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AN ANALYSIS OF TECHNICAL EFFICIENCY AND SERVICE EFFECTIVENESS FOR FREIGHT RAILWAYS IN AFRICAN AND EUROPEAN COUNTRIES

BY

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ABSTRACT

For the past decades, technical efficiency and service effectiveness have become topical as performance measures in various sectors. However, a comparison of technical efficiency and service effectiveness for freight rail transport has received less attention in African and European countries. To address this challenge the current study seeks to analyse technical efficiency and service effectiveness of rail freight in African and European countries. Due to data unavailability in other countries, this study selected four African countries (South Africa, Morocco, Democratic Republic of Congo and Algeria) and four European countries (Lithuania, Austria, France and Germany). The data has been collected from the World Bank, International Union of Railway Statistics and Knoema for the period 2017. Input oriented and output oriented data envelope analysis (DEA) were used to analyze technical efficiency and service effectiveness, respectively.

The application of DEA requires the selection of appropriate inputs, production and output variables. This study selected a number of employees and length of rail lines as input variables, gross train tonne kilometres (km) as production variable, tonnes carried and tonne kilometres (km) as output variables. The result shows that five out of eight countries were technical efficient and their services effective with values equal to 1.00. The Pearson correlation coefficient was used to analyse the relationship between technical efficiency and service effectiveness. The results indicate that there is a statistically significant positive correlation between technical efficiency and service effectiveness.

To determine the impact exogenous variables on technical efficiency and service effectiveness, a Tobit regression analysis was conducted. The results show that technical efficiency and service effectiveness are not significantly affected by exogenous variables. On the other hand, technical efficiency is significantly affected by the number of employees while service effectiveness is significantly affected by gross train tonne km. This study recommends the use of less labour intensive assets and monitoring of gross train tonne km should be viewed as important strategies to improve technical efficiency and service effectiveness, respectively.

DECLARATION

I, **Azania Mfiyo**, solemnly declare that the dissertation titled “An analysis of technical efficiency and service effectiveness for freight railways in African and European countries” submitted in fulfilment of the requirements for the degree of Master of Commerce (Economics) at the University of Fort Hare is my own work. This study has not been submitted and will not be presented at any University in a similar or any award of degree.

Signature :

Date : 04/06/ 2021

PLAGIARISM

I, **Azania Mfiyo**, the undersigned, hereby declare that this dissertation is my own original work that has not been taken or stolen somewhere else, and that it complies with the University of Fort Hare plagiarism policy rules.

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Date : 04/06/2021

RESEARCH ETHICS CLEARANCE

I, **Azania Mfiyo** student number **201816276,** hereby declare that I am fully aware of the University of Fort Hare’s policy on research ethics and I have taken every precaution to comply with the regulations. I have obtained an ethical clearance certificate from the University of Fort Hare’s Research Ethics Committee and my reference number is...........N/A..........

Signature :

Date : 04/06/2021

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Above all, God is omniscient, omnipotent and omnipresent.

DEDICATION

This research work is dedicated to my late father, Mr. Khehlana Mfiyo, may his soul continue to rest in peace, until that glorious day.

LIST OF ABBREVIATIONS

ACI	Airport Council International
AE	Allocative Efficiency
ASEAN	Association of Southeast Asian Nations
AXEF	Aggressive Cross-Efficiency
BCC	Banker Charnes Cooper
BCC-I	Banker Charnes Cooper-Input
BCC-O	Banker Charnes Cooper-Output
BRT	Bus Rapid Transit
CAT	Categorical
CCR	Charnes Cooper Rhodes
CEIC	Census and Economic Information Center
CNG	Compressed National Gas
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CONCOR	Container Corporation
CRS	Constant Return to Scale
DB	Deutsche Bahn
DEA	Data Envelopment Analysis
DMUs	Decision Making Units
DRC	Democratic Republic of Congo
DRS	Decreasing Return to Scale
EDP	Expectancy Disconfirmation Paradigm
EE	Economic Efficiency
EXO	Exogenous
FDEA	Fuzzy Data Envelopment Analysis
FDH	Free Disposal Hull
FSO	Federal Statistical Office
FTE	Full-Time Employee

GDP	Gross Domestic Product
GNI	Gross National Income
GNI	Per capital gross national income
GNP	Gross National Product
GTR	Raddi of Classification ranking
HNDEA	Hyperbolic Network Data Envelopment Analysis
IATA	International Air Transport Association
ICAO	International Civil Association Organization
IDEA	Integrated Data Envelopment
IEA	International Energy Agency
IRS	Increasing Returns to Scale
KLM	Koninklijke Luchtvaartmaatschappij
Km	Kilometres
MS-DEA	Mixed Separate-Data Envelopment Analysis
Mtoe	Million tonne
NDEA	Network Data Envelopment Analysis
NEs	Number of Employees
OECD	Organization for Economic Cooperation and Development
OLS	Ordinal Least Squares
ONCF	Office National des Chemins Fer
OPEC	Organisation of the Petroleum Exporting Countries
PD	Population Density
PSA	Port Singapore Authority
RCCR	Ranked Efficiency
RLs	Rail Lines
RMA	Recife Metropolitan Area
RMR	Recife Metropolitan Region
SARS	Severe Acute Respiratory Syndrome
SAS	Scandinavian Airlines
SBM-DEA	Slack-Based Measurement Data Envelopment Analysis

SDEA	Stochastic Data Envelopment Analysis
SEFFE	Service Effectiveness
STUs	State Transport Undertakings
SXEFF	Cross-efficiency
T	Tonnes
TE	Technical Efficiency
TEFFFI	Technical Efficiency
TEU	Twenty-foot equivalent unit
TFTE	Total Factor Transport Efficiency
Tkm	Tonne kilometre
T-PLs	Third-Party Logistics
UIC	Union International des Chemins
UN	United Nations
US	United States
VRS	Variable Return to Scale
WHO	Wealth Health Organization

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CHAPTER 1

INTRODUCTION AND BACKGROUND OF THE STUDY

1.1 Introduction

Engstrom (2016) describes the transport infrastructure as an essential component that support manufacturers by ensuring that goods and services are in the location where they are required by the customers, while also improving the use of transportation systems. Percoco (2014) state that the availability of adequate transport infrastructure in developing countries plays a vital role, as it maintains low transportation costs, while enhancing the attractiveness and competitiveness of the region. This does not only apply in developing countries, but also in developed countries and thus, Crum (2015) claims that the role of transport infrastructure is undeniable. However, the possible development of countries has been declining due to low infrastructure investment spending, and this inflated the size of unmet demand. The decline in infrastructure spending has been attributed to tight budgetary constraints created by fiscal adjustments and policy rules that have reduced the marginal propensity to invest. Xue (2017) argue that transport contributes to economic development by supporting production, facilitating supply chain processes and consumption activities through the provision of efficient and effective transportation system that ensures timeous movement and availability of unprocessed and finished goods.

During the past decades, rail transport has been considered as the most important mode of transportation (Li and Hu, 2011). In recent years, rail transport has not been performing well owing to its poor-quality services and lack of reliability associated with poor infrastructure, outdated technologies, abandoned railroads and lack of adequate maintenance services. This is further shown by a significant decline in the European freight rail market share from 32.6 percent in 1970 to 16.7 percent in 2006 (European Communities, 2008). Recently, the European rail market recorded a decline of more that 1 percent from 18.7 percent in to 17.4 percent in 2016 (International Union of Railways, 2019). While, Africa's rail market recorded a decline of more than 2 percent from 136.5 billion tonne-km in 2015 to 133 billion tonne-km in 2016.

European Communities (2008) explain that the performance of European railways started to decline during the late 1960s with both passenger and freight rail transport services, finding it difficult to compete with the evolving road and air transport system and to adapt to new customer requirements. However, following significant structural changes, such as open rail market to greater competition and increased technical harmonisation, freight rail transport started to improve. In Africa the rail market has been struggling to regain momentum and dominate land transport, following a successful deregulation of the transport industry in early 1990s. Currently, the transport sector is dominated by the road transportation system for both passenger and freight movement. Road transportation accounts for 80 percent of freight and 90 percent of passenger movement in Africa (United Nations, 2019), whereas in Europe, it is responsible for approximately 75 percent, with rail and inland waterways transport responsible for 18 percent and 16 percent, respectively (Kapfenberger-Poindl, 2018).

This shows that road transportation has become the most preferred mode of transportation around the world. This is further supported by Dadsena, Sarmah and Naikan (2019) that due to their reliability, flexibility and punctuality, road transportation has become increasingly important, particularly the trucking subdivision which plays a predominant role in freight transportation. The road transportation links all individuals involved in the supply; suppliers, producers and warehouses, ensuring that products are delivered in the right quantity, at the right time and to the right location, thereby improving customer satisfaction. Although road transport is the most preferred mode of transport, Road Traffic Management Corporation (2016) warned that road transportation result in externalities, such as traffic congestion, increasing number of accidents, pollution in the forms of air and noise, and the emission of greenhouse gases. Consequently, an increase in traffic congestion reduces the travelling speed, productivity and also hinder the accessibility of different locations that are located within the city centres.

These externalities are usually excluded in the cost of using the road networks (Browne and Ryan, 2011). The International Energy Agency (2017) revealed that approximately 29 percent of the world’s overall energy consumption and approximately 85 percent of the world’s oil consumption relate to the transport industry.

As a result, the transport sector alone accounts for approximately 23 percent of global fossil fuel emissions, 17 percent of which is linked to road transportation with the remaining 6 percent shared by other modes of transportation (international Energy Agency, 2016). The Department of Environmental Affairs (2014) assert that, under normal circumstances rail transport has the potential to provide both passengers and freight with reliable, reasonably priced and harmless transport services, making the economy more reliable while offering a sustainable transport system. Energy efficiency, low carbon emissions and low transportation costs are some of the key benefits offered by rail transportation (African Development Bank, 2015). In addition, relative to other modes of transportation, rail transport is capable of transporting large volumes of passengers and goods simultaneously, while reducing traffic congestion, accidents and travel times as they use fixed routes and schedules. General, rail transport has been considered as the safest mode of transportation around the world, although it provides no assurance that no fatal accident will occur (Maswanganyi, 2017). On the other hand, road transportation uses crude oil to run their day to day operations.

Gross, Cristina and Butz (2012) state that Europe is highly depended on imported oils to meet its energy demands, while 38 out of 53 African countries are net oil importers (Africa Development Bank, 2009). Nkomo (2006) advised that countries highly dependent on imported oil are likely to be impacted by political uncertainty and systematic changes occurring in the country of the origin. For instance, in 1973 just 10 days before the Arab-Israel War, the Arab Organisation of the Petroleum Exporting Countries (OPEC) deliberately cut their oil output by 5 percent, which resulted to increased prices of their oil (Baumeister and Kilian, 2016). South Africa was adversely affected by the East Asian crisis in 1998, when trade emancipation and other institutional adjustments adapted to its global activities (Glenday, 2008). Following the 2008/2009 financial crisis, the crude oil price reached the highest price of $145 per barrel (Sibanda, Gonese, Mukarumbwa, Hove-Sibanda, 2018). Ncanywa and Mgwangqa (2018) argue that hikes in oil prices, result in oil scarcity, increases the cost of production, decreases productivity and output growth. Therefore, it is worthwhile for policy makers to select alternative modes of transportation that will help reduce road transportation, energy consumption, traffic congestion and greenhouse gas emissions.

1.2 Background of the study

Following the introduction of road transportation, rail transport rail market share has been declining. Unreliability and poor service quality of rail transport services has forced both passenger and freight customers to their business to road transportation. For any organisation that seeks to improve performance, efficiency and effectiveness are considered as two important measures of performance. According to Yu (2008), technical efficiency describes the relationship between input factors and generated intermediate service output, while service effectiveness explains the firm's performance in completing maximum ridership from a given generated intermediate service output. In the market for storable goods, technical efficiency and service effectiveness can be used interchangeably as they have the same measures. This is not the case with market for non-storable such as transport sector since the surplus of service produced during the period of low demand cannot be stored for later consumption or use during the period of high demand (Chiou, Lan and Yen, 2007). Hence, technical efficiency is differentiated from service effectiveness. Dassah (2011) argue that, although efficiency and effectiveness are two different performance metrics, they are complementary and the relationship between them cannot be ignored.

Mouzas (2016) state that focusing on efficiency and neglecting effectiveness can results in an ephemeral profitability, yet focusing on effectiveness and neglecting efficiency may result in an unprofitable growth if the opportunity cost of capital is higher than the resulting profits. Therefore, an input-oriented data envelopment analysis (DEA) and output oriented DEA have been used to analyse technical efficiency and service effectiveness, respectively. Georgiadis, Politis and Papaioannou (2014) define data envelopment analysis (DEA) as a non-parametric technique used to estimate the efficiency of firms performing same tasks and responsible for converting multiple inputs into multiple outputs. Banker, Emrouznejad, Bal, Alp and Cengiz (2013) point out that one of the benefits of using the DEA method is that it presumes no specific functional form of the data. DEA techniques have been used by various scholars in different sectors to estimate technical efficiency and effectiveness. These include, but are not limited to; agriculture (Richard, 2014), tourism (Yu and Lee, 2009), education (Chitekedza, 2016), transport

(Singh and Jha, 2017), and business management (Keh, Chu and Xu, 2006). However, the bulk of the existing literature in transport has placed more focus on estimation of technical efficiency with less attention devoted to service effectiveness. Thus, the literature analyzing the relationship between technical efficiency and service effectiveness is very scarce. This study is motivated by the lack of literature analysing both technical efficiency and service effectiveness of freight railways, particularly in Africa and Europe. Initially, the objective was to analyze technical efficiency and service effectiveness in selected African and European countries, however, due to data unavailability in other countries, this study is limited to four African countries (South Africa, Democratic Republic of Congo (DRC), Algeria and Morocco) and four European countries (Germany, Austria, Lithuania and France).

1.3 Problem statement

International Union of Railways (2019) reveals that Asia, the Russian Federation and America are the main contributors to the world total rail freight tonne-km, with Europe and Africa responsible for a smaller share. Asia is responsible for the highest share of 38 percent, followed by America and the Russian Federation, which account for 30 percent and 23 percent, respectively (International Union of Railways, 2019). While Europe contributes 7 percent and Africa 2 percent, proving far less than their counterparts. Lan and Lin (2006) linked the decline in market share with best service offered by other alternative modes of transportation or poor technical efficiency and service effectiveness of freight railways. For instance, rail transport can take up to 48 hours to transport freight between Lyon (France) and Milan (Italy), while trucks can deliver within 8 hours. In organizations that seeks to achieve robust and everlasting growth-oriented outcomes, evaluating technical efficiency and service effectiveness has become topical.

Scholars like Kottas and Madas (2018); Lozano and Gutierrez (2014); Movahedi, Abtahi and Motamedi (2011) and Wanke and Azad (2018) contributed to the formulation of literature of this nature in the transport sector. The previous scholars examined technical efficiency and service effectiveness in the transport sector and yielded different findings, depending on the method and variable used. In addition, the relationship between technical efficiency and service effectiveness was studied and different results were obtained. Some scholars found that there is a statistically significant positive correlation between technical efficiency and service effectiveness (Singh and Jha, 2017) or negative correlation (Doomernik, 2015; Karlaftis and Tsamboulas, 2012), while others found no clear correlation (Georgiadis *et al.*, 2014) between the two. Yet, none of these interests spilled to Africa's and Europe's deteriorating state of freight rail transportation. In response to this challenge, this study seeks to analyse technical efficiency and service effectiveness of freight railways in African and European countries. It is envisaged that this study will provide answers to the following research questions; (1) Do freight railways in Africa and Europe provide efficient and effective services? (2) Is there an existing relationship between the two performance measures? (3) To what extent does exogenous variables affect the performance of freight railways?

1.4 Objectives of the study

The primary objective of this study is to analyse technical efficiency and service effectiveness for freight railways in African and European countries by using the standard DEA methods. Secondly, this study seeks to:

- Present trends on key variables used in the study, for both African and Europe;
- Empirically analyze the degree of association between technical efficiency and service effectiveness of freight railways, with specific reference to African and European countries;
- Identify the impact of exogenous variables on freight railways performance by using Tobit regression analysis;
- Draw conclusion and provide recommendations based on the findings of the study.

1.5 Hypothesis of the study

$H1_a$: There is no significant association between technical efficiency and service effectiveness of freight railways.

$H1_b$: There is a significant association between technical efficiency and service effectiveness of freight railways.

$H2_a$: Technical efficiency is not significantly affected by the exogenous factors.

$H2_b$: Technical efficiency is significantly affected by the exogenous factors.

H3$_a$: Service effectiveness is not significantly affected by the exogenous factors.

H3$_b$: Service effectiveness is significantly affected by exogenous factors.

1.6 Justification of the study

As previously indicated, the technical efficiency and service effectiveness have become topical in various sectors of the economy that seek to achieve robust and everlasting growth-oriented results. However, this topic has received less attention in transport sector, particularly rail freight transportation in Africa and Europe. The existing literature in transport sector includes, but is not limited to, airlines (Kottas and Madas, 2018; Lozano and Gutierrez, 2014), maritime (de Koster, Balk and van Nus, 2009; Barros and Athanassiou, 2004), road (Singh and Jha, 2017; Georgiadis *et al.,* 2014), passenger railways (Link, 2016) and Asian freight railways (Wanke and Azad, 2018).

Therefore, this study has contributed to the formulation of the literature analyzing performance of freight railways in Africa and Europe. Moreover, this study can be used by other researchers as a point of reference and to explore other possible areas of research. Bababeik, Khademi, Chen and Nasiri (2017) highlighted that rail transportation has received less attention in public debates compared to other modes of transportation. This study can help to revive interest in the rail sector. This study can be used to present the status quo of rail freight transportation so that the policy makers can revert with corrective measures.

1.7 Organization of the study

Following the introductory Chapter is the overview of the study in Chapter 2, theoretical and empirical literature in Chapter 3, research methodology in Chapter 4, presentation and discussion of the empirical findings in Chapter 5 and the conclusion, delimitations and recommendations in Chapter 6.

CHAPTER 2

AN OVERVIEW OF THE FREIGHT RAILWAYS IN AFRICA AND EUROPE

2.1 Introduction

This chapter provides an overview of railways in eight African and European countries. These countries consist of four African countries (South Africa, Morocco, Democratic Republic of Congo and Algeria) and four European countries (Lithuania, Austria, France and Germany). The analysis further includes trends on key variables employed in this study for the period 2014 to 2017. The variables are categorized into inputs, production (intermediate), outputs and exogenous variables. Subsection 2 presents an overview of countries being studied. Subsection 3 presents trends on inputs variables (number of employees and length of rail lines). Subsection 4 presents trends on intermediate (production) variable (gross train tonne kilometres). Subsection 5 present trends on exogenous variables (population density and per capita gross national income. The need for rail freight transport in Africa and Europe is presented in subsection 6. Lastly, subsection 7 presents conclusion.

2.2 An overview of freight railways in Africa and Europe

2.2.1 South Africa

According to PriceWaterhouseCoopers (n.d) South Africa is ranked as the 14th largest rail network in the world and is known for its developed rail system in relation to those of other African countries. Freight rail transport managed by Transnet in South Africa, is a division that operates world-class heavy haul, general freight and containerized freight (Transnet, 2019). The division maintains an extensive route of 20 953 kilometres (km) with approximately 31 400 track km, of which 1500 km are heavy haul lines and 3 928 km are branch lines that serves main routes. Their main purpose is to provide links between ports, terminals and production hubs, providing connectivity with the railways of the Southern African Development Community (SADC) to support regional integration. For the year 2017, Transnet Freight Railways recorded revenue increase of 5.9 percent from R36 953 million in 2016 to R39 114 million in 2017.

According to Transnet (2018) this increase was driven by 2.3 percent increase in freight volumes from 214.2 million tonnes (mt) in 2016 to 219.1 million tonnes (mt) in 2017. This increase was further complemented with a slightly increase in the average R/ton, increasing from R168, 74 in the prior year in 2016 to R174, 95 in 2017.

2.2.2 Morocco

Akoudad and Jawab (2018) state that the Moroccan railway network consists of 2 109 km, of which 1284 km are electrified and 633 km double track. The railway network serves both passengers and freight with 120 stations. The Moroccan freight rail, managed by the National Office of Railroads (Office National des Chemins de Fer (ONCF)) is responsible for transporting agricultural produce, and products, automotive products, energy inputs (coal, fuel and petroleum, construction materials, and chemicals). During the period 2012-2016, the amount of goods transported rail amounted to 53.9 million tonnes, making the Office National des Chemins de Fer (ONCF) the most important transporter of goods in the United Kingdom (Organisation for Economic Co-operation and Development (OECD), 2018). This amount excluded phosphate which amounted to $50.6 million in 2016. Generally, transportation of goods and minerals contributes 60 percent of ONCF's revenue, according to OECD (2018). While transportation of other goods and phosphate represents 15 percent and 51 percent, respectively.

2.2.3 Algeria

The Algerian railway network, managed by Societe Nationale des Transport Ferroviaires (SNTF) is made up of 4 573 kilometres (km) as of 2017, of this 3 854 km were operationally with 175 stations (Oxford Business Group, 2018). Moreover, 449 km were double-track lines and a total of 323 km were electrified. The freight rail transport sector accounted 2 percent of overall land transport in 2014 compared to rail passenger transport responsible for about 97 percent rail activity, according Oxford Business Group (2018). For the past years, Algeria recorded no further extension in their networks. On the other hand, the SNTF had intentions to expand the rail network to 12 500 km by 2025, however the government Algeria has revised that figure to about 6 300 km by 2030.

2.2.4 Democratic Republic of Congo

According to World Bank (2018), Democratic Republic of Congo (DRC) railway network is divided into three railways totaled to 5 033km. The first railway network is 366 km long track operated by the Office National des Transport (Chemin de fer Matadi-kinshasa). The second rail network, which is the largest in DRC consisted of 3 641 km operated by the National Railway Company of DRC (Societe Nationale des Chemins de fer du Congo-SNCC). The third rail network is 1 026 km long operated by the Chemin de fer des Ueles, however this rail network is currently inactive. According to Cross-Border Road Transport Agency (2019) the amount of goods transported by rail in DRC increased by 11.5 percent from 174 million-ton km in 2016 to 194 million-ton km in 2017.

2.2.5 Lithuania

Lithuanian railway network is made up of 1 911 km, of which 1 458 km are single tracks, 452 km are double tracks and 152 km are electrified (International Union of Railways, 2017). Lietuvos Gelezinkeliai group responsible for management of rail networks in Lithuania, provides freight transportation, logistics and forwarding, cargo loading and unloading, wagon rental in Lithuania and abroad, coordinates the work of locomotives and brigades in Lithuania and abroad, and also leases them (Lietuvos Gelezinkeliai, 2019). According to Lietuvos Gelezinkeliai (2017) Lithuanian rail network is ranked 7^{th} place in terms of freight transportation (Lietuvos Gelezinkeliai, 2017). In year 2017, freight transported by rail increased by 10.5 percent to 52.6 million tonnes in 2017 compared 47.65 million recorded in 2016 (Lietuvos Gelezinkeliai, 2017). In addition, the rail freight transportation generated about EUR381.5 million of the EUR448.1 million revenue received from overall freight transportation, representing the largest share of the market.

2.2.6 France

According to International Trade Administration (2016) the rail network in France is ranked as the second in Europe and the third in the world after China and Germany. The rail network consists of more 300 companies dealing infrastructure, equipment, rolling stock, suppliers, engineering, rail equipment, and track to signaling. France has the largest rail network of about 28 422 km, 2 600 are high-speed lines, 58 double track and

16 097 km are electrified lines. Over the past 30 years, the rail freight transport in France has been decreasing with about 5 000 km track of lines deteriorated due to poor track conditions. According to Knoema data (2017), the amount of goods transported by rail in France increased by 2.68 percent from 32 569 million ton-km to 33 442 million ton-km in 2017. An increase in revenue from €16 033 million in 2016 to €16 625 million in 2017 was recorded, representing an increase of 3.6 percent.

2.2.7 Germany

According to International Union of Railways (2017) Germany rail network encompassed 33 488 km, of which 18 472 km were double track or more and 20 233 km were electrified. Boston Consulting Group (2017) ranked Germany fourth among national European rail systems during the year 2017 European Railway Performance Index assessing intensity use, quality of service and safety. In terms of performance, rail freight in Germany generated €5.7 billion revenue in 2017, representing an increase of €0.1 billion from €5.6 billion in 2016 (Bundesnetzagentur, 2018). While volumes of goods transport by rail recorded a decline of 1 million tonnes from 412 million tonnes in 2016 to 411 million tonnes in 2017.

2.2.8 Austria

Austrian rail network consists of 4 953 km, of which 2 133 km are double track or more and 3 557 km are electrified (International Union of Railways, 2017). The Austrian rail network is owned by the national rail company OBB. In 2017, the company transported about 115.2 million tonnes (consolidated), representing an increase of 6 percent from 109.0 million tonnes in 2016 (OBB, 2017). In addition, a total of EUR 2 199.8 revenue was generated in 2017. This shows an increase of 6 percent from EUR 2 079.0 revenue generated in 2016.

2.3 Input variables

The first stage, technical efficiency, of measuring performance in transport sector starts with selection of appropriate inputs and outputs. In the rail sector, labour and capital are the most commonly used input variables (Li and Hu, 2011).

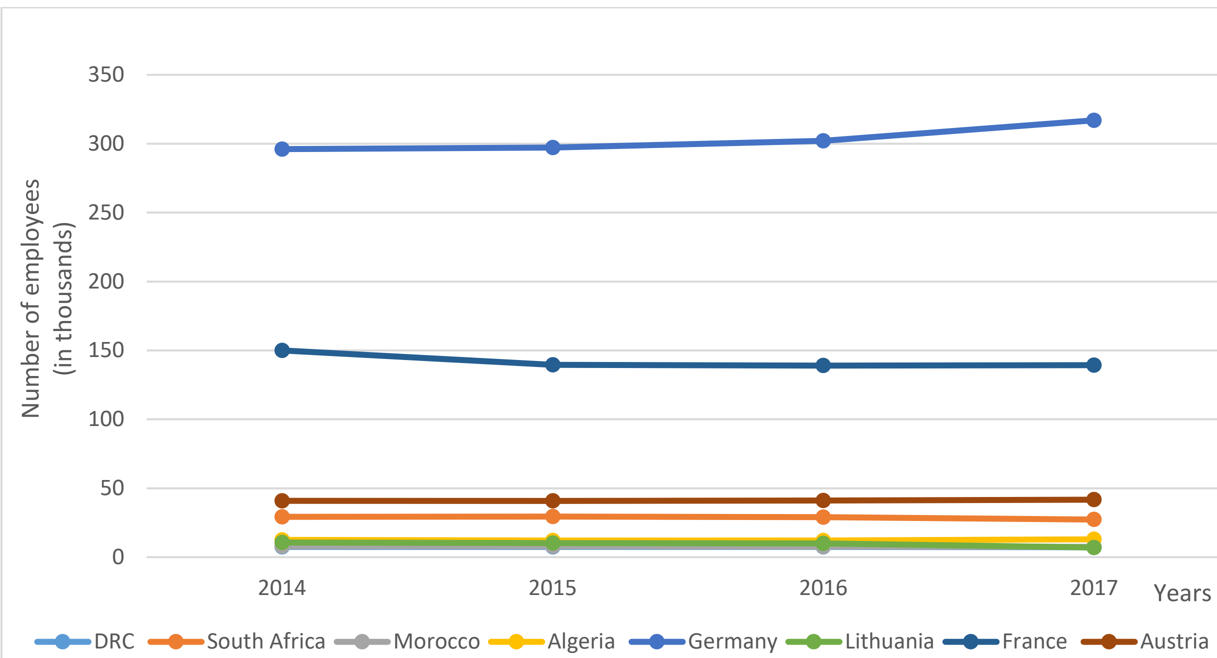
These variables are further classified into physical factors and cost factors, in monetary terms (Catalano, Daraio, Diana, Gregori, and Matteucci 2018). Furthermore, the physical variables consist of variables, such as the number of workers and hours of work, while cost variables consist of variables, such as capital expenditure and operation expenses. Following Link (2016) and Wanke and Azad (2018), this study selected a number of employees and rail lines as input variables. For an entity that seeks to improve efficiency, it is recommended that it should either increase outputs or reduce inputs (Ozcan, 2014). However, if inputs and outputs are increasing simultaneously, the rate of increase in the outputs should be higher than the rate of increase in inputs, or if inputs and outputs are decreasing simultaneously, the rate of decrease in output should be lower than the rate of decrease in inputs (Ozcan, 2014).

In this study, this implies that when the rail decision-making units seek to improve efficiency, it should either increase the output or reduce the number of employees and length rail lines. If there is a simultaneous increase in production and the number of employees and rail lines, the rate of increase in output should be higher than the rate of increase in the number of employees and rail lines. But if there is a simultaneous decrease in the number of employees and rail lines and output, the rate of decrease in the output should be less than the rate of decrease in the number of employees and rail lines. Kabir (2016) notes that efficiency signifies a performance level that describes a process that achieves the maximum outputs utilizing the minimum input factors.

According to Maredza (2009), a firm is considered technically efficient if it achieves a maximum output with the least inputs. Then, technical inefficiency exists when the railway decision-making unit produces too little output using too much input (Lan and Lin, 2008). Maredza (2009) also agrees that technical inefficiency occurs as a result of excessive use of inputs and lack of managerial oversight. Therefore, for rail transport services to be considered efficient, it should produce more output using fewer employees and rail lines.

2.2.1 Number of employees

According to Kasuso (2015, p. 25), “an employee is (a) any person other than an independent contractor who works for another person or for a state and who receives, or is entitled to receive, any remuneration, and or (b) any person who is any way assists in the operation of the business or running the business of an employer". Kottas and Madas (2018) describe the number of employees as human resources dealing with planning, performance and supervision of the whole spectrum of operations. Moreover, the number of employees is often used interchangeably with the full-time equivalent (FTE), which represents the average hours of service as the number of full-time employees. Dahkoul (2018) notes that through their success, workers create a competitive advantage for organizations. In addition, employee performance is an indicator of their efficiency and competitiveness, contributing to the accomplishment of an organizational objective through their positive participation, as the performance of employees would eventually result in the organisations overall performance. The figure below displays trends on the number of employees in rail sector for the period 2014-2017.



Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

Figure 2.1 Number of employees in African and European railways (2014-2017)

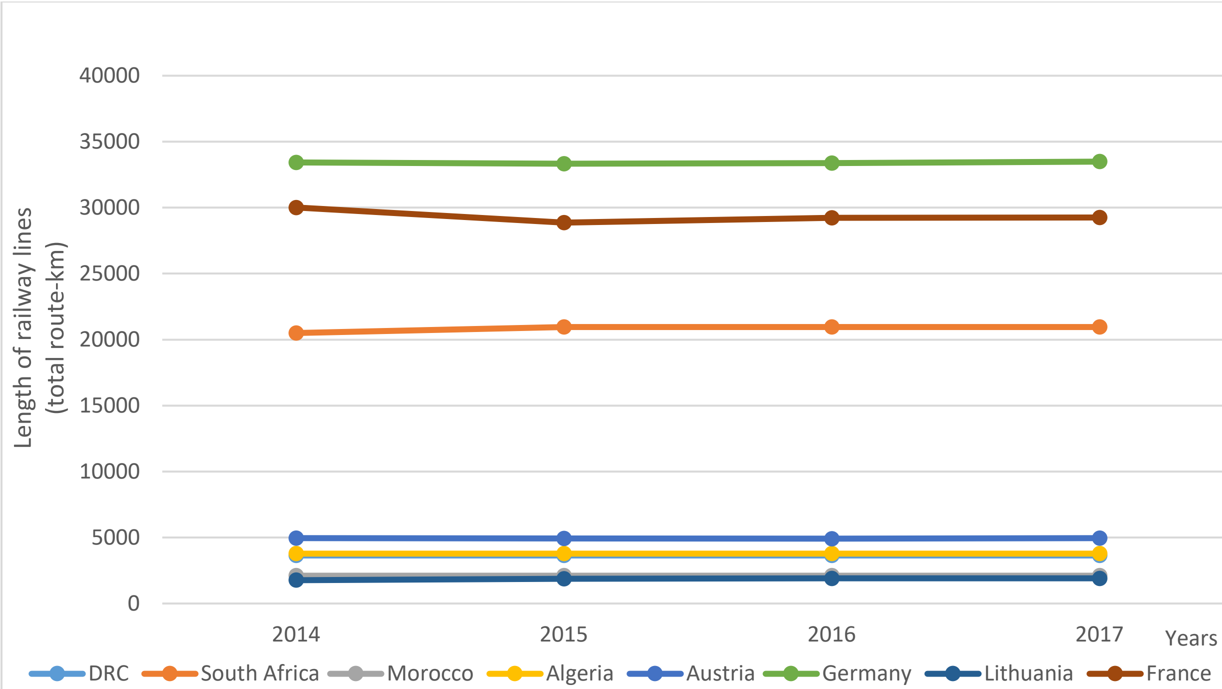
It is clear from Figure 2.1 that, over the past four years, the rail industry has seen slight fluctuations in the number of employees. In Germany, the number of employees rose dramatically from 296 000 in 2014 to 317 000 in 2017, representing an increase of 7.09 percent.

This increase was associated with an increase in the number of contract workers, maintenance and repairs, construction projects and a number of long distance and freight transportation jobs (Deutsche Bahn (DB), 2018). While France recorded a decline of 7.3 percent from 150 000 in 2014 to 139 000 employees in 2017. According to Barrow (2017), this decline was due to one of the rail companies, specifically the French national railway company, cutting its employees by almost 50 percent from 14 933 to 7 420 in 2008 and 2015, respectively.

South Africa recorded a decline of 6.9 percent from 29 000 in 2014 to 27 000 in 2017 in the number of employees working in the rail sector. The contributing factors behind the decline in the number of employees include the filling of critical operational vacancies and exit of employees due to natural attrition and people who took early retirement (Transnet, 2018). The number of employees in Austria has increased from 41 000 in 2014 to 42 000 in 2017, representing an increase of 2.4 percent. This increase was significantly below an increase of 8.3 percent recorded in Algeria, increasing from 12 000 in 2014 to 13 000 in 2017. Lithuania recorded the largest decline of 36.4 percent in the number of employees from 11 000 in 2014 to 7 000 in 2017. There were no major increases in the number of employees in the rail sector of the Democratic Republic of Congo (DRC) between 2014 and 2017.

2.2.2 Length of rail lines (total route-km)

Length of rail lines measured in total route-km is defined by Asmild, Holvad, Hougaard and Kronborg (2009) as the length of active rail networks, regardless of the number of parallel tracks. The International Energy Agency (2019) states that the length of railways is an indicator of the priority given to rail infrastructure and network capability investments. For the past years, the state of rail networks has deteriorated due to lack of, or differed, rail transport infrastructure investment and budget constraints (Mathabatha, 2015). The figure below presents trends for rail lines measured by the length of railways in four African countries and four European countries for the period 2014-2017.



Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

Figure 2.2 Length of railway lines in Africa and Europe (2014-2017)

Figure 2.2 indicates that there has been no major improvement reported in the length of railways in all eight countries over the past four years, starting in 2014 through to 2017. The figure further shows that amongst the eight nations, Germany is the top country by rail lines (total route-km). Despite being the largest rail network amongst other countries in the study, Germany recorded a marginal growth rate of 0.2 percent expansion, improving from 33 426 km in 2014 to 33 488 km route in 2017. The length of rail lines in South Africa has increased from 20 500 in 2014 to 20 953 km in 2017, this represents an increase of 2.2 percent. In 2012, Transnet launched the Market Demand Strategy, worth approximately R300 billion in capital investment projects for the following seven years (Emwanu, 2014).

The main emphasis was placed on the expansion of rail lines, port and pipeline infrastructure. In 2017, 303 km rail network between Ermelo and Majuba power station was refurbished and 68 km new rail network was installed (Department of Economic Development, 2017). France rail network deteriorated by 2.5 percent from 30 013 km in 2017 to 29 248 km rail network in 2017.

Austria recorded a decline of less than 1 percent from 4 956 km in 2014 to 4 953 km in 2017. The length of railway lines in Lithuania has increased to 1 911 km in 2017, increasing by 8.1 percent from 1 767 in 2014. The increase was attributed to repair works, including the replacement of tracks with long rail and completed repairs (Lietuvos Gelezinkeliai, 2017). On the other hand, Algeria recorded no significant changes in length of railways. Styles (2019) states that the period of civil war in the 1900s severely affected the rail networks in Algeria, but plans are underway to build 1 300 km of high-speed rail on the east-west line that is expected to cross between Tunisia and Morocco.

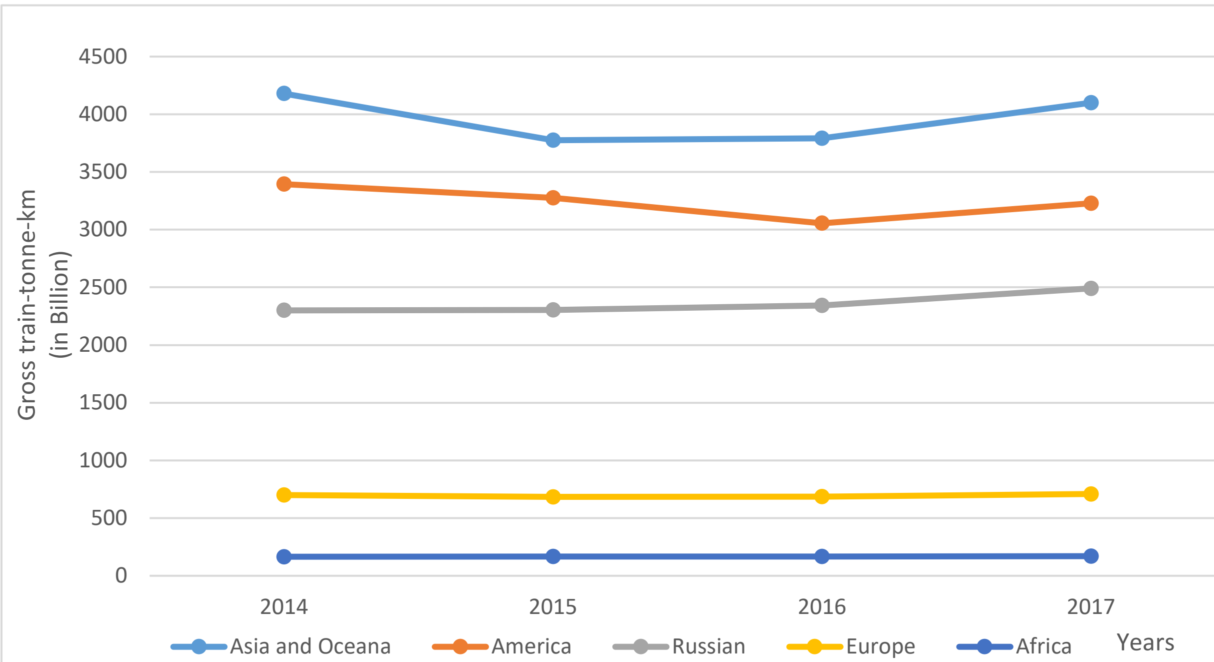
2.3 Production (intermediate) output variable

The second stage, service effectiveness, of measuring performance in the transport sector involves the selection of production (intermediate) service output, which is, in turn, input and selection of outputs. Rail transport is generally an example of a decision-making unit that consists of several components and processes during the production phase, since it provides both passenger and freight transportation services. Yu and Lin (2008) clearly state that the production factors used as output when estimating relative efficiency at the first stage, is in turn used as input when estimating service effectiveness at a later stage of measuring performance. For instance, Chiou, Lan and Yen (2010) evaluated performance of non-storable services by selecting two factor inputs (buses and active networks) two production variables (bus runs and bus-km) and four output variables (revenues, passenger-km and average number of passengers on board).

While Doomernik (2015) used two inputs; length of rail lines and size of the fleet, one production variable; train-km and two output variables; ridership and travel volumes. This study selected number of employees and rail networks as input variables and gross train tonne km is selected as a production (intermediate) variable. Once intermediate service output, such as gross train tonne km, is produced from the transformation of inputs, such as number of employees and rail lines, it must be fully utilised, if not they will be wasted and ineffectively utilised. This implies that, for an organisation to achieve service effectiveness, it should make sure that all of the available produced intermediate service output is consumed immediately. Thus, Yu (2008) described service effectiveness as the ability of an entity to attain maximum trips from the available produced output or production (intermediate) output.

2.3.1 Gross train tonne kilometres

Index Mundi (2019) defines gross train tonne kilometres (Gttkm) as a measure that includes all rail wagons weights for both empty and loaded movements. Gttkm is also called trailing tonnes or total tonnes being hauled. The figure below presents trends for Gttkm in four African countries and four European countries for the period 2014 – 2017.



Source: Authors own analysis using UIC (2019) data

Figure 2.3 Gross train tonne kilometres in Africa and Europe (2014-2017)

Figure 2.3 shows that Asian railway has an important rail market share of the annual volume of rail freight tonnes around the world. However, having more gross train tonne kilometres does not necessarily mean the rail system is effective, until all of the Gttkm is fully utilised. In 2017, the Gttkm in Asia was 4 099 million tonne-km, representing 38 percent of the overall rail freight market, followed by America in the second place with 3 229 million tonne-km, representing 30 percent, and Russia in the third place with 2 491 million tonne-km, representing 23 percent. While Europe contributed 709 million train tonne-km and Africa 170 million train tonne-km, representing 7 percent and 2 percent, respectively.

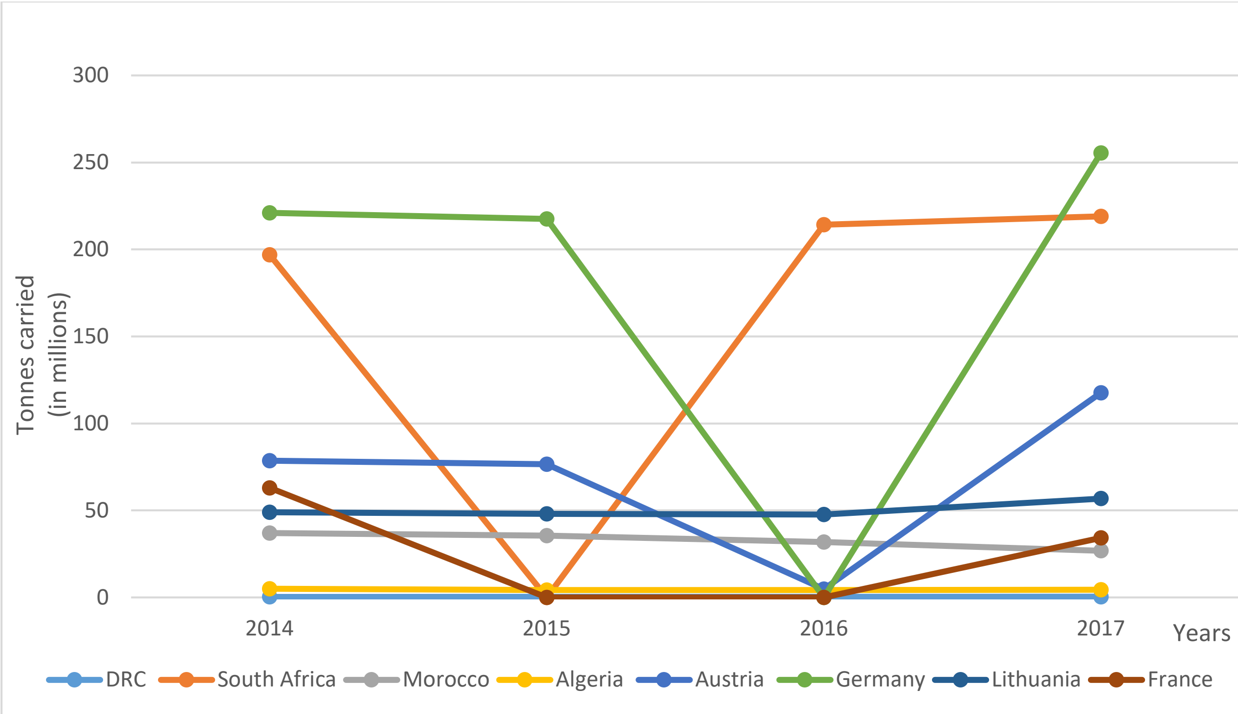
Both Africa and Europe recorded no significant changes in the annual volume of freight transported around the world and, when compared to other counterparts, have a smaller share of rail market. Asia is renowned as the centre of the recent improvement in the rail sector (International Energy Agency, 2019). This growth was further complemented with an abundance of natural resources that can be efficiently utilized, if traded extensively and frequently transported over long distance (domestic or international) by rail freight transport. For instance, Russia is rich in coal, timber and minerals and has therefore, developed an extensive rail network for freight to promote and expand international trade of the resources, with more than 50 percent of freight activities transported by rail (International Energy Agency, 2019). Moreover, United States products, such as coal, grain, grain mill and chemicals are amongst the products mostly transported by gross trains.

2.4 Output variables

The last stage of measuring performance in transport services involves the consumption of intermediate (production) output to produce final outputs. Karlaftis (2004) states that the produced transport service must be consumed immediately, or if a portion of the service is not consumed it would be ineffectively used. In this study, gross train tonne-km is selected as an intermediate (production) variable used to produce output, such as tonnes carried and tonne kilometres. Therefore, an increase in output is a good indication that the available intermediate (production) output is being effectively utilised and this can be indicated by the increase in number of tonnes carried and tonne kilometres.

2.4.1 Tonnes carried

According to European Communities (2003), tonne is a metric unit of weight that is equal to 1000 kilograms. The figure below demonstrates trends in the amount of goods conveyed by rail transport in African and European countries between 2014 and 2017.



Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

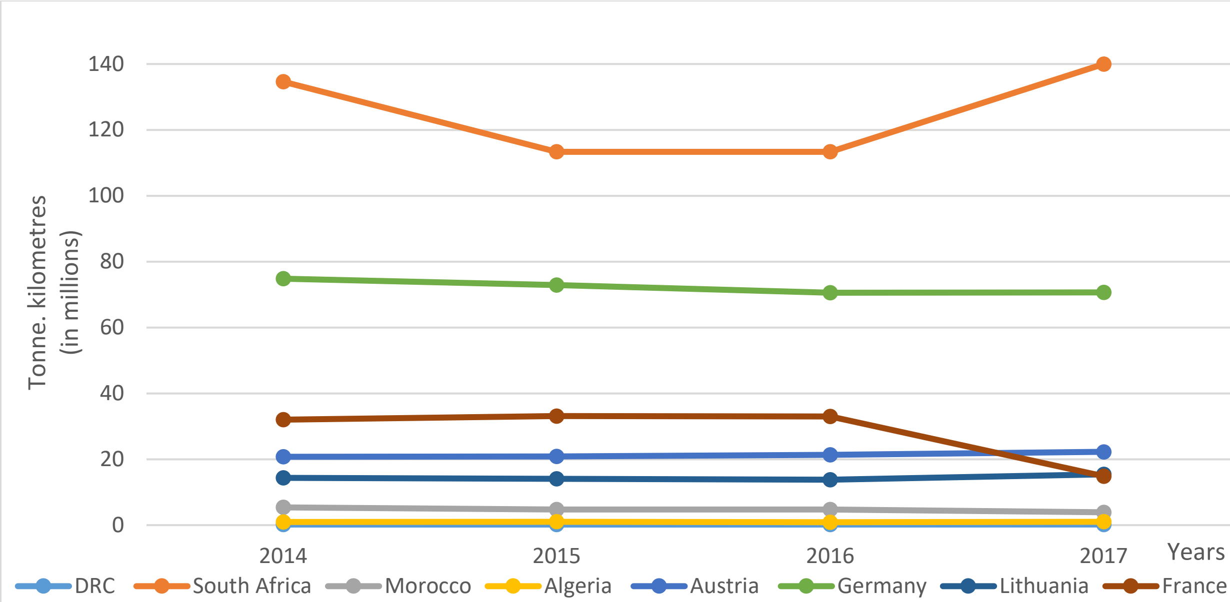
Figure 2.4 Tonnes carried throughout the world (2014-2017)

Figure 2.4 represents the year on year tonnes (T) carried by rail freight transport around the world for the period under consideration, 2014 to 2017. The number of goods carried by rail in Germany was 255.5 million tonnes in 2017, representing an increase of 15.6 million from 221 million in 2014. South Africa transported 219 million tonnes of goods by rail transport, showing an increase of 11.6 percent from 197 million tonnes in 2014. Some of the factors which contributed towards the growth of 219 million tonnes in South Africa include; a growth of 6.3 percent exceeding the projected 2.1 percent in mineral mining and chrome trade, remarkable recovery in the Ore and Manganese trade, the Container and Automotive business, and the opening of a Steel Hub at Isando which has contributed to increased railage of finished steel products in South Africa and neighbouring countries (Transnet, 2017). Austria has increased its rail freight transportation by almost 50 percent from 78.5 million tonnes in 2014 to 117.7 million in 2017. The DRC recorded an increase of 46.7 percent from 300 000 in 2014 to 440 000 tonnes carried in 2017. Tonnes carried by rail in Lithuania increased by 15.9 percent from 49 million in 2014 to 56.8 million in 2017.

On the other hand, France recorded a sharp decline to 34.3 million in 2017, decreasing by 45.6 percent from 67 million tonnes carried in 2014. France rail freight transport experienced a serious tide of weak demand and strong competition from other modes of transportation (Barrow, 2017). Furthermore, freight rail transport in France was found in a fragile state and not economically viable. Morocco recorded a decrease of approximately 27.5 percent in freight carried by rail transportation, decreasing from 37 million in 2014 to 26.8 million in 2017. According Rensma and Hamoumi (2018), this decline was caused by a decline in the amount of non-phosphate and phosphate transported by rail transport. In addition, the number of containers transported between 2015 and 2016 has significantly dropped to less than 20 000 twenty-foot equivalent unit (TEU). Algeria recorded a decrease of 11.6 percent in freight carried by rail transportation, decreasing from 5 million in 2014 to 4.42 million in 2017.

2.4.2 Tonne kilometres

According to Eurostat Statistics (2013), tonne-kilometre (Tkm) is a unit of cargo transport measure denoting the carriage by rail, road, air, sea, pipeline and inland waterways of one tonne of goods, including packing and tare weights for intermodal transport units, over a distance of 1 kilometre. Figure 2.5 below present trends on tonnes kilometres for the period 2014–2017 in four African and European countries.



Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

Figure 2.5 Tonne kilometre in Africa and Europe (2014-2017)

On average, South Africa recorded an increase of approximately 4.0 percent from 134.6 million in 2014 to 140 million tonne kilometres in 2017, which show the largest increase amongst the eight countries being studied. Tonnes kilometre in Germany declined by 5.6 percent, declining from 74.82 million in 2014 to 70.61 million in 2017. The decline in the rail freight transportation in Germany was attributed to decline in volume of goods specifically suited to be transported by rail (Deutsche Bahn, 2018). These included coal, mineral oil and chemicals. In addition, the closure of the European corridor between Karlsruhe and Rastatt, which lasted up to seven weeks, impacted significantly on the transportation of goods (Deutsche Bahn, 2018).

France recorded a sharp decline of about 53.6 percent, declining from 32.0 million in 2014 to 14.8 million in 2017. According to Barrow (2017), these trends were largely driven by a decline in heavy industries and exacerbated by the poor conditions of rail networks that compromised the reliability of paths allocated for gross trains and quality of services considered essential by shippers, which have therefore, switched traffic to other modes of transportation. The transportation of freight by rail transport in Morocco declined from 5.38 million in 2014 to 3.9 million tonnes in 2017, representing a decline of 27.8 percent. On the other hand, DRC recorded an increase of 27.5 from 150 000 tonnes in 2014 to

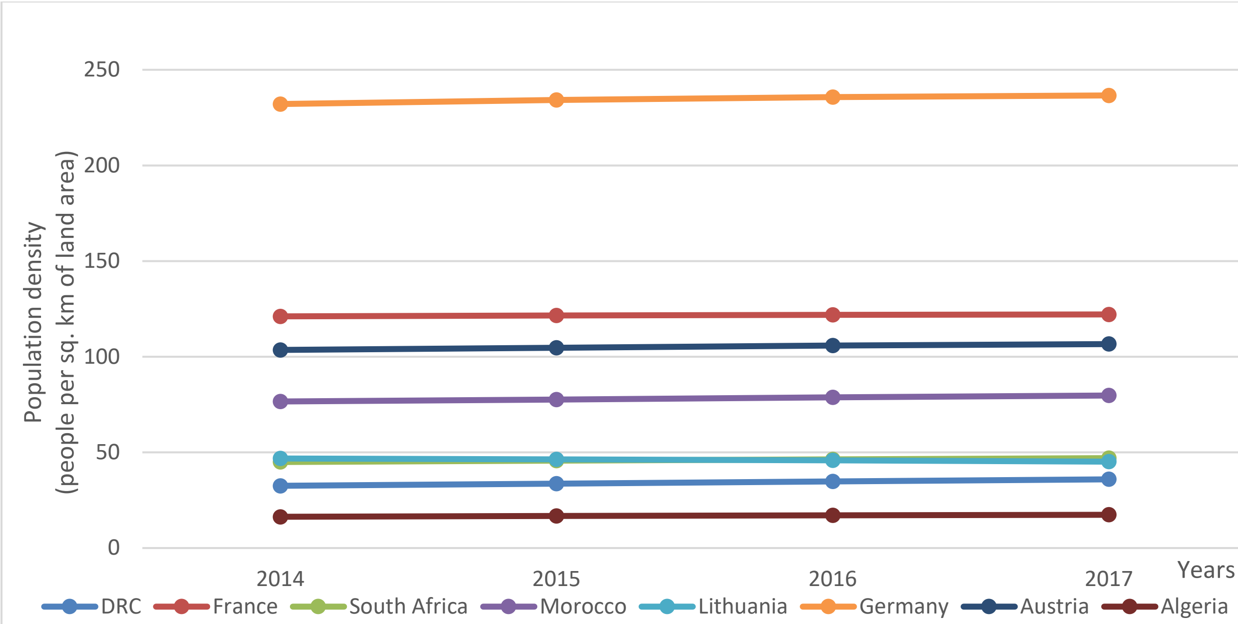
190 000 tonnes in 2017. While Algeria's rail tonnes carried by rail was about 1 million tonnes, increasing by 8.6 percent from 930 000 tonnes.

2.5 Exogenous variables

Exogenous variables are defined as factors whose value is determined by factors outside the model under review (Engle, Hendry and Richard, 1983). In terms of rail transport, Lan and Lin (2003) define exogenous variables as that which is not within the control of the entity but could potentially impact rail performance. Yu and Lin (2006) advised that the impact of exogenous factors on the efficiency and effectiveness values cannot be neglected, since data for exogenous variables vary from region to region and different railways are facing different exogenous factors. For instance, Lan and Lin (2003) found that the data envelopment analysis values for efficiency and effectiveness are significantly determined by population density and per capita gross national income. While Li, Yang, Zhang and Cao (2016) found that economic development and government influence can decrease overall efficiency, while industrial structure, population density, and geographical position can influence transport efficiency and the influence of these factors depends on each region. Due to the complexity of other variables and unavailability of data in other variables, this study selected population density (PD) and per capital gross national income (GNI) as exogenous variables.

2.5.1 Population Density (PD)

According to Cooke and Behrens (2017), population density is the number of people within a given gross area per unit of area. Globally, 55 percent of the population reside in urban areas, and by 2050 it is estimated that the current population of 4 billion will exceed 6 billion (Dingil, Schweizer, Rupi and Stasiskiene, 2018). Rehman (2017) on the other hand, notes that increase population result in an increase in energy demand, increased industry and transportation that increases fossil fuel emissions. Lan and Lin (2003) found that data envelopment analysis values for efficiency and effectiveness were positively affected by population density. This implies efficiency and effectiveness improves as a result of a unit increase in population density. The figure below demonstrates trends on population density of four Africa and four European countries for the period 2014 – 2017.



Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

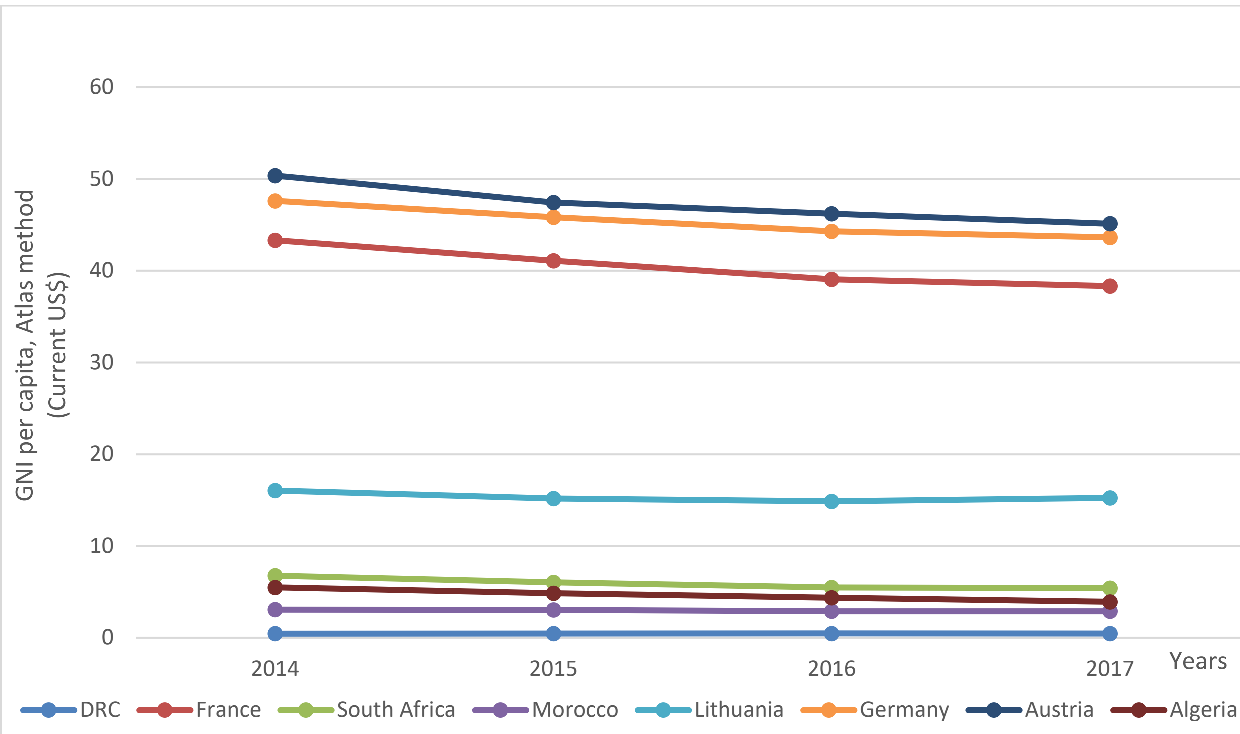
Figure 2.6 Population density in Africa and Europe (2014-2017)

From Figure 2.6, it is evident that most countries experienced a slight growth in population density. Germany is a highly dense country with 237 inhabitants per square meter for 2017, with an increase of 2.1 percent from 232 inhabitants per square meter in 2014. The population density in France has slightly increased to 122 inhabitants per square meter in 2017, increasing by 0.8 percent from 121 inhabitants in 2014. As of 2017, population density in Austria was 107 inhabitants per square meter in 2017, 2.9 percent higher than 104 inhabitants in 2014.

Lithuania experienced a decrease of 4.3 percent from 47 inhabitants per square metre in 2015 to 45 inhabitants per square metre in 2017. Algeria is a less population dense country with 16 inhabitants per square metre in 2014, increasing by 6.25 percent to 17 inhabitants per square metre in 2017. Since 2017, population density in South Africa has been 47 inhabitants per square metre, increasing by 4.4 percent from 45 inhabitants per square metre. DRC recorded an increase of 9.1 percent in population density, increasing from 33 inhabitants per square metre in 2014 to 36 inhabitants per square metre in 2017.

2.5.2 Per capita GNI

World Bank (2020) defines "per capita gross national income (previously called per capita gross national product) as the gross national income, converted to U.S (United States) dollars using the World Bank Atlas method, divided by the midyear population". Hitge and Gqaji (2011) note that cities with high density and a higher quality transportation system appear to have higher income per gross capita than high density and low-density countries with poor quality transportation systems. Lan and Lin (2003) found that per capita gross national income impacted positively on both efficiency and service effectiveness. This implies that a unit increase in per capita GNI improves both efficiency and service effectiveness. Figure 2.7 below demonstrates trends on per capital gross national income for the period 2014 – 2017.



Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

Figure 2.7 Per capita gross national income in Africa and Europe (2014-2018)

From Figure 2.7, it is evident that all countries observed a decline in per capita gross national income. Since 2017, per capita gross national income in Austria was US$45 12, decreasing by 10.4 percent from US$50 370 in 2014. Germany's GNI per capita in 2017 was US$43 640, with a decline of 8.4 percent from US$47 620 in 2014. France recorded a decline of 11.5 percent from U$43 320 in 2014 to U$38 330 in 2017. Lithuania recorded a decline of 5 percent from U$16 040 in 2014 to U$15 240 in 2017.

The GNI per capita in South Africa was US$5 410 in 2017, declining by 20 percent from US$6 760 in 2014. Algeria recorded the largest decline of 28.6 percent from U$5 490 in 2014 to U$ 3920 in 2017. Morocco recorded a decline of 5.9 percent from U$3 060 in 2014 from U$2 880 in 2017. DRC recorded an increase of 4.5 percent from U$440 in 2014 to U$460 in 2017.

2.6 The need for rail transport in Africa and Europe

This section presents the benefits associated with the development of freight railway transportation in Africa and Europe.

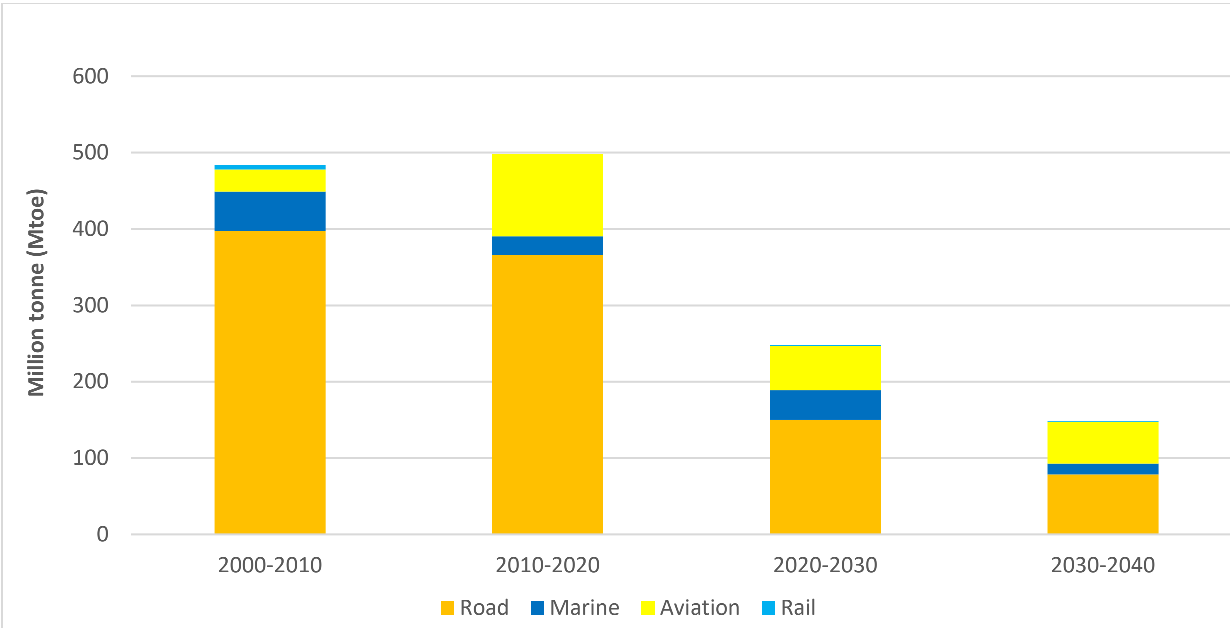
Rail transport has played a pivotal role in ferrying both passenger and freight at a low cost and facilitating development in mining and agricultural sectors over the past decades (Olievschi, 2013). As previously indicated, in Africa road transport is responsible for approximately 80 percent of goods and approximately 90 percent of passenger traffic (United Nations, 2019). In Europe, road transport accounts for 75 percent, rail and inland waterway transport accounts for 18 percent and 7 percent, respectively (Kapfenberger-Poindl, 2018). The following section presents the need for a freight shift from road to rail transportation.

2.6.1 Benefits associated with rail freight transportation

Transportation, accounting for 23 percent of the energy related carbon dioxide (CO_2) emissions, is the fastest growing major contributor to global climate change (Asian Development Bank, 2010). Road transport alone accounts for 16.5 percent of the total CO_2 emissions and the remaining 6.5 percent of CO_2 emissions relate to other modes of transportation. Whereas, rail freight transportation reduces energy consumption and CO_2 emission (International Energy Agency, 2019).

Investing in rail freight transportation instead of road freight transportation can be more energy efficient, while reducing logistics costs and vehicle emissions (World Bank, 2017). Blumenfeld, Wemakor, Azzouz and Roberts (2019) claim that it is possible to reduce external transportation costs by at least 47.5 percent per passenger kilometre and 75.4 percent per tonne kilometre by either using diesel or electricity-powered rail transport.

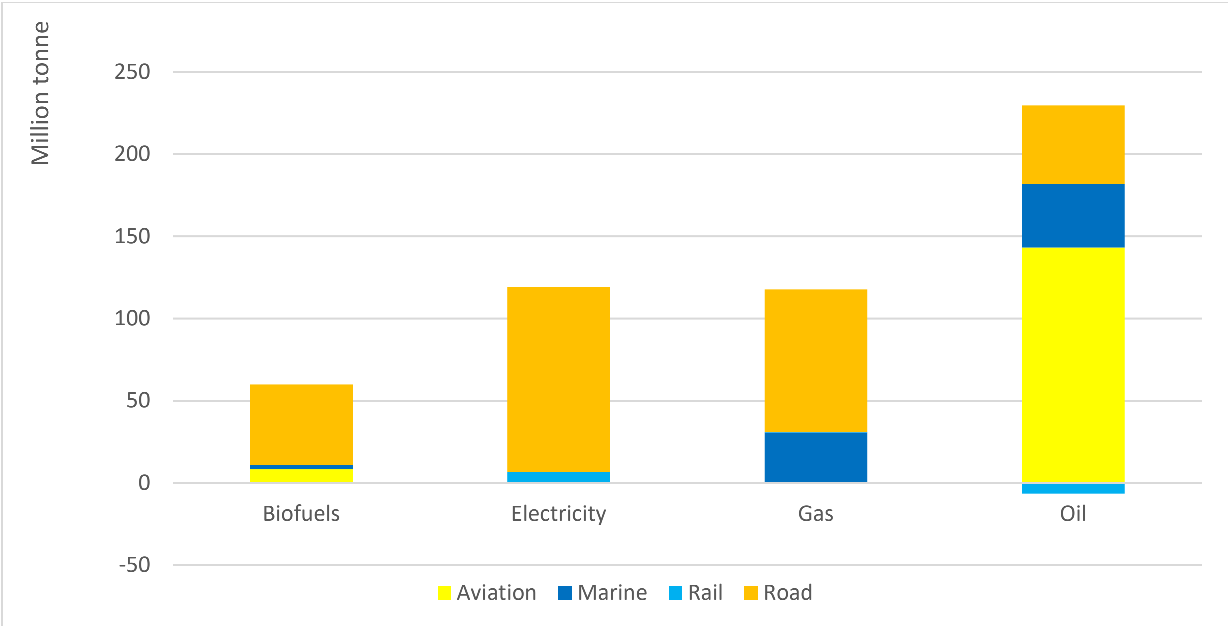
Rail freight transportation, while contributing to boarder economic benefits, such as agglomeration effects, can provide mass transit, minimize congestion on roads, as well as save valuable and scarce space (International Energy Agency, 2019). The figure below demonstrates the past, present and projected energy consumption growth by each mode of transport.



Source: Author's own graph using British Petroleum (BP) Energy Outlook data (2019)

Figure 2.8 Final energy consumption: growth by mode

From Figure 2.8 it is clear that rail transport systems, compared to other alternative modes of transport, such as road, marine and aviation, requires less energy. For example, between 2000 and 2010, rail transport systems consumed 5.8 million tonnes of energy, compared with 397.5 million tonnes of road energy, 51 million tonnes of marine energy, and 29.1 million tonnes of aviation energy. It is anticipated that the energy required would have declined between 2030 and 2040 but road sector will still demand more tonnes of energy (78.5 million tonnes), followed by Aviation (54.5 million), marine (14.4million tonnes) and rail transport (600 000million tonnes). The following figure, Figure 2.9, presents the final energy consumption growth by the fuel and mode of transport. The following figure demonstrates the amount and type of energy demanded by each type of transport.



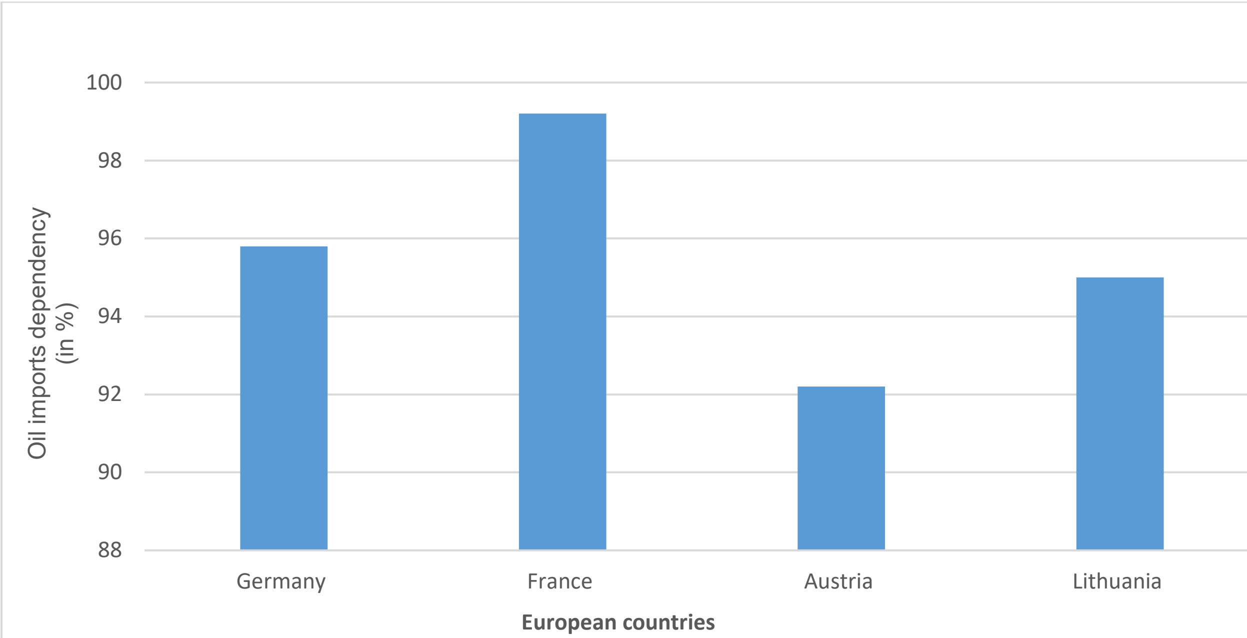
Source: Author's own graph using BP Energy Outlook data (2019)

Figure 2.9 Final energy consumption in transport: growth of fuel and mode

Figure 2.9 demonstrates that road transportation requires more biofuels, electricity and gas than any other mode of transport, such as aviation, marine and rail. While rail demands less biofuels, electricity and no gas. Rail has also recorded a deficit of 7 million tonnes of oil.

2.6.2 Oil imports

According to Marbuah (2017), crude oil is the main driver of industries, manufacturing, transportation and trade at national, regional and global level. Furthermore, crude oil and other related products, such as liquefied gasoline, petroleum, gas and kerosene are necessary for domestic companies, agriculture and the transport sector in order to boost economic growth. This is further supported by Gupta (2008) who states that for a sustainable economic and social development, oil is the fuel that drives the economy and its regular supply is necessary. 38 of 53 countries in Africa are net oil importers (African Development Bank, 2009) and more than half of the energy required in Europe to meet energy demands is imported (Eurostat, 2019). Nkomo (2006) notes that countries heavily dependent on imported oil are likely to be impacted by political uncertainty and systematic changes occurring in the country of the origin in order to meet their energy needs. The figure below presents the oil dependence of four European countries.

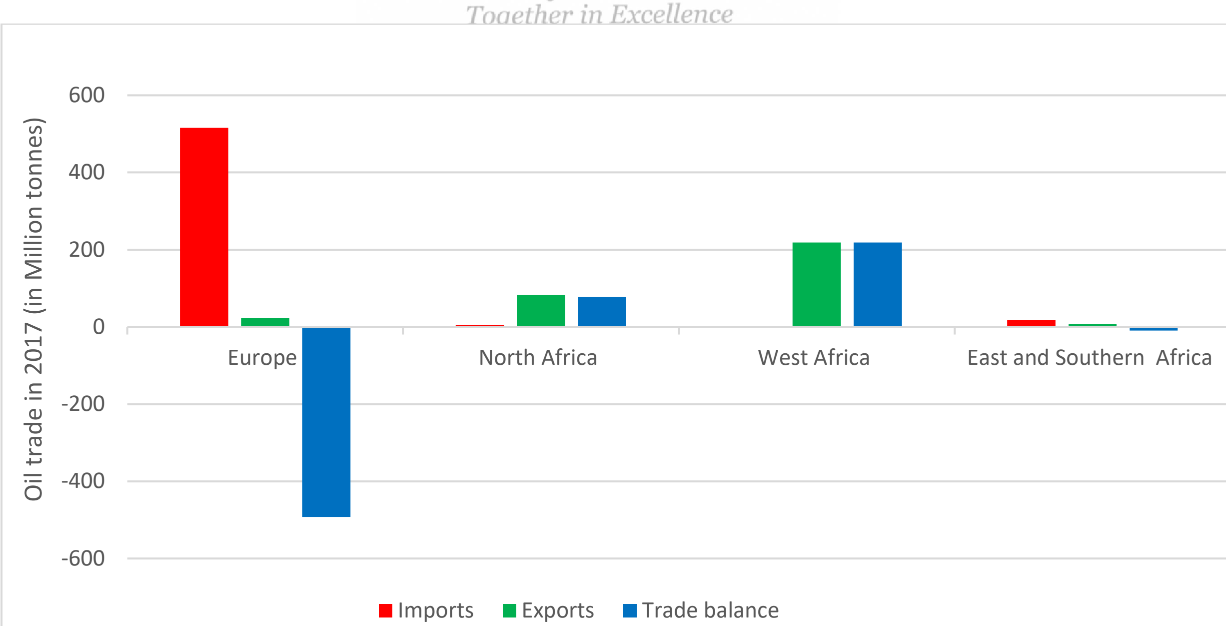


Source: Author's own graph using Eurostat (2020)

Figure 2.10 Oil import dependency (in %) for European countries

Figure 2.10 shows that European countries are highly dependent on imported oil, with the dependency ratio ranging between 90 to approximately 100 percent. Two thirds of the final oil market are accounted for by the transport industry and 50 percent of the final demand for petroleum products relates to road transport (Transport Environment, 2016). An, Wang, Qu and Zhang (2018) warned that growing dependency on imported oil worsens a country to the effects of oil shocks, as risks may occur during the oil importing process. For instance, the major suppliers of oil in Europe are from geographically unstable regions where terrorism, internal and border conflicts (wars) have increased (Transport environment, 2016). According to Transport environment (2016) the main suppliers of oil in Europe, include Russia which represents 30 percent of crude imports, followed by Nigeria and sub-Saharan Africa with 16 percent and a further 16 percent from the Middle East. Cirovic (2014) added that countries such as Russia, Iran, Venezuela and other major oil suppliers have been willing to use their energy resources to pursue their strategies and political objectives. Nkomo (2006) identified political instability as one of the factors contributing to high oil prices rather than market forces.

High oil prices affect the production by increasing the cost associated with factors of production and this further results in inflation, with a low demand for non-oil products and low investments in net importing countries (International Energy Agency, 2014). Additionally, the balance of trade and exchange rates are amongst macroeconomic elements exposed to oil price volatility. The autoregressive structural vector model used by Shi, Yang and Li (2012) to examine the relationship between crude oil volatility and the freight industry show that freight is primarily affected by crude oil supply shocks. A study conducted by Behmiri and Manso (2015) on how oil consumption influences the economic growth of sub-Saharan Africa shows that reducing crude oil consumption without implementing successful policies would have a negative impact on the economic development of the region. Behmiri and Manso (2015) recommend that countries which seek to reduce dependency on the external oil supply must shift towards energy efficient transportation systems. Therefore, diversifying transportation systems or provisioning alternative means of transportation to road transportation can help to overcome the challenge of high oil demand and energy demand from external suppliers. The figure below presents the amount of oil imported and exported by each region, trade deficit and a trade surplus for the year 2017.



Source: Author's own graph using BP Statistical Review of World Energy (2019)

Figure 2.11 Crude oil trade in 2017

Figure 2.11 shows that Europe is the net importer of crude oil, this is shown by a large trade deficit of approximately 492.3 million tonnes in 2017, while the African region shows no significant trade deficit. According Anyanwu (2010), Africa is a region well-endowed with oil and natural gases, hence there were no significant oil trade deficits.

2.7 Conclusion

The data presented above shows that there has been no significant progress in rail freight transportation industry. This is shown by the growth rate in the amount of inputs (length of rail lines and number of employees) invested in the sector. Currently, the transport industry is dominated by road transport with rail sector taking the backseat due to large investment backlog, delayed maintenance and replacement of depreciated assets. This resulted in poor quality services in rail sector and as result the sector is struggling to compete with evolving road transport. Although literature assessing both technical efficiency and service effectiveness is still limited in rail sector, scholars such as Lan and Lin (2003) argue that technical efficiency and service effectiveness of passenger rail transport are positively affected by population density, electrified lines, per capita GNI, and average length of passenger trips. While Li, Yang, Zhang and Cao (2016) argue that economic development and government influence can reduce overall transport efficiency, while industrial structure, population density, and geographical position can influence transport efficiency and the influence of these factors vary depending on the region.

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

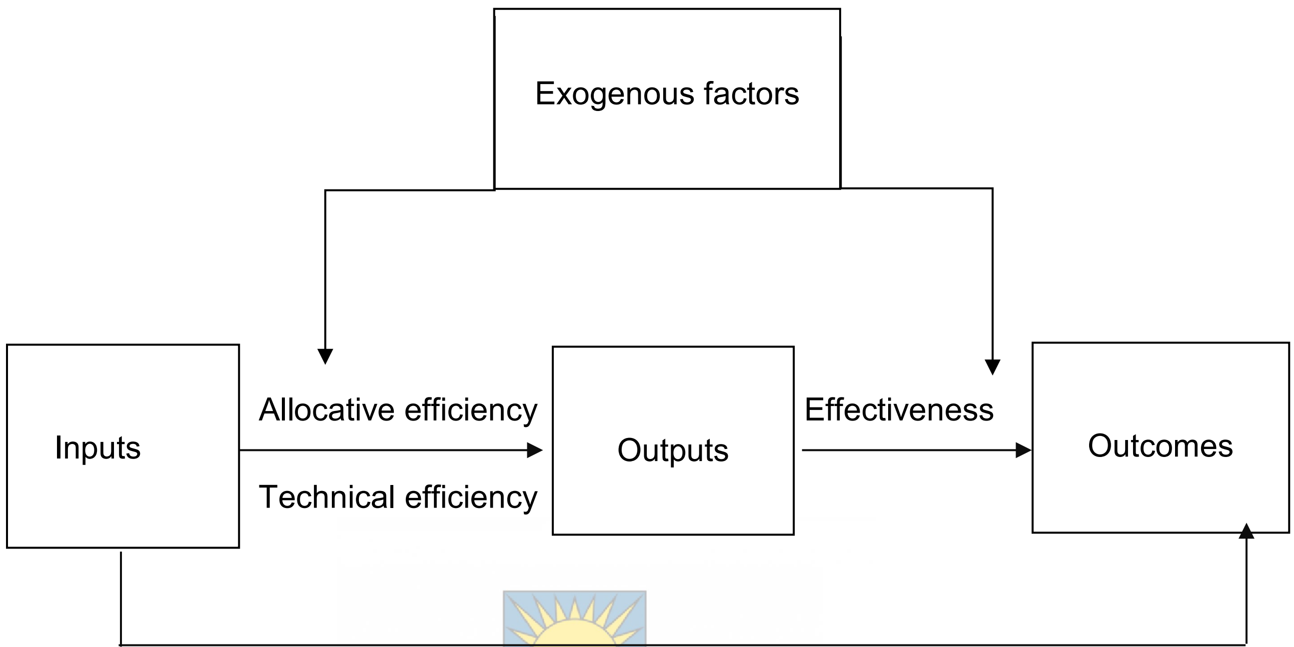
The theoretical and empirical literature relating to technical efficiency and service effectiveness is discussed in this chapter. Firstly, this chapter will start by conceptualizing the term "technical efficiency" and "service effectiveness". Secondly, theoretical literature consisting of; the theory of efficiency, expectancy disconfirmation paradigm and comparison level theory will be discussed. Empirical literature consisted of empirical studies from different modes of transportation and assessment of the empirical are discussed in the fourth and fifth section of the chapter, respectively.

3.2 Conceptualization efficiency and service effectiveness

According to Chiou, Lan and Yen (2010), the ratio of production (intermediate) variables to input factors is called technical efficiency, while the ratio of output to production is called service effectiveness and the ratio of output to input factors is called technical effectiveness. In summary, Ozcan (2014, p. 16) describes efficiency as "the ratio of outputs over inputs". While Yao, Xu and Li (2020) observe technical efficiency as comparison of the actual or observed output(s) and input(s) values with the optimum input(s) and output(s) values use in the production process. Service effectiveness is described by Minaiu, Opreana and Cristescu (2010) as the ratio of the attained outcomes to expected outcomes. Førsund (2017, p. 93) added that efficiency is about "doing things right" and effectiveness is about "doing the right thing".

Ozcan (2014) states that, a firm that seeks to improve efficiency should consider increasing outputs and reducing inputs. However, if both input and output increases, the increase in the output should be greater than the increase in the input and if both input and output decreases, the decrease in output should be less than the decrease in input (Ozcan, 2014). Introducing technological changes, or reengineering services and processes), as well as lean management which will reduce inputs and increase the ability to produce more outputs, is the best way to improve efficiency (Ozcan, 2008).

Using the following example extracted from Minaiu *et al*. (2010) the relationship between efficiency and effectiveness can be explained.



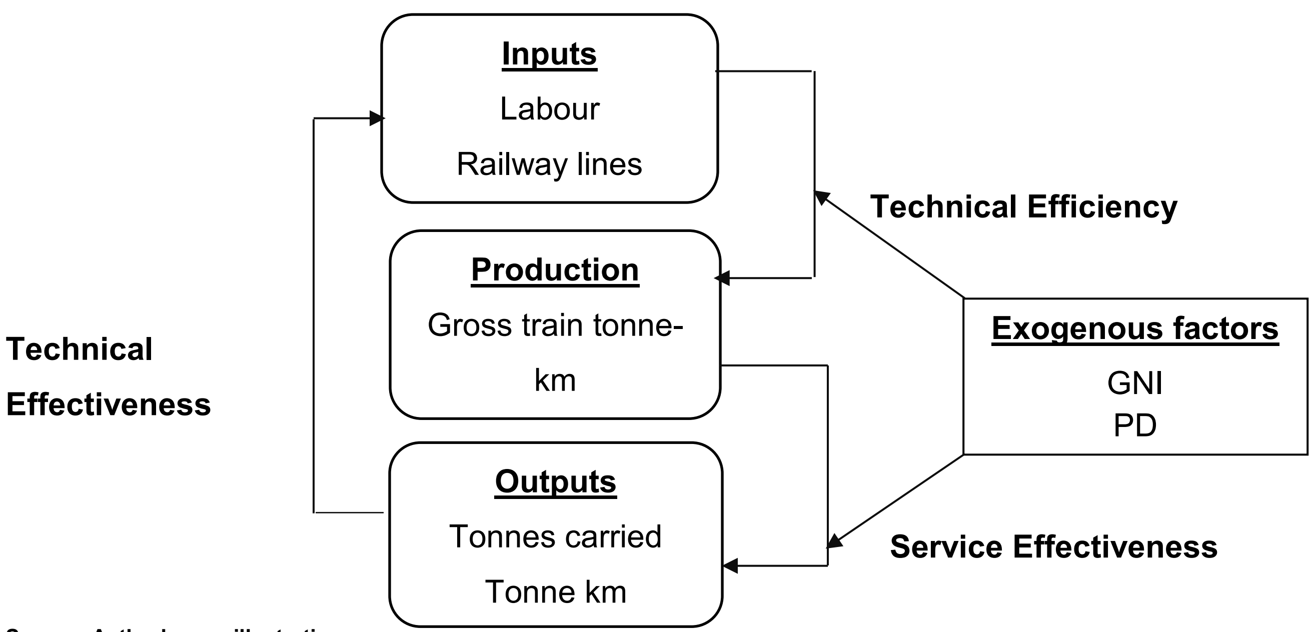
Source: Mihaiu et al. (2010)

Figure 3.1 Conceptualization of efficiency and effectiveness

This study adopted the process of Mihaiu *et al*. (2010) to conceptualise efficiency and effectiveness. Farrell (1957), the pioneer of the term ‘efficiency’ as the measure of performance, classified efficiency into technical efficiency and allocative efficiency. According to Porcelli (2009), technical efficiency is the ratio between the observed output and the maximum output, while keeping all input fixed or the ratio between the observed input and minimum input, while keeping all output fixed. While, allocative efficiency is the ability, in light of the prevailing prices, to combine both inputs and outputs in optimum proportions, or the ability to select the best optimum combination of inputs given input prices. Both technical efficiency and service effectiveness combined result in overall efficiency or economic efficiency. Since it is not practically possible to obtain the input prices in this case, the main focus in this study is of technical efficiency. Allocative efficiency is particularly suitable for the financial sector and thus, the bulk of the literature is found in the financial sector (Olegi, Michael and Andreas, 2006; Kumbhakar and Tsionas, 2006; Maredza, 2009; 2014).

Service effectiveness is a measure of customer satisfaction with service delivery (Carvalho, Syguiy and Silva, 2015). Service effectiveness measures how fast the intermediate or production service output is consumed (Shavazipour, 2014). Porcelli (2009) states outcome accessibility, quality and appropriateness are key elements often used to define service effectiveness. Yu and Lin (2008) describe transport services as non-storable services and thus, the measures of efficiency and effectiveness are completely different.

Yu and Lin (2008) further claim that rail transport efficiency measurements include, but are not limited to; the rail network and cars, for both staff and passengers, as input factors and freight cars and train kilometres, for both freight and passengers, as production (intermediate) service output. Service effectiveness measurements consist of train-kilometres for passengers and freight as input factors and passenger-kilometres and tonne-kilometres as output factors. Therefore, to achieve technical efficiency, the firm must employ the least inputs to produce maximum outputs and for service effectiveness, the production (intermediate) outputs must be fully utilised, if not they will be ineffectively utilised and become a waste. Figure 3.2 presents a railway conceptualisation framework as follows:



Source: Author's own illustration

Figure 3.2 Efficiency and service effectiveness conceptualisation framework

Figure 3.1 demonstrates how the technical efficiency is derived from the transformation of input factors (number of employees and rail lines) and production (gross train tonne-km) and further demonstrates how the service effectiveness is derived from production (gross train tonne-km) and output variables (tonnes carried and tonne-km). Maredza (2009) argues that technical efficiency exists when the selected inputs achieve the maximum output with the least number of inputs. Conversely, technical inefficiency is usually caused by excessive usage of inputs (Maredza, 2009). Service effectiveness measures how fast the production (intermediate) output is consumed to produce final outputs. If the production (intermediate) output is fully utilised immediately, then the provided service is considered effective (Shavazipour, 2014). However, if the production (intermediate) output is not fully utilised, it becomes wasteful and is ineffectively utilised (Lan and Lin, 2006).

Yu (2008) for instance, describes service effectiveness as the ability of an entity to obtain maximum trips from the available produced output or production (intermediate) output. Chiou *et al*. (2007) claim that, if part of the production is unsold, technical effectiveness, which accounts for the combined effect of efficiency and effectiveness would be lower than technical efficiency. Engle *et al*. (1983) define exogenous variables as factors whose value is determined by factors outside the model under review. Per capita gross national income (GNI) and population density (PD) are selected exogenous variables.

3.3 DEA models

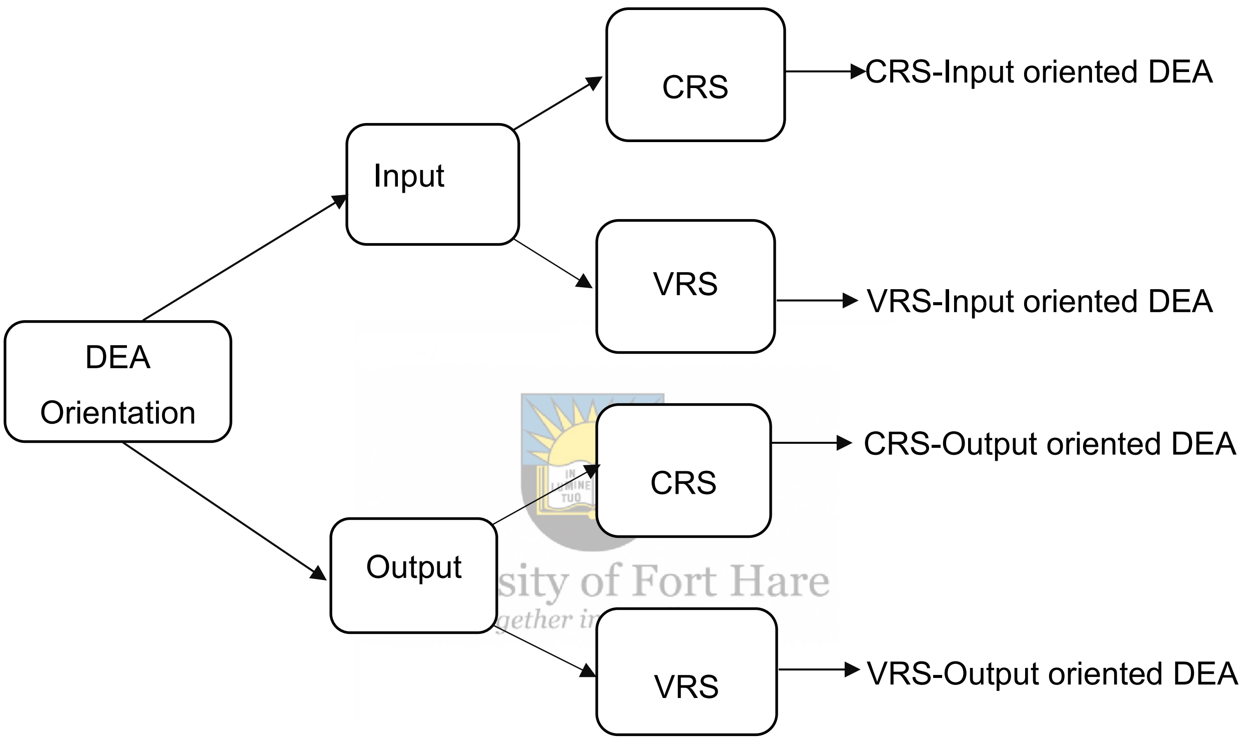
According to Tavassoli, Faramarzi and Saen (2014) data envelopment analysis (DEA) is a mathematical non-parametric approach for calculating the relative efficiency of decision-making units (DMUs) performing similar tasks. A decision-making unit is an entity responsible for producing multiple outputs from given multiple inputs and whose efficiency is to be measured (Kottas and Madas, 2018). The DEA started as a single input and single output model proposed by Farrell in 1957. Charnes, Cooper and Rhodes (1978), subsequently modified Farrell’s model to account for multiple inputs and multiple outputs under the assumption of constant return to scale (CRS). Banker, Charnes and Cooper (1948), further extended Charnes, Cooper and Rhodes (CCR) model by relaxing the assumption of constant return to scale.

They added convexity constraints that resulted in variable return to scale (VRS). According to Ozcan (2014), constant return to scale assumes that economies of scales stay the same even if there is a change in the size of the facility, while variable return to scale assumes that economies scale vary with the size of the facility. Increasing returns to scale (IRS), constant returns to scale (CRS) and decreasing returns to scale (DRS) are three components of variable return to scale. The significant contribution made by Charnes, Cooper and Rhodes (CCR) and Bankers, Charnes, Cooper (BCC) resulted in the DEA model being classified into the CCR-DEA and BCC-DEA model. The CCR and BCC data envelopment analysis methods have been used to calculate efficiency of various modes of transportation. For instance, airline (Kottas, and Madas, 2018; Lozano and Gutierrez, 2014), maritime (Barros and Athanassiou, 2004; de Koster, Balk and van Nus, 2009), road (Li, Yang, Zhang and Cao 2016; Singh and Jha, 2017) and rail (Movahedi et al., 2011; Wanke and Azad, 2018).

Lan and Lin (2003) further categorized efficiency measurement methods into input-oriented and output-oriented DEA models to capture the feature of non-storability in transport services. This arose after they realized that technical efficiency alone is not a sufficient measure of performance in the transport sector, since transport services is non-storable and technical efficiency only focuses on the production, or supplier's, side (Lan and Lin, 2003). The input-oriented DEA model was introduced to calculate the performance between input factors and production and output-oriented DEA to calculate the performance between production and output. In a market for storable goods, where the production output can be stored until it is fully utilised or consumed and no loss is recorded during the transformation process, the single measure of performance, that is efficiency, was regarded appropriate (Shavazipour, 2014).

Thus, the term 'technical efficiency' and 'service effectiveness' are used interchangeably. However, this is not practically possible in a market for non-storable goods and services since the measures or variables used measure performance differ completely. Input-oriented DEA is used to determine the maximum possible decrease in all inputs, while keeping all outputs fixed with output-oriented DEA determines the maximum possible increase in outputs while keeping all inputs fixed (Lan and Lin, 2005).

The input-oriented DEA technique is used to measure technical efficiency and output oriented DEA technique is used to measure service effectiveness. In summary, the traditional DEA method is divided into four methods; CRS input-oriented DEA, CRS output-oriented DEA, VRS input-oriented DEA and VRS output-oriented DEA. This classification can be further presented diagrammatically as follows:



Source: Ozcan (2014)

Figure 3.3 Basic DEA classification models

This figure shows that technical efficiency estimated through application of an input-oriented DEA can be estimated using the CRS or VRS method. While, service effectiveness estimated through application of an output-oriented DEA can be estimated using CRS or VRS method.

3.2.1 Determination of the efficiency values

According to Sharma, Debnath, Oloruntoba and Sharma (2016), efficiency can be determined as the ratio of output over input factors and, mathematically, it can be presented by the following equation:

$$Efficiency = {}^{Output}/_{Input} \qquad 3.1$$

Equation 3.1 is a representation of a single input-single output equation for estimating efficiency. For multiple inputs-multiple outputs, efficiency is estimated as follows:

$$Efficiency = \frac{Weighted\ sum\ of\ the\ outputs}{Weighted\ sum\ of\ the\ inputs} \qquad 3.2$$

$$Efficiency = {\sum u_i\, y_i}/{\sum u_i\, x_i}$$

Where:

$\sum u_i\, y_i$ = summation of weighted outputs

$\sum u_i\, x_i$ = summation of weighted inputs

3.2.2 Estimation of the technical efficiency

As previously explained, technical efficiency can be estimated through application of input-oriented constant return to scale (CRS) and variable return to scale (VRS) data envelopment analysis method. Lan and Lin (2003) presented the CRS input-oriented DEA estimation equation as follows:

$$\begin{aligned} &Min_{\theta,\lambda}\theta \\ &s.t.\ -y_i + Y\cdot\lambda \geq 0 \qquad (3.3) \\ &\theta\cdot x_i - X\cdot\lambda \geq 0,\ \lambda \geq 0 \end{aligned}$$

Where;

X = Input matrix of i^{th} firm, represented by the vector x_i

Y = Output matrix of i^{th} firm, represented by the vector y_i

λ = Vector of constant

θ = scalar showing the efficiency of i^{th} firm

Therefore, by solving Equation 3.3, efficiency values for i^{th} firm under a constant return to scale can be obtained. Then, the efficiency value for i^{th} firm under a VRS can be obtained by solving the following equation:

$$Min_{\theta,\lambda}\theta$$

$$s.t.\ \ -y+Y\cdot\lambda\geq 0 \qquad (3.4)$$

$$\theta\cdot x_i-X\cdot\lambda\geq 0,$$

$$\sum\lambda=1,\lambda\geq 0$$

Where;

$\sum\lambda=1$ = Convexity constraint (added to produce variable return to scale and if eliminated it produce a constant return to scale in Equation 3.3).

Technical efficiency values ranging from 1 (representing technical efficient firm) to less than 1 (representing technical inefficient firm) can be achieved by solving the input-oriented DEA model, either CRS or VRS, or using both methods presented in Equation 3.3 and 3.4.

3.2.3 Estimation of service effectiveness

By solving the output-oriented DEA model, either CRS or VRS or both methods, service effectiveness values can be obtained. Lan and Lin (2003) presented CRS output-oriented DEA estimation equation as follows:

$$Max_{\emptyset,\lambda}\emptyset$$

$$s.t.-\emptyset\cdot y_i+Y\cdot\lambda\geq 0 \qquad (3.5)$$

$$x_i-X\cdot\lambda\geq 0$$

$$\lambda\geq 0$$

Service effectiveness values for i^{th} firm under constant return scale will be obtained by solving Equation 3.5. Then, service effectiveness values for i^{th} firm under the assumption of variable return to scale can be obtained by solving the following equation:

$$Max_{\emptyset,\lambda}\emptyset$$

$$s.t.-\emptyset\cdot y_i+Y\cdot\lambda\geq 0 \qquad (3.6)$$

$$x_i-X\cdot\lambda\geq 0$$

$$\sum\lambda=1,\lambda\geq 0$$

Where:

$Y, X, x_i\ y_{i,}$	=	Remain as explained in equation 3.3
$\emptyset$	=	Proportional increase in output (ranging from 1 to infinite)
$1/\emptyset$	=	Service effectiveness for i^{th} firm (ranging from 1 to less than 1)
$\sum \lambda = 1$	=	Convexity constraint (added to differentiate VRS from CRS)

By solving Equation 3.5 and 3.6, service effectiveness values can be obtained ranging from 1 (representing perfectly effectiveness) to less than 1 (representing service ineffectiveness).

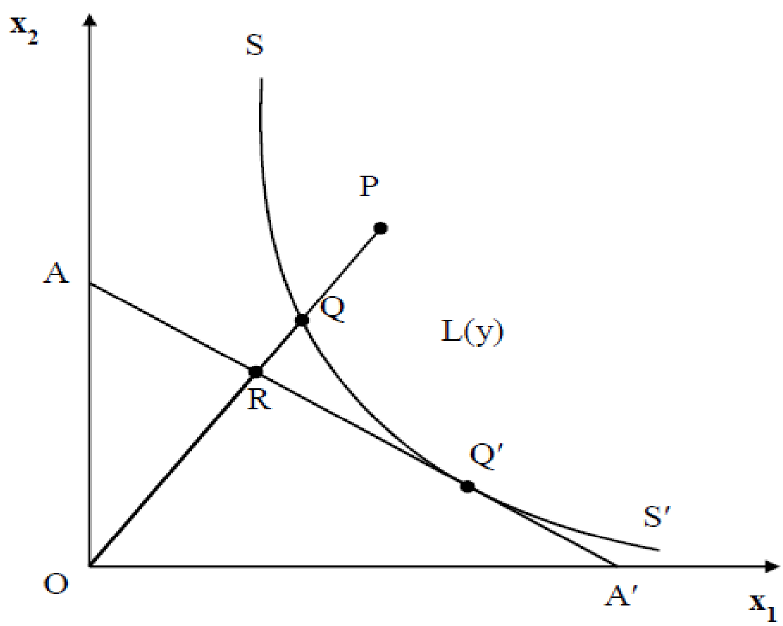
3.4 Theoretical literature

Theoretical literature for both efficiency and service effectiveness is addressed in this subsection. Technical efficiency and allocative efficiency, expectation disconfirmation paradigm and comparison level theory are part of the theoretical literature discussed in the following sub-section.

3.4.1 Theory of efficiency

Farrell (1957), the pioneer of the term 'efficiency', categorized efficiency into technical efficiency and allocative efficiency. Technical efficiency, according to Koopmans (1951), is when an increase in output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one other output. While Porcelli (2009) describes technical efficiency as, under the assumption of a fixed output, the ratio of the observed input to the minimum input, or as the ratio between the observed output and the maximum output.

According to Debreu and Farrell's measure, technical efficiency is defined by "one minus the maximum equi-proportionate reduction in all inputs that still allows the production of given outputs, a value of one that indicates technical efficiency and a score of less than one or unity indicates technical inefficiency" (Porcelli, 2009, p. 2). According Porcelli (2009, p. 3), allocative efficiency "is the ability of the producer to optimally combine inputs and outputs, taking into account the prevailing prices and it is usually determined by comparing the observed versus the optimum cost or observed profit versus optimum profit". Price is the main factor that differentiates allocative efficiency from technical efficiency. Farrell (1957) selected x_1 and x_2 as two input factors and y_1 as an output to illustrate the technical efficiency using an input-oriented approach. This is further graphically illustrated as follows:



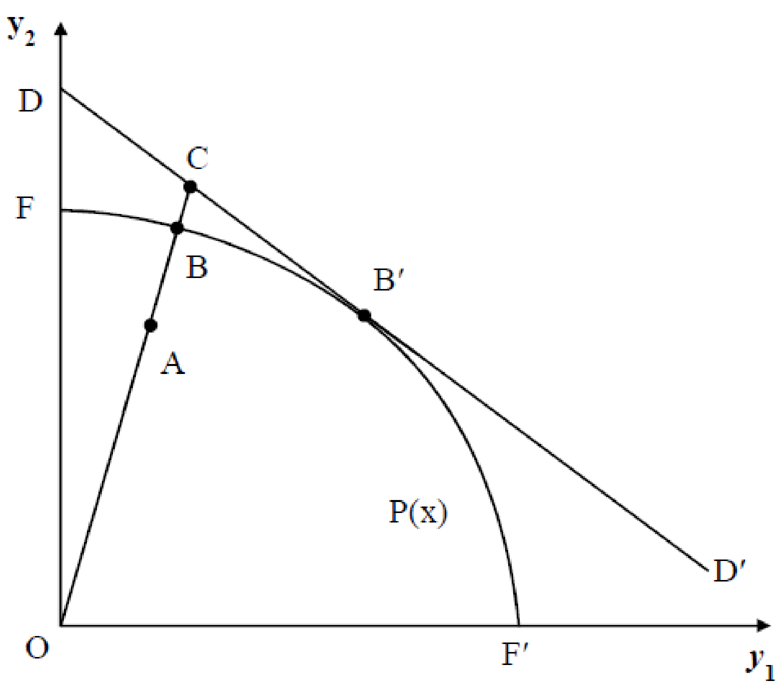
Source: Farrell (1957)

Figure 3.4 Input oriented: technical and allocative efficiency

Point 'P' in Figure 3.4 indicates the two inputs per output unit that are observed to be used by a particular organization. An efficient firm using the same ratio of inputs as 'P' is shown by point 'Q'. Firm P technical efficiency (TE) is determined by the ratio ${OQ}/{OP}$, where the firm attained a efficiency value of one. This makes it possible to measure TE on a limited scale ranging between 0 and 1, and to determine TE as 1$-{OQ}/{OP}$. The value 1 implies that the company has achieved a fully efficient condition. Isoquant AA' represents the input price ratio if it is known and therefore, allocative efficiency can be measured. Technical efficiency points are presented by point Q and Q' on the production frontier and have technical efficiency value equal to 1. Point $'Q'$ represents the costs of production as a fraction ${OR}/{OQ}$ of those at point Q and therefore, the ratio ${OR}/{OQ}$ is a measure of allocative efficiency. Distance between R and Q can be interpreted as the cost reduction that occurs when the firm moves from Q (the point of allocative efficiency) to Q (the point of technical efficiency). If it is possible to calculate both technical efficiency (TE) and allocative efficiency (AE), then economic efficiency (EE) or overall efficiency (OE) will be computed easily since it is defined by the combined effect of technical efficiency and allocative efficiency. In this case, both technical efficiency and allocative efficiency can be determined therefore, economic efficiency can be determined by using the following ratios:

$$EE = TE \cdot AE \quad \text{..........} 3.7$$
$$= \left({OQ}/{OP}\right) \cdot \left({OR}/{OQ}\right)$$
$$= {OR}/{OP}$$

The following graph displays technical efficiency and allocative efficiency based on the output-oriented approach using two outputs (y_1 and y_2) and one input (x_1).



Source: Farrell (1957)

Figure 3.5 Output oriented: economic efficiency

Technical efficiency and allocative efficiency based on an output-oriented approach are shown in Figure 3.5. Two outputs (y_1 and y_2) and one input (x_1) were selected. The efficient production frontier is presented by curve FF'. Inefficiency is shown by point 'A' which lies below point 'B' and is further presented by the distance between point A and B. A producer seeks to improve efficiency from point 'A' to point 'B', this can be done by increasing output to point B with increasing input. In this case, technical efficiency (TE) is determined by 0A over 0B ratio, which is further shown by the following equation:

$$TE = {}^{OA}/_{OB} \qquad (3.8)$$

The output-oriented approach assumes that optimizing revenue is the main objective of each and every organisation. ISO-revenue line DD' represent price and the line BC shows an increase in revenue when moving from point B to B', which can be used to define allocative efficiency, given by ratio $AE = {}^{0B}/_{0C}$. Then, overall efficiency or economic efficiency is presented by the following equation

$$\begin{aligned} EE &= TE \times AE \qquad (3.9) \\ &= \left({}^{0A}/_{0B}\right) \cdot \left({}^{0B}/_{0C}\right) \\ &= {}^{0A}/_{0C} \end{aligned}$$

3.4.2 The theory expectancy disconfirmation

The theory of expectancy disconfirmation, also known as the expectancy disconfirmation paradigm (EDP) was pioneered by Oliver (1977) and Oliver (1980) as a theory for evaluating customer satisfaction. According to Yuksel and Yuksel (2001), this theory is grounded on the notion that consumers are purchasing commodities with pre-purchase expectations about the anticipated performance. The theory of expectancy disconfirmation is one of the important frameworks which describes customer satisfaction by suggesting that satisfaction is the product of the disparity between expectations and perceived results (Aziz, Ariffin, Omar and Yoon 2011). The theory compares the predetermined standard against the actual good or service once the final product is used. The anticipated level serves as a set standard against the perceived performance comparison (Aziz et al., 2011).

If the results are in line with expectations, confirmations occur. However, if there is disparity between expectations and outcomes, disconfirmation occurs (Yuksel and Yuksel, 2001). The disconfirmation can either be positive or negative. Aziz *et al*. (2011) advised that positive disconfirmation occurs when the actual product outcomes or experiences (service effectiveness) exceeds the customers' initial expectations, resulting in customer satisfaction and thus, motivates the customer to purchase the product again in the future. While, if the actual product outcomes or experiences fall short of the customers initial expectations, negative disconfirmation is created, resulting in a customer dissatisfaction and this discourages the customer to repurchase the product.

3.4.3 Comparison level theory

The expectancy disconfirmation theory has been criticized by several scholars on the basis that this theory recommends predictive expectations generated by suppliers, companies' reports, or other sources as the key factors determining customer satisfaction (Yuksel and Yuksel, 2008). These scholars include La Tour and Peat (1979) who claim that the theory of expectation disconfirmation overlooks previous customer experience and the experience of other customers with similar constructs as sources of customer expectations. Thibaut and Kelley (1959) developed the comparison level theory to overcome all the inefficiencies of the EDP theory. Unlike the expectation disconfirmation theory, which uses predictive or situationally-produced expectations as the comparison standard, the comparison level theory argues that there is more than one fundamental determinant of a product's comparative levels (Kinisa, 2019).

These include; (i) previous customers' experience with same commodity, (ii) situationally generated expectations, formed through advertisements and promotion efforts, and (iii) the experience of other clients who serve as reference points (Kinisa, 2019). In comparison to the expectancy disconfirmation theory, which focuses on predictive expectations, the comparison level theory state that customers may bring several comparison levels into the consumption experience (Yuksel and Yuksel, 2008). As customers may use predictive expectations based on external interactions, or advertising, before making any decision or purchase, whereas after the purchase different factors, such as previous experience and customer experience, recommended by La Tour and

Peat (1979) may become more likely. However, during the consumption experience, there is insufficient information about what requirements are being verified and disconfirmed by the customers (Yuksel and Yuksel, 2008).

3.5 Empirical literature

Technical efficiency and service effectiveness have been used in different modes of transportation and transport related sectors to analyse performance. The empirical literature in this study consists of literature from rail, airline, sea, and road transportation.

3.5.1 Rail transportation

The empirical findings of the study conducted by Link (2016) on performance of passenger railway franchises in Germany show that procurement policies and contract design impacted positively on the efficient use of funds. Link noted that high tendering share, gross contracts and long-lasting small contracts can improve performance of passenger railways in Germany. To ensure efficiency in the use of public funds, Link (2016) suggested that the period of a contract should be longer than the existing average of 9 years and 6 months. This study is one of the few empirical studies that applied the data envelopment analysis (DEA) to estimate efficiency values and further identify variables that impact on the efficiency through the use of the Tobit regression analysis.

While other researchers ignored the issue of bias when estimating efficiency scores, Merkert, Smith and Nash (2010) employed bootstrap DEA to correct the bias which arose when they were analysing the efficiency and effectiveness of 43 British, Germany and Swedish active railway companies. In addition, the author analyzed the impact of institutional, environmental and transactional variables on the performance of railways using Tobit regression. Transactional variables were identified as the key variables influencing the efficiency of railways, while the effect of institutional and environmental variables was insignificant on efficiency. Although factors affecting performance measures were analysed, the association between efficiency and effectiveness was ignored. Multi-activity network DEA was used by Yu and Lin (2008) to calculate technical efficiency, service effectiveness and technical effectiveness of 20 railways around the world. The authors argue that the conventional DEA analyzed technical efficiency, service effectiveness and technical effectiveness separately, while all of these activities occur concurrently. Therefore, the benefit of using the multi-activity network DEA approach is that it allows the decision-making units to engage in different activities to determine performance in each activity simultaneously (Yu and Lin, 2008). The rail transport sector is of the multi-activity and multi-stage businesses as it offers both passenger and freight transportation services. The findings of the author's study reveal that technical efficiency, service effectiveness and technical effectiveness vary considerably. The author's further note that high technical efficiency values do not necessarily mean high service effectiveness, whereas high values of technical efficiency or service effectiveness can result in higher technical effectiveness.

Madubanya and Akinlabi (2016) deviated from the most commonly used DEA technique for evaluating performance in the transport sector and distributed 132 questionnaires to road and rail transport organisations to evaluate operational efficiency of freight rail volumes in South Africa. It was found that employees acknowledged the low performance and were frustrated by dissatisfaction received from customers who ended up taking their businesses to road transportation. Key elements that impacted on customer satisfaction included quality management and management of challenges experienced by customers during delivery. Involvement to empower and motivate the team, education and training of employees were recommended to regain the trust of customers. Although this study provided first-hand information, which is much needed by researchers to gain a complete perception of the problem at hand, it overlooked the definition of efficiency, which states that efficiency is a range from 0 to 1, and is the ratio of output over input. Therefore, this study recommends that the use questionnaires should be complemented with one of DEA techniques when evaluating performance.

Instead of combining input-oriented and output-oriented DEA results to attain technical effectiveness values of 76 railways selected around the world, Lan and Lin (2003) employed the Hyperbolic DEA. Lan and Lin (2003) also noted that the traditional DEA ignored environmental variables, while the construction of transport infrastructure is often associated with negative externalities, such as loss of local ecosystems, changes in landscape, emission, in terms of air and noise, and changes in the quality of the ecosystem (Broniewicz and Ogrodnik, 2020). Exogenous fixed input model (EXO DEA) and categorical (CAT) DEA models were introduced to account for environmental factors. Data from the year 1999 up to the year 2001 were gathered from the International Union of Railway Statistics. Lan and Lin (2003) found that the input-oriented and output-oriented DEA results were lower than the results of Hyperbolic DEA, EXO DEA and CAT DEA models. Moreover, the performance of 76 selected railways is largely dependent on the length of electrified lines, population density and per capita gross national income, while service effectiveness was largely determined by the average length per tonne carried and per capita gross national income.

Movahedi *et al*., (2011) investigated the efficiency of Iran railways, in comparison with international railways. Service effectiveness as a measure of performance and factors affecting performance were included in the study. Data for 60 countries was obtained from international Railway Statistics for the year 2007. The findings indicated that the Iran railways were technically inefficient compared to other railways. The average performance of 60 countries (0.454) was much higher than the technical inefficiency results of Iranian railways placed under a constant return to scale which was very poor (0.072), this indicates that Iran is still far from achieving an optimum scale efficiency (Movahedi et al. 2011). Sengupta (1995) notes that by analyzing average efficiencies, industrial competitiveness or efficiency can be determined.

George and Rangaraj (2008) benchmarked the performance of 16 Indian Railway zones over a period of four years by using the input-oriented DEA method. Data consisted of nine railway zones for the period of 1998 – 1999 and 16 current railway zones for the period 2004 – 2005 were collected from Indian railway's Annual Statistical Statement published by the Ministry of Railway and Government of India. The results show that four out nine zones were efficient in 1999 and seven out of 16 were also efficient for the year 2004.

Sharma *et al*. (2016) benchmarked service performance of 16 Indian Railways by applying output-oriented DEA over a period of three years starting from 2010 to 2012. Data for the period 2010 – 2012 was gathered from the Annual Statistics Statement of the Efficiency Directorate of the Ministry of Railway based in New Delhi. The results indicate that 12 of 16 railways in India were relatively effective throughout the period under review and the rest showed service ineffectiveness with values ranging from 0.785 to 0.996. This study did not provide any clarification as to why certain railways were performing very well, while others were not, throughout the period under review, which rendered the study incomplete for DMUs that seeks to improve performance.

While George and Rangaraj (2008) and Sharma *et al.* (2016) were mainly focusing on Indian railway zones, Bhanot and Singh (2012) compared the performance of companies dealing with railway containers in India by applying the DEA method. These companies included Container Corporation (CONCOR), Adani and Gateway logistic companies. CONCOR performance has been analysed using data for the period 1995–1996 to 2010–2011 and comparative analysis for all three companies was performed using data for the period 2005 – 2006 to 2010 – 2011. The findings show that the efficiency of CONCOR has been fluctuating due to haphazard infrastructure development which was better than the efficiency fluctuations in the private sector that ranged from 38.31 percent to 77.59 percent concurrently.

Wanke and Azad (2018) compared the Fuzzy DEA and Stochastic DEA approach and further examined the effect of randomness and fuzziness on performance for six Asian operating railways. Time series data for a period of 10 years, starting from 2004 to 2014 was collected from Association of Southeast Asia Nation-Japan Transport Partnership. One of the advantages of using Fuzzy DEA is that it handles fuzziness found in the data collection, or in variables used as input and out measures, whilst the Stochastic DEA is a good measure of efficiency when random variance is presented in all the outputs generated from the transformation of inputs. The findings reveal that rating of the railways is largely determined by the selected model and Fuzzy DEA and Stochastic DEA can generate similar results. Moreover, the performance of Asian railways is dependent on fuzziness and randomness and the results of Fuzzy DEA comply with the results obtained from Stochastic DEA under various systems of tail dependency to some degree.

While the main focus on the existing literature was on passenger rail transportation, Marchetti and Wanke (2017) analysed efficiency of 60 Brazilian rail freight transportation through the application of the two-stage DEA. Bootstrapped truncated repression was performed to explain the relationship between the efficiency of the concessionaire and exogenous variables, instead of a widely used Tobit regression analysis. The findings indicate that broad-gauge track commodities were the key determinants of performance and despite regular incentives, the impact of shared infrastructure on efficiency was insignificant. Marchetti and Wanke (2017) indicate that well-directed regulations would enable the concessionaire to increase efficiency by promoting agricultural and mineral commodities carried in the North and Centre West Brazil's broad-gauge track.

Through the application of the standard DEA method, Kabasakal, Kutlar and Sarikaya (2015) analyzed the efficiency of 31 railways operating globally for the period 2000 to 2009. Kabasakal *et al*. (2015) note that the variable return scale model produced more efficient railways than the constant return to scale. The constant return to scale results show that 18 railways were technically efficient in the year 2009, increasing from 17 in the year 2000, while the variable return to scale show that 24 railways were found technically efficient in the year 2009, having increased from 20 previously.

Following the existing literature, Kapetanovic, Milenkovic, Bojovic and Avramovic (2017) evaluated the efficiency of 34 European railway companies by applying DEA. The results show that only a few railways demonstrated better performance in passenger and freight railways and railways were either performing better in passenger or freight transportation. Railways operating in Western Europe performed better in passenger transportation and in overall transport performance, relative to Central and Eastern Europe, although it was not the case with freight transportation (Kapetanovic *et al*., 2017). Moreover, the efficiency levels were inconsistent throughout the period under consideration and no clarifications were provided with regards to fluctuations in performance levels.

Through application of the non-parametric approach, Cantos, Pastor and Serrano (1999) managed to trace back the evolution of productivity during the period 1970 – 1995 in 17 European railways. The authors argue that the non-parametric approach enables productivity improvements to be broken down into variation in efficiency technical adjustments. The results indicate that the period of 1985 to 1995 was the decade of productivity development, the period in which the majority of companies conducted process adjustments.

Cantos *et al*. (1999) concurs with Ozcan (2014), one of the scholars who contributed tremendously to the formulation of efficiency, that technological progress is a key driver behind improved efficiency. In addition, it was also noted that higher autonomy and financial independence contributed to high levels of efficiency and technical change.

Doomernik (2015) compared four of Asia's high-speed railway systems with four European high-speed rail systems for the period 2007 and 2012 through application of the DEA. The primary objective was to find the best performing high-speed railway systems and also identify the determinants of high performance in production and marketing. The results show that a growth rate of 26.6 percent in productivity was recorded in Asia during the period of 2007 and 2012, while a decline of 14.4 percent was recorded in Europe, despite a significant improvement of 16.6 percent in technology. Asia's productivity increase was due to 17.9 percent improvement in technical efficiency and 7.6 percent technological improvement. From these findings, it is evident that effect of technological progress differs from region to region. Doomernik (2015) also noted that production efficiency and service effectiveness are negatively related.

Through the application of the DEA technique, Cowie (1999) compared private and public sector railway performance in Swiss railway for the period of 1997. Data of 58 railways, consisting of 43 public and 14 private railways, were gathered from the Swiss Federal Statistics Office (FSO). The results indicate that, although organisational efficiency variations were less pronounced due to outcome changes, private sector railways were performing much better than the public sector, in terms of technical and managerial organisational efficiency.

To overcome inefficiencies of the traditional DEA, Lan and Lin (2006) proposed a four-stage DEA to study efficiency of 44 railways, taking into account the effect of environmental changes, noise and slacks. Lan and Lin (2006) claim that both conventional DEA and three-stage DEA were constrained by the challenge of including environmental variables, data noise and slacks which could potentially lead to serious biases. They note that the four-stage DEA method has slightly more realistic outcomes compared to the three-stage DEA results, which prove far better than those computed by using conventional DEA models.

The finding reveals that there is clear evidence that performance, productivity and the possibility of sales growth were overstated, given that the environmental, data noise and slacks were not adjusted.

Driessen, Lijesen and Mulder (2006) note that competitive tendering, which is in line with economic intuition and expectation on the design of competition, improves productive efficiency of railways in Europe. Moreover, efficiency is negatively affected by unrestricted entry since railway operators may be unable to gain economies of density. On the other hand, Driessen *et al*. (2006) flagged that the majority of incumbent railway companies operating as state-owned companies face less competition. Therefore, increased independence in the absence of adequate competition and adequate regulation could exacerbate incentives for productive performance.

While Friebel, Ivaldi and Vibes (2010) selected 11 European railways to explain the influence of reforms on the efficiency of railways. The reforms occurred between the period 1980 and 2004. Data for this period was collected from the World Bank (2004) and International Union of Railway Statistics (2001). Friebel *et al*. (2010) found that the sequential implementation of third-party access to rail networks, the creation of an independent regulator and vertical separation reforms improve efficiency, whereas, implementation of these reforms as a package impact negatively on efficiency. They further acknowledge that the effect of the changes, on the other hand, depends on timing. Although this study examined both passenger and freight rail transportation and analysed factors impacting on the efficiency railroad, it excluded African countries.

With data collected from International Union of Railways, Coelli and Perelman (2000) studied the efficiency of 17 European railways for the period 1988 to 1993. The findings reveal that the average efficiency was 0.86 percent, which was slightly higher than 0.78 for the Netherlands and slightly below 0.98 for Italy. In addition, the results show significant differences in parameter estimates and technical efficiency ranking, casting significant doubt on the reliability of the single-output model, particularly when the total revenue measure is used to proxy to total output.

Lan and Lin (2006) employed the input distance inefficiency effect to estimate the relative efficiency and stochastic consumption function with the ineffectiveness function to evaluate service effectiveness of 39 passenger and freight railways selected globally. It was found that railways operating in Western Europe performed better than railways operating in non-European areas. It is further noted that per capita gross national income, number of electrified networks, and line density reduces technical inefficiencies and service ineffectiveness.

Oum and Yu (1994) were among the first scholars who contributed towards the formulation of efficiency literature in the transport sector. Oum and Yu (1994) applied DEA to obtain the efficiency of railways in organisation for economic cooperation and development (OECD) countries for the period of 1978 to 1979. To identify the effect of public subsidies and the degree of managerial autonomy on efficiency, the Tobit regression was performed. Their findings reveal that railway systems which were heavily dependent on public subsidies were far less efficient than railway systems that were less dependent on subsidies. It is further noted that, with a high degree of managerial autonomy from a regulatory authority, railway network operators tend to achieve higher efficiency.

3.5.2 Airline transportation

Following the non-parametric approaches used in the railway transport sector to evaluate performance, several studies were conducted in the airline sector, analysing both efficiency and effectiveness. The first airline study to use the data envelopment analysis was conducted by Schefczyk (1993) and since then DEA techniques have gained popularity within the airline sector as a measure of performance. Recent studies in the airline industry include empirical studies by Tavassoli *et al*. (2014), and Kottas and Madas (2018).

Sarkis (2000) supplemented the traditional DEA models with simple cross-efficiency (SXEFF), ranked efficiency (RCCR), aggressive cross-efficiency (AXEF), and radii of classification rankings (GTR) method to analyze the efficiency of 44 major airports in the United States. The benefit of using more than one performance estimation technique is that one technique can be used to overcome the shortfalls or inefficiencies of another model. On the other hand, previous studies gathered data from different organisations to analyse performance, Sarkis (2000) collected data from the Airport Council International

(ACI) and further sent two mail surveys to selected airports. The results indicate that at least 22 airports were technically efficient in 1 of the 5 years being studied, while 14 airports were efficient throughout the entire period under review. The other models (SXEF, AXEF, GTR and RCCR) indicated that at least two airports were consistently efficient, while five airports were the least efficient airports throughout the period under review. What is missing in this study is the estimation of service effectiveness and factors affecting United States airline performance.

Kottas and Madas (2018) departed from the models employed by Sarkis (2000) and applied integrated DEA with super-efficiency. The benefit of using integrated DEA and super-efficiency is that the former allows decision-making units (DMUs) engage in multi-activity/multi-stage to estimate the performance of each activity in a unified manner, while the latter allows the efficiency values to exceed the truncated value of 1 and thus, called super-efficient. Super-efficiency also aids in identifying possible outliers, with the influence of alliance membership of 30 airlines estimated through using an intertemporal approach. The findings suggest that members of the alliance and super-efficiency of airlines were not significantly correlated. Kottas and Madas (2018) also found that in airlines with a lower share of freight traffic, revenue tends to be less efficient compared to airlines with a high share of revenue as they tend to be more efficient. Lastly, the statistically significant superior efficiency is substantiated for Asian and European air carriers over American air carriers.

To calculate the efficiency of 17 Europeans airlines, Fethi, Jackson and Weyman-Jones (2000) applied the DEA model and Tobit regression analysis to evaluate the effect of the explanatory variables on the explained variable. It was found that the efficiency of airlines in Europe was significantly determined by the overall load factor and regulations appears to have resulted in a more efficient airline industry which promotes quality services.

Fethi *et al*. (2000) further notes that there was no significant association between the state ownership and reduction in efficiency. However, it is clear that most airlines, whether private or public, were affected by the globalization of economic activities which occurred in 1990. Although this study analysed efficiency and factors affecting efficiency, service effectiveness was neglected.

Sharma *et al.* (2014) states that the issue of increasing efficiency and effectiveness of transportation systems extends beyond increasing infrastructure and capacity, it includes other intangible factors, such as enhancing service quality to satisfy customers.

On the other hand, Lozano and Gutierrez (2014) applied the network data envelopment analysis to analyze efficiency of 16 airlines. The findings indicate that 6 out of 16 airlines were technically efficient, but no explanation was provided as to why the other 10 airlines were inefficient and what the key determinants were of the airline efficiency in Europe.

Hong and Zhang (2010) analysed the effect of a high degree of freight operators on the operational efficiency of a mixed passenger or cargo airline. 29 airlines were selected during the period of 1998 – 2002 and results show that airlines with a high share of cargo business are significantly more efficient than airlines with a low share of cargo operations in their overall operations. However, no statistically significant differences were found between airlines with similar levels of cargo business.

3.5.3 Sea transportation

Following on the data collection methods of Sarkis (2000), de Koster *et al*. (2009) benchmarked the performance of the two largest container operators. Primary data relating to the year 2006, and some up to 2005, were collected from two of the largest container operators, APMT with 39 terminals and Port of Singapore Authority (PSA) with seven terminals, and secondary data was collected from Drewry for the year 2006 and 2007, respectively. De Koster *et al*. (2009) found that the largest terminals were more efficient than import/export terminals and that trans-shipment to terminals were substantially efficient. Moreover, there were no major variations between terminals in different parts of the world, between terminals run by different operators, and with different material handling systems for stacking.

3.5.4 Road transportation

With data collected from Indiana Annual Transit Reports for the period of 1983 – 1994, Karlaftis and McCarthy (1997) explained the effect of subsidy on public transit performance.

The authors found a negative association between system performance and subsidies and recommend that subsidies should be allocated based on the performance.

Karlaftis and Tsamboulas (2012) applied neutral, stochastic frontier function and DEA to measure public transport efficiency and assess the sensitivity of the results to the models. Their aim was to address the following questions; (i) do different methodologies of evaluating efficiency produce similar results?, (ii) is there a significant association between efficiency and effectiveness?, (iii) are the findings of this study sensitive to the model specifications used? Firstly, the findings reveal that the efficiency and effectiveness values differ depending on the evaluation method used. Secondly, the results show that the model used was responsive to efficiency values and related recommendations. Lastly, efficiency and effectiveness are weakly negatively related.

Karlaftis (2004), on the other hand, analysed the efficiency and effectiveness of 256 urban transit systems in the United States by using DEA. Karlaftis (2004) found that there was a strong positive association between efficiency and effectiveness, while the extent of economies of scale was significantly determined by the output specifications.

Carvalho *et al*. (2015) analyzed the efficiency and effectiveness of public transport in Brazilian cities and found that municipalities with the highest infrastructure efficiency tends to achieve low service effectiveness.

The technical efficiency of India's state transport undertakings was estimated by Agarwal, Yadav and Singh (2011) using the conventional DEA method. Agarwal *et al*. (2011) note that Indian state transport undertakings performed well, however, they were still very far from achieving an optimum level. It has been noted that the overall mean efficiency of 83.26 percent implies that the state transport undertaking has the capacity to produce the same units with the inputs of 16.74 percent lesser than the current level (Agarwal *et al*. 2011).

Sampaio, Neto and Sampaio (2008) used the traditional DEA techniques to analyse the efficiency of 12 European and 7 Brazilian countries' transport systems, a lesson in institutional planning.

The results indicate that nine out of 12 European countries were efficient and at least one out seven Brazilian countries were efficient. Sampaio *et al*. (2008) acknowledged that efficient transport networks have followed a more egalitarian division of power between communities and have set up a wider system of tariffs. It is further recommended that the Recife Metropolitan Region (RMR) should adopt a system that enables the various municipalities comprising the Metro Area to be divided more equally, including members of user groups, such as employee associates and syndicates. Moreover, a more flexible tariff system should be in place, providing benefits to typical customers, thereby reducing costs and increasing operational efficiency.

Li *et al*. (2016) applied super-slack based measurement data envelopment analysis (S-SBM DEA) to study the influence of transport investment on the efficiency of the regional integrated transport system in China. Super-slack based measurement data envelopment analysis (S-SBM DEA) is similar to EXO DEA and CAT DEA models, they account for undesired outputs, such as air pollution emissions, which were not incorporated in the standard DEA models. The results indicate that during the period of study, most of the provinces in China did not perform well in transportation and on average, total factor transport efficiency in China was low. Li *et al.* (2016) further added that the decreasing trend from eastern to western China exhibited the spatial pattern of transport efficiency, which correlates with the growth of spatial patterns in China. On the other hand, it is also noted that technical efficiency in transportation was adversely affected by economic growth and the role of government, while the influence of industrial structure, population density and geographical location on efficiency in transport differs from region to region.

Hahn, Kim and Kho (2009) neglected service effectiveness and analyzed technical efficiency of 18 Seoul city exclusive bus routes by using a variable return to scale input-oriented DEA. The findings show that two out of 18 bus lines showed CRS and the other 16 bus lines showed IRS. The study modelled factors affecting efficiency and results indicated that efficiency was significantly affected by the length of interval between the buses. Therefore, to improve the performance of bus lines, there should be changes to the length of intervals between buses, the distance between routes and the number of passengers (Hahn *et al*. 2009).

It is further suggested that an establishment of improved schemes based on the length of intervals between buses, the distance between routes and the number of passengers would improve the efficiency of bus lines with particular emphasis on improving the intervals between buses.

Hahn, Kim, Kim and Lee (2013) extended a study conducted by Hahn *et al*. (2009) by using both standard DEA and network DEA to evaluate the efficiency of 58 bus companies in Seoul city situated in Korea. Expansion of bus rapid transit systems and establishment of additional stops of median bus lanes for express and arterial bus routes were suggested as the policies required to improve the efficiency in bus companies. These findings differ from the findings of Hahn *et al*. (2009), which suggest that the length of intervals between buses should be minimized, in order to improve efficiency of Seoul city bus exclusive. Moreover, to support inefficient bus companies to run more pro-environmental buses, clear tax-cut measures related to environmental issues should be introduced (Hahn *et al*. 2003).

Chiou *et al*. (2007) evaluated the efficiency and effectiveness of 15 companies operating buses in Taipei by using an integrated data envelopment analysis (IDEA). This type of DEA method allows firms to measure key elements of performance that is efficiency, effectiveness and technical effectiveness, in a unified manner. Chiou et al. (2007) noted that the number of productive companies identified by the standard DEA models was much higher than those identified by the IDEA model.

A mixed separate DEA (MS-DEA) system with actual and fuzzy data was proposed by Shavazipour (2014) to estimate the performance of 10 intercity car companies in Iran. Shavazipour (2014) claims that the previous DEA models in the transport sector evaluated performance measurements separately and a joint measurement with shared input was required to fully capture the overall results. Shavazipour (2014) found that the decision-making unit’s effectiveness and efficiency differs from region to region. For instance, decision-making unit 10 was technically efficient but ineffective, while decision-making unit 9 achieved a service effectiveness score but was technically inefficient.

Georgiadis *et al*. (2014) evaluated the performance of 60 bus lines in Thessaloniki in Greece for the period of 2009 to 2011. Data envelopment analysis was used to analyse performance and results have shown that the efficiency of local bus lines is slightly better than the efficiency of operations, without showing a strong positive or negative correlation between efficiency and effectiveness. Georgiadis *et al*. (2014) noted that the models used for assessing efficiency and effectiveness do not always show the same return to scale technology, and advised that it is important to make careful comparisons between rankings related to different performance measurements. It has also been found that scheduling buses with fewer seats would be a more efficient indicator of performance improvement, as opposed to reducing their service period. Moreover, the authors state that performance of bus lines was significantly determined by population density and traffic conditions.

Through the application of standard DEA techniques, Singh and Jha (2017) estimated the efficiency and effectiveness of Indian state transport undertakings and further estimated factors affecting their performance. Singh and Jha (2017) concur with Karlaftis (2004) that efficiency and effectiveness were strongly correlated. However, the size of the STUs and return to scale was negatively correlated, with large companies showing a declining return to scale, whereas small companies show improved returns to scale.

A two-stage DEA method was adopted by Chapin and Schmidt (1999) to measure efficiency and effectiveness of value mergers, respectively. The results of the first stage of the DEA model indicate that mergers improved technical efficiency, but the efficiency of the scale was reduced and the majority of merged companies were larger than the efficiency scale, while the second stage of DEA model results show that efficiency and effectiveness were not significantly determined by mergers, although there were significant improvements after deregulation, but this was not due to mergers.

A study conducted by Pina and Torres (2001) comparing the performance of the public sector with that of the private sector, indicates that public management of urban transport service was more efficient compared to private management, concluding that exogenous factors being studied were irrelevant. The exogenous variables included income per capita, age of the population, the number of cars, the geographical extension of the city and industrial or concentrated on services. While truncated and limited regression was used in the previous studies, multiple linear regression, logit regression and cluster analysis were used in this study. The findings of this study differ from a study conducted by Cowie (1999) in the Swiss rail sector, which found that private sector performed much better than the public sector, in terms of technical and managerial organisational efficiency.

3.6 Assessment of the literature

The existing scholars agrees that technical efficiency and service effectiveness are the most relevant measurements of performance in the transport sector. The efficiency and effectiveness of a transport service are evaluated by using data envelopment analysis (DEA). This has undergone numerous modifications since its inception by Farrell in 1957. Charnes *et al*. (1978) and Bankers *et al*. (1984) were amongst the scholars who made significant modifications in Farrell's efficiency model. However, it is still not clear which technique is highly recommended, these techniques Multi-activity DEA, Network DEA, Integrated DEA, Exogenous DEA (EXO DEA) and Categorical DEA (CAT DEA) emerged. The primary objective of developing these techniques was to capture the non-storability feature of transport services, account for environmental factors and allow firms that perform different activities to determine performance in a unified manner.

Although several methods of estimating efficiency and effectiveness were put forward, technical efficiency and service effectiveness remained limited between 0 and 1. From the above literature it can be observed that the focus has been on technical efficiency, neglecting service effectiveness. While other studies analyzed both efficiency and effectiveness, the correlation between the two was overlooked. These scholars Karlaftis (2004), (Doomernik, 2015), Georgiadis *et al*. (2014), Singh and Jha (2014), (Karlaftis and Tsamboulas, 2012) concluded that the relationship between technical efficiency and service effectiveness varies by region. Pina and Torres (2001) employed multiple regression and logit regression but it is evident that the Tobit regression analysis remains the relevant method of identifying factors impacting on the efficiency and effectiveness pertaining to transport sector.

3.7 Conclusion

This chapter provided the conceptual framework of the key variables used in the study, starting from definition of efficiency and effectiveness, followed by a performance assessment framework and its applicability in rail sectors. The empirical literature shows that many studies were conducted in transport and the concept of service effectiveness is still an infant in transport sector. This is shown by the bulk of literature focusing on technical efficiency. Following several critiques from different scholars concerning Farrel's techniques of measuring efficiency, Multi-activity DEA, Network DEA, Integrated DEA, Exogenous DEA (EXO DEA) and Categorical DEA (CAT DEA) techniques were developed. Although they are different, the values of technical efficiency and service effectiveness are limited between 0 and 1. It is also noted that the results of efficiency and effectiveness differ by region and also depends on the variables used. In case of Africa and Europe, technical efficiency and service effectiveness have been studied, however, the literature on freight rail transport is scarce. This may be due to data unavailability or the deteriorating state of rail transport with road transport taking the forefront.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

Research methods which were followed to accomplish the objectives of this study are discussed in this chapter. This chapter is organized into the following subsections; 4.2 Input-oriented and output-oriented data envelopment analysis models, 4.3 Model specifications, 4.4 Prior expectations, 4.5 Data sources and ethical considerations, 4.6 Estimation technique, 4.7 Diagnostic checks and 4.8 Chapter summary.

4.2 Technical efficiency and service effectiveness measures

According to Lan and Lin (2006), technical efficiency is measured by using input-oriented data envelopment analysis (DEA). They further explained that technical efficiency is a measure of maximum possible proportional decrease in all inputs, keeping all outputs fixed. In contrast, service effectiveness is measured by using output-oriented DEA, a measure of maximum possible proportional expansion in all output with all inputs kept unchanged. The advantage of using the DEA method also known as non-parametric approach is that; (i) it is easy to compute, (ii) it does not have many restrictions, and (iii) it does not assume any specific functional form compared to parametric approach that requires model specification (Asmare and Bagashaw, 2018). Additionally, the DEA method can be used to estimate technical efficiency and service effectiveness without causing any complications.

Since transport services are classified as non-storable service, the input oriented and output oriented DEA was deemed suitable for measuring both technical efficiency and service effectiveness. Therefore, this study employed input-oriented DEA model under the assumption of variable return to scale (also known as Bankers, Charnes and Cooper) as a measured of technical efficiency. Output oriented DEA model under the assumption of variable return to scale was also employed as a measure of service effectiveness. The variable return to scale techniques were selected since the rail sector is characterized by a huge capital investment backlog, budget limitations and imperfect competition which makes it difficult to apply the assumption of constant return to scale (CRS).

The assumption of constant return to scale is believed to appropriate in firms operating at an optimum level. Lan and Lin (2003) presented the BCC input-oriented DEA model as follows:

$Minimum_{\theta,\lambda}\theta$

$Subject\ to \quad Y \cdot \lambda - y_i \geq 0$ .... (4.1)

$\theta x_i - X \cdot \lambda \geq 0,\ i = 1, 2, 3, \dots \dots ... N$

$\sum \lambda = 1$

Where;

X	=	Input matrix for the i^{th} firm, represented by the vector x_i ;
Y	=	Output matrix for the i^{th} firm, represented by the vector y_i;
λ	=	Vector of constant;
θ	=	Scalar showing the efficiency of i^{th} firm;
$\sum \lambda = 1$	=	Convexity constraint;

Therefore, technical efficiency values ranging between 0 and 1 can be obtained by solving Equation 4.1. The value equal to 1.00 (100 percent) shows technical efficiency and any value less than 1.00 (100 percent) shows technical inefficiency. For service effectiveness, Lan and Lin (2003) presented the BCC-output oriented DEA models as follows:

$Maximum_{\emptyset,\lambda}\ \emptyset$

$Subject\ to \quad Y \cdot \lambda - \emptyset y_i \ \geq 0$ .... (4.2)

$x_i - X \cdot \lambda \quad \geq 0, i = 1, 2, 3,$ ....N

$\sum \lambda = 1$

$\lambda \geq 0$

Where;

$\emptyset$	=	Proportional increase in production, which range from 1 to ∞;
N	=	Number of decision making units;
$1/\infty$	=	Service effectiveness for i^{th} firm, ranging between 0 and 1;
Y, X, x_i, y_i, λ	=	Remain as defined in equation 4.1.

The value of 1 characterises service effectiveness, and any value of less than 1 characterises service ineffectiveness.

4.3 Variables used in BCC input and BCC output DEA models

In general, the process of evaluating technical efficiency and service effectiveness involves the selection of appropriate inputs and outputs. According to George and Rangaraj (2008), inputs are resources used to produce outputs and outputs refer to a product or service produced by inputs. The table below shows the input factors, production (intermediate) and output variables used in the DEA models.

Table 4.1 DEA variables

Input variables
Number of employees
Length of railway lines
Production variable
Gross train tonne kilometres
Output variables
Tonnes carried
Tonne kilometres

Source: Authors own compilation

4. 3 Model specification

Following the footprints of the recent scholars (Link, 2016; Singh and Jha, 2017), this study conducted the Tobit regression analysis to identify the influence of independent variables on dependent variables. This study regressed technical efficiency $(TEFFI)$ on; number of employees *(NEs)*, gross train tonne kilometres $(Gttkm)$, population density (PD), per capita gross national income (GNI), and services effectiveness $(SEFFE)$ is regressed on gross train tonne-km $(Gttkm)$, population density (PD) and per capita gross national income (GNI). This study adopted and modified the model presented by Oum and Yu (1994). The model was initially specified as follows:

$Lh_k = Z'_k \beta_k + \eta_k$ if $Lh_k < 0, k = 1, \dots, n$ .... (4.3)

= 0 otherwise

Where;

Lh_k	=	Logarithm of the DEA gross efficiency index;
Z_k'	=	Vector of the logarithm factors that are likely to affect efficiency;
β	=	Vector of coefficients to be estimated;
η_k	=	Error term.

Then, for technical efficiency equation 4.3 is modified as follows:

$$TEFFI = \beta_0 + \beta_1 NEs + \beta_3 Gttkm + \beta_4 PD + \beta_5 GNI + \mu \qquad (4.4)$$

Where,

$TEFFI$	=	Technical Efficiency
β_0	=	Constant or intercept
$\beta_1 \beta_2 \beta_3 \beta_4$	=	Coefficients of the explanatory variables
NEs	=	Number of employees
$Gttkm$	=	Gross train tonne kilometres
GNI	=	Per capita gross national income
PD	=	Population density
μ	=	Error term

For service effectiveness, Equation 4.3 is modified and presented as follows:

$$SEFF = \beta_0 + \beta_1 Gttkm + \beta_2 PD + \beta_3 GNI + \mu \qquad (4.5)$$

Where;

$SEFFE$	=	Service Effectiveness
β_0	=	Intercept or constant
$\beta_1, \beta_2, \beta_3, \beta_4$	=	Coefficients of the explanatory variables
$Gttkm$	=	Gross train tonne kilometres
GNI	=	Per capita gross national income
PD	=	Population density
μ	=	Error term

4.4 Prior expectations

According to Kasuso (2015, p. 25), “an employee is (a) any person other than an independent contractor who works for another person or for a state and who receives, or is entitled to receive, any remuneration, and or (b) any person who is any way assists in the operation of the business or running the business of an employer”. Therefore, the number of employees is the overall number of employees hired in a state transport undertaking (STU) and usually denotes labour input (Agarwal *et al*., 2010). Number of employees is expected to negatively impact on technical efficiency values. According to Pina and Torres (2001), input factors or resources are measurement units that represent the variables used to accomplish the service delivery. It is further asserted that, given a specific level of a deliberate action, efficiency improvement involves a reduction in the inputs consumed.

Gross train tonne kilometres (Gttkm) are expected to positively affect technical efficiency. Index Mundi (2019) defines gross train tonne kilometres (Gttkm) as a measure which includes all rail wagon weights for both empty and loaded movements. Kabir (2016) notes that efficiency signifies a performance level that describes a process of achieving maximum outputs utilizing the minimum input factors. Therefore, a unity increase in gross train tonne kilometres is expected to increase technical efficiency. Moreover, input-oriented DEA, a measure of technical efficiency, determines the maximum possible decrease in all inputs, while keeping all outputs fixed. Gross train tonne kilometres, which in turn is used as input in the process of estimating service effectiveness, is expected to negatively affect service effectiveness. As previously explained by Pina and Torres (2001), efficiency improvement requires a reduction in the inputs consumed. In addition, output-oriented DEA measures the maximum possible expansion in outputs, while all inputs remain unchanged (Lan and Lin, 2005).

It is anticipated that population density will positively affect technical efficiency and service effectiveness. Simelane (2002) defines population density as a measure of concentration of inhabitants within a given area. This shows the amount of people to be provided with transport services or the possible demand of transport services. Moreover, every 10 percent increase in population density is associated with an increase of approximately 6 percent in light rail transit boarding stations (Felcman and Silha, 2015). According to the World Bank (2020), per capita gross national income is the amount of value added by all resident producers, plus any commodity taxes, minus subsidies, not included in the production valuation, plus net primary revenue receipts (employee wages and property income) from abroad. Per capita gross national income (GNI) is expected to positively affect technical efficiency and service effectiveness. Hitge and Gqaji (2011) claim that cities with improved transport networks and higher density populations have a higher per capita income than low and high population density cities with poor transit. Saboori, Sapri and bin Baba (2014) argue that economic growth and rapid population growth, rapid urbanization, rise in disposable income, social diversity, leisure activities, and fast rising number of private vehicles and unequal distribution of material capital are the main drivers of transport demand. On the other hand, Rehman (2017) argues that more people mean higher energy demand for power, industry and transport, resulting in higher emissions of fossil fuels.

4.5 Data sources and ethical considerations

Guided by the literature review presented in Chapter 3, this study employed secondary data. The data for four African and four European countries was collected from the World Bank, Knoema and International Union of Railway Statistics for the period of 2017. The year 2017 was selected as it contained all the necessary data required to accomplish the research objectives. An email was sent to International Union of Railway Statistics requesting a subscription to their data website. Data collected from the International Union of Railway Statistics consisted of, but was not limited to, the number of employees, length of railway lines, gross train kilometres, tonnes carried, tonne kilometres and population density.

However, the data sets were incomplete for other regions, thus this study was conducted subject to data availability in African and European countries. Data was also collected from the World Bank and Knoema website which consisted of population density, per capital gross national income, rail lines and tonne kilometres. This study was conducted in a manner that does not infringe on other people's right, and the use of offensive, discriminatory and unacceptable languages was avoided.

All the sources used were referenced using the Harvard referencing style as instructed by the University of Fort Hare Research Department. An application for an exemption for ethical clearance certificate was submitted to University of Forth Hare Research Ethics Committee.

4.6 Estimation technique

Sameni, Preston and Sameni (2016) state that the estimation of data envelopment analysis (DEA) values does not explain why certain decision-making units are efficient or effective and hence, Tobit regression analysis is performed on the last stage to explain the effect of independent variables on the dependent variable. Tobit regression analysis has been performed by several scholars in the transport sector, some of the scholars include; Oum and Yu (1994); Link (2016); Fethi et al. (2000). According to Sameni *et al*. (2016), Tobit regression is used when the explained variable is limited within a certain threshold. This model is also known as limited dependent variable regression because of the constraint imposed on the values taken by the dependent variable (Gujarati, 2009). The Tobit regression was selected as the value of efficiency and effectiveness ranges between 0 to 1, 1 being the perfectly efficient and effective decision-making unit, while any value less than 1 is considered inefficient and effective. According to Fethi *et al*. (2000), the standard Tobit regression model is presented as:

$y_i^* = \beta' x_i + \varepsilon_i$

$y_i = y_i^*$ if $y_i^* > 0$, and

$y_i = 0$, Otherwise

Where,

y_i	=	Observed dependent variable or DEA score (s)
y_i^*	=	Latent variable
$\varepsilon_i \sim N(0, \sigma^2)$, x_i and β	=	Vectors of explanatory variables and unknown Parameters.

4.7 Diagnostic checks

This subsection is intended to present methods used in the process of reviewing and checking the validity of the estimated model of technical efficiency and service effectiveness. In other words, this section seeks to ensure that the presented models are correctly specified and meet the properties of ordinal least squares. Since autocorrelation is mostly available in time series data, the main focus of this study is placed on methods of checking normality and heteroscedasticity.

4.7.1 Heteroscedasticity checks

Heteroscedasticity exists when the variance of the error term or the disturbance term takes various forms, this implies that the assumption of homoscedasticity is violated. A correctly specified model is one displaying equally spread variance or homoscedastic. This study used Breusch-Pagan or Cook-Weisberg to check whether the assumption of homoscedasticity was not violated. This diagnostic test involves the formulation of the hypothesis which reads as follows:

$H1_a$: Variances are homoscedastic

$H1_b$: Variances are heteroscedastic

4.7.2 Residual normality checks

Skewness and Kurtosis have been used in this study to check residual normality. The skewness and Kurtosis test require the probability of skewness and Kurtosis to be greater than the significance level of 0.05. The hypothesis for the normality check reads as follows:

$H1_a$: Residuals are normally distributed

$H1_b$: Residuals are not normally distributed

4.8 Conclusion

Chapter 4 provided the research methods followed in this study in order to accomplish the research objectives listed in Chapter 1. Following the footprint of the existing literature (Singh and Jha, 2017 and Sameni, Preston and Sameni, 2016) in transport sector this study selected input-oriented DEA techniques and Tobit regression to examine efficiency and factors affecting efficiency, respectively. Additionally, correlation coefficient was used to determine the extent of the relationship between technical efficiency and service effectiveness.

CHAPTER 5

DISCUSSION AND PRESENTATION OF THE EMPERICAL RESULTS

5.1 Introduction

Through the presentation of the empirical findings, this chapter seeks to address the research objectives listed in Chapter 1. The analysis consists of four African countries (South Africa, Morocco, Democratic Republic of Corgo and Algeria) and four European countries (Lithuania, Australia, France and Germany). This chapter starts by explaining descriptive statistics of four African through use of Stata version 14.0 software. The following subsections are organized as follows; 5.3 Presentation of Bankers, Charnes and Cooper (BCC) input-oriented and outputted data envelopment analysis (DEA) results, 5.4 Outlines the extent of association between two performance metrics which is explained by the Pearson correlation coefficient, 5.5 presents Tobit regression models and diagnostics tests for both technical efficiency and service effective performance metrics, and 5.6 presents the summary of the chapter.

5.2 Descriptive statistics

This section presents the descriptive statistics of two inputs (number of employees and rail lines), production (gross train tonne-km), two outputs (tonnes carried and tonne-km) and two exogenous variables (population density and per capita gross national income). Input variables as explained by Pina and Torres (2001) are unit measurements that represent the variables used to accomplish the service delivery of a given task. The authors further mention that efficiency improvement involves a reduction in the inputs consumed. Production or intermediate variables are consumption services produced during the transform of initial inputs, which in turn, are used as inputs in the process of producing service outputs. The output indicators measure the yield or the level of activity of programs and services, according to Pina and Torres (2001). Service effectiveness is therefore, achieved when all of the produced consumption service output is fully utilised. Chiou *et al*. (2007) state that, if the produced consumption service outputs are not fully utilised, they will be ineffectively utilised and thus, result in service ineffectiveness. Exogenous variables are variables that can affect the performance of the firms, but are not within their control.

Table 5.1 presents the descriptive statistics for African and European freight railways

Table 5.1 Descriptive statistics for African and European freight railways

Variables								
		Inputs		Intermediate	Outputs		Exogenous factors	
Statistics	Obs	NEs (1)	LRLs (2)	Gttkm (1)	T (1)	Tkm (2)	PD (2)	GNI (2)
EU region		'000'	'000'	'000'	'000'	'000'	'000'	'000'
Mean	4	105.16	17.389	153 657.75	116 055	30 781.5	0.128	35.581
Std dev.	4	142.56	16.253	138 876.563	99 414.67	26 767.77	0.08	13.871
Minimum	4	7.28	1.911	31 308	34 270	14 842	0.045	15.24
Maximum	4	316.9	33.44	336 912	255 500	70 614	0.237	45.12
African region								
Mean	4	14.055	7.621	55 920.25	62 692.5	36 274.75	0.045	3.168
Std dev.	4	9.409	8.82	102 779.99	104 915.71	69 168.41	0.026	2.082
Minimum	4	7.03	2.109	448	440	194	0.017	0.460
Maximum	4	27.28	20.953	210 000	219 100	140 000	0.080	5.410
Total								
Mean	8	70.195	12.51	104 789	89 3737.5	33 528.13	0.086	19.375
Std dev.	8	109.031	13.223	124 588.76	98 826.59	48 682.57	0.071	19.609
Minimum	8	7.03	1.911	448	440	194	0.017	0.49
Maximum	8	316.9	33.440	336 912	255 500	140 000	0.237	45.120

(1) Source: International Union of Railways (2019) **(2) World Bank Indicators**

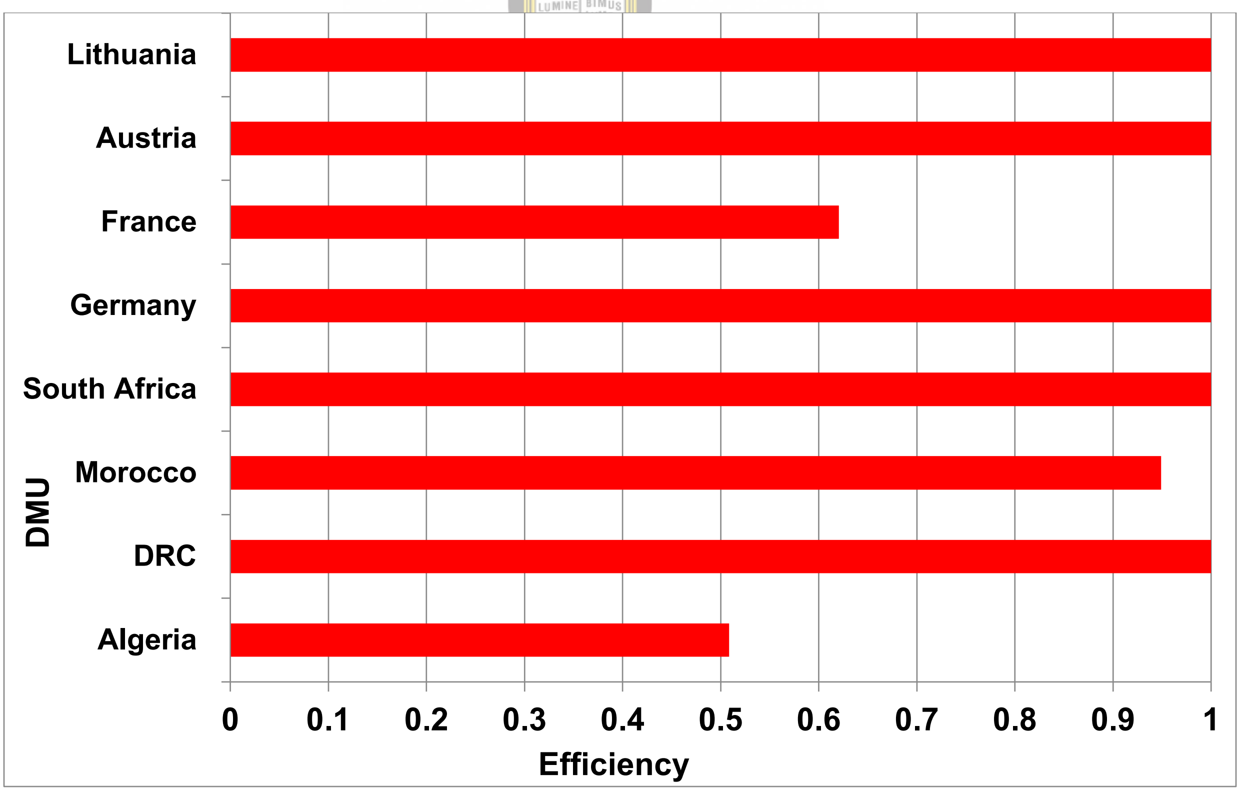
Note: EU denotes the European Unions, Obs denotes observation, NEs denote the number of employees, LRLs denote Rail Lines measured in kilometres, Gttkm denotes gross train tonne-km, T denotes tonnes carried, Tkm denotes tonne kilometres, PD denote Population Density, GNI denotes per capita gross national income measured in US Dollars.

From Table 5.1, it evident that European region has the largest rail network relative to African region. This is shown by the maximum number of employees (NEs) and Length of rail (LRLs). In addition, the amount of gross train tonne km in Europe is greater than the amount of gross train tonne km in Africa. On the other hand, Europe is the most population dense region and has the highest per capita gross national income. Lu (2016) claims that social development and economic growth show that there is high demand for railway networks and rail services.

5.3 Technical efficiency and service effectiveness

This section presents the technical efficiency and service effectiveness result extracted from BCC input oriented and output oriented data envelopment analysis (DEA), respectively. This section addresses one of the research objectives, which is to empirically analyze technical efficiency and service effectiveness for freight railways in African and European countries through the application of the standard DEA method.

5.3.1 Technical efficiency

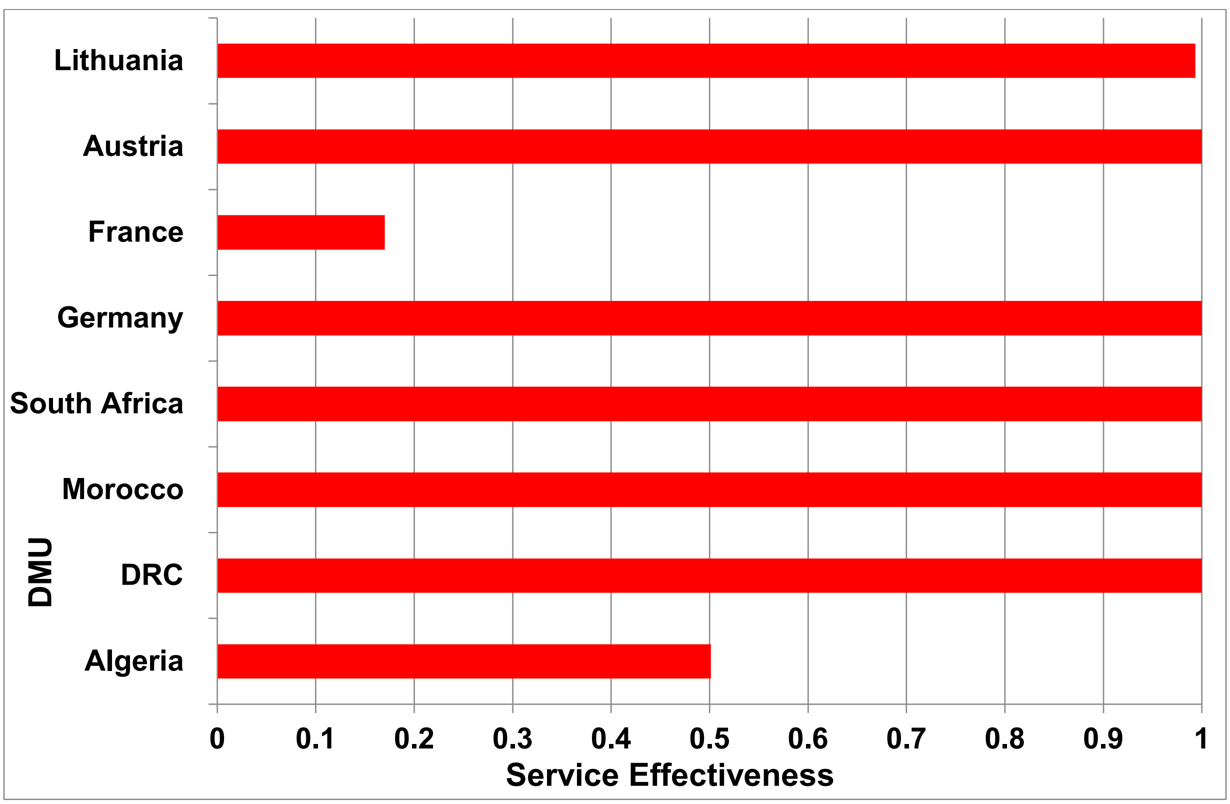


Source: Authors own analysis computed using UIC data (2019) and World Bank and Knoema data (2017)

Figure 5.1 Technical efficiency results

Figure 5.1 shows that five out of eight countries being studied show that their rail freight transportation systems were technically efficient with the BCC input-oriented results equal to 1.00 (100 percent). These countries include; South Africa, Germany, Democratic Republic of Congo (DRC), Austria and Lithuania. The rest of the countries; France, Morocco and Algeria, were technically inefficient, with the BCC input-oriented DEA results of less than 1. These findings slightly differed from the findings of Movahedi and Motamedi (2011), who found that South Africa, the DRC and Austria were technically efficient, while Germany (0.298), Lithuania (0.466) and Algeria (0.936) were technically inefficient. The current findings compared with Movahedi and Motamedi (2011) show that the efficiency of railways in Germany and Lithuania has improved. This difference can be attributed to the data changes and number of variables used.

5.3.2 Service effectiveness



Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

Figure 5.2 Service effectiveness results

Figure 5.3 indicates that five out of eight countries being studied achieved service effectiveness values equal to 1.00 (100 percent), while the other three did not manage to achieve service effectiveness values equal to 1, which present them as service ineffective. The results further show that, during the period of the study, Austria, Germany, South Africa and the DRC achieved both technical efficiency and service effectiveness equal to 1. While Lithuania was technically efficient, but service ineffective with BCC output-oriented value of 0.9934, which is less than the effective value of 1.00. Kumar and Gulati (2010) assert that high technical efficiency does not necessarily indicate high service effectiveness. Kaucikas (2017) claims that the railway capacity of Lithuania was not utilized to its full potential capacity due to inadequate intermodal terminals and constrained effectiveness of the interoperability.

Germany and Austria achieved 6.1 out of 10 overall ratings for intensity of use by both passenger and freight in performance ranking conducted by Boston Consulting Group (2017). Export-Import Bank of India (2018) indicated that, although the performance of Africa lags behind those in most developed countries, South Africa and other African countries can be seen to be performing better. South Africa is also ranked as the 14th largest rail system in the world and is a well-developed rail system in sub-Saharan Africa. Morocco was considered technically inefficient and effective with BCC input-oriented DEA and BCC output-oriented DEA of 0.9491 and 1.00, respectively. The combined effect (technical effectiveness) for France was less than 1, since technical efficiency (0.17) and service effectiveness (0.62) were less than a unit of 1. Boston Consulting Group (2017) reveals that France has lost some ground of performance with an overall rating of 6.0 out of 10, driven by very good ratings for intensity of use by passengers, quality and safety.

5.4 Correlation between technical efficiency and service effectiveness

From the literature review presented in Chapter 3, it is evident that the association between efficiency and effectiveness has received attention, particularly in freight railways. Therefore, to overcome this challenge, the current study seeks to empirically analyse the level of association between technical efficiency and service effectiveness of freight railways, with specific reference to African and European countries. This is done with the help of the Pearson correlation coefficient. According to Tsounis and Vlachvei (2020), the Pearson correlation coefficient is a measure of the linear dependence between two variables. Gujarati and Porter (2009) assert that the Pearson correlation coefficient varies between 0 and 1, and the negative and positive signs are used to indicate the direction of the association between the two variables being studied. Thereby determining the correlation coefficient, the following hypotheses will be addressed:

$H1_a$: There is no significant association between technical efficiency and service effectiveness.

$H1_b$: There is a significant association between technical efficiency and service effectiveness of freight railways.

Table 5.2 below presents the Pearson correlation coefficient results for technical efficiency, service effectiveness and technical effectiveness. Technical efficiency and service effectiveness remain as defined in the previous section. Chiou *et al.* (2007) defines technical effectiveness as a combined effect of both technical efficiency and service effectiveness. They further explain that technical effectiveness scores can be obtained from the product of the scores of technical efficiency and service effectiveness.

Table 5.2 Pearson correlation coefficient results

Correlations				
		Technical efficiency	Service effectiveness	Technical effectiveness
Technical efficiency	Pearson Correlation	1	.905**	.964**
	Sig. (2-tailed)		.002	.000
	N	8	8	8
Service effectiveness	Pearson Correlation	.905**	1	.986**
	Sig. (2-tailed)	.002		.000
	N	8	8	8
Technical effectiveness	Pearson Correlation	.964**	.986**	1
	Sig. (2-tailed)	.000	.000	
	N	8	8	8
** Correlation is significant at the 0.01 level (2-tailed).				

Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

The findings in Table 5.2 show that technical efficiency and service effectiveness are highly positively related, with a statistically significant Pearson correlation coefficient of 0.905. This led to the rejection of the null hypothesis and acceptance that technical efficiency and service effectiveness are significantly related, since r (6) = 0.002 < 0.01. This means that there is a 99 percent chance that the observed correlation between technical efficiency and service effectiveness is true, and there is a 1 percent probability of this being false. While technical efficiency and technical effectiveness are strongly positively related, with a Pearson correlation coefficient of 0.964 and the association is statistically significant since r (6) = 0.000 < 0.01. On the other hand, service effectiveness and technical efficiency are highly positively related, with a statistically significant Pearson correlation coefficient of 0.986 and the association is statistically significant, since (6) = 0.00 < 0.01.

Previous scholars analyzed the relationship between efficiency and effectiveness and yielded different results. These scholars include; Karlaftis (2004), Karlaftis and Tsamboulas (2012), Georgiadis *et al*. (2014), Doomernik (2015), and Singh and Jha (2017). However, this study supports the findings by Karlaftis (2004), Singh and Jha (2017) that state a significant association exists between the two-performance metrics. Through the application of the DEA technique, Karlaftis (2004) and Singh and Jha (2017) evaluated efficiency and effectiveness and their findings reveal that a strong positive relation exists between technical efficiency and service effectiveness. While Doomernik (2015) employed the Network DEA and the Malmquist Productivity Index to benchmark the performance of high-speed rail systems and found that productive efficiency and service effectiveness are negatively correlated.

Karlaftis and Tsamboulas (2012) applied stochastic frontier production, DEA and Neutral Network DEA techniques to evaluate the performance of public transports. Their findings reveal that efficiency and effectiveness are weakly negatively correlated. Georgiadis *et al*. (2014) applied the DEA with bootstrapping to measure the performance of local bus lines in Thessaloniki. It was noted that the efficiency of bus lines was slightly better than operational effectiveness without showing a clear positive or negative correlation.

Pina and Torres (2001) note that DEA outcomes vary depending on the type of inputs and outputs used.

5.5 Tobit regression analysis

In this section, a Tobit regression is performed to determine the impact of the independent variables on the dependent variables. Firstly, technical efficiency $(TEFFI)$ is regressed on number of employees(NEs), gross train tonne-km$(Gttkm)$, per capita gross national income (GNI) and population density(PD). Secondly, service effectiveness $(SEFFE)$ is regressed on gross train tonne-km$(Gttkm)$, per capital gross national income (GNI) and population density (PD). In addition, the following hypothesis were formulated:

- **H2a:** Technical efficiency is not significantly determined by the exogenous factors
- **H2b:** Technical efficiency is significantly determined by the exogenous factors
- **H3a:** Service effectiveness is not significantly affected by the exogenous factors
- **H3b:** Service effectiveness is significantly affected by the exogenous factors

Table 5. 3 presents the Tobit regression results for Model 1: Technical efficiency

Table 5.3 Tobit regression results, Model 1: Technical Efficiency

TEFFI	Coef.	Std. Err.	t	P> t
NEs	-0.0050627	0.0016644	-3.04	0.005
Gttkm	0.000081	0.0002553	0.32	0.764
GNI	-0.1591338	1.374123	-0.12	0.912
PD	0.0843486	0.5841553	0.14	0.891
_cons	99.86261	30.91283	3.23	0.023

Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

Using the mathematical equation, the results in Table 5.3 are further presented as follows:

TEFFI = 99.8626 – 0.0051NEs + .0008$Gttkm$ –.1591GNI – .084PD 5.1

Equation 5.1 indicates that $TEFFI$ is negatively influenced by the number of employees (NEs) and their relationship is statistically significant, since the t-statistic value is greater than 2 and the probability is less than 0.05 significance level. On the other hand, technical efficiency is not significantly determined by gross train tonne-km $(Gttkm)$, population density (PD), and per capita gross national income (GNI), since the t-statistic values are less than 2 and the probability values are greater than the 0.05 significance level. The results in Equation 5.1 suggest that a unit increase in the number of employees reduces technical efficiency of freight railways by 0.0050627 and the relationship is statistically significant, since the t-statistic value (-3.04) is greater than minus 2 and the probability of 0.005 is less than the 0.05 significance level.

Conversely, the technical efficiency of freight railways is not significantly determined by the per capita GNI, $Gttkm$ and PD. This implies that a unit increase or decrease in these variables will not influence technical efficiency of freight railway. This study fails to reject the null hypothesis and accepts that technical efficiency is not significantly affected by exogenous variables. These findings differ from the findings by Lan and Lin (2003) which shows that technical efficiency of passenger railways is positively influenced by electrified lines, PD, GNI, and average length of passenger trips. Table 5.4 presents the Tobit regression results for Model 2: Service Effectiveness.

Table 5.4 Tobit regression results, Model 2: Service Effectiveness

SEFFE	Coef.	Std. Err.	t	P>t
Gttkm	-.0000806	.0000271	-2.98	0.006
PD	1.379559	1.436289	0.96	0.381
GNI	-3.128662	3.015872	-1.04	0.347
_cons	99.58943	44.05432	2.26	0.073

Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

The results in Table 5.4 are further presented in the form of a mathematical equation as follows:

$SEFFE$ = 99.58943 – 0.0000806 $Gttkm + 1.613502PD - 3.657053GNI$..................5.2

Equation 5.2 shows that the gross train tonne-km (Gttkm) is negatively related to the service effectiveness (SEFFE) and the relationship is statistically significant, since the t-statistic is greater than minus 2 and the probability of 0.006 is less than the 0.05 significance level. The results in Equation 5.2 suggest that a unit increase in gross train tonne-km reduces service effectiveness by 0.0000806. On the other hand, service effectiveness of freight railways is not significantly impacted by per capita (GNI) and (PD). This suggests that service effectiveness is not significantly determined by exogenous variables (PD and per capita GNI).

Therefore, a unit increase or decrease in exogenous variables (PD and GNI) will not affect the service effectiveness of freight railways in four African countries and four European countries. This study fails to reject the null hypothesis and accepts that service effectiveness is not significantly determined by exogenous variables. While Lan and Lin (2003) found that service effectiveness of passenger railways is positively influenced by electrified lines, PD, per capita GNI, and average length of passenger trips.

5.5.1 Diagnostic tests

This section presents the diagnostic checks used to test the validity of the model of technical efficiency and service effectiveness presented in Equation 5.1 and 5.2, respectively. A good model must be free from serial correlation, heteroscedasticity and the residuals must be normally distributed. This study employed Breusch Pagan/Cook-Weisberg and White to check homoscedastic and Skewness/Kurtosis to check residual normality. Table 5.5 presents the diagnostic check results for Model 1.

Table 5.5 Diagnostic checks for Model 1

Test	**Hypothesis**	**Prob > Chi-square**
Breusch Pagan/ Cook-Weisberg	H_0: Variances are homoscedastic H_1: Variances are heteroscedastic	0.2550
White test	H_0: Variances are homoscedastic H_1 : Variances are heteroscedastic	0.3326
Skewness/ Kurtosis tests	H_0: Residuals are normally distributed H_1: Residuals are not normally distributed	0.2377

Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

The Breusch Pagan/Cook-Weisberg test shows Prob > Chi-square = 0.2550 is much higher than the 0.05 significance level and therefore, this study fails to reject the null hypothesis, since p = 0.2550 > 0.05 and concludes that the variances are homoscedastic.

The White test shows that Prob > Chi-square value of 0.3326 is much higher than Breusch Pagan/Cook-Weisberg test results. Since the Prob > Chi- square = 0.3326 > 0.05, the null hypothesis cannot be rejected and therefore, and this study accepts that no heteroscedasticity is detected in the model shown in Equation 5.1. Skewness/Kurtosis results show that the Prob > Chi-square = 0.2377 is greater than the statistical significance level of 0.05 percent.

Based on the results that p = 0.2377 > 0.05 percent, the null hypothesis cannot be rejected and therefore, this study concludes that residuals are normally distributed.

Table 5.5 Diagnostic checks: Model 2

Test	**Hypothesis**	**Prob > Chi-square**
Breusch Pagan /Cook-Weisberg	H_0: Variances are homoscedastic H_1: Variances are heteroscedastic	0.1184
White test	H_0: Variances are homoscedastic H_1: Variances are heteroscedastic	0.3326
Skewness/ Kurtosis tests	H_0: Residuals are normally distributed H_1: Residuals are normally distributed	0.1753

Source: Authors own analysis using UIC (2019), World Bank and Knoema data (2017)

Breusch Pagan or Cook- Weisberg and White test indicate that there is no heteroscedasticity, all variances are all equally distributed. This is shown by Prob > Chi-square of 0.1184 for Breusch Pagan or Cook- Weisberg and 0.3326 for White test, which are both greater than the 0.05 percent significance level. Therefore, the null hypothesis cannot be rejected, and this study concludes that variances are equally distributed. The results of the Skewness/Kurtosis tests show that Prob > Chi-square of 0.1753 and this study concludes that the null hypothesis cannot be rejected, since the residuals for Model 2 are normally distributed.

5.5 Conclusion

Chapter 5 presented the empirical findings of the study. This study was motivated by lack of literature analysing both technical efficiency and service effectiveness in transport, particularly in freight transportation. Therefore, the aim of this study was to; (i) provide technical efficiency and service effectiveness results for African and European countries; (ii) to explore the relationship between the two technical efficiency and service effectiveness? (iii) to find an existing relationship between the two performance measures; and (iv) to establish the extent to which exogenous variables affect the performance of freight railways. The results show that four out eight countries achieved technical efficiency score equal to 1. 00 (100), and, the same number of countries achieved service effectiveness values equal to 1.00 (100). The Pearson correlation show that technical efficiency and service effectiveness of freight rail are highly positively correlated with a Pearson correlation coefficient of 0.905 and the relationship is statistically significant, since r (6) = 0.0002 < 0.01. Results from Tobit regression show that technical efficiency and service effectiveness are not significantly affected by the exogenous factors (population density and per capita gross national income).

CHAPTER 6
CONCLUSION, LIMITATION AND RECOMMENDATIONS

6.1 Introduction

The purpose of this chapter is split in two folds. Firstly, this chapter seeks to summarize empirical findings for policy implications. Secondly, to summarize the contribution of this study to knowledge.

6.2 Summary of findings

Primarily, this study sought to assess technical efficiency and service effectiveness for freight railways in African and European countries through the application of the standard DEA method. The Banker, Charnes and Cooper (BCC) input oriented data envelopment analysis (DEA) and BCC output-oriented DEA were used to measure technical efficiency and service effectiveness, respectively. The results extracted from the BCC input-oriented DEA shows that five out eight countries were technical efficient, while the BCC output-oriented results show that five of eight countries being studied achieved service effectiveness. Countries that achieved technical efficiency equal to 1.00 (100 percent) include Austria, Germany, South Africa and Democratic Republic of Congo (DRC) and the rest which include France (0.6206), Morocco (0.9491) and Algeria (0.5058) were technical inefficient with BCC input-oriented results of less than 1.00 (100 percent).

On the other hand, South Africa, Morocco, DRC and Germany achieved service effectiveness values equal to 1.00 (100 percent), while Lithuania (0.9934), France (0.1701) and Algeria (0.5012) achieved service effectiveness values of less than 1.00 (100 percent). France was the least performing country in both technical efficiency and service effectiveness. Barrow (2017) claim that France rail freight transportation experienced a serious tide of weak demand and strong competition from other modes of transportation. Kaucikas (2017) assert that the railway capacity of Lithuania was not utilized to its full potential capacity due to inadequate intermodal terminal and constrained effectiveness of the interoperability.

The second objective of the study was to provide an overview of freight railways in four African countries and four European countries, through trend analysis. Trends showed that, during the past four years, starting from 2014 to 2017, there has been no significant developments in the rail sector, particularly rail freight transportation. This is shown by slow development in the length of rail lines, closure of rail networks due to the lack of adequate maintenance, damages, slow growth in gross train tonne-km and slowing of rail freight market shares owing to poor technical efficiency and service effectiveness, as well as high quality services offered by other transportation systems.

The third objective of the study was to analyze the degree of association between technical efficiency and service effectiveness of freight railways, with reference to African and European countries. The Pearson correlation coefficient was used to analyse the relationship between technical efficiency and service effectiveness. The results show that technical efficiency and service effectiveness of freight railways were highly positively related with a Pearson correlation coefficient of 0.905 and the relationship was statistically significant, since $r(6) = 0.0002 < 0.01$. This study concurs with the findings presented by Karlaftis (2004) and Singh and Jha (2017) that there is positive correlation between technical efficiency and service effectiveness.

The fourth objective of the study was to explain the impact of exogenous variables on technical efficiency and service effectiveness through analysis of the Tobit regression. Since both technical efficiency and service effectiveness values range between 0 and 1, Tobit regression was used to determine the relationship between technical efficiency and service effectiveness. The results show that technical efficiency and service effectiveness of freight railways were not significantly determined by the exogenous factors (population density and per capita gross national income). The fifth objective of the study was to draw conclusion and proffer recommendations based on the findings of the study. This is presented in the following section that is section 6.3.

6.3 Recommendations

Following the application of the Tobit regression analysis, which shows that input variables are significant factors affecting both efficiency and effectiveness, this study recommends that the rail sector should invest in technologically advanced rail assets which would reduce labour and increase output. In terms of service effectiveness, the study recommends a demand-driven approach or an expansion of rail activities as the need arises. The Department of Public Service and Administration (n.d) state that the public should be consulted regarding the service they are to receive, in order to determine the needs and expectations of the end users. Consultation can be in the form of surveys and pilot studies. This will ensure that the decision-making unit supplies a service which meet the needs and expectations of the customers.

6.4 Study limitations and potential areas for further research

Incomplete data in some countries within the African and European region was the key limitation of this study. Furthermore, it proved difficult to find data, such as the sum of train wagons, operating expenses and litres of fuel consumed during transportation of goods and services, which is commonly used to present inputs. Hence, this study was limited to eight countries; four African and four European countries. Another challenge was the availability of complete data for the past ten years encompassing all required variables. The majority of the existing literature, including this study, employed secondary data to compute both efficiency and effectiveness scores, therefore a mixed research approach is recommended as it will allow researchers to gain comprehensive insight for the problem at hand.

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Appendix A Technical efficiency

Model = BCC-I									
No.	DMU	Score	Rank		Reference (Lambda)				
1	Algeria	0.5085	8	DRC	0.076	Lithuania	0.924		
2	DRC	1	1	DRC	1				
3	Morocco	0.9491	6	DRC	0.154	Lithuania	0.846		
4	South Africa	1	1	South Africa	1				
5	Germany	1	1	Germany	1				
6	France	0.6206	7	South Africa	0.802	Germany	0.013	Austria	0.185
7	Austria	1	1	Austria	1				
8	Lithuania	1	1	Lithuania	1				

Average	0.8848
Max	1
Min	0.5085
St Dev.	0.2007

Appendix B Service effectiveness

Model = BCC-O									
No.	DMU	Score	Rank		Reference (Lambda)				
1	Algeria	0.5463	7	DRC	0.894	Morocco	0.053	Austria	0.053
2	DRC	1	1	DRC	1				
3	Morocco	1	1	Morocco	1				
4	South Africa	1	1	South Africa	1				
5	Germany	1	1	Germany	1				
6	France	0.1701	8	South Africa	0.826	Austria	0.174		
7	Austria	1	1	Austria	1				
8	Lithuania	1	1	Lithuania	1				

Average	0.8396
Max	1
Min	0.1701
St Dev.	0.3136

Appendix C Tobit regression results

Model 1: Technical efficiency

```
Tobit TEFFI NE Fttkm GNI PD, ll (0) ul (1)

Tobit regression

Tobit regression                                     Number of Obs  =     8
LR chi2 (5)     =       7.08
Prob > chi2     =     0.2146
Log likelihood = -.91116187                          Pseudo R2      =     0.7954
```

TEFFI	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
NE	-.0050627	.0016644	-3.04	.005	-.0084839	-.0016416
Ft-km	.000081	.0002553	.32	.764	-.0005752	.0007371
GNI	-.1591338	1.374123	-.12	.912	-3.691429	3.373161
PD	.0843486	.5841553	.14	.891	-1.41727	1.585968
_cons	99.86261	30.91283	3.23	.023	20.39866	179.3266
/sigma	39.45932	18.84602			-8.985926	87.90456

0 left-censored observations

3 uncensored observations

5 right-censored observations at TEFFI >= 1

Diagnostic checks for model 1

regress TEFFI NEs Gttkm GNI PD

estat hettest

```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         Variables: fitted values of TEFFI
         Chi2 (1)     =     1.30
         Prob > chi2 =     0.2550
```

estat imtest, white

```
White's test for Ho: homoscedasticity
         against Ha: unrestricted heteroscedasticity
         chi2 (7)      =      8.00
         Prob > chi2   =    0.3326
Cameron & Trivedi's decomposition of IM-test
```

Source	chi2	df	p
Heteroscedasticity	8.00	7	0.3326
Skewness	4.47	3	0.2151
Kurtosis	0.48	1	0.4863
Total	12.95	11	0.2964

predict resid, residuals

sktest resid

Skewness/Kurtosis tests for Normality

Variable	Obs	Pr (Skewness)	Pr (Kurtosis)	adj chi2 (2)	Prob>chi2
Resid	8	0.1253	0.9747	2.87	0.2377

Model 2: Service effectiveness

SEFFE	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Fttkm	-.000000806	.000000271	-2.98	0.006	-.00000136	-.000000250
PopD	1.379559	1.436289	0.96	0.381	-2.312539	5.071656
GNI	-3.128662	3.015872	-1.04	0.347	-10.88121	4.623885
_cons	99.58943	44.05432	2.26	0.073	-13.65579	212.8347
/sigma	57.26383	26.52808			-10.92877	125.4564

0 left-censored observations

3 uncensored observations

5 right-censored observations at SEFFE >= 1

estat hettest

```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         Variables: fitted values of SEFFE
         chi2 (1)       =     2.44
         Prob > chi2    =   0.1184
```

regress SEFFE Gttkm GNI PD

estat imtest, white

```
White's test for Ho: homoscedasticity
         against Ha: unrestricted heteroscedasticity
         chi2 (7)        =      8.00
         Prob > chi2     =    0.3326
Cameron & Trivedi's decomposition of IM-test
---------------------------------------------------
              Source |       chi2     DF       p
--------------------------------------------------
  Heteroscedasticity |       8.00      7    0.3326
            Skewness |       5.20      3    0.1580
            Kurtosis |       0.14      1    0.7122
--------------------------------------------------
               Total |      13.33     11    0.2722
```

----

predict r, resid

Skewness/Kurtosis tests for Normality

Variable	Obs	Pr (Skewness)	Pr (Kurtosis)	adj chi2 (2)	Prob>chi2
r	8	0.1091	0.5385	3.48	0.1753

Appendix D Email requesting subscription

Miss Azania Mfiyo
Master of Commerce student
Department of Economics
University of Fort Hare

Assistante Administration des Ventes

INTERNATIONAL UNION OF RAILWAYS

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<u>Email requesting subscription</u>

Good day UIC team

I am Azania Mfiyo, a Master of Commerce student at University of Fort Hare, Eastern Cape: South Africa, conducting a research study titled "An assessment of technical efficiency and service effectiveness for freight railways in African and European countries". The estimation of technical efficiency and service effectiveness requires these variables: number of employees, operational expenses, number of rails, number wagons, length of rail lines, fuel used, gross train tonne-km, revenues, tonnes carried, and tonne-km. I therefore, kindly request you to grant me credentials to login in your data website.

I would greatly appreciate your assistance.

Thanks,

Regards.

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