & Bandara, 2021). The Makambura Multimodal Center (MMC) was designed to resolve the issues of the fragmented Colombo network; however, it still operates under an individual ticketing regime, and minimal digital infrastructure (Kumarage, Sri Lanka Transport Sector Policy Note, 2012).

In contrast, European cities have successfully implemented integrated transport networks like the German Verkehrsverbund model. This model unifies the public modes of transport into one single ticket regime, incentivizing use of the public transport network. In Vienna, the Verkehrsverbund Ost-Region allows passengers to use one ticket to use multiple modes of transport, while supplementing real time tracking of transport, allowing smooth connection between services. The

Netherlands has adopted a nationwide solution, OV-Chipkaart, enabled by an NFC (Near Field Communication) chip that can be filled with credit or various tickets as well, this enables seamless use of public transport (Buehler, Pucher, & Dümmler, 2021). The seamless integration between different modes of transport makes use of public transport more convenient and enables the public to travel worry-free.

Similar integrations like the OV-Chipkaart, with multiple multimodal hubs in cities around Sri Lanka have been introduced. However, the lack of will to create a centralized transport authority, and lack of inter-agency coordination continue to delay these much-needed reforms (Sri Lanka Ministry of Transport , 2023). Consequently, there needs to be greater political will to push forward reforms that will efficiently integrate the various transport operators. Overall, these differences present the stark contrasts in safety protocols, accessibility, and multi modal integration. Europe benefits from advanced technology, inclusive design standards, and integrated ticketing systems, while Sri Lanka on the other hand continues to face push backs on outdated infrastructure, accessibility barriers, and poor intermodal connectivity. By adapting the best practices of Europe, such as the Verkehrsverbund model, Sri Lanka can significantly improve efficiency, safety, and user satisfaction.

5.3 Shortfalls of European Transport

Despite being known for their efficiency and technological advancement, European public transport systems, including railways, face several key challenges challenging its growth. These challenges range from competition barriers to environmental concerns.

To begin with, a notable challenge poised against the Sri Lankan rail is the struggle balancing customer sensitivity with open access and competition. According to (Alexandersson, 2009), after two decades of liberalization and reforms, many national barriers remained, and the market was left to be dominated by a handful of large multinational companies. One such company is the former state-owned monopoly DB AG, otherwise known as Deutsch Bahn, continues to dominate 90% of the rail market, adversely affection competition, benefitting from rail access and continued

government support, while newer private firms do not have access to state support. Similarly in France, private operators are required to be under the helm of the SNCF, the French national railway operator, which ensures a monopoly and lack of competition

While talking about the outcome of liberalization reforms, some regions have benefited from increased competition, others have witnessed the rise of duopolies and restricted market entry, particularly in Western and Southern Europe. Consequently, these regions have experienced higher fares and reduced service frequencies during peak hours due to infrastructure access charges (Gutiérrez-Hita, Cruz, & Ramos-Melero, 2022). These increased charges disincentivize passengers to use the rail, and makes the railway a much less appealing choice, this would consequently lead to consumers choosing more environmentally damaging alternatives, as we saw in chapter 4.1, the railway is the least polluting form of transport, at around 22g/passenger at the lower end, thus any alternative taken must be more polluting. Additionally, infrastructure constraints such as network congestion, aging tracks, and insufficient investment in modernization have further impeded the efficiency of European railways. The Latvian electrification study (Rozentale, et al., 2020) highlights that while electrified railways reduce emissions, many regions in Europe still rely on diesel locomotives, which undermines environmental sustainability efforts. Approximately 40% of Europe's mainline network continues to operate with diesel locomotives, contributing to CO2 emissions and delaying the transition to more environmentally friendly transport solution (Rozentale et al., 2020). This degree of transition from diesel underscores the difficulty that even successful pioneers of sustainable rail transport still face difficulty, and that electrification is not going to be the only solution when modernizing railways.

Chapter 6 Policy Recommendations & Feasibility Strategies

6.1 Cost-Effective Infrastructure Maximization

Developing cost-effective strategies plays a crucial role in ensuring the financial sustainability and operational efficiency of the SLR. By examining successful models from Europe, particularly in terms of rail privatization, public-private partnerships (PPP), and infrastructure access, Sri Lanka can learn to adopt policies that could positively enhance the service quality of the railway

organism. Additionally, straying away from the European Models, we see a very successful model in Hong Kong with the Rail and property strategy. This model will show solution which can take be taken advantage of to generate long term real estate infrastructure, during development.

European rail systems have long strived to ensure sustainable development of their railway systems, thus cost-effective infrastructure management played a central role in its growth. The Swedish model of vertical separation, introduced in 1988, separated railway infrastructure from operations, thus separating the ownership of the rails to those who can operate on it. This approach allowed the introduction of new players to be able to use the infrastructure that has already been built, and breaking the government monopoly. This approach improved competition, reduced costs, and enhanced service quality (Kumara & Bandara, 2021). Similar strategies have also being seen in Germany, where the introduction of Flix train has brought long distance train fares to as low as €5 for long distance connections, where the national railway company could cost up to four times more in similar routes (Comprabus, 2025). Such a vertical separation model could liberalize the use of rail tracks by private enterprise, thereby leading to increased investment without the government bearing full financial burden (Kumara & Bandara, 2021).

Furthermore, the German regionalization model delegates the operational responsibilities to the individual federal states, while the infrastructure required is to be maintained at a national level, leading to improved localized management and operational efficiency. A similar strategy could be implemented in Sri Lanka, where railway management could be allocated to each province, and consequently improved resource allocation could be achieved. These optimizations could not only improve national railway efficiency but would have a significant change for the high demand routes like Colombo-Galle, and Colombo-Kandy (Kumara & Bandara, 2021).

If the Sri Lankan Railway could effectively pursue the policy of vertical separation, it could adapt dynamic pricing on infrastructure access charges. These prices could vary based on peak and off-peak hours, ensuring optimal utilization and revenue generation. Such a model would not only enable usage for passenger transport but also incentivize the use for freight transport (Gutiérrez-Hita, Cruz, & Ramos-Melero, 2022). If Sri Lanka were to implement the dynamic pricing model, it would help balance the passenger loads during peak periods, and provide more affordable

options during off-peak hours, thus creating a cost-effective maximization of railway infrastructure, without significant investments into it.

The ongoing financial deficits of Sri Lanka Railways (SLR) can be attributed to its state-owned monopoly structure, outdated infrastructure, and limited private investment (Kumara & Bandara, 2021, p. 53). Operational inefficiencies, including low-speed tracks, inadequate maintenance, and outdated signaling systems, have led to a decline in passenger numbers and financial viability. To mitigate these challenges, comprehensive reforms are imperative that integrate cost-effective infrastructure management strategies and technological advancements (Kumara & Bandara, 2021, p. 54)

A promising approach to maximizing infrastructure efficiency involves adopting Public-Private Partnerships (PPPs). In Sweden, PPPs have successfully provided essential capital for infrastructure upgrades while retaining regulatory oversight (Alexandersson, 2009).Sri Lanka could similarly attract PPP investments for high-demand routes like Colombo-Galle and Colombo-Kandy, focusing on track modernization and station upgrades.

Furthermore, implementing an open access policy for private freight operators, as discussed earlier in relation to the dynamic pricing model, could generate additional revenue comparable to the EU model. This approach would enable logistics companies to utilize railway infrastructure for freight transportation (Gutiérrez-Hita, Cruz, & Ramos-Melero, 2022). This policy would be particularly beneficial on underutilized lines, where freight traffic such as the container transport discussed in chapter 4.1 could maximize the capacity of underutilized lines.

However, privatization is a delicate matter in Sri Lanka, particularly in the context of the railways, which are an integral component of the country's socio-economic fabric. Firstly, unions would fiercely oppose any form of privatization, as any cost-cutting measures would inevitably result in job losses. Sri Lankans generally favor privatization efforts such as the British Railway, where the potential benefits of not privatizing remain highly regarded. However, they also acknowledge the Indian Railway, where the private sector showed no interest even for a five percent stake. This dichotomy is reflected in the political landscape, where the current government was elected on the

platform of promising reduced or no privatization of state assets, consistent management, and the establishment of appropriate regulations to enhance public confidence (Jayasuriya, 2023).

Lastly, a non-European model, which is the Hong Kong Rail and Property strategy provides key insights in which the SLR could leverage its position in generating revenue sources. This strategy involves utilizing lands already owned by the railway, or acquire lands around future stations, which could then be developed into commercial and residential property that generates sales and rent to finance and maintain railway infrastructure. Although this strategy is not strongly prevalent in Europe, it is an extremely successful model, even enabling the transit company to become a profit maker funding the government, rather than the usual loss making public good (PolyMatter, 2019). This model could serve as the supplementary funding mechanism for not only the railway, but possibly other parts of the transport infrastructure, or even the national government spending. Although, this strategy may be successful in Sri Lanka, it does require a higher initial capital investment, and further research needs to be conducted.

6.2 Digitization & Smart Ticketing (Integrated Ticketing Solutions)

Technology integration is another crucial component of cost-effective infrastructure management. Implementing IoT, Internet of Things based real-time monitoring systems for track maintenance can reduce long-term costs by enabling predictive maintenance and preventing major failures (Kumara & Bandara, 2021, p. 58). Furthermore, adopting automated ticketing systems would minimize operational costs associated with manual ticket sales and enhance revenue collection efficiency. Automated ticketing would also enable more stringent and efficient enforcement of fare evasion, leading to improved farebox recovery. Farebox recovery is calculated as the ratio of total revenue to total expenditure, and a higher recovery rate is better.

As a matter of fact, the Sri Lankan government has identified the disadvantages stemming from the lack of digitization, and had consequently introduced digitization measures, such as E-ticketing and online seat reservation. However, there has been a lack of follow ups to analyze if the systems introduced have been effective. A study was conducted to see the effects of the new measures

(Gamage, 2024), and it highlighted that many stations in Sri Lanka, have not completely adapted to the use of the E-ticketing systems, and this has led to the material and labor cost not being affected significantly. Another issue with the lack of e-ticketing integration is that the usage of paper will remain prominent. However, the study did indicate a high desire among younger people, especially younger tourists to use digital ticketing as means of getting around, which emphasized the need to strategically target younger people (Gamage, 2024). Consequently, it is of great importance that the railways implement targeted awareness campaigns to the younger demographics, while innovating easier methods for the older demographics.

Further, implementing digital and seamless integration of multi-modal ticketing systems, as successfully adopted across European transit systems, is crucial for enhancing efficiency and accessibility. Germany's Deutsche Bahn (DB) exudes this with a fully digitized ticketing system that allows passengers to use mobile applications, NFC (Near Field Communications)-based smart cards, and QR (Quick response)-code scanning for seamless travel. Urban transit systems have also adopted the use of bank cards and online digital tickets (Smith, 2020). Italy's Trenitalia and regional transport authorities operate on an integrated fare system, enabling passengers to use contactless smart cards across various transport modes, including buses, metro, and intercity trains (Fragiacomo & Piraino, 2019). The UK's Oyster and Contactless Payment System further simplifies public transport in London by allowing travelers to use their bank cards directly, or the readily available chip card, reducing the need for separate ticketing infrastructure (Jones & Patel, 2021). These examples offer valuable insights into how Sri Lanka can modernize its ticketing system while addressing local challenges. Implementing policies such as smart cards, and integrated bank cards would not only make transit more streamlined, but more sustainable for the Sri Lankan railways.

Consequently, a phased approach could be optimal for Sri Lanka. While considering the European models, we can phase in smart ticketing systems. These systems could be initiated by strengthening existing online ticketing systems and expanding mobile integration. The implementation of RFID (Radio Frequency Identification) based smart cards for long distance travelers would further strengthen the system, allowing automatic fare deduction, or digitize already existing monthly subscriptions of railway use, leading to streamlined office procedures (Balasingham, et al., 2025).

Additionally, the introduction of automated vending machines at major stations would mitigate the bloated operations of the railway operations.

The second phase should prioritize seamless integration of various transportation modes, including buses and metro networks. Implementing an Integrated Tariff System (ITS) would enable passengers to use a single ticket for trains, buses, and metro lines (Kumarage, 2020). Drawing inspiration from Italy's "Biglietto Integrato" system (Rossi, 2019), contactless NFC smart cards, combined with digital measures, could streamline fare collection across different transport services. This integration would enhance commuting efficiency and reduce costs for passengers.

The final phase should strive for complete automation and the establishment of a sophisticated train management system. Real-time tracking and passenger management utilizing GPS and IoT technologies would significantly enhance operational efficiency (Wijayaraja, 2025). Furthermore, while implementing the use of transit cards, and bank cards, the use of real time tracking would aid commuters in making informed decisions while commuting, and mitigate frustrations caused by delayed trains. The reduced frustration of having real time information on delays has been noted in many studies, especially in a study conducted in Seattle, USA (Ge, Jabbari, MacKenzie, & Tao, 2017), where the introduction of information displays had limited effect in the beginning, but was met with positive reactions from the public, possibly indicating more comfort from implementation, but since it has limited initial effect it should be left for last.

6.3 Improving public transport perception

To improve the image and effectiveness of Sri Lanka's public transport system, several policy interventions can be implemented. These interventions encompass enhancing the quality of service, reforming public attitudes, and consolidating government involvement.

Firstly, enhancing service quality is essential to build confidence in the system in Sri Lanka. Studies have continuously found factors such as cleanliness, computerized ticketing, and service frequency as key determinants to ensure satisfied commuters (Bagwell, 2020). Implementing a

digital ticketing system, particularly with contactless payments, can streamline operations and reduce boarding delays at stations. However, these measures must be taken carefully, as such systems would be very new to Sri Lankans, and as there exists quite a sizable community of people who don't have bank card, a system such the Dutch OV-Chipkaart, possibly created from the foundations of paper-based season ticket system would help many Sri Lankan remain satisfied with transport services. Furthermore, increasing the frequency of buses and trains, especially during peak hours, will help alleviate overcrowding and enhance reliability (Ramos, Vicente, Passos, Costa, & Reis, 2019). Additionally, ensuring that vehicles are clean, modern, and well-maintained is crucial in changing public attitudes toward public transport (Friman, Lättman, & Olsson, 2020).

Secondly, shifting societal attitudes toward public transport is crucial in eliminating the stigma associated with its use. To improve public perception, targeted awareness campaigns can highlight the economic benefits, while educating the public on the importance of environmental protectionism. These campaigns can emphasize cost savings and benefits to the planet from carbon emissions (Ramos, Vicente, Passos, Costa, & Reis, 2019). In addition, these campaigns could utilize social media to present how the commuters come from all different backgrounds, and that the use of public transport is not necessarily an indicator (Ramos, Vicente, Passos, Costa, & Reis, 2019)c of social standing. Additionally, offering more premium services like express routes and enhanced seating arrangements can attract middle- and upper-class commuters who often avoid public transport due to concerns about comfort and social status (Bagwell, 2020). Furthermore, addressing the issue of prioritizing facilities for tourists over local commuters, as observed in previous railway renovations, is essential for restoring public trust in the system (Friman, Lättman, & Olsson, 2020). The inequalities in access to public facilities may be resolved by introducing a tier-based payment system, enabling the government to maintain more cleaner facilities, without sacrificing the access of citizens who are willing to pay more for a better service (Warakapitiya, 2017).

Finally, the government could intervene by implementing a framework that would set a roadmap to sustainably improve public transport. The establishment of benchmarks for all service providers regarding punctuality, safety, and comfort will enhance accountability and reliability on the system

(Bagwell, 2020). Moreover, implementing successful policies from the European transport models, where strong government roles are played could help bring not only a successful railway network, but a well-functioning public transport network. Consequently, learning from European models could provide valuable insights (Friman, Lättman, & Olsson, 2020). Lastly, ensuring a transparent and efficient customer grievance resolution system can foster public trust in government processes, leading to a considerable perceived improvement in transport services (Ramos, Vicente, Passos, Costa, & Reis, 2019). Successful implementation of customer appeasement could drastically improve public transport from being a "last resort" service to a practical and appealing commuting option, reducing congestion, and promoting sustainable urban mobility.

Conclusion & Future Directions

Modernizing Sri Lanka's rail infrastructure is not only an infrastructure undertaking, but also one of economic, social, and environmental importance. This thesis has explored the key challenges affecting the Sri Lankan Railway system and demonstrated that the best value for the nation can be attained by optimizing the available rail infrastructure, rather than by expanding the rail infrastructure. Sri Lanka can make the rail infrastructure more efficient, access-enhanced, and environment-favorable through electrification, multi-modal connectivity, electronic ticketing, and PPPs by using best European models.

However, reforms need to come immediately. Inaction will only aggravate the sector's deterioration through rising congestion, rising emissions, and fiscal inefficiencies. Electrifying high-density routes and supplementing this through the adoption of an integrated fare structure for enhanced multimodal connectivity is the utmost-priority need. An open regulatory environment also must be established for the encouragement of PPP investments for the sector's fiscal soundness over the long run.

By the examination of European models, this thesis explored effective strategies that Sri Lanka can adopt to enhance rail efficiency and sustainability. European countries have successfully integrated digital ticketing, multi-modal transport solutions, electrification, and public-private

partnerships (PPPs), enabling them to create efficient high performance rail networks. Due to the circumstance Sri Lanka finds herself in; the policies implemented must reflect the current resources, and such policies could be infrastructure optimization, in which the utilization of existing infrastructure is maximized rather than building and expanding. Furthermore, the rail infrastructure should be built to complement the existing bus system to maximize infrastructural utilization. Policies such as smart ticketing and digitalization could enhance passenger experience, and streamline current operations, improving efficiency. In terms of energy, electrification and renewable integration should be a part of the long-term vision, while low density sectors could benefit from the implementation of hydrogen powertrains. Further financial reforms such as public-private partnerships could attract much needed investment to improve service quality, and continuous policy reforms to increase accessibility and public perception of public transport could lift ridership rates.

While these solutions provide a strategic roadmap forward, several obstacles persist. Financial limitations, political interference, and regulatory shortcomings may impede the implementation of these reforms. Consequently, future research should concentrate on developing financing mechanisms, such as Public Private Partnerships (PPPs), debt restructuring for railway investments, and alternative revenue generation strategies, like the Hong Kong Rail + Property model. Furthermore, in-depth studies should delve into data-driven optimization of railway operations, encompassing AI-based scheduling, predictive maintenance, and real-time passenger flow management.

In conclusion, for Sri Lanka's railroad to succeed, its policymakers must act boldly, enacting focused reforms consonant with international best practice and the local context for the country's socio-economy. New research will require the measurement of the cost-benefit implications, regulatory reforms, and financing models for the longevity of improvements. If tactically applied, the reforms will transform Sri Lanka's railroad into an efficient, sustainable, and financially sound backbone for the country.

Bibliography

Abeysekara, A. (2021). *The impact of transport infrastructure investment on economic growth*. Colombo: NSBM Green University Press.

Abrate, G., M., P., & D, V. (2008). *The Impact of Integrated Tariff Systems on Public Transport Demand: Evidence from Italy*. Torino: Università di Torino.

Alexandersson, G. (2009). Rail Privatization and Competitive Tendering in Europe. *Built Environment*, 43-58.

Bagwell, T. J. (2020). Factors Affecting Service Quality in Public Bus Transportation in Sri Lanka. *Global Journal of Marketing and Management*, 67-89.

Balasingham, D., Samarathunga, S., Bandara, A., Arachchige, G. G., Gamage, N., & Wijayaraja, J. L. (2025). *Enhancing Train Transportation in Sri Lanka: A Smart IOT based Multi-Subsystem Approach using MQTT*. Sri Lanka Institute of Information Technology.

BloombergNEF. (2020, 06 11). *Oil Demand From Road Transport: Covid-19 and Beyond*. Retrieved from BloombergNEF: https://about.bnef.com/blog/oil-demand-from-road-transport-covid-19-and-beyond/

Blumenfeld, M., Townsend, W., Brechemier, D., Plummer, P., & Chebl, P. B. (2023). *BRIDGING THE RAIL FINANCE GAP*. UIC.

Buehler, R., Pucher, J., & Dümmler, O. (2021). *Verkehrsverbund: The Evolution and Spread of Fully-Integrated Regional Public Transport in Germany, Austria, and Switzerland*.

Chicago Metropolitan Agency for Planning. (2023). *B4: Fare integration*. Chicago: PART: Plan of Action for Regional Transport.

Comprabus. (2025). *FlixTrain - Railway company in Germany*. Retrieved from Compra Bus: https://www.comparabus.com/en/train/railway-companies/flixtrain#:~:text=Flixtrain%20is%20a%20subsidiary%20of,prices%20start%20at%205€.

Danthanarayana, P., & Kumarage, Y. M. (2021). *Railway operational efficiency and financial performance in Sri Lanka*. Colombo: Sri Lanka Transport Research Forum.

European Commision. (2021). *Attitudes of Europeans towards tourism*. European Public Affairs.

European Environment Agency. (2020). *The European environment — state and outlook 2020*. European Environment Agency.

European Union. (2020). *European Railway Safety Standards: Accessibility and Environmental Considerations*. Rail Vehicles Environment Safety and Security Report.

European Union Agency for Railways. (2024). *Railway Safety and Interoperability in the EU*. European Union.

Fragiacomo, P., & Piraino, F. (2019). Fuel cell hybrid powertrains for use in Southern Italian railways. *International Journal of Hydrogen Energy 44*, 27930-27946.

Friman, M., Lättman, K., & Olsson, L. E. (2020). *Public Transport Quality, Safety, and Perceived Accessibility*. Karlstad: MDPI.

Gamage, L. (2024). Examining the association between passengers' acceptance and intentions toward E-Ticketing and reservation systems in Sri Lankan Railways. *Sri Lanka Journal of Economics, Statistics, and Information Management*, 91-108.

Gamalath, I., Perera, H., & Bandara, J. (2014). Environmental Impact Assessment of Transport Infrastructure Projects in Sri Lanka: Way Forward. *Journal of Tropical Forestry and Environment*, 85-96.

Ge, Y., Jabbari, P., MacKenzie, D., & Tao, J. (2017). Effects of a Public Real-Time Multi-Modal Transportation Information Display on Travel Behavior and Attitudes. *Journal of Public Transportation,*, 40-66.

Glasson, J., Therivel, R., & Chadwick, A. (2005). *Introduction to Environmental Impact Assesment*.

Government of Sri Lanka. (2025). *Sri Lanka Railways*. Retrieved from Ministry of Transport, Highways, Ports and Civil Aviation: https://www.transport.gov.lk/web/index.php?option=com_content&view=article&id=24&Itemid=144&lang=en#rolling-stock

Guerra, C. F., Reyes-Bozo, L., Vyhmeister, E., Salazar, J. L., Caparrós, M. J., & Clemente-Jul, C. (2021). Sustainability of hydrogen refuelling stations for trains using electrolysers. *International Journal of Hydrogen Energy 46*, 13478-13759.

Gunaruwan, T. L., & Dilrukshi, M. H. (2022). Contributions of railway services towards socio-economic equity and environmental sustenance: Reflections from post-lockdown restrictions on train operations in the Western Province of Sri Lanka. *University of Colombo Review*, 182-196.

Gunatillake, H., & Samaliarachchi, L. A. (2022). A Regenerative Braking Model to Predict the Energy Efficiency Improvement of Railway Electrification: A Case Study in Sri Lanka. *The Institution of Engineers, Sri Lanka* , 97-110.

Gutiérrez-Hita, C., Cruz, O. d., & Ramos-Melero, R. (2022). Infrastructure access charges, service differentiation, and strategic competition in the EU railway passenger market. *Transportation Research Part B 164* (pp. 87-104). Madrid: ELSEVIER. Retrieved from ScienceDirect.

IEA. (2022, 09 22). *Well-to-wheel (wake/wing) GHG intensity of motorised passenger transport modes*. Retrieved from IEA: https://www.iea.org/data-and-statistics/charts/well-to-wheel-wake-wing-ghg-intensity-of-motorised-passenger-transport-modes-2

Jayasuriya, R. (2023, 09 20). *Why Sri Lanka should privatize the Railways but not give it to the usual wheeler dealers?* Retrieved from Daily Mirror: https://www.dailymirror.lk/opinion/Why-Sri-Lanka-should-privatize-the-Railways-but-not-give-it-to-the-usual-wheeler-dealers/172-267577

Jayatilaka, K.D.P.R, Abanwela, L., Dahanayake, K., Kulatunga, A., & Dharmapriya, U. (2012). *Railway based container transportation to greening supply chains: A case study in Sri Lanka*.

Jones, M., & Patel, R. (2021). ontactless payment adoption in the UK transport sector. *Transport Economics Journal*, 101-119.

Kesavan, R., Chandrakumar, C., Kulatunga, A., Gowrynathan, J., Rajapaksha, R., Senewiratne, R., & Laguleshwaran, D. (2015). 150 Years of Sri Lankan Railways:

Evaluation of the Services from Employee and Customer Perspectives. *International Journal of Emerging Technology and Advanced Engineering*, 512-523.
Kumara, E., & Bandara, Y. (2021). Towards Reforming Sri Lanka Railways: Insights from International Experience and Industry Expert Opinion. *Sri Lanka Journal of Economic Research*, 51-80.
Kumarage, A. S. (2010). *Review of Sri Lanka Transport Sector.* World Bank.
Kumarage, A. S. (2012). *Sri Lanka Transport Sector Policy Note.* World Bank.
Kumarage, A. S. (2020). Multimodal transport systems: Case studies from Sri Lanka. *Urban Mobility Review*, 55-70.
Müller, F., Gürster, M., Schmidt, K., Obrenovic, N., & Bierlaire, M. (2019). *Model-based economic analysis of electrification in railway.* Monte Verità / Ascona: Swiss Transport Research Conference.
Machado, B. (2025, 02 13). *ECHR ruling expected to boost environment litigation in Europe*. Retrieved from EURACTIV: https://www.euractiv.com/section/eet/news/echr-ruling-expected-to-boost-environment-litigation-in-europe/
Matsika, E., Rici, S., Mortimer, P., Georgiev, N., & O'Neill, C. (2012). Rail vehicles, environment, safety and security. *Research in Transportation Economics*, 1-16.
Milewicz, J., Mokrzan, D., & M. Symanski, G. (2023). *Environmental Impact Evaluation as a Key Element in Ensuring Sustainable Development of Rail Transport.* Poznan: MDPI.
Ministry of Transport. (2025, 01 26). *Main Line Development*. Retrieved from Colombo Suburban Railway Project: http://csrp.lk/main_line.php?id=3
Perera, H., & Shaja, M. (2023). A Study on the Importance of Introducing Railway Organizational Structural Reforms in Sri Lanka: A Passenger Transport Perspective. *The 06th International Conference on Business Innovation* (pp. 337-354). Colombo: NSBM Green University.
Perera, M., Nazeer, F., & Alwis, A. D. (2023). The Customer Satisfaction on the railway infrastructure in Sri Lanka: A study on railway stations. *The 11th World Construction Symposium* (pp. 1039-1048). ResearchGate.
PolyMatter. (2019, 09 20). *How Hong Kong Built the World's Best Transit*. Retrieved from YouTube: https://www.youtube.com/watch?v=ELy9fOX8vtc
Ramos, S., Vicente, P., Passos, A. M., Costa, P., & Reis, E. (2019). *Perceptions of the Public Transport Service as a Barrier to the Adoption of Public Transport: A Qualitative Study.* Lisbon: social sciences.
Rozentale, L., Mo, G. B., Gravelsins, A., Rochas, C., Pubule, J., & Blumberga, D. (2020). System Dynamics Modelling of Railway Electrification in Latvia. *Environmental and Climate Technologies*, 247-257.
Sirimanna, B. (2014). *Sri Lanka embarks on a countrywide multi model integrated transportation hub system.* the Sunday Times.
Siyambalapitiya, T. (2021). Colombo Suburban Railway Project: Review of the feasability study and proposal for the way forward. *Journal of South Asian Logistics and Transport*, 115-131.
Smith, J. (2020). Digital ticketing in European railway networks. *Journal of Railway Innovation*, 12-29.
Sri Lanka Ministry of Transport . (2023). *Transport Sector Policy Note* .

Sri Lanka Railways. (2019). *Administration Report - 2019*. Colombo 10: Department of Sri Lanka Railway.

Sri Lanka Railways. (2021). *Administration Report 2021*. Sri Lanka Railways.

Thalpawila, O. N. (2016). Post –War Reconstruction in Sri Lanka: Reconstruction and Development of the Socio-Economic Sectors . *International Journal of Liberal Arts and Social Science* , 43-56.

UN General Assembly Economic and Social Council. (2024). *Progress towards the Sustainable Development Goals*. New York: United Nations.

United Nations. (2008). *Figure 1 - uploaded by Sharika Thiranagama*. Retrieved from ResearchGate: https://www.researchgate.net/figure/Map-of-Sri-Lanka-Source-The-United-Nations_fig1_231951063

United Nations. (2015). *The 17 Goals*. Retrieved from United Nations: https://sdgs.un.org/goals

Vorisek, D., & Shu, Y. (2020). *Understanding the Cost of Achieving the Sustainable Development Goals*. World Bank Group.

Warakapitiya, K. (2017). *Passengers hold their noses at racist, incompetent railway.* the Sunday Times.

Weerasinghe, N., Weerasinghe, A., Perera, Y., Tennakoon, S., Rathnayake, N., & Jayasinghe, P. (2023). Sustainability practices and organizational performance during the COVID-19 pandemic and economic crisis: A case of apparel and textile industry in Sri Lanka. *PLoS one*, 1-31.

Wijayaraja, J. L. (2025). IoT and GPS-based train tracking systems for Sri Lanka. *Engineering & Technology Review*, 75-90.

Wright, G. (2025, 02 9). *Minister blames monkey for Sri Lanka nationwide power cut*. Retrieved from BBC: https://www.bbc.com/news/articles/c8d92n28pqjo

Acknowledgements

I would like to express my deepest gratitude to everyone who has supported me throughout this journey. Their encouragement, guidance, and unwavering belief in me have played a crucial role in bringing this thesis to completion.

First and foremost, my heartfelt thanks go to my parents and sister, whose endless love, patience, and encouragement have been the foundation of my education. Their belief in me, even during moments of doubt, gave me the strength to keep pushing forward. I truly could not have done this without them.

I am also incredibly grateful to my supervisor for his invaluable guidance and mentorship. His insightful feedback, patience, and constant encouragement challenged me to think critically and refine my research. His support has been instrumental in shaping this thesis and my academic growth.

A special thank you to my dear friend, Giorgio, whose unwavering support carried me through the most difficult moments. His encouragement, reminders of my goals, and belief in my abilities kept me going even when motivation faltered. His friendship has been a true pillar of strength.

I also wish to extend my sincere appreciation to Ravindu for his guidance in refining my research skills and clarifying key concepts. His insights greatly contributed to improving the quality of my work.

Lastly, I am thankful to all my friends, colleagues, and faculty members who have offered their knowledge, encouragement, and inspiration along the way. Each of you has, in some way, shaped this journey, and for that, I am deeply grateful.

This thesis is not just my achievement—it reflects the kindness, support, and generosity I have been fortunate to receive. Thank you all from the bottom of my heart.