RAIL INFRASTRUCTURE DEVELOPMENTS AND THEIR PRODUCTIVITY IMPACT WITH SPECIAL REFERENCE TO INSTITUTIONS IN FIVE SOUTHERN AFRICAN DEVELOPMENT COMMUNITY COUNTRIES

BY

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Declaration

This thesis is submitted under the University of the Witwatersrand Regulations for the award of Doctor of Philosophy degree by research. I confirm that the work submitted is my own and work of others is duly acknowledged through citation.

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Abstract

This thesis investigates the determinants of rail infrastructure investment and its impact on productivity growth in Botswana, Namibia, South Africa, Zambia and Zimbabwe for the period 1960 to 2018. The descriptive analysis of rail infrastructure data covers the period from 1939 to 2018. With the exception of South Africa, data availability limited the study analytics to start from 1960. The five Southern African Development Community (SADC) countries share a common history in terms of development, and their rail networks are interconnected. The focus of the study is on the quantity of rail infrastructure.

Based on the augmented Bond, Mairesse, and Mulkay (1997) investment model, we apply the Pooled Mean Group estimator of Pesaran, Shin and Smith (1999) on novel datasets of rail infrastructure measures to estimate the drivers of rail infrastructure investment and efficiency in Botswana, Namibia, Zambia and Zimbabwe. Estimation results suggest that economic, geostrategic and institutional factors drive rail infrastructure investment, efficiency and productivity growth in the four countries. GDP is found to have an insignificant impact on rail infrastructure investment.

South Africa being distinctly different from the other four countries provides a different contextual setting to investigate the determinants of rail infrastructure investment and efficiency, and its impact on productivity growth. We separately apply time series analysis in the case of South Africa using the Bounds Test technique of Pesaran, Shin and Smith (2001). Estimation results suggest that GDP has a significant negative impact on rail infrastructure investment in South Africa. Government investment has a significant negative impact on rail infrastructure investment.

Research results suggest that geostrategic factors have a significant positive impact on rail infrastructure investment in the four countries, and insignificant on rail infrastructure efficiency except in the case of passenger rail infrastructure investment where the impact is negative. In contrast, geostrategic factors have an insignificant impact on rail infrastructure investment in South Africa except for mixed rail infrastructure investment where the impact is negative. The impact of geostrategic factors on rail infrastructure efficiency in South Africa is found to be positive.

Domestic institutions are found to have a positive impact on passenger and mixed rail infrastructure investment, and an insignificant impact on freight and rail track infrastructure investment in the four countries. Domestic institutions have a positive impact on rail locomotive and wagon efficiency in the four-country case. The impact on the other rail infrastructure efficiency measures is insignificant. In the case of South Africa, the results indicate that domestic institutions have an insignificant impact on rail infrastructure investment. The impact of domestic institutions on rail infrastructure efficiency is found to be positive on locomotive and passenger coach efficiency, and negative on the other rail infrastructure efficiency measures.

The results and conclusions remain generally the same irrespective of the different settings and method of analysis although there are differences in whether the effect is positive or negative in some cases. Overall, the research results, lead us to conclude that economic, geostrategic and institutional factors are important determinants of rail infrastructure investment and efficiency in the five SADC countries.

Productivity growth impact of rail infrastructure investment is estimated using the PMG estimator of Pesaran *et al* (1999) in the case of Botswana, Namibia, Zambia and Zimbabwe. The results indicate that rail infrastructure investment particularly rail track infrastructure investment has a direct positive impact on productivity growth while the impact on total factor productivity is negative. Government investment is found to have a positive direct and indirect impact on productivity growth. The results also indicate that the impact of domestic institutions on productivity growth in the four countries is negative while that of geostrategic factors is mixed.

The Bounds Test technique of Pesaran *et al* (2001) is applied in the case of South Africa to investigate the productivity impact of rail infrastructure investment. Results suggest that rail infrastructure investment has a negative and weakly significant direct impact on productivity growth, and a negative impact on TFP. Government investment is found to have a negative direct impact on productivity growth and a positive indirect impact through enhancing total factor productivity. Human capital formation is found to be a significant economic driver of productivity growth in South Africa. Geostrategic factors are found to have an indirect positive impact on productivity in South Africa. The direct and indirect impact of domestic institutions on productivity growth is positive in the case of South Africa.

Conclusions following from our research results are that investment in rail infrastructure and rail infrastructure efficiency are driven by a mix of economic, geostrategic and domestic institutional factors in the five SADC countries under study rather than a uni-causal narrative. Rail infrastructure investment has a direct positive impact on productivity growth and a negative indirect impact through depressing total factor productivity in the case of Botswana, Namibia, Zambia and Zimbabwe. The productivity growth impact of rail infrastructure investment is negative in the case of South Africa.

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List of acronyms

AAC		Anglo American Corporation
AARA		Association of American Railroads
ARA		Australasian Railways Association
ADF	-	Augmented Dickey Fuller
AIC		Akaike Information Criterion
ARDL	-	Autoregressive Distributed Lag
BBR		Beitbridge Bulawayo Railways
BOT		Build Operate and Transfer
BR		Botswana Railways
BNZZ		Botswana Namibia Zambia Zimbabwe
BSAC		British South Africa Company
CES		Constant Elasticity of Substitution
CFLM		Caminho de Ferro de Lourenco Marques
CGR		Cape Government Railways
COMESA	-	Common Market for Eastern and Southern Africa
CRS		Constant Returns to Scale
CSAR		Central South African Railways
CT		Colonial Tenure
CTC		Centralized Train Control
DFE		Dynamic Fixed Effects
DRC		Democratic Republic of Congo
ECM	-	Error Correction Model
FDI	-	Foreign Direct Investment
FI		Freight Investment
FRII		Freight Rail Infrastructure Index
GDP		Gross Domestic Product

GE		General Electric
GI		Government Investment
GM		General Motors
GNI	-	Gross National Income
GTKM		Gross Tonne Kilometres
GTM		Gross Tonne Miles
IPS	-	Im, Pesaran and Shin
MDS		Market Demand Strategy
MG	-	Mean Group
MI		Mixed Investment
MRII		Mixed Rail Infrastructure Index
MRPC		Marginal Revenue Product of Capital
NoB		North of Bulawayo
NRZ		National Railways of Zimbabwe
NSC		North South Corridor
NTKM		Net Tonne Kilometre
NZASM		Nederlandsche Zuid-Afrikaansche Spoorweg-Maatschappij
OAU		Organization of African Unity
OECD		Organization for Economic Cooperation and Development
OMEG		Otavi - Minen und Eisenbahngesellschaft
PCA		Principal Component Analysis
PEA		Portuguese East Africa
PI		Passenger Investment
PMG	-	Pooled Mean Group
PRII		Passenger Rail Infrastructure Index
RR		Rhodesia Railways
RI		Road investment

RRI		Land Transport Investment
RRL		Rhodesia Railways Limited
RSZ		Railway Systems of Zambia
SADC		Southern African Development Community
SARA		Southern African Railways Association
SAR		South African Railways
SAR&H		South African Railways and Harbours
SoB		South of Bulawayo
SSA		Sub-Saharan Africa
SSATP		Sub-Saharan Africa Transport Policy
STI	-	Surface Transport Infrastructure
SWA		South West Africa
TAZARA		Tanzania Zambia Railway Authority
TCL		Tanganyika Concessions Limited
TFP	-	Total Factor Productivity
TFR		Transnet Freight Rail
TPS		Transnet Long Term Planning Strategy
TTI		Rail Track Investment
UAR		Union of African Railways
UK		United Kingdom
UNCTAD		United Nations Conference on Trade and Development
UNECA		United Nations Economic Commission for Africa
UDI		Unilateral Declaration of Independence
WB		World Bank
WDI		World Development Indicators
XCONST		Executive Constraints
ZRL		Zambia Railways Limited

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

This Chapter provides the background to the research problem, problem statement, research questions, research objectives, significance of the study, delineations and limitations, and finally the thesis structure.

1.2 Background

The importance of infrastructure in an economy has received extensive support in literature. A number of studies support the important role played by infrastructure in an economy[1]. Infrastructure affects the economy as a factor of production and also through attracting foreign direct investment, enhancing productivity of other factors of production, and opening new markets. Therefore, good infrastructure is a prerequisite for improved economic performance and growth.

Sub-Saharan Africa (SSA) is facing a challenge of inadequate infrastructure (World Bank, 1994; Calderon & Serven, 2008; Foster & Briceno-Garmendia, 2010). It has been observed by for example, Luiz (2010) that Africa's infrastructure challenges have had a negative effect on its international competitiveness, cost of doing business, foreign direct investment flows and contributing to the retardation of economic growth.

Regarding infrastructure investment, Esfahani and Ramirez (2003) for example, identify institutional and policy variables, and production opportunities in the economy as major determinants. Literature suggests that institutions reduce uncertainty and costs of exchange and production[2]. Countries with better quality institutions achieve higher investment levels and higher productivity of investment hence higher economic growth rates (Dawson, 1998; Aghion & Schankerman, 1999; Gwartney, Holcombe, Lawson, 2006).

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[1] For example World Bank (1994), Ndulu, Kritzinger van Nierkerk and Reinikka (2005), Perkins, Fedderke and Luiz (2005), Agenor and Dodson (2006), Calderon and Serven (2008), Fedderke and Garlick (2008), Luiz (2010) and, Foster and Briceno-Garmendia (2010)

[2] North (1990), Aron (2000), Bardhan (2005), and Engerman & Sokoloff (2008)

Whereas existence of good institutions promotes investment through their uncertainty reducing effect as observed by for example Rodrik, Subramanian, and Trebbi (2004), Kirkpatrick, Parker & Zhang (2006); Benassy-Quere, Coupet and Mayer (2007) and Fedderke and Luiz (2008), infrastructure investment in developing countries is negatively affected by weak institutions which have the effect of increasing risk, uncertainty and transaction costs (World Bank, 1994).

Transport infrastructure is part of core infrastructure in the economy. It plays the important role of providing mobility and integrating markets. Transport has the potential to promote wider economic benefits due to the multiplicity of links it has with other sectors of the economy. Efficient transport infrastructure can therefore promote trade within and among countries. This promotes connectivity and regional integration. Variation of the transport costs across countries arises from differences in infrastructure quality, institutional and regulatory frameworks, and efficiency of the distribution systems (UNCTAD, 2009). The role of transport makes it an important ingredient of economic growth.

Rail transport is one of the two major land transport modes, the other one being road transport. However, the rail transport sector in SSA and the SADC region in particular has suffered from lack of infrastructure investment resulting in a significant decline in rail infrastructure capacity and rail transport services. Rail infrastructure declined from being about one third of global infrastructure stock in the 1960s to about 6% in the 2000s (Fay & Yepes, 2003). Despite having made a positive contribution to the economic history of Africa over the past century by facilitating trade, investment and creating an enabling environment, investment in rail infrastructure declined over the years (Fedderke, Perkins & Luiz, 2006; Luiz, 2010). UNCTAD (2009) observes the crucial role of the cost of transport services in determining competitiveness of SADC countries. To this end, AFDB (2014) contends that reliability of transport infrastructure is a contributory component to the competitiveness of countries. It is argued by for example, Luiz (2010) that the existing rail infrastructure gap in the Southern African Development Community (SADC) has adverse effects on regional rail performance resulting in negative effects on competitiveness and economic growth.

At the global level, Thompson (2007) argues that current institutional frameworks are inadequate to address rail infrastructure investment challenges and recommends the development of holistic frameworks to mitigate these challenges. He proposes a framework which should address:

(i) Government policy

(ii) Relative costs of railway and road infrastructure;

(iii) Incentive structure for infrastructure investors and users; and

(iv) Technology.

In the SADC region, studies on institutional indicators specific to some countries[3] suggest that institutional factors are important determinants of investment. However, institutional failure has been identified as one of the major causes of the poor condition of railway infrastructure and performance in SSA (Kessides, 1993; World Bank, 1994; Thompson, 2007; Foster & Briceno-Garmendia, 2010).

On the contrary, road transport has benefited from the continuous increase in road infrastructure investment compared to the stagnant investment in rail infrastructure that has resulted in faster growth of road traffic (Fedderke *et al*, 2006; Foster & Briceno-Garmendia, 2010). Advantages of road transport are that it is faster, flexible and can offer door to door services.

The focus on rail transport is motivated by the benefits it offers which can contribute towards economic, financial and environmental sustainability. Compared to road transport, rail transport offers the following benefits:

(i) Relatively cheaper bulk carrier;

(ii) Fuel efficient - the fuel consumption rate of rail transport is about one third of road transport per tonne kilometre (Association of American Railroads, 2008);

(iii) Lower emission levels - rail transport emissions per tonne kilometre are about one quarter of road emissions (Association of American Railroads, 2008);

(iv) Better safety record; and

(v) Does not suffer from congestion.

Apart from lower transport costs, rail transport has low external costs compared to road transport (Forkenbrock, 2001; Chaudhury, 2005).

Africa has the highest transport costs compared to all other continents because of inefficiency and the use of expensive modes of transport (UNCTAD, 2003; Agenor & Moreno-Dodson, 2006;

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[3] For example studies by Fedderke, de Kadt and Luiz (2001), Zaaruka and Fedderke (2011), Fedderke, Lourenco and Gwenhamo (2011) and (Gwenhamo, Fedderke and de Kadt (2012)

Mbekeani, 2007; Naude & Matthee, 2007; Gwilliam, 2011). Although there is agreement that lower transport costs promote competitiveness and growth[4], Africa's international costs are about twice the world average (UNCTAD, 2003; AFDB, 2010). Lack of investment in transport infrastructure has been identified as one of the contributory factors to the high transport costs in Africa (Naude & Matthee, 2007; Calderon & Serven, 2008).

Distance to global markets and the bulk nature of commodities transported in most African countries suggest rail as the most ideal transport mode. Mineral products that are bulk in nature dominate exports from SADC countries. The bulk composition of exports makes rail the most suitable mode of transport (Naude & Matthee, 2007; Foster & Briceno-Garmendia, 2010; Luiz, 2010; Gwilliam, 2011). Besides transport costs, rail transport can address economic, financial and environmental sustainability challenges in most countries (Ackermann, Gwilliam & Thompson, 1998; Brazzaville Declaration, 2006).

Countries stand to benefit from increased use of rail transport through reduced transport costs. This points to the need to shift traffic from road to rail transport. The European Union for example, came up with a deliberate policy to shift freight from road to rail in view of the benefits of using rail transport (Thompson, 2007). A shift of freight from road to rail transport is also required in Southern Africa but rail infrastructure capacity is inadequate to accommodate additional traffic. Investment in rail infrastructure is therefore required first to increase rail capacity to enable handling of additional traffic and competition against road transport.

The African Union Ministers responsible for railways came up with the Brazzaville Declaration in 2006 where they acknowledge the benefits of rail transport and raised concern on the lack of investment in railways on the African continent. At SADC[5] regional level, the decline in rail capacity and market share prompted the formation of the Southern African Railways Association (SARA) in 1996 to lobby governments and champion regional railway policy to promote investment and use of rail transport (SARA, 2016).

[4] Observed by for example, Radelet & Sachs (1998); Limao & Venables (2001); UNCTAD (2003); Kessides (2004), UNCTAD (2009) and Jorgensen (2010).

[5] The SADC region is made up of sixteen countries namely Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia and Zimbabwe.

Investment in rail infrastructure is required in order to expand rail capacity. Identification of the determinants of investment in rail infrastructure will help in the establishment of a conducive environment for investment in the rail sector.

1.3 Problem statement

Transport infrastructure forms part of core infrastructure with strong linkages with other sectors of the economy. Rail is a major land transport mode with the potential to promote economic, financial and environmental sustainability in the SADC region. These benefits cannot be realized due to the decline in rail infrastructure investment over the past six decades. The decline in rail infrastructure capacity has adverse effects on regional transportation costs and competitiveness of Southern Africa. Consequently, benefits attributable to increased use of rail are forgone and will continue to be lost if there is no investment in rail infrastructure.

Although lower transport costs promote competitiveness and growth, lack of investment in transport infrastructure has been identified as one of the contributory factors to the high transport costs in the SADC region. Poor rail transport services resulting from infrastructure capacity challenges in the Southern African Development Community (SADC) negatively affect regional competitiveness and stifle economic growth. As a result, SADC countries struggle to narrow the income inequality gap with the developed countries.

The decline in rail infrastructure investment resulted in a decline in rail capacity leading to the deterioration of rail transport services. Due to lack of rail capacity, shippers use more of road transport which is relatively expensive. Rail transport in the SADC region used to command a market share of over 80% of freight traffic in the 1980s but this has since fallen to below 15% due to declining capacity and liberalization of the transport market (AFDB, 2014; SADC, 2017). This is cause for concern to both policy makers and shippers because of the high transportation costs of using road transport.

As a bulk carrier rail transport offers relatively are lower transportation rates than that of road with positive impact on the economy. This is important when considering low value bulk commodities like agricultural products and export minerals transported in the region (Naude & Matthee, 2007; Foster & Briceno-Garmendia, 2010; Luiz, 2010; Gwilliam, 2011). Rail is economic in terms of fuel consumption per tonne kilometre and is environmentally friendly in terms of lower emissions compared to road (Ackermann, Gwilliam & Thompson, 1998; Brazzaville Declaration, 2006).

Apart from being expensive, increased use of road transport causes congestion on the roads, increases maintenance costs for roads and fuel consumption to the detriment of the economy. The high maintenance costs of roads resulting from excessive usage due to lack of capacity on the part of rail transport may be alleviated if rail capacity is boosted through infrastructure investment. High emission levels from road transport which are harmful to the environment will be reduced if more of rail transport is used instead of road transport.

There is a case of rail being underutilized. Rail used to transport over 80% of freight traffic in the 1980s but this has declined to below 15% due to competition from road (AFDB, 2014; SADC, 2017). This implies that rail is moving freight which is below its design capacity. We need to understand reasons for its lack of use. While a shift of traffic from road to rail transport is desirable for the SADC region, the challenge is that rail transport does not have adequate capacity to handle additional traffic due to lack of investment. To resolve this challenge, there is need to understand the drivers of investment in rail infrastructure to facilitate the development and alignment of policies to address capacity challenges of rail transport. In view of resource limitations faced by SADC countries against the need to promote growth, it is pertinent to establish the productivity growth impact of rail infrastructure investment to guide resource allocation among transport modes especially against road transport. This will help highlight the relevance of rail transport and provide justification for rail infrastructure investment. Identification of key drivers and productivity growth impact of rail infrastructure investment in Botswana, Namibia, South Africa, Zambia and Zimbabwe is the main focus of this research.

Data is required for the better understanding of this problem. However, lack of data is one of the challenges hampering research in Africa and in the SADC region in particular. Apart from South Africa, rail infrastructure data is a challenge for the other four sample countries. Assembling country specific time series rail infrastructure data sets for the sample countries was a huge challenge. It entailed utilization of various sources, visiting rail operators and rail libraries of South Africa, Zambia and Zimbabwe, national archives in Zambia and Zimbabwe, National Statistics offices for Zambia and Zimbabwe, consulting Statistics Botswana and the Ministry of Works and Transport of Namibia. It also involved separation of aggregated rail data for Rhodesia Railways which once operated as a single company in Botswana, Zambia and Zimbabwe, and finally generation of novel rail infrastructure measures for the sample countries using principal component analysis (PCA).

This resulted in the compilation of a unique novel data set that is presented in this research. This new data set constitutes an important contribution as it did not exist before. This new data set can benefit a number of stakeholders. First, analysis of this research would not have been possible without this data set. Second, the data set can be utilized by other researchers to further the rail infrastructure debate. Third, the data set can support rail transport policy development and rail management. The disaggregated data for each country provides opportunities to track and better understand rail developments in each individual country to inform future country specific policy and interventions. It therefore enables a better understanding of rail infrastructure development and management in Southern Africa specifically for Botswana, Namibia, South Africa, Zambia and Zimbabwe.

1.4 Research questions

This study addresses the following research questions;

(i) What are the determinants of investment in rail infrastructure in Botswana, Namibia, South Africa, Zambia and Zimbabwe?

(ii) Does investment in rail infrastructure affect productivity growth in the five SADC countries?

1.5 Objectives of the study

The study has two main objectives. The first objective is to determine the drivers of investment in rail infrastructure in Botswana, Namibia, South Africa, Zambia and Zimbabwe. This is done through construction of time-series rail infrastructure measures and estimating their relationship with economic, geostrategic and institutional factors. The aim is to establish how rail infrastructure development in these countries is influenced by these factors. The five SADC countries share a common history in terms of development and their rail networks are interconnected.

The second objective is to estimate the impact of rail infrastructure investment on productivity growth in the five SADC countries. The aim is to determine whether the various rail infrastructure investment measures make a positive contribution to GDP per capita growth in order to guide resource allocation.

The core findings of the study are twofold. Firstly, economic, geostrategic and institutional factors jointly drive investment in rail infrastructure and rail operational performance in the five SADC countries. Secondly, the productivity growth impact of rail infrastructure investment is indirect through total factor productivity (TFP), positive and significant in the panel context of Botswana, Namibia, Zambia and Zimbabwe. The productivity impact is negative and insignificant in the case of South Africa.

The construction of the core network in the four countries was influenced by economic and geostrategic considerations. Economic factors are more pronounced in the case of Namibia, Zambia and Zimbabwe being dominated by mining activities. Branch lines in these countries were constructed for the purpose of serving mines. Botswana is principally a transit route as its generation of traffic from within is low. Transit traffic through Botswana was significantly reduced following the construction of the Beitbridge-Bulawayo rail line which provided the shortest route through Zimbabwe to South African sea ports. This rail line was constructed by the private sector for purely business considerations. Agriculture also led to the construction of rail lines to the sugar estates and some farming areas in Zimbabwe.

Being land locked countries, Botswana, Zambia and Zimbabwe needed access to the sea for their exports and imports. As a result, geostrategic factors were at play especially in the case of Zambia and Zimbabwe leading to the construction of alternative rail routes leading to the sea. The TAZARA rail line to Dar es Salaam was constructed in the case of Zambia. In the case of Zimbabwe, alternative rail lines leading to Mozambican and South African seaports were constructed. Botswana did not construct an alternative rail route to the sea because it is not a major producer or consumer of rail transportable traffic. It served mainly as a transit route. As a coastal country, Namibia did not consider alternative rail routes to the sea once the core rail network was in place.

Institutionally, the rail companies in the four countries are State owned and therefore funded by the government. However, there is no elaborate and sustainable funding mechanism for rail infrastructure investment as is the case for road. In this regard, land transport policy appears to be pro-road. Policy inconsistency had an impact in the case of Zimbabwe and Zambia which resulted in railways' failure to invest in infrastructure. Passenger services in these four countries are loss-making and funded by the State as social service obligations.

In the case of South Africa, economic considerations dominate. South Africa is a big economy dominated by mining, agriculture and manufacturing. Mining was a major driver of rail infrastructure development in South Africa. Geostrategic considerations serve economic interests. Geostrategic positioning between the Afrikaners and the British was significant prior to unification in 1910. The rail route from Pretoria to Maputo was constructed by the Afrikaners to avoid British controlled territories and sea ports. The railways are predominantly State owned and the funding mechanism for rail infrastructure is also not as elaborate as for road infrastructure investment.

The study contributes to the body of knowledge surrounding infrastructure by narrowing the literature gap and advancing the debate on rail infrastructure development in the SADC region. It develops novel datasets of rail infrastructure measures for the five countries which are an important enabler for rail transport policy development, rail infrastructure management and further research. The data sets enabled us to identify the determinants of rail infrastructure investment and its productivity growth impact in this research. The data sets will thus promote better understanding and advance the debate on rail infrastructure development and management. The study also provides policy and managerial insights on rail infrastructure development and management which can help to improve rail transport capacity and operational performance.

1.6 Delineations

The study analyses rail infrastructure stock in terms of quantity measures and does not cover issues related to the quality of infrastructure. While an understanding of the quality of rail infrastructure would have provided more insights on the state of rail infrastructure and efficiency in the five countries, the study does not comprehensively deal with this but presents some evidence.

The study does not cover investment in road infrastructure in detail except for comparative purposes as a major surface transport mode.

1.7 Limitations

Data availability limited the study to start from 1960. Pre-1960 rail issues are not covered by the analysis. Data availability also limited the geographical coverage of the study to only five (5) of the twelve (12) SADC member states with rail. Quality of rail infrastructure was not exhaustively dealt with.

1.8 Organization of the thesis

The thesis comprises of six chapters with this chapter serving as the introduction.

Chapter Two provides an overview of the historical development of rail in Southern Africa and what the major interpretations of this development are in literature. Economic, geostrategic and institutional factors emerge as possible drivers of rail infrastructure development in Southern Africa.

Chapter Three progresses from the previous Chapter by detailing how novel datasets for rail infrastructure measures are constructed. The evolving status of rail infrastructure and efficiency is analyzed through descriptive data analysis. The rail infrastructure trends and the corresponding operational performance of railways in each of the five countries are contrasted against economic, geostrategic and institutional factors highlighted in Chapter Two to bring to the fore specific issues surrounding rail infrastructure investment and efficiency.

Chapter Four estimates the determinants of rail infrastructure investment and efficiency. The determinants are framed on the basis of economic, geostrategic and institutional drivers identified through the historical overview in Chapter Two and descriptive data analysis in Chapter Three.

Chapter Five estimates the impact of rail infrastructure investment on productivity growth in the five countries under study and compares it with the impact of road infrastructure investment on productivity growth as well in view of the competition for resources from the fiscus by the two major surface transport modes who compete and also complement each other.

Chapter Six provides the summary of findings and their implications, contribution, conclusions and policy recommendations. Suggestions for further research are also provided.

CHAPTER TWO

EVOLUTION OF RAIL NETWORKS IN FIVE SOUTHERN AFRICAN DEVELOPMENT COMMUNITY COUNTRIES

2.1 Introduction

This chapter provides an overview of the historical development of rail in Southern Africa, and what the major interpretations of the development are in the literature. It provides a historical and economic context of the chronological development of railway networks in Botswana, Namibia, South Africa, Zambia and Zimbabwe. We concentrate on the five countries because their rail networks are interconnected, and they share a common history in terms of historical development. The institutional and historical background of Angola and Mozambique are too distinct to be readily treated in conjunction with the countries specified for this study. The latter had in common a minimum of administrative and institutional unity based on membership of the British Empire. Though outside the scope of this study, the development of some rail lines in the Portuguese flanks of Angola and Mozambique are briefly considered given their links with the networks under study and the significant role they played in regional rail transport. An understanding of this historical background will assist, partly in appreciating the foundation, historical role and the dynamics which shaped rail development in these countries. Appreciation of overlaps in ownership and operations which had a direct impact on performance reporting by the railways will guide data generation and analysis in subsequent chapters. This background will also assist in understanding how the railways in these countries evolved up to their current state and possibly provide insights on how their performance could be improved.

Our contribution to existing literature is four-fold. First, we provide an overview of the historical development of rail in Southern Africa, and what the major interpretations of the development are in the literature. Second, we demonstrate that infrastructure development in Southern Africa was driven by both economic and geostrategic priorities, with relative importance of the two forces depending on time and context. Third, in addition to economic and geostrategic drivers, we argue that domestic institutions also matter to the development of rail infrastructure. Fourth, the literature tends to focus on physical capacity, but we highlight the need to make an important distinction between capacity and efficiency.

2.2 Railway Infrastructure Development in Five SADC Countries

The development of the rail network in Southern Africa was shaped by political and mining interests. Frenkel (1943) observes that transport and communications were a necessity for penetrating Africa as they provided the enabling environment for international trade. Strong links existed between mine and railway owners. For example, Wolfe (1963) and Lunn (1992) argue strongly that rail construction was through overlapping relationships among private sector developers, financiers, rail contractors and mining companies. Cecil John Rhodes[6] was at the centre of rail network development from the Cape through Bechuanaland (now Botswana) and the Rhodesias (now Zambia and Zimbabwe) up to the border with the Belgian Congo (now Democratic Republic of Congo).

Railways were a conduit through which resources, mostly minerals extracted from the continent were exported. Luiz (2010) argues that rail infrastructure was developed for extractive purposes especially for mining and agriculture products that served the interests of colonizers. Literature further suggests a strong link between mining and railway development.[7]

Frenkel (1943) asserts that mineral discoveries or potential shaped early rail network development in Southern Africa. This view is supported by Katzenellenbogen (1974) who observes that development of railways northwards was driven by the copper mines of Katanga Province of the Belgian Congo (later Zaire and now Democratic Republic of Congo). Bullock (2005) and Perkins, Fedderke and Luiz (2005) also highlight the role of mining in shaping rail network development in Southern Africa. This view is reinforced by Luiz (2010) who contends that railways were historically a business enabler which facilitated trade and investment.

While mining was found to have played an important role in rail development in Angola, the Democratic Republic Congo and South Africa, Katzenellenbogen (1974) contends that initial railway development in Southern and Northern Rhodesia (now Zimbabwe and Zambia

[6] Cecil John Rhodes was a British businessman and politician with major interests in mining and railway development in southern Africa who founded Rhodesia, the present day Zimbabwe and Zambia.
[7] For example Wolfe (1963) & Katzenellenbogen (1974).

respectively) was not motivated by any business case as the mining potential of these countries was not known then. However, later development of railways in these countries revolved around mining especially development of branch lines. Frenkel (1943) contends that railways were not only developed for economic reasons, but also for strategic and administrative purposes. However, empirical determination of the relative impact of the business and strategic factors in driving rail infrastructure development in Southern Africa is difficult.

Lack of significant infrastructure developments in terms of constructing new lines, rehabilitation and maintenance post-independence in most of the regional countries is well documented in literature (for example Kessides, 2004; Matthee and Naude, 2007; Foster and Briceno-Garmendia, 2010). There is consensus in literature that regional rail tracks have suffered from lack of maintenance over the years hence their declining capacity and deteriorating services. In the case of South Africa, Fedderke and Luiz (2006) found that changes in rail route kilometres were insignificant after the 1930s. They however note an increase in the rolling stock beyond this period.

The Tanzania Zambia Railway Authority (TAZARA) rail line linking Tanzania and Zambia built in the early 1970s is an exception in this regard. Tanzania and Zambia constructed a 1 860km railway line from Kapiri Mposhi in Zambia to Tanzania's Dar es Salaam Port on the Indian Ocean.

Although economic interests were at the core of rail network development in Southern Africa, political considerations too shaped regional rail infrastructure development. Economic ties among regional countries were affected by their colonial status. There was always competition among imperial powers and tension between newly independent states and those under colonial governments. We therefore argue that railways were an integral component of the colonial powers' extractive strategy. We further argue that rail infrastructure development in Southern Africa was as a result of economic, geostrategic and institutional factors with neither of the three being less important. It will be incorrect to analyse rail infrastructure development in Southern Africa and make conclusions based on a uni-causal narrative.

Funding of rail construction in South Africa (Cape Colony), Botswana, Zimbabwe, Zambia and Mozambique (Beira to Mutare section) was provided through resources mobilized by Cecil John Rhodes. Frenkel (1943) observes that funding of primary railway construction was through debenture capital guaranteed by the British South Africa Company (BSAC), Rhodes' Chartered

Company. In this regard, seven companies were formed to facilitate financing of various sections of the railway northwards of Vryburg (National Historical Association of Rhodesia, 1975)[8]. It would appear though that apart from facilitating resource mobilization, the disaggregation of the project was intended to:

(i) Break the project into manageable components;
(ii) Create flexibility to undertake the projects in parallel;
(iii) Address unique territorial features; and
(iv) Deal with unique and specific business opportunities.

Rhodes' infrastructure development strategy was anchored on the British South Africa Company (BSAC), The Chartered Company[9] which turned out to be a formidable force in shaping the economic and administrative space of the hinterland through Botswana, Zimbabwe and Zambia. Apart from being a private company, the Chartered Company was the government for the Rhodesias (Northern and Southern) from 1889 until 1923 when Southern Rhodesia was given Responsible Government status and in 1924 when the Crown took over Northern Rhodesia (Doganis, 1967). It would appear that no other company has had such a profound impact in shaping the historical, economic and social discourse of Southern Africa particularly the Rhodesias.

Rhodes did not live to see the full realization of his dreams as he died in 1902, twelve years after the granting of the Charter. However, it can be argued that rail network development continued beyond Rhodes' time because of the solid institutional platform provided by the Chartered Company and attraction from the mineral resources north of the Zambezi.

2.2.1 South Africa

Rail network construction in South Africa originated from the ports into the hinterland. At inception, the railways developed within the colonies to meet transportation needs of these colonies. The Cape Colony and Natal were at the forefront of rail network construction in South Africa. Rail construction in South Africa began in the second half of the 19th century with the Natal

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[8] Beira Railway Co. Ltd 1892; Bechuanaland Railway Co. 1893; Beira Junction Railway Co. 1895; Mashonaland Railway Co. Ltd 1897; Rhodesia-Katanga Railway Junction Railway Co. 1908; Blinkwater Railway Co. Ltd 1914; Shabani Railway Co. Ltd 1929.

[9] The 1889 Charter empowered the BSAC to, among other things form alliances through treaties, pass laws, maintain peace, own a police force, acquire new concessions and generally provide, and develop infrastructure of a new Colony.

line which was opened in 1860. The line was the first to be opened on the African continent being driven by demand from the coalfields, agriculture and timber (Hopkins, 1922).

Discovery of goldfields on the Witwatersrand in the Transvaal attracted extension of the network northwards through the Orange Free State reaching the border with Transvaal in 1891. The line between Durban and Johannesburg was operational by January 1896. The Natal Railway network was initially constructed on 1 435mm gauge and later changed to 1 067mm which had been adopted as the standard rail gauge in South Africa. The latter is called the Cape Gauge in recognition of its origin.

Construction of the Natal line within the Durban vicinity was followed by the Cape Town Railway and Dock Company's Cape Town – Wellington line (Transnet, 2010). Both Natal and Cape Town were British colonies. Discovery of diamonds in Kimberly and gold in Witwatersrand in 1869 and 1886 respectively drew the rail lines from the seaports into the hinterland. Cape Town was connected to Kimberley in 1885. This line was constructed by the Cape government (Bolze, 1968).

Construction of rail lines in both colonies was initially funded by the private sector under various Acts promulgated by the respective colonial governments but would later be taken over by governments. The rail lines were initially constructed on standard gauge (1 435mm) but later changed to the narrower Cape gauge (1 067mm) in 1873. This would become the gauge to be used in all mainline rail networks developed in Southern Africa.

The Cape Colony government took over the private rail lines in 1874 marking the birth of the Cape Government Railways (CGR). Other rail lines were constructed from East London and Port Elizabeth into the interior. The discovery of gold in Witwatersrand motivated the CGR to construct the rail line through Orange Free State to the border with Transvaal, a task achieved in 1891. The Orange Free State nationalized all rail networks within its territory in 1896. The CGR therefore lost the potential connection to the Transvaal but were compensated for their assets (Hopkins, 1922).

Despite both being British colonies, the Cape and Natal colonies were competing to reach the Transvaal in order to access abundant mineral resources to support their rail networks and seaports.

The British – Afrikaner rivalry had a bearing on the routing of the rail network as it made it difficult for the British to progress the line into the Afrikaner controlled Transvaal Republic which was then under President Paul Kruger elected in 1883. Firstly, the rail line from Kimberley northwards reached Vryburg in 1890, being constructed by the Cape government with funding from the British South Africa Company (Bolze, 1968). The routing avoided passing through Transvaal. Secondly, the rail route from Pretoria to Lourenco Marques port (now Maputo) in Portuguese East Africa (Mozambique) was constructed to reduce the Transvaal's reliance on British controlled ports in Natal and Cape colonies. The line was opened in 1895.

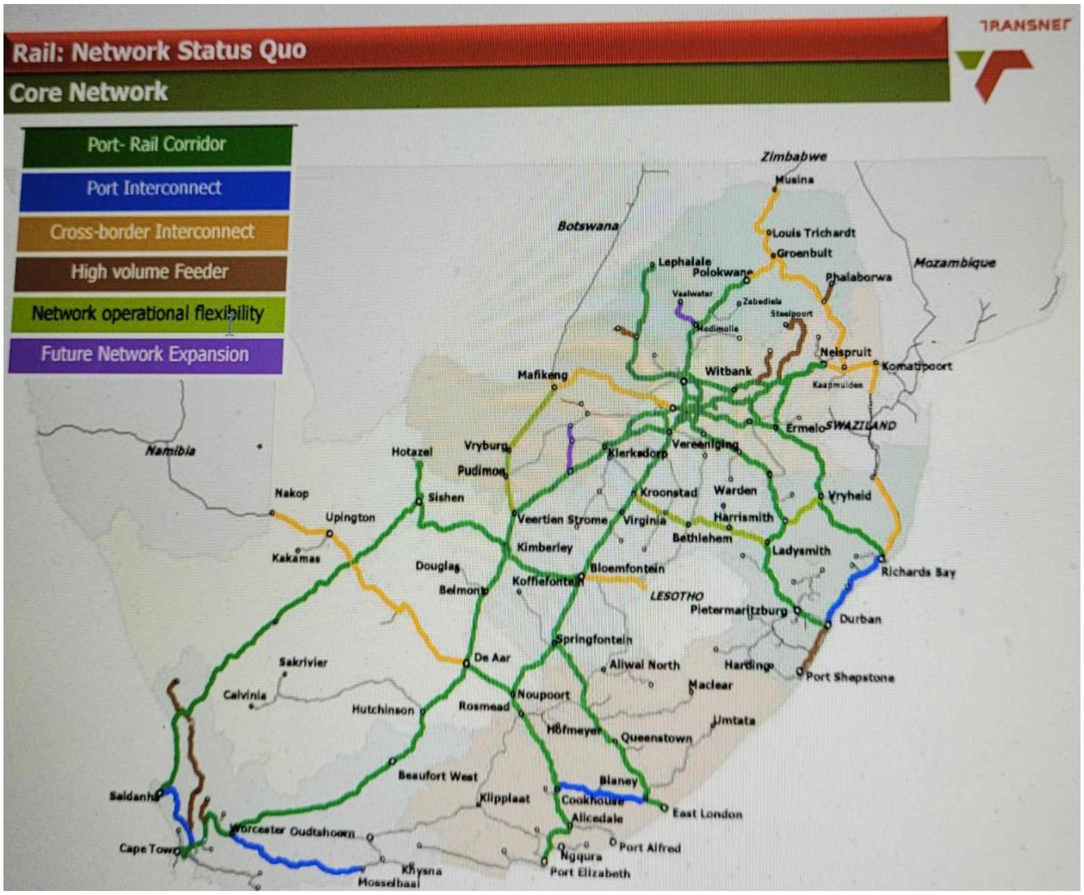
Hopkins (1922) observes that individual development of rail networks by colonies necessitated coordination to facilitate harmonization of operational and technical aspects of rail business. In response to this need, the first all stakeholder railways conference was held in Petermaritzburg in 1897.

The formation of the Union of South Africa in 1910 was a significant milestone in the creation of the South African State under which rail network development would follow a coordinated approach. The British-Afrikaner rivalry which for some time had frustrated rail infrastructure development across different territories was thus eliminated following unification. The existing railway companies in the colonies then were amalgamated in 1910 to form the South African Railways and Harbours (Hopkins, 1922).

The South African rail network was connected to Namibia in 1914 followed by the annexation of the Namibian rail network in 1922. The decade from 1914 saw further development of the internal branch-lines rail network in South Africa especially supporting mining and agriculture. The 861km heavy haul Sishen – Saldanha iron line was constructed by Iscor in 1976 and transferred to South African Railways and Harbours (SAR & H) in 1977. South Africa has many branch lines constructed over a long period of time.[10]

[10] South African Railways & Harbours (1962). GM Report: Statement Showing, in Chronological Order, The Date of Opening and the Mileage of Each Section of Railway. Statement No. 18.

Figure 1: Major rail routes of South Africa



Source: Transnet Freight Rail

Figure 1 above shows the current rail network of South Africa (major routes). The total track and route lengths are 34 000 and 20 500 kilometres respectively. The track length includes sidings and crossing loops whereas the route length measure excludes these two.

It would appear that the shaping of the rail network in South Africa was influenced more by internal political and economic dynamics given the abundance of mineral resources, a long coastline which is partly on the Indian and Atlantic Oceans and the pre-Union fragmentation. Transit of rail routes was never a major consideration for South Africa as a country post-unification in 1910 because the rivalry among Afrikaner and British territories was no longer an issue, and the country had its own seaports. The rail network linked mines, production centres, cities, seaports and other countries. Minerals were the major driver for rail development in South Africa which appears to have been sustained on that basis.

2.2.1.1 The Pretoria – Delgoa Bay Railway

The Transvaal Boer Republic always wanted to have access to the sea through non-British territory. This would be possible through Portuguese East Africa (now Mozambique) to Lourenco Marques now Maputo (de Jong, 1996). There were both economic and political considerations underpinning this desire. Firstly, the route was the shortest and most direct route to the sea for the Transvaal Republic. Secondly, customs charges imposed by the British would be eliminated thereby reducing the cost of imports. Thirdly, the Transvaal wanted to have direct control over the transportation of its exports and imports by reducing reliance on seaports falling under British colonies.

Portuguese East Africa (PEA) supported the Transvaal Republic's project to develop the rail route to the sea through its territory for purely economic reasons. The project would promote trade between the two. The Portuguese granted the concession to construct and operate the section of the line on its territory to Edward McMurdo, an American in 1884 (de Jong, 1996). McMurdo failed to complete construction of the line due to lack of capital resulting in the cancellation of the concession by the Portuguese and establishment of Caminho de Ferro de Lourenco Marques (CFLM) to take over. The 80km section of the rail line on the PEA territory was completed in 1889.

Unlike in most cases where rail construction concessions were directly tied to mining concessions, the concession granted to Edward McMurdo appears to have been motivated by the desire to exploit the business opportunity of transporting traffic between Portuguese East Africa and the Transvaal. However, the booming mining industry appears to have been the major attraction as was the case with the development of rail networks from the British colonies to Witwatersrand.

The construction of the section of the rail line on the Transvaal territory (Eastern Line) was financed by the Nederlandsche Zuid-Afrikaansche Spoorweg-Maatschappij (NZASM) founded in 1887 with Dutch and German finance following the provisional agreement between Paul Kruger and a committee of financiers signed in Amsterdam in April 1884 (de Jong, 1996). Construction commenced at the end of 1889 when the section on the Mozambican territory had already been completed. Despite the rivalry between the British colonies and the Transvaal, the Cape government assisted NZASM with finance for immediate needs and loan facilities in Europe when the latter was beset with financial challenges (de Jong, 1996). The conditions for the assistance were that the Transvaal government would allow extension of the line from Bloemfontein to the Witwatersrand and to monopolise rail traffic to the Rand until the completion of the Eastern Line. The Eastern Line was completed in 1894 and became operational in 1895. The rail line was taken over in 1902, by the Central South African Railways (CSAR) which would later become part of the South African Railways and Harbours (SAR&H) in 1910 following unification (de Jong, 1996).

The construction of the Pretoria – Maputo rail line illuminates a number of pertinent issues:

(i) The line was the shortest and direct route to the sea;
(ii) Geopolitical manoeuvring is very evident especially between the Transvaal and the British colonies;
(iii) The private sector was largely responsible for the construction of the line in both Mozambique and South Africa;
(iv) Business and geopolitical considerations can be balanced if common interests exist as shown by financial support from the British towards construction of the East Line;
(v) Interconnectivity and interoperability of rail networks is important as evidenced by the adoption of the Cape gauge which is the main gauge in Southern Africa; and
(vi) Negotiations and rapid industrialization played a key role towards development and convergence of rail networks on the Witwatersrand.

2.2.2 Namibia

Development of the rail network in Namibia can be traced under three eras relating to the German occupation from 1895 to 1915, South Africa from 1915 to 1989 and post-independence Namibia to date. The German Colonial Authority developed the rail network from the Atlantic Ocean to the hinterland. Network development under the Germans was internally focused on economic and political reasons (Dierks, 2004).

The German Colonial Authority constructed the rail line from Swakopmund on the Atlantic Ocean to Windhoek from 1895 to 1902. Soon after the completion of the rail line from Swakopmund to Windhoek by government, the Otavi Mining and Railway Company (Otavi - Minen und

Eisenbahngesellschaft-O.M.E.G) constructed another rail line from Swakopmund to Tsumeb through Octavi from 1903 to 1906 including a branch line from Otavi to Grootfontein completed in 1908. The line was to serve mines in Tsumeb. The railway network by both the government and O.M.E.G was initially built on 610mm gauge and gradually upgraded to the Cape Gauge (1 067mm) as follows; Swakopmund to Windhoek, 1920 and Otavi to Tsumeb and Grootfontein, 1959-1960 (Dieks, 2004).

The State Railway South from the port of Luderitz reached Aus in 1906, Keetmanshoop in 1908 and Karasburg 1909. The line was connected to Windhoek in 1912. Unlike the rail line from Swakopmund to the North, the South Railway from Luderitz to Windhoek was built on Cape gauge (1 067mm). This was logical given its proximity to South Africa where the Cape gauge was the adopted standard and the potential for future interconnectivity across the two countries. Some short lines to serve mines were also constructed during the German occupation.

Development of railways in Namibia by South Africa was initially motivated by the need for a supply route to support the war effort by South Africa against the Germans in Namibia at the outbreak of the First World War. This saw the construction of the 227km railway section between Prieska in South Africa and Nakop in Namibia in 1914-1915 and later Nakop to Karasburg. Another section of the internal network developed during the same period was the 39km from Walvis Bay to Swakopmund. South Africa took over the railways in Namibia in terms of both assets and operations in 1922 following the defeat and displacement of Germans. The Windhoek to Gobabis line (228km) was constructed in 1930.

Table 1:Branch Line Railway Network Extensions in Namibia

Branch Line	**Distance (km)**	**Year of Construction**	**Product Transported**
Otavi – Grootfontein	91	1908	Copper, Lead, Zinc
Windhoek – Gobabis	228	1930	Agriculture produce, passengers
Tsumeb – Ondangwa	246	2006	Goods and passengers
Ondangwa-Oshikango	60	2012	Goods and passengers
Ondangwa-Oshakati	28	2017	Goods and passengers

Sources: Dierks (1985), Jourdan (1990) and Ministry of Transport and Works Namibia publication.

The Namibian rail system changed names over the years from State Railway to National Transport Corporation in 1988, and TransNamib. The company was taken over by the Namibian government in 1990. Post-independence, the government of Namibia extended the line to the north from Tsumeb to Ondangwa (246km), Ondangwa to Oshikango border with Angola (60km), and Ondangwa to Oshakati (28km) completed in 2006, 2012 and 2017 respectively. The intention is to connect with the Angolan rail system to serve the southern part of Angola. The line is for both goods and passengers.

As a coastal state Namibia did not have so much pressure on international transit issues or access to the sea. Its network development appears to have been shaped by the need for political dominance and access to mineral resources. The neighbourhood effects of South Africa appear to be dominant. Namibia and Botswana are predominantly desert, a situation which restricts economic opportunities and trade between the two, more so given their small populations. The two are not connected by rail to this day despite them being neighbours.

Figure 2: Major rail routes of Namibia

Source: <u>TransNamib Holdings Limited</u>

Figure 2 shows the current rail network of Namibia. The total track and route lengths are 2 682km and 2 382km respectively.

2.2.3 Botswana

The rail line to Bechuanaland (now Botswana) extended from Vryburg in north western South Africa in 1893 being developed by the British South Africa Company (BSAC), a Cecil John Rhodes conglomerate which was granted a royal Charter in 1889. The Bechuanaland Railway Company was formed in 1893 as a subsidiary of the BSAC to oversee construction of the rail line through Botswana (Due, 1977; Lunn, 1992). There was not much business interest in Botswana because of its desert terrain. The target was therefore to reach Rhodesia (now Zimbabwe). Routing of the rail line through the north western part of South Africa northward to Botswana and beyond was to avoid the hostile Transvaal Republic due to Afrikaner – British rivalry as observed by Bolze (1968; Due, 1979).

The core rail network in Botswana was the 398.5miles (641km) transit route from the Ramahlabama border with South Africa to the Ramokwebana border with Zimbabwe. The Zimbabwe border was reached in 1897, the same year that the rail line reached Bulawayo town, 100km in the Zimbabwean interior. Construction of the line from Vryburg to Bulawayo was financed by debenture capital organized by Cecil John Rhodes (Bolze, 1968). The Bechuanaland Railway Company was renamed Rhodesia Railways in 1899 who maintained ownership of the rail network in Botswana.

Development of the internal rail network in Botswana consisting of three branch-lines serving mines was funded by the government of Botswana even though the main line was owned by Rhodesia Railways during this period (Lionjanga & Raman, 1990).

Table 2 : Botswana railways branch lines

Branch Line	**Distance (km)**	**Year of Construction**	**Product Transported**
Serule - Selebi Phikwe	56.3	1973	Iron Ore
Palapye - Morupule	16	1974	Coal
Francistown – Sua Pan	174.5	1992	Soda Ash, Salt

Source: Lionjanga & Raman (1990)

Rhodesia Railways and its successor the National Railways of Zimbabwe owned and operated the rail network in Botswana following take over from South African Railways in 1966 (Due, 1983) until 1987 when the Government of Botswana purchased the rail network in Botswana territory.

Figure 3: Major rail routes of Botswana

Source: Botswana Railways

Figure 3 above shows the current rail network (major routes) of Botswana. The total route length of Botswana Railways is 888km.

2.2.4 Zimbabwe

The railway from South Africa through Botswana reached the Zimbabwean border (Rhodesia then) in 1897 and Bulawayo in the same year (Due, 1977; Croxton, 1982; Lunn, 1992). The line was operated by South African Railways until 1966. Although the line was intended to provide access to farmers and farmland in Rhodesia (Due, 1977), there is consensus in the literature that rich mineral resources in Zambia and the Democratic Republic of Congo (Northern Rhodesia and Zaire respectively then) were the major attraction to Rhodes (Doganis, 1967; Katzenellenbogen, 1974). The line was constructed by the Bechaunaland Railway Company whose name was later changed to Rhodesia Railways in 1899 (Due, 1977)

Literature suggests that the routing of the rail line to the north of Rhodesia (now Zimbabwe) beyond the Zambezi River would have been through Salisbury (now Harare) had it not been for lack of economic and political justification (Katzenellenbogen, 1974). Mineral and agriculture output volumes were not adequate to support this development. According to the National Historical Association of Rhodesia (1975), routing of the rail network from Bulawayo to the north was subsequently influenced by the discovery of huge coal reserves at Wankie (now Hwange). Coal output from Wankie Colliery provided a dual role as a source of revenue for the BSAC through sales and rail transportation, and also locomotive power for the steam engines. The BSAC had a dominant stake in Wankie Colliery (Lunn, 1992). The rail line from Bulawayo reached Wankie in 1903 and crossed the Zambezi River through Victoria Falls into Northern Rhodesia (now Zambia) later in the same year.

Parallel to the development of the line from Vryburg through Botswana to Rhodesia was also the construction of the line from Fontesvilla[11] in Portuguese controlled Mozambique towards Salisbury (now Harare). The line, whose construction commenced in 1892 reached the border town of Umtali (now Mutare) in 1898 (Bolze, 1968; Croxton, 1973; Lunn, 1992). The line was later extended to Beira by the Beira Junction Company in 1896 due the fact that Fontesvilla was not a suitable port location (National Historical Association of Rhodesia, 1975; Lunn, 1992). Compared to the Vryburg to Bulawayo rail line, the Beira Umtali rail route was shorter and on a narrower gauge. It however took longer time to complete due to difficulties posed by flooding, disease and hostile terrain (Lunn, 1992). The line was later upgraded to Cape gauge in 1900 (National Historical Association of Rhodesia, 1975; National Railways of Zimbabwe, Facts and Figures).

Lunn (1992) argues that following his resignation as Premier of the Cape Colony, Rhodes focused on controlling Rhodesia in terms of administration and factors of production. He contends that mineral discoveries in Rhodesia did not match those in South Africa as was originally assumed

[11] Fontesvilla was 35miles inland from Beira port

therefore the decision to have a rail route to Beira port in Mozambique was motivated by political considerations.

The extension of the rail line from Mutare to Harare was carried out by the Mashonaland Railway Company formed in 1897. Construction of the Cape gauge line commenced in 1897 reaching Harare in 1899. The upgrading to Cape gauge of the entire rail section from Beira to Salisbury was motivated by the need for internal connectivity to avoid transhipment and the realization that the Beira route would provide the shortest rail route to the sea for Rhodesia in the long-term.

Bulawayo –Gwelo - Harare Railway Link

Construction of the Bulawayo – Gwelo section which commenced in 1899 under Rhodesia Railways was affected by the Boer War in the same year which disrupted supply of construction materials through South Africa (National Historical Association of Rhodesia, 1975). This development necessitated the construction of the rail link from the Salisbury end importing construction materials through the port of Beira in Mozambique instead of the original plan to construct it from the Bulawayo end. The line reached Gwelo and Insiza[12] in 1902. Zimbabwe was thus connected by rail to ports in South Africa and Mozambique before the railway crossed into Zambia in 1903.

Bannockburn - Chicualacuala Railway Line

In order to improve access to the sea, the Government of Rhodesia constructed a connecting railway line in 1955 from Bannockburn near Shabanie (now Zvishavane) to Chicualacuala, the border with Mozambique to the south eastern part of Zimbabwe towards Maputo port. This line meant Rhodesia was now connected to two sea ports in Mozambique namely Beira and Maputo.

Rutenga - Beitbridge Railway Line

The UDI government considered Mozambique to be hostile as it was hosting some of Zimbabwe's liberation war fighters. Rhodesia was denied access to its preferred nearer Mozambican ports hence the shift to South African ports (Reichardt and Duncan, 1990). This prompted Rhodesia to seek an alternative route to the sea resulting in the construction a rail link from Rutenga, a rail

[12] Insiza is the point where the link from the Bulawayo end stopped following the outbreak of the Boer War in 1898.

station on the rail line from Rhodesia to Maputo, to the South African rail system at Beitbridge border in 1974.

Beitbridge Bulawayo Railways

Post-independence, Zimbabwe had 173km of new rail line constructed by the private sector under a Build Operate and Transfer (BOT) arrangement in 1997. The new line connected to the 150km Heany Junction to West Nicholson branch line at West Nicholson to the South Africa-Zimbabwe border at Beitbridge. The branch line section from Heany Junction to West Nicholson was subsequently upgraded to mainline for it to be able to accommodate higher traffic volumes comprising of local and transit traffic. This new route had the effect of diverting transit traffic from Botswana Railways as it became the shortest route to and from the South African ports for DR Congo, Zambia and Zimbabwe traffic[13].

Development of Branch Lines

The internal branch rail network in Zimbabwe linking to the Rhodesia Railways was constructed over a number of years being funded by private companies involved mostly in mining and agricultural activities.

[13] The Southern African Railways Association's Marketing Policy of 2001 dictates that international railway traffic follows the shortest route.

Table 3: Branch Line Railway Network in Zimbabwe

Branch Line	Year of Construction	Distance (km)	Product Transported
Harare – Banket	1902	105.35	Gold, Chromite, Agriculture
Gweru - Shurugwi	1903	38.5	Chrome Ore
Heany Junction – Gwanda	1903	118.73	Clinker
Gwanda – West Nicholson	1905	48.27	Agriculture, minerals
Banket - Eldorado	1905	25.44	Gold, Chromite, Agriculture
Lyndhurst Junction - Mvuma	1909	87	Gold
Kadoma – Effiel Flats	1912	8.66	Gold
Mount Hampden - Shamva	1913	117.56	Gold
Mvuma - Masvingo	1914	111.77	Lithium Ore
Somabhula - Zvishavane	1928	101.51	Asbestos
Maryland - Kildonan	1930	39.33	Chrome Ore
Chinhoyi – Zave	1930	33.6	Copper
Mbizi - Chiredzi	1964	90	Sugar Cane
Chiredzi - Nandi	1965	14	Sugar Cane
Bindura - Trojan	1969	6.5	Nickel Ore

Source: National Railways of Zimbabwe, Facts and Figures 1994; System Map (distances)

Zimbabwe’s rail network connects major mining, industrial and agricultural production centres and all its neighbouring countries, both coastal and hinterland. Zimbabwe’s central location in the sub-region makes it one of the transit countries.

Figure 4 above shows the current rail network (major routes) of Zimbabwe. The total track and route lengths are 4 312km and 2 583km respectively.

Figure 4: Major rail routes of Zimbabwe

Source: National Railways of Zimbabwe

2.2.5 Zambia

The Zambian rail network extended from Rhodesia (now Zimbabwe) crossing the Zambezi River at Victoria Falls in 1903 (Due, 1979). Unexploited reserves in Zambia and Katanga in DRC provided the incentive for the northwards development of the railways. The first major milestone for the rail line was reaching Broken Hill (now Kabwe) in 1906, a town with lead and zinc deposits (Katzenellenbogen, 1974; Due, 1979). This would also be the last point where the BSAC individually constructed the line to the north towards the DRC. The last portion of the rail network from Kabwe to the border with DRC was constructed through a financial alliance with Tanganyika

Concessions[14], a British company with mining interests in Katanga (Katzenellenbogen, 1974; Due, 1977). British mining companies in Katanga wanted to have access to the sea through the Rhodesia Railways network.

The BSAC wanted to use the construction of the last portion to the border as a bargaining chip for them to access and share the mineral resources of Katanga in Congo as its construction would be dependent on the BSAC being granted half of the mineral resources in Katanga, a demand rejected by King Leopold II of Belgium (Katzenellenbogen, 1974). Serious financial challenges for the BSAC in 1908 provided an opportunity for it and Tanganyika Concessions to agree on the construction of the portion of the line from Kabwe to the Congolese border (Katzenellenbogen, 1974; Lunn, 1992). Croxton (1973) observes that the need for Wankie coke and coal by the copper mines in Katanga forced financiers in Katanga to provide funding beyond Kabwe to Congo. This section of the line was constructed from the Congolese side and reached Kabwe in 1909 (Due, 1977; 1979). The section of the line would later be purchased by Rhodesia Railways in 1928 in accordance with the financial agreement for the construction of the line.

The rail network and assets in Zambia remained part of Rhodesia Railways under the British South Africa Company. Rhodesia Railways was purchased by the government of Rhodesia for £23 642 266 in 1947 and became a statutory body in 1949 (Doganis, 1967; Due, 1977; National Railways of Zimbabwe, 1981/2). Croxton (1973) points out that resources required to restore capacity post World War II were beyond the capacity of the private sector hence their willingness to relinquish ownership to the government. Frenkel (1943) contends that earlier attempts by government to own the railways was difficult because of financial obligations obtaining then and the territorial jurisdiction of Rhodesia Railways which straddled over four countries at one stage.

The company was transferred to the Federation of Rhodesia and Nyasaland[15] in 1954 until its dissolution in 1963. Following the dissolution of the Federation, Rhodesia Railways operated as the Unitary Railway System jointly owned by the Governments of Northern Rhodesia (now Zambia) and Southern Rhodesia (now Zimbabwe).

[14] Tanganyika Concessions was owned by Sir Robert Williams who once worked with Cecil John Rhodes in Kimberley (Katzenellenbogen, 1974) .

[15] The Federation of Rhodesia and Nyasaland comprised of Rhodesia (now Zimbabwe), Northern Rhodesia (Zambia) and Nyasaland (Malawi).

Attainment of political independence by Zambia in 1964 triggered the separation of Rhodesia Railways through the Zambia Railways Act 1967 which resulted in the disbanding of the Rhodesia Railways Unitary System on the 30th of June, 1967. Zambia Railways Limited was subsequently born on the 1st July 1967 (Due, 1977).

The internal rail network in Zambia branching from the Rhodesia Railways mainline saw the development of a number of branch lines linking to the mines and one branch connecting to timber sawmills as follows;

Table 4: Branch Line Railway Network in Zambia

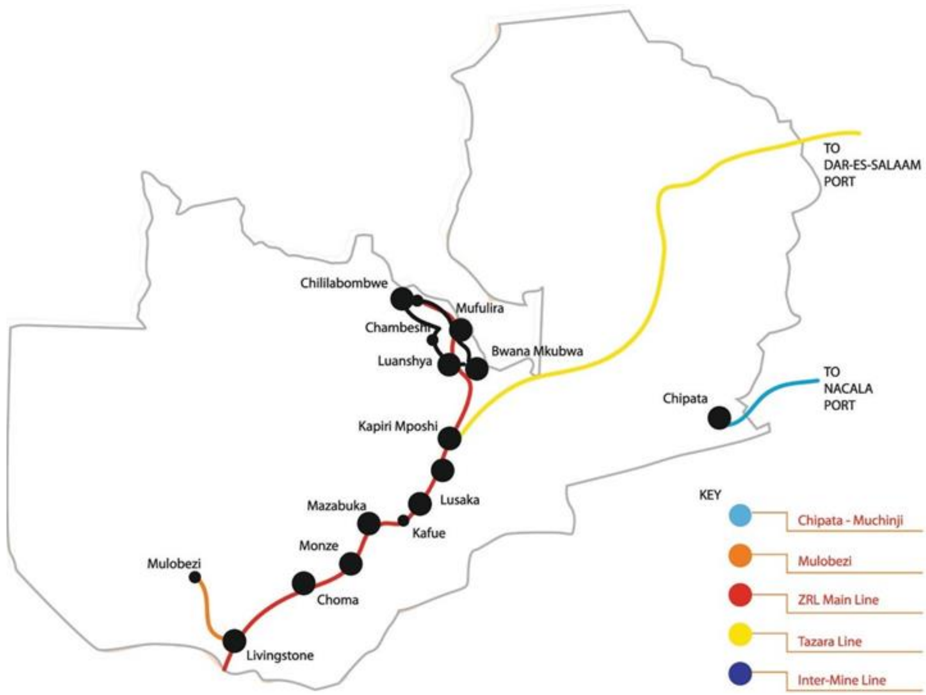
Branch Line	**Year Constructed**	**Distance (km)**	**Product Transported**
Ndola to Luanshya	1929	37	Copper
Ndola to Kitwe	1930	49	Copper
Zambezi Sawmills Railway	1930	162.6	Timber
Kitwe to Chingola	1931	68	Copper
Chambeshi to Mufulira	1932	34	Copper
Luano Junction to Chililabombwe	1957	35	Copper
Choma to Masuku	1971	66	Coal

Source: Zambia Railways Facts and Figures, June 1987.

The major rail infrastructure development post-independence Zambia was the construction of the 1860km (885km and 975km in Zambia and Tanzania respectively) Tanzania Zambia Railway Authority (TAZARA) rail line from Kapiri Mposhi in Zambia to Dar es Salaam port in Tanzania funded and constructed by China from 1973 to 1976. Construction of the TAZARA line was necessitated by the political hostilities between independent Zambia and the UDI government in Rhodesia, and outbreak of the civil war in Angola which resulted in the closure of the Benguela rail line to the port of Lobito on the Atlantic Ocean (Due, 1977). Zambia had to find a route to the sea for its mineral exports which were dominated by copper.

Figure 5 below shows the current rail network (major routes) of Zambia. The total track and route lengths are 2 141km and 1 791km respectively.

Figure 5: Major rail routes of Zambia



Source: Zambia Railways Limited

2.2.6 Benguela Railway

Access to the sea was a major concern for the landlocked countries in Southern Africa (Griffiths, 1989; Reichardt & Duncan, 1990; de Jong, 1996). The Benguela railway provided such access for mineral products from Katanga province of the Belgian Congo (now the Democratic Republic of Congo) through Angola to the port of Lobito. The rail line was constructed by Tanganyika Concessions Limited (TCL), a British company owned by Robert Williams (Hance & van Dongen, 1956; Doganis, 1967; Due, 1977). Robert Williams was once Cecil John Rhodes' associate in Kimberley (Katzenellenbogen, 1974).

According to Katzenellenbogen (1974), Williams secured the Katanga mining concessions in 1900 and the concession to build the 2 080km Benguela line in 1902. He formed Union Manière in 1906 to exploit the rich mineral deposits of Katanga (Hance & van Dongen, 1956; Doganis, 1967; Katzenellenbogen, 1974). Discovery of rich mineral deposits in Katanga necessitated development of a dependable transport system leading to the construction of the Benguela railway which would be the shortest and most direct route for transportation of minerals from Katanga and then Northern Rhodesia (Zambia) to Europe and North America. The railway also transported passenger traffic from the Zambian Copperbelt and Katanga to Europe, mostly mining experts from overseas (Hance & van Dongen, 1956).

Construction of the line started in Lobito in 1903 with 90% of initial capital contribution by Tanganyika Concessions and reached the border with the Democratic Republic of Congo (DRC) in 1928 (Hance & van Dongen, 1956).[16] Delays in completion were due to financial difficulties, difficult terrain and international politics[17] The Benguela railway was built on the Cape gauge like the other railways in southern Africa to which it was connected through Katanga in 1931 (Katzenellenbogen, 1974; Due, 1977; 1979). With the competition of this link, connectivity and interoperability of the rail lines in the region through Elizabethville (now Lubumbashi) in DRC and Zambia to the south was assured. This would, however, provide opportunities for competition among the rail routes and seaports. In this regard, Griffiths (1989), and Reichardt and Duncan (1990) indicate that construction of the Benguela railway was opposed by Rhodesian interests as it would compete with the rail line to the port of Beira.

The line was severely damaged during the Angolan civil war leading to its closure in 1975. The line was rehabilitated in phases after the civil war starting from 2006 to 2013 (Duarte, Santos & Tjønneland, 2014).

The case of Benguela railway, though outside the scope of this study clearly reinforces the argument that both economic and geopolitical factors were at the core of rail network development in southern Africa. Specifically, construction of Benguela railway illuminates the following:

(i) The railway was developed to provide transportation of minerals;
(ii) Belgian, British, German and Portuguese interests were visible;
(iii) Initial railway construction was driven by the private sector;
(iv) Intertwining of mining and railway development interest;
(v) Potential for competition among railway routes;

[16] The connection from the Belgian Congo (Democratic Republic of Congo) reached the border at Dilolo three years later (Hance & van Dongen, 1956).
[17] Hance & van Dongen (1956) and Reichardt & Duncan (1990) highlight these challenges.

(vi) Interconnectivity and interoperability of rail networks is important as evidenced by the adoption of the Cape gauge which is the main gauge in southern Africa.

2.3 Emerging Issues

The historical review of rail network development in the five SADC countries provides insights on the economic and political factors that shaped rail development in Southern Africa. In essence, the review confirms our observation that infrastructure development in Southern Africa was jointly driven by economic, geostrategic and institutional factors to varying degrees depending on the context and time.

2.3.1 Business Motivation

This section provides a synthesis of emerging issues from the various country contexts in section 2.2 above where events, dates and the motivation behind rail infrastructure development are indicated.

(i) Railways were constructed to support mining activities through providing conduits to seaports for exporting minerals and importing inputs and supplies. Although the governments took over railways at a later stage in the various countries, initial railway development was mostly by the private sector which was involved in mining activities. However, in some cases private companies were used to achieve political ends as was the case with Cecil John Rhodes.

(ii) Railway companies were often owned by the mining companies. Branch lines in particular ensured that railheads reached the Mining centres.

(iii) Funding presented challenges at various stages of rail construction and as a result it was used to leverage access to mineral resources and shareholding. Mineral discoveries influenced routing and pace of construction as they provided funding generated from sales and transportation. Viability of railways was thus anchored on traffic volumes.

(iv) Financial engineering skills are required in mobilizing funds for infrastructure development as evidenced by Cecil John Rhodes financial strategy which provided for context specific instruments.

(v) Landlocked countries are naturally disadvantaged in terms of distance and access to the sea as they are vulnerable to negative economic, social and political developments in the coastal countries through which their traffic has to transit. For example, the civil war in Mozambique damaged rail infrastructure and affected rail access to its seaports for traffic from Malawi, Zambia and Zimbabwe. The closure of the Benguela railway in Angola in 1975 negatively affected copper exports from Zambia through Lobito port and resulted in some Zambian wagons being trapped in Angola. Staff strikes at Transnet Freight Rail and South African seaports negatively impact on rail and road transport transit services for exports and imports for countries to the north.

2.3.2 Political Content/Geo-political posturing

Geo-politics of the day affected rail development in terms of routing, competition and political rivalry among imperial powers. A number of political events triggered construction of some new railway lines, separation of railway companies and re-routing of traffic. Most of the rail lines were constructed before independence of the five countries at the turn of the 20th century and these played a significant role in shaping the development of cities which were invariably linked to mining centres.

(i) The British – Afrikaner rivalry affected the routing of the line from Kimberly to countries to the north of South Africa (Zimbabwe, Zambia and Democratic Republic of Congo) which was forced to go through Botswana.

(ii) Integrated rail systems are better than individual systems which may suffer from lack of coordination and failure to effectively compete against road transport. The formation of the Union of South Africa in 1910 resulted in the amalgamation of the rail networks in the four former colonies which formed a solid base over which rail development would expand in a coordinated manner.

(iii) The dissolution of the Federation of Rhodesia and Nyasaland resulted in the unbundling of Rhodesia Railways and loss of benefits of scale economies.

(iv) Construction of the rail line between Pretoria and Maputo opened in 1895 was motivated by the need to reduce dependence of the Afrikaner controlled Transvaal Republic on British controlled ports in the Cape and Natal colonies.

(v) Rhodesia Railways (RR) split in 1967 following Zambia's attainment of independence in 1964 because Zimbabwe (where the headquarters of RR was domiciled) was not yet independent then.

(vi) The rail line from Rutenga to Beitbridge constructed in Zimbabwe in 1972 was to reduce the country's dependence on hostile Mozambique's ports as it was supporting Zimbabwe's liberation struggle.

(vii) The TAZARA rail line which is jointly owned by Tanzania and Zambia was constructed due to hostilities between the newly independent Zambia and the Unilateral Declaration of Independence (UDI) government in Rhodesia (now Zimbabwe). The closure of the Benguela Railway Line due to the civil war which broke out in Angola in 1975 also affected Zambia's access to the sea.

(viii) War has negative effects on business as it comes with instability, destruction of infrastructure, diversion of resources towards war effort and risk hence the increased cost of doing business.

2.3.3 Institutional factors

The 1889 Charter for the BSAC represented an institutional instrument which created the enabling environment for Cecil John Rhodes' investment in the hinterland of Southern Africa. The 1889 Charter empowered the BSAC to, among other things form alliances through treaties, pass laws, maintain peace, own a police force, acquire new concessions and generally provide, and develop infrastructure of a new Colony. Conferring such sweeping powers equivalent to State powers to a company was unusual and represented the highest level of imperial ambition and disregard of rights and value systems of other populations.

The Charter possessed both economic and political institutional aspects. The powers granted to Rhodes by the Charter provided the assurances an investor of that time would have required. The birth and growth of Rhodesia Railways was due to the pivotal role of the Charter which conferred rights to investors in terms of guarantees and investment climate. It may be argued that the Charter conferred property rights to the BSAC.

2.4 Conclusion

This chapter has highlighted the key milestones, motivation and major players in rail network development in the five SADC countries. Financial, economic, institutional and geostrategic (political) considerations are identified as the major determinants of rail network development including the timing of construction and operations. The factors jointly drove rail infrastructure development in Southern Africa, and it may be difficult to empirically rank these determinants in terms of their relative impact. The chronological review of progress undertaken in this chapter will assist in addressing data issues regarding the assets and performance of individual railways. It has also provided insights and better understanding of broader issues affecting rail infrastructure development and performance. This chapter has provided the necessary context for better understanding data on rail infrastructure to be covered in the following chapter.

CHAPTER THREE

DESCRIPTIVE ANALYSIS OF RAILWAY INFRASTRUCTURE AND PERFORMANCE IN FIVE SADC COUNTRIES

3.1 Introduction

The preceding Chapter on evolution of rail networks in five countries in the Southern African Development Community (SADC) identified business, geostrategic and institutional factors to be possible drivers of rail infrastructure development in Southern Africa particularly for Botswana, Namibia, South Africa, Zambia and Zimbabwe.[18] This finding on the drivers of rail infrastructure development in the five SADC countries is based on literature review. An empirical perspective is thus required to validate this finding. The first step of our empirical enquiry is the generation of new data that will facilitate analysis. Data generation is one of the key contributions of this chapter.

Comprehensive rail infrastructure and performance data sets are essential for the purpose of analysis for research and guiding decision making, strategy and policy development at company, national and regional levels. The data generated in this chapter forms the basis of analysis for this research. In particular, the data sets are used for estimating determinants of rail infrastructure investment and analysing their impact on national output in subsequent chapters. The data sets may also be used by other researchers and academics in future. Lack of data has often hampered research in Africa; therefore, the data sets are an important contribution towards resolving this problem.

This Chapter serves a number of purposes. First, it seeks to explain how time series data sets and novel infrastructure measures upon which this research is anchored are generated. Second, the chapter seeks to validate the emerging issues from the previous Chapter through trend analysis, particularly confirming whether economic, geostrategic and institutional factors are part of the rail story. Third, the Chapter illuminates the historical and current status of rail infrastructure and performance through descriptive data analysis, thereby highlighting key rail infrastructure and performance issues. Fourth, the Chapter highlights the evolving story of rail transport in Southern

[18] The basis of selecting these five countries is that they share a common history in terms of development and their railway networks are interconnected.

Africa. Fifth, the Chapter provides a bridge from the history to empirical analysis of rail infrastructure development by providing the basis of framing the determinants of rail infrastructure investment, efficiency and productivity in the following Chapters.

In this chapter, we compile and present a unique novel time series data set for rail infrastructure measures through principal component analysis, and rail operational time series data sets for each of the five countries under study. This is a major contribution since no such data sets on rail exist for the five countries for the 1930 – 2018 time frame except for South Africa. The data sets are therefore a novel contribution to the understanding of infrastructure development in Southern Africa.

We address data issues relating to rail networks, locomotives, wagons and coaches of the five SADC countries. Specific data issues addressed are:

(i) Compilation of railway infrastructure and performance data sets for each of the five countries from existing records;

(ii) Generating estimates of new rail infrastructure and performance data sets for Botswana, Zambia and Zimbabwe by disaggregating data for the years when Rhodesia Railways operated as a unified company in the three countries;

(iii) Estimating rail operations data sets for Namibia from 1939 to 1989;

(iv) Proposing and generating composite rail infrastructure indices for each country; and

(v) Analysing rail capacity and performance trends against economic, geostrategic and institutional drivers.

The generated data sets are analyzed to evaluate the state of rail infrastructure and provide the context of rail performance in the five SADC countries. Our analytical framework is informed by the findings from the preceding chapter indicating that rail infrastructure development in Southern Africa was driven by economic, geostrategic and institutional factors. We analyze the generated rail infrastructure datasets to determine how these factors affect rail infrastructure capacity and efficiency in each country over the study period to provide the context of rail performance. Generated data for the five countries is analysed to get insights on individual and collective performance of the railways over the study period. Changes in capacity of the railways are assessed through trend analysis of individual infrastructure categories. An understanding of the context of rail performance provides the basis of framing the determinants of rail infrastructure investment and policy development.

Operational performance indices of railways in each country and individual resource categories are calculated for the study period to facilitate comparisons across countries and over time in each country. Through the historical analysis of rail infrastructure capacity and performance trends, and literature review, we show that the data is consistent with the economic, policy and institutional factors affecting rail operational performance directly and also indirectly through investment in rail infrastructure. The study thus provides a regional perspective of the railways in the five countries through an integrated analysis of selected infrastructure and performance indicators.

We also investigate how rail infrastructure capacity and efficiency have developed over the years. Our analysis indicates South Africa's rail infrastructure capacity was on the rise up to 1980 followed by a decline thereafter, with a mirror image in terms of the efficiency measures which fall to the 1980/90 period, and then sharply rise. The other four countries reflect declining capacity and efficiency.

To the best of my knowledge, this study is the first attempt to (i) disaggregate rail data sets for Rhodesia Railways to construct estimates of country specific data sets for Botswana, Zambia and Zimbabwe from 1939 to 1987, (ii) propose and construct composite rail infrastructure indices for the countries under study and (iii) construct operational datasets for Namibia for the period from 1939 to 1989 where such records do not exist.

3.2 Railway performance in context

Railways have been found to effectively support economic growth in other regions like the United States of America, Australia, China and Europe. Based on their historical role in supporting economic development through providing transportation services to key sectors of the economy at a relatively cheap cost, it would be expected that railways in the SADC region will equally support regional competitiveness and economic growth by providing cheap transportation services.

Contrary to this expectation, the rail market share in transport in the SADC region has declined significantly over the years even though the regional economies have been growing. This may suggest that economic growth is being supported by other transport modes, a situation which has the potential to harm competitiveness and retard much-needed economic growth.

Although railways have been losing market share to road transport, they possess desirable characteristics compared to road transport. The following specific benefits of railway transport have been cited in literature:[19]

(i) Lower cost per tonne kilometre due to economies of scale – the average rate per tonne kilometre of road is more than three times that rail;

(ii) Fuel efficiency – rail is four times more fuel efficient than road;

(iii) Low emission levels – rail emits about one third of pollutants emitted by road;

(iv) Lower external costs – road external costs (accidents, air pollution, greenhouse gases and noise) are above four times those of rail.

(v) Reducing congestion on the roads.

The above attributes suggest the appropriateness of railways and their potential resolve challenges confronting developing countries, promote competitiveness and sustainable growth. In view of the potential economic role of railways and the negative effects of current policy disparities, Kopicki and Thompson (1995), Perdersen (2001), Kessides (2004), Jorgensen (2010), and Foster and Briceno-Garmendia (2010) advocate for a shift in land transport policy towards promotion of transport mode equity between road and rail. They argue that the policy shift will be beneficial to the economy through long-term growth and competitiveness arising from reduced transportation costs. In view of the compelling benefits of rail, the European Union (EU) adopted a deliberate policy to shift freight traffic from road to rail (Thompson, 2007).

The decline in rail performance has been attributed to a number of factors. Particular challenges that have negatively impacted on rail performance include[20]:

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[19] For example, Forkenbrook (2001), CE Delft *et al* (2011), Nocera, Cavallaro & Galati(2018), Blumenfeld, Wemakor, Azzouz & Roberts (2019 European Union (2019)

[20] For example, Due (1979), Kopicki and Thompson (1995); Kessides (2004); Bullock (2005); Foster and Briceno-Garmendia (2010) highlight these railway challenges.

(i) Competition from road;
(ii) Changes in technology in favour of road;
(iii) Lack of investment resulting in declining capacity;
(iv) Lack of capacity due to under investment in track, locomotives, wagons and coaches;
(v) Inefficiencies inherited from monopoly background in rail;
(vi) Mismanagement arising from government ownership and interference;
(vii) Loss making social service obligations - operating unprofitable branch-lines and passenger services; and
(viii) Policy failure.

Most rail networks in SADC are very old having been constructed mostly in the late 19th and early 20th centuries. Apart from the rail networks suffering from lack of investment and maintenance over the years, it is also argued that railways were initially constructed without provision for high traffic volumes hence their quick deterioration and failure to compete against road (Due, 1979; Luiz, 2010; Gwilliam, 2011).

Fay and Yepes (2003) found that rail share of total global infrastructure dropped from 29% in 1960 to 6% in 2000 whereas for road the drop was from 47% to 44% during the same period. Fedderke, Perkins and Luiz (2006) observe that road infrastructure developed faster than rail infrastructure providing additional capacity to carry more traffic compared to rail over the years.

Railways' ability to compete against road is restricted by capacity constraints. This would imply that railways are unable to transport high traffic volumes necessary to generate enough revenues to support their operations and investment in infrastructure and equipment. Literature suggests that road competition against rail is strongest in Southern Africa because the region has the largest trucks, the best roads and a competitive transport market structure[21].

Unprofitable rail passenger services and branch lines impose costs on railways by tying down resources that could otherwise be used on profitable freight traffic. This has a negative impact on the level of profitability and ability to reinvest in the rail business.[22] . It is therefore argued that

[21]For example, Foster and Briceno-Garmendia (2010) and Gwilliam (2011).

[22] Donaldson, *et al* (1997); Kessides (2004), Bullock (2005), Thompson (2007) and Gwilliam (2011)

cross-subsidization of passenger by freight rail services reduces overall profitability of railways hence their inability to invest in infrastructure (Donaldson, Sader & Wagle, 1997; Kessides, 2004).

Railway challenges were compounded by globalization induced competition which resulted in transformation of production systems in response to customer demands for faster, more reliable and more flexible transportation services[23]. Failure of railways to adjust to the new global business order has left them in a vulnerable position hence the continued decline in capacity and market share.

Ownership of rail networks in Southern Africa has largely remained in the hands of government although the private sector was initially at the forefront of rail development. This ownership structure comes with managerial inefficiencies associated with government and inappropriate business approach and culture. The change from private to public status of railways might have had the effect of de-linking the owners of traffic and transport service providers considering that owners of mines (traffic providers) and rail owners were predominantly the same at the beginning. While it was in the interest of the private sector to use rail transport due to interlocking interests, the situation was different following takeover railways by government as the private companies were free to use other modes of transport. Therefore, the loss of business by railways could have been partly due to the fact that owners of transportable traffic had the option to use alternative modes of transport especially road.

Participation of the private sector in railways may assist in improving the capacity and efficiency of railways through improved funding and managerial efficiency. The government may possibly focus on provision of passenger services and unprofitable branch lines which are of economic importance but unattractive to the private sector.

Government currently provides infrastructure for both road and rail and develops policies that affect these dominant land transport modes. The ability of each of the two transport modes to compete depends on both external and internal factors that include its characteristics and capacity, government policy and management. While road may appear to have advantages, related to speed, efficiency and flexibility, the total external costs arising from its usage are not well understood or quantified. Forkenbrock (2001), CE Delft (2011) and Nocera *et al* (2018), Blumenfeld, Wemakor,

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[23] Kopicki and Thompson (1995), Kessides (2004), and Foster and Briceno-Garmendia (2010)

Azzouz, and Roberts (2019) demonstrated that external costs for road are significantly higher than those of rail.

A recent study by the European Union (2019) found that road contributed 83% of the total external costs from transport in 2016 compared to rail's 1.8% contribution. There are, therefore, cost implications to the economy arising from distribution of traffic across modes due to the differences that exist for each transport mode (Kopicki & Thompson, 1995; Kessides, 2004; Naude & Matthee, 2007).

African governments are considered to be pro-road because they allocate more resources to road while railways have been neglected to varying degrees when governments are addressing surface transport problems (Howe, 1975; Due, 1977). This view is reinforced by Perdersen (2001), Kessides (2004), Foster and Briceno-Garmendia (2010) who observe that the way in which governments in Sub-Saharan Africa (SSA) allocate infrastructure investment resources between road and rail transport, and regulation thereof reflects policy failure.

Governments allocate more resources to road infrastructure development compared to rail and railways are subjected to a high level of economic regulation. The allocation of more resources to road infrastructure could be possibly due to immediate graft and rent seeking opportunities that come with road infrastructure construction projects. While road transport is able to offer door to door services and reach out to dense populations, which needs more resources, what drives investment in rail infrastructure is freight more than population. Deliberate government policy to financially support rail passenger services is required given that they are loss-making. It is therefore argued that the playing field between road and rail is not even. Kessides (2004) contends that rail problems have been exacerbated by misguided regulation that has the effect of reducing incentives for railways and limiting their ability to compete against other transport modes.

At global level for example, Thompson (2007) advocates for the importance of a sound institutional framework for infrastructure development and contends that current policy and institutional frameworks are inadequate to address freight rail infrastructure in the next thirty years. This challenge needs to be resolved in order to create an enabling environment for investment in rail infrastructure and promote efficient operations.

Thompson (2007) asserts that resolving the rail infrastructure challenge will be achieved through a management framework which clearly defines the economic and financial forces that determine the incentive structure faced by infrastructure providers and freight operators, the high cost of rail infrastructure relative to road, technology and government policy. He observes that rail management models differ as a result of history, culture and political preference. The problem with the high cost of rail infrastructure is that governments also externalize the costs.

These fundamental observations provide the premise upon which the investment function for rail infrastructure to be estimated can be formulated.

3.3 Data

This research covers Botswana, Namibia, South Africa, Zambia and Zimbabwe over the period from 1939 to 2018. As indicated earlier, the five countries were selected on the basis of common history in terms of development and interconnected rail networks. The time run of 79 years is sufficient to allow for tracking of the evolution of railways in the five SADC countries. It is also considered sufficient to cater for the long-term nature of railway investment. This is a major step in providing long time series beyond any previous study for the countries under study except for the case of South Africa.

The five countries under study can be clustered on colonial history lines. The Anglo cluster comprises of Botswana (Bechuanaland), Zambia (Northern Rhodesia) and Zimbabwe (Southern Rhodesia) while the Afrikaner cluster is made up of Namibia (South West Africa) and South Africa. The Anglo cluster is landlocked whereas the Afrikaner Cluster has a coastline. The Afrikaner cluster is made up of countries where the Afrikaners controlled the economic activities for a long time while the Anglo cluster comprises of former British colonies (Zambia and Zimbabwe) and Botswana, a former British protectorate. Each cluster has strong historical and economic ties that have had a bearing on data reporting for these countries over the study period. While this clustering provides analytical convenience, it is important to note that generally, South Africa is also considered Anglo as it was at some stage under British control. The clusters also help in better understanding investment behaviour of the countries due to their unique cluster characteristics. Literature also indicates that colonial background and history have been found to have strong bearing on the subsequent performance of countries after independence, particularly as regards the impact of institutions (Acemoglu, Johnson & Robinson, 2001).

Historical ties among Southern African Development Community (SADC) countries affected their political and economic relationships. These relationships had profound impact on rail network development and operations as indicated in the previous chapter on the review of the evolution of rail network developments in five SADC countries[24]. For instance, South African Railways once operated the rail network in South West Africa (now Namibia) and Rhodesia Railways owned and operated the rail networks in Bechuanaland (now Botswana), Northern Rhodesia (now Zambia) and Southern Rhodesia (Zimbabwe) as one unified company.

This presents challenges arising from the need to have separate country datasets throughout the study period to facilitate analysis at country level. Rail infrastructure and operational performance datasets are compiled for Botswana, Namibia, South Africa, Zambia and Zimbabwe over the study period from 1939 to 2018 utilizing existing records and generating new datasets where they do not exist.

South Africa maintained distinct records throughout the study period. It is the only country among the five whose data can be readily compiled from the records. Fedderke, Perkins and Luiz (2006) compiled similar datasets for South Africa for the period 1875 to 2001 though for more dimensions of infrastructure.

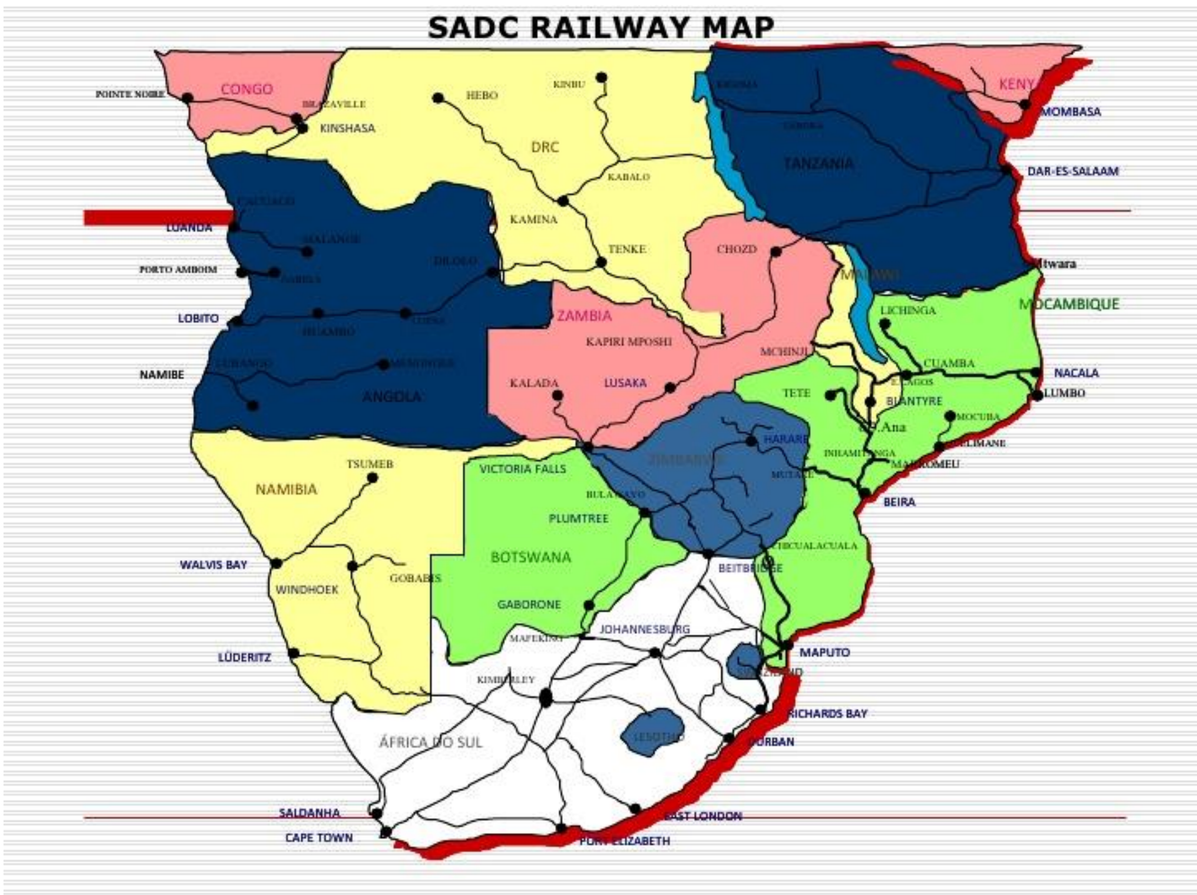
Rail data for Namibia relating to rail track, locomotives, wagons and coaches is contained in the Annual Reports and other management reports of South African Railways for the period from 1939 to 1989. There is, however, no data on operational performance of Namibia railways for the same period although South Africa Railways operated the Namibian rail network during this period. We therefore construct new rail operational datasets for Namibia for the period South African Railways operated the Namibia rail network.

Rhodesia Railways maintained one set of annual and financial reports for its operations in Botswana, Zambia and Zimbabwe. We construct new separate rail datasets for Botswana, Zambia and Zimbabwe from 1939 to 1987 by disaggregating annual data for the Rhodesia Railways era.

[24] Countries covered by the study are Botswana, Namibia, South Africa, Zambia and Zimbabwe.

It was observed during the data collection process that the quality of reporting in terms of the content and level of detail deteriorated over the years for all the rail companies under study, with a marked difference in post-independence operational performance data reporting.

Figure 6: Southern Africa rail networks



Source: Southern African Railways Association (2011)

The rail story can be illuminated through numbers. In order to clearly develop this story, it is necessary to situate railways in the broader regional economic and political context of the five countries under study. This is achieved by segmenting the study period into three sub-periods and identifying major events for each sub-period which had a bearing on developments in the regional rail sector.

The study considers the data over three distinct periods in order to capture the episodic development of the railways as follows; 1940 – 1967; 1968 – 1987; 1988 – 2018.

There are intervening events during the study period which would have implications on the political and economic relations of the countries to the extent of affecting regional rail network configuration and routing of international rail traffic. The major ones are enumerated below;

1940-1967: Railways on the Rise and Early Nationalism

Significant developments during this period were that:

(i) World War II took place from 1939 to 1945;
(ii) Rhodesia Railways was purchased by the government of Southern Rhodesia in 1949;
(iii) Zambia attained political independence from Britain in 1964;
(iv) The Federation of Rhodesia and Nyasaland was formed in 1953 and dissolved in 1963;
(v) The railway link from Rutenga on Rhodesia Railways in the south eastern part of Rhodesia to Maputo port in Mozambique was opened in 1955-would ordinarily affect routing of traffic especially that destined to or originating from South Africa and beyond;
(vi) Unilateral Declaration of Independence (UDI) by the Southern Rhodesia government in 1965 which resulted in the imposition of international sanctions on the country;
(vii) Botswana declared independence from Britain in 1966; and
(viii) Zambia Railways separated from Rhodesia Railways in 1967.

1968-1987: End of Rhodesia Railways Era and Birth of TAZARA

A number of important events took place during this period.

(i) Mozambique attained political independence from Portugal in 1975;
(ii) The Tanzania Zambia Railway Authority (TAZARA) railway line linking Zambia to Dar es Salaam port in Tanzania was constructed and became operational in 1976;
(iii) The Angolan civil war broke out in 1975 resulting in the disruption of Benguela Railways operations;

(iv) Zimbabwe attained political independence from Britain in 1980 and Rhodesia Railways changed its name to National Railways of Zimbabwe in the same year; and

(v) The Southern African Development Coordination Conference (SADCC) was formed in 1980 and later changed its name to the Southern African Development Community (SADC) in 1992.

(vi) Botswana Railways came into existence following separation from National Railways of Zimbabwe in 1987.

These developments had an effect on rail traffic volumes and routing.

1988-2018: Era of Political Independence and Railway Reforms

Major developments that would affect rail traffic movements during the period were;

(i) Namibia attained political independence from South Africa in 1990;

(ii) South Africa underwent its democratic transition in 1994;

(iii) Construction of the Beitbridge Bulawayo Railways (BBR) railway line in Zimbabwe in 1997 under a 30-year concession;

(iv) Concessioning of the Zambia Railways rail network to Railway Systems of Zambia (RSZ) from 2004 to 2012;

(v) Formation of the Southern African Railways Association (SARA) in 1996[25];

(vi) Liberalization of the transport sector and the rise of road competition; and

(vii) Termination of passenger services by Botswana Railways in 2010.

Attainment of political independence at different times by the countries under study was always a source of political and economic destabilization among neighbouring countries or with transit countries as a result of differences between the independent and non-independent countries. This also negatively impacted on cross-border rail transport services through the impact on rail network and traffic routing. In view of this reality, attainment of independence by all the five countries under study ushered in a new business order free of political and economic hostilities. Establishment and membership of the Southern African Development Community (SADC) is

[25] The Southern African Railways Association was formed as the regional railways' collective response to declining railway market share. Its objective was to provide a platform for lobbying for surface transport policy equity and advocating for railway industry development. All the railways under study are members of the Southern African Railways Association.

demonstration of the regional countries' desire to cooperate economically as well as politically as espoused by the SADC Treaty.

Data collected for this study relate to operational performance and physical rail infrastructure. Railway capacity is defined in terms of rail route length, number of locomotives, wagons, coaches and employees available. Traffic volume measured in metric tonnes and passengers are the primary measures of rail performance. The historical review of regional rail performance provides the context for the analysis and interpretation of data trends, and also provides pointers on the comparative economic contribution to be expected from the railways in each country. Annual operational performance data include net tonnes transported, net-tonne kilometres, passenger trips (passenger transported) and passenger kilometres. Physical infrastructure includes length of rail route, number of locomotives, wagons and coaches. Data on number of employees was also collected.

Annual reports of the companies for various years were the primary sources of data. Major sources of data are Annual Reports, internal statistical publications, company records and the Southern African Railways Association database.[26] For Rhodesia Railways, annual reports are available from 1939 to 1980.

Three overarching assumptions are made in the data generating process as follows:

(i) Origins and destination of rail traffic are relatively fixed due to the fixed nature of rail networks and traditional traffic sources;

This assumption means that sources of rail traffic and where the traffic is transported to are relatively the same. This allows us to apportion aggregated traffic volumes among countries over years on the basis of rail track length specifically for Botswana, Zambia and Zimbabwe where Rhodesia Railways data is aggregated.

(ii) Resource requirements are dependent on the level of traffic volume; and

This assumption means that the demand for operating resources is dependent on the business volume. This assumption facilitates apportionment of aggregated operating

[26] Southern African Railways Association is an association of railways organisations in the SADC region, some of their customers and suppliers.

resources like locomotives, wagons, coaches and staff where the business volume is known in the case of Rhodesia Railways.

(iii) Technological change in the rail sector of the five countries took place at the same time across the countries due to the interconnectedness of their rail networks and the need for interoperability of infrastructure and equipment.

These assumptions ensure that rail infrastructure is generally comparable across countries.

3.3.1 Namibia and South Africa

The case of Namibia and South Africa does not present challenges of aggregated data as the records for the two countries are distinct notwithstanding the fact that South African Railways operated the Namibian rail network from 1922 to 1989. However, no operational data records for Namibia were found for this period.

In the case of South Africa's railway freight business, only data for Transnet Freight Rail (TFR) is used. Data for both TFR and Passenger Rail Agency of South Africa (PRASA) is used in the case of passenger services. Annual infrastructure and operational data for South Africa was readily available from the annual reports for most of the years. For Namibia, no operational data is available for the period from 1939 to 1989, the period during which South African Railways operated the Namibia rail network. The challenge on the Namibian data is to estimate traffic volume and its derivatives over the years prior to 1990.

Namibia's economy is driven by mining, tourism and port activities. The country is mostly desert hence agriculture is mainly cattle ranching. Namibia has two main ports namely Walvis Bay and Lüderitz. Walvis Bay and Lüderitz are both accessible by rail and linked to the main rail line. The Namibian rail network is only connected to South Africa through Nakop.

Pre-independence, TransNamib (railways in Namibia) was owned by South Africa Railways until 1989. The data for TransNamib has however been accounted for separately. Namibia got its independence from South Africa in 1990.

3.3.2 Botswana, Zambia and Zimbabwe

Rhodesia Railways operated as one entity up to 1967 owning the rail networks in Botswana, Zambia and Zimbabwe with its headquarters in Bulawayo in the then Southern Rhodesia now Zimbabwe. Zambia Railways separated from Rhodesia Railways in 1967 following Zambia's attainment of political independence from Britain in 1964. Rhodesia Railways continued to exist comprising of rail networks in Botswana and Zimbabwe up to 1987.

The historical development and ownership structure of railways in Botswana, Zambia and Zimbabwe had a bearing on the reporting of company assets and operating performance. For the period under study, the consolidated reports by Rhodesia Railways presented a challenge of combined data for the three countries for the period from 1939 to 1967, and for Botswana and Southern Rhodesia (later Zimbabwe) from 1968 to 1987. The company produced one set of annual reports and financial statements for operations in the three countries.

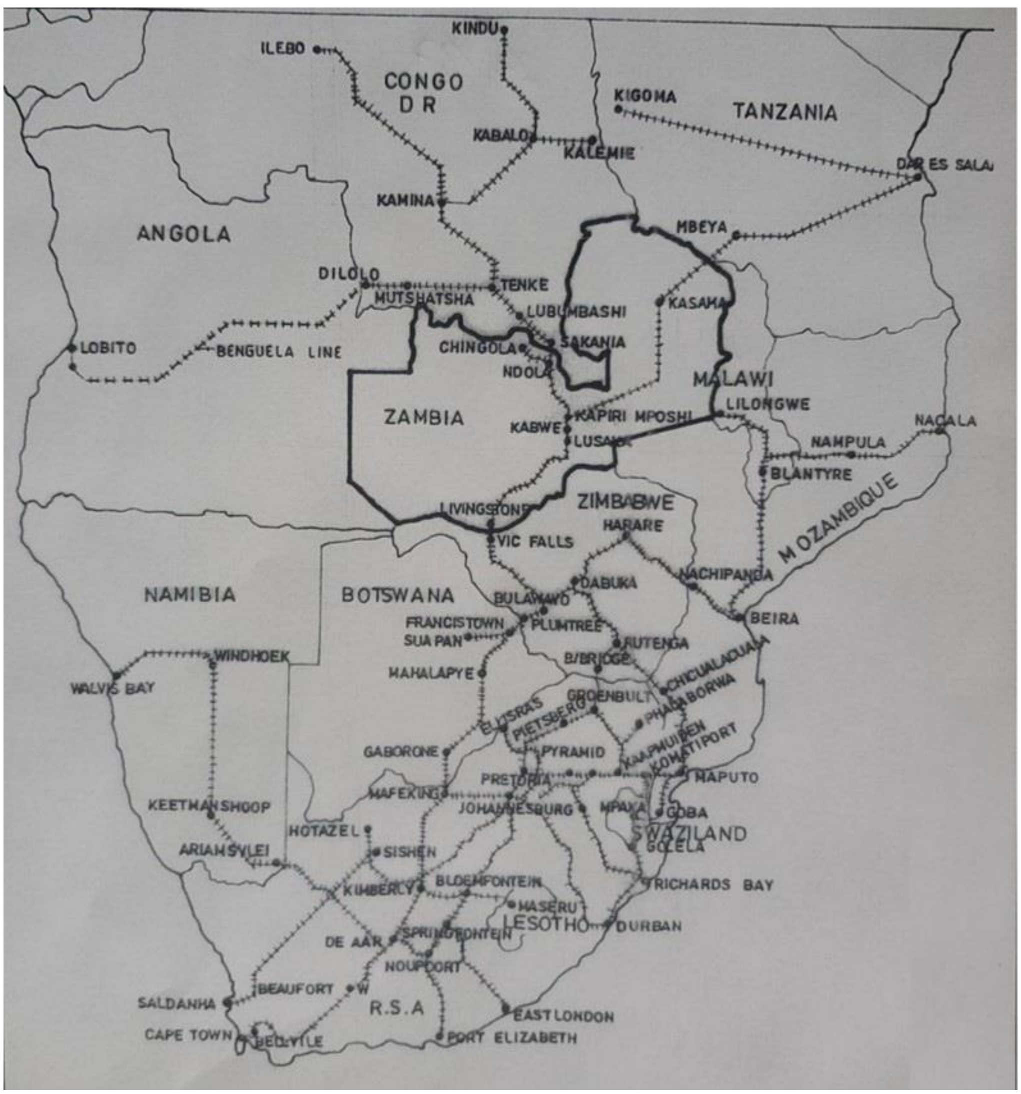
The challenge is to compile estimates of individual country datasets through disaggregation for the duration of the subsistence of Rhodesia Railways. The aggregated data for Rhodesia Railways requires a separation strategy that yields reasonable estimates for each country based on available information.

We follow a number of sequential steps in generating data estimates for the three countries. A key feature of the data reporting by Rhodesia Railways is that it is based on two distinct geographical areas, North of Bulawayo and South of Bulawayo. Southern Rhodesia (now Zimbabwe) straddled the two territories. North of Bulawayo covers the whole of Zambia and the northern and eastern part of Zimbabwe connecting to Beira Port in Mozambique. South of Bulawayo includes the whole of Botswana and the rail line section between Bulawayo and Bakaranga (the Botswana/Zimbabwe border). The headquarters of Rhodesia Railways was in Bulawayo,

Traffic volumes for each country over the years are estimated first to enable estimation of resource requirements (number of locomotives, wagons, coaches and employees) given that resource requirements are driven by business volume. Net tonne kilometres are used as the main business volume indicator for the derivation of resource requirements.

Compilation of data on rail route length is straight forward because the rail network is geographically fixed in the respective countries. This attribute is exploited to apportion traffic volume, mobile operating resources (locomotives, wagons, coaches) and employees in some cases assuming that the longer the route length, the more the required resources, and also considering that a signification portion of traffic is transit traffic passing through the three networks. New datasets for Zambia were generated from 1939 to 1967 and that for Botswana and Zimbabwe from 1939 to 1987. Thereafter each country has separate records and datasets. Figure 7 below shows Southern Africa rail routes to the ports.

Figure 7: Southern Africa rail routes to ports



Source: Zambia Railways Limited

3.3.3 Traffic Volumes

3.3.3.1 Tonnes moved per country

Annual tonnage moved per country represents the total freight business of railways in that country. It measures the combined performance of rail infrastructure assets used in a particular year. Traffic data for Botswana, Zambia and Zimbabwe is aggregated for the years Rhodesia Railways operated as one company. The company produced one set of Annual Reports. Reporting is based on two operating territories for namely North of Bulawayo and South of Bulawayo for the period 1939 to 1960.[27]

North of Bulawayo covered part of Zimbabwe and the whole of Zambia. South of Bulawayo covered part of Zimbabwe (70 miles from Bulawayo to Botswana border), the whole of Botswana (398.5 miles from Zimbabwe border to Ramathlabama) and part of South Africa (112 miles from Ramathlabama to Vryburg).

Sectional annual gross and net tonne miles for Bulawayo to Zimbabwe/Botswana border, Zimbabwe/Botswana to Ramathlabama and Ramathlabama to Vryburg are apportioned on the basis of distance since most of the traffic conveyed over the line sections was the same transit traffic. There was little production in Botswana as the country was mostly desert with a very small population in Botswana. The rail network in Botswana was also a straight line. Tonnage for South of Bulawayo is assumed to be the same throughout the route.

Annual tonnes and net tonne kilometres for North of Bulawayo region are apportioned on the basis of network size. The rail network configuration in the two countries (Northern and Southern Rhodesia) was almost similar then comprising of both main and branch lines. The flow of traffic between the two countries was almost similar although it was tilted in the Southern Rhodesia (Zimbabwe) direction. Zambia had three export and import rail routes during this period. The Zimbabwe route through Victoria Falls branched in Bulawayo to Beira port to the north east in Mozambique through Salisbury (now Harare), and to South Africa and South African ports

[27] Rhodesia Railways produced one set of Annual and Financial Reports from the time before the study period.

through Botswana. Traffic routing through Zimbabwe to Mozambique and South African ports was preferred when Eastern Europe and Far East markets were involved.

The third option was through Belgian Congo/Zaire (now Democratic Republic of Congo) to the Benguela rail line in Angola leading to Lobito Port on the Atlantic Ocean. This route was preferred for goods from or destined to Western Europe and the Americas because it was shorter.

Southern Rhodesia was also exporting and importing through Zambia for traffic to Zambia and Zaire (now DRC), mostly coal used in the mines from Wankie Colliery. Traffic for Southern Rhodesia to and from Western Europe and the Americas used Lobito port through the Benguela rail route because of geographical proximity. Network size is therefore considered a reasonable basis of apportioning gross and net tonne kilometres between Northern and Southern Rhodesia.

Network size (route length) per year for each country is expressed as a proportion of the total for the two countries for the same year multiplied by total tonnage for that year. The whole of Zambia is included in the North of Bulawayo section therefore traffic estimates for Zambia are obtained directly from this manipulation. Totals for Zimbabwe are obtained by adding total tonnage for the Bulawayo to Zimbabwe/Botswana section of the South of Bulawayo territory to the North of Bulawayo component separated from the Zambia component.

Zambia Railways' separate data is available from 1968 following separation from Rhodesia Railways in 1967. The total route length of the TAZARA railway line is 1860km of which 885km are in Zambia. The rail route length of Zambia therefore increased by 885km from 1976, the year TAZARA became operational. The route length is used to apportion both operating resources and business volume per annum between Tanzania and Zambia. The Zambian share of TAZARA resources and business is added to Zambia Railways Limited's totals to obtain the totals for Zambia per year.

Rhodesia Railways[28] continued to exist from 1968 to 1987 owning and operating the rail networks in Botswana and Zimbabwe. Aggregated data for this period is available in Annual Reports and the National Railways of Zimbabwe Facts and Figures[29] booklets from 1968 to 1987 for most

[28] The name was changed to National Railways of Zimbabwe in 1980/82 following attainment of independence in 1980.
[29] NRZ Facts and Figures is an annual statistical publication whose first edition was published in 1982.

variables of interest. Data for this period is disaggregated to come up with separate datasets for Botswana and Zimbabwe.

A special publication by Statistics Botswana (2016)[30] marking 50 years of Botswana's independence contained disaggregated data for net tonnes in terms of domestic and transit for the period 1980 to 2014. This provided the basis for compiling datasets for Zimbabwe for eight years from 1980 to 1987 by simply subtracting the component for Botswana. Each country kept separate records beyond 1987. Statistics for Botswana Railways (BR) and National Railways of Zimbabwe (NRZ) data is complete for 1988 to 2018.

The Beitbridge Bulawayo Railways (BBR) rail line is a concessioned new rail line completed in 1997 which provides a shorter and direct rail link from Bulawayo in Zimbabwe to the Beitbridge border with South Africa. The effect of this new line was to divert transit, export and import traffic that originally passed through Botswana Railways to and from South Africa and its seaports. The traffic volume of Botswana Railways was thus seriously reduced due to the diversion of traffic to the BBR line resulting in a dispute that was escalated to Heads of State level between Botswana and Zimbabwe[31] in 1999.

Concessioning of the Zambia Railways network affected business volume through loss of inter-mine traffic and a shift from rail to road due to high tariffs charged by Railway Systems of Zambia (RSZ).[32] The parent company for BBR in Zimbabwe and RSZ in Zambia was the same therefore the company directly influenced the flow of traffic in its favour at the expense of Botswana Railways and National Railways of Zimbabwe. The RSZ concession was cancelled in 2012.

Main sources of data are Annual Reports, internal statistical publications, company records and the Southern African Railways Association database.[33] Contrary to popular belief that private sector information and data are confidential, Railway Systems of Zambia (RSZ) data for the entire period of the concession from 2004 to 2012 is available based on submissions to SARA. Zambia

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[30] Botswana at 50: Selected Statistical Indicators 1966-2016 -Enabling Stakeholders formulate policies, plan and make decisions.
[31] NRZ records for various years.
[32] RSZ charged more than three times the rate per tonne kilometre charged by other railway operators on the same corridor.
[33] Southern African Railways Association is an association of railways organisations in the SADC region, some of their customers and suppliers.

Railways' pre and post concession period data is available mostly from the annual reports. Zambia Railways Limited (ZRL) does not have a consistent statistical publication therefore annual reports provided the main source of information supplemented by company records and other reports.

The underlying assumption on the strategy employed to disaggregate the data is that resource requirements are based on the level of activity. Estimates of annual tonnage and its derivatives provide the basis for estimating locomotives and wagons as their demand is driven by business volume. Gross tonne miles provide a better measure of the level of activity as they incorporate tonnes moved (including wagon weight) and distance covered. GTMs were however not available for all the years hence the use of tonnage where GTMs are not available. Operating resources are a function of the level of activity hence their apportionment is based on business volume.

3.3.3.2 Passengers moved by country

Apportionment of passengers North of Bulawayo is primarily based on network size of each country expressed as a proportion of the total for the two countries (Zambia and Zimbabwe). While the estimates for Zambia are directly obtained from this manipulation, Zimbabwe requires that estimates from the Bulawayo to Zimbabwe/Botswana border be added to obtain the total for the country.

3.3.4 Railway Key Operating Resources

3.3.4.1 Track

Compiling data for the rail track in the five countries was fairly straight forward because of its fixed nature and also the sectional reporting by country in the records. Once laid, the rail track remains geographically fixed and hence the relative ease of tracking changes in its length. The route length is indicated by country per year in miles up to 1970 and in kilometres thereafter. Miles were converted to kilometres for comparability purposes.

3.3.4.2 Locomotives and Wagons

Constructing datasets for locomotives and wagons for Botswana, Zambia and Zimbabwe presented challenges arising from their joint ownership, high operational mobility across the three countries and combined reporting. Early records of operational statistics report on two major geographical areas namely North of Bulawayo and South of Bulawayo. The challenge is to apportion the locomotives and wagons among the three countries. Estimates for each country per year are obtained on the basis of track length and tonnage moved (or its derivatives like net tonne km, gross tonne km and train km). Business volume (tonnage) per annum provides a sound basis of allocating locomotives and wagons given that resource requirements are business volume driven and that origins and destinations of rail traffic are relatively fixed for long periods arising from the fixed nature of the rail network and production centres.

3.3.4.3 Passenger coaches

Data for the combined number of coaches is available from various sources. Estimates for each country per year are estimated on the basis of track length and passengers moved. Reporting on passenger kilometres is not done on a continuous basis otherwise this could have been a better basis of apportioning the coaches. Passenger revenue is also used as a basis of apportionment where detailed sectional information is provided.

3.3.5 Railway Infrastructure Composite Indices

Construction of railway infrastructure composite indices is motivated by the fact that rail transportation services are provided through a combination of different infrastructure components, which include track, locomotives, wagons and coaches. The complementary nature of physical rail assets justifies an investigation into their joint impact therefore the composite indices are required to provide insights on this issue.

Rail infrastructure composite indices are constructed using Principal Component Analysis (PCA) for three scenarios relating to freight, passenger and mixed rail business. The indices are respectively freight rail infrastructure index (*FRII*), passenger rail infrastructure index (*PRII*) and mixed rail infrastructure index (*MRII*) for combined freight and passenger business. PCA is a multivariable statistical approach commonly used for reducing the dimension of the data and can be applied to any data matrix in which common variables are measured for each of the units of analysis, countries in this instance, (Krzanowski, 1979). Put simply, PCA creates uncorrelated indices or components that are a linear weighted combination of the original variables of interest. The weights for each component are given by eigenvectors of the covariance matrix when the variables are standardized. The components are ordered in such a way that the first principal component (PC_1) represents or accounts for the greatest possible variation in the data as measured by an eigenvalue of one or greater of the corresponding eigenvector. To formalise the mathematical definition, suppose for instance we have a given set of variable K_{i1} through K_{in} for each country i,

$$PC_{i1} = a_{i11}K_{i1} + a_{i12}K_{i2} + \cdots + a_{i1n}K_{in}$$

$$.$$

$$PC_{im} = a_{im1}K_{i1} + a_{im2}K_{i2} + \cdots + a_{imn}K_{in}$$

where a_{imn} represents the weight for the m^{th} principal component for the n^{th} variable and the i^{th} country. The first principal component, PC_{i1} accounts for the largest variability in the data, subject to the restriction that, $\sum(a_{i11}^2 + a_{i12}^2 + \cdots + a_{i1n}^2) = 1$ and is our composite measure for rail infrastructure for each country i, abbreviated here as RII_i. The value that we obtain for PC_{i1} – our composite rail infrastructure index, can be positive or negative which complicates its interpretation and possible comparisons across countries. For this reason, we rescale the calculated index to compute a standardized rail infrastructure index ($SRII_i$), which is bounded in the $[0, 1]$ interval i.e. $[0 < SRII_i < 1]$. The standardized rail infrastructure index for the i^{th} country is calculated using the following mathematical formulation as follows:

$SRII_i = \left(\frac{(\widehat{RII}_i - \widehat{RII}_{i,min})}{\widehat{RII}_{i,max} - \widehat{RII}_{i,min}}\right) \times 100$, where $\widehat{RII}_{i,min}$ and $\widehat{RII}_{i,max}$ are the minimum and maximum values of the predicted (via PCA) rail infrastructure index, respectively. This standardization procedure is a commonly adopted practice in empirical research (see for example, Antony & Rao, 2007; Chatterji, Lahiri & Song, 2013).

While we summarise the procedure involved in computing the standardized rail infrastructure index that we represent as $SRII_i$ for each country, in essence we are creating three separate indices namely; freight rail infrastructure index, passenger rail infrastructure index and mixed rail infrastructure index. In other words, $SRII_i$ is representing three indices [$SFRII_i$; $SPRII_i$; $SMRII_i$] that are all standardized to the $[0, 1]$ interval as mentioned earlier. The freight rail infrastructure index was calculated using the variables: track, locomotives and wagons. The first principal components (or the retained components with an eigenvalue of one or greater) for $FRII$ explained a large share of the variability in the data and ranged from 73% for Namibia to 98% for Zimbabwe. The passenger rail infrastructure index was calculated using the variables: track, locomotives and coaches. The first principal components for $PRII$ explained a large share of the variation in the data and ranged from 60% for Namibia to 73% for South Africa. Finally, the mixed rail infrastructure index was constructed using the following variables: track, locomotives, wagons and coaches. The first principal components for explained a sizable amount of variability in the data and ranged from 66% for Namibia to a high of 96% for Zimbabwe. Given that, our calculated rail infrastructure indices capture at least 60% of the variability in the data; these represent good summary measures for rail infrastructure capacity across countries. All the analysis was done using Stata version 15.1 (StataCorp, 2017).

3.3.6 Employees

The hard infrastructure requires human resources for their deployment, operations and management. Technical skills are required for rail operations. Management skill and experience matter. Performance of the railways will therefore depend on how the infrastructure is managed. The number of employees was obtained from company reports.

In the case of Botswana, Zambia and Zimbabwe, apportionment of employees for the Rhodesia Railways era was based on business volume (tonnes).

3.4 Historical Analysis of Railway Capacity and Performance

The analysis below is based on compiled datasets for this study. Ten-year averages are used to smooth fluctuations over short periods in order to clearly identify the trends over the entire study period and also for space economy for presentation purposes. Railway operations require the rail track, locomotives (motive power), wagons and coaches (rolling stock), and employees. The number and quality of the key assets define any railway's operational capacity. In this section, we seek to examine various issues pertaining to railway capacity.

This study does not cover quality of physical infrastructure in detail. However, where necessary, infrastructure quality is proxied by the rate of depletion of each infrastructure category. Infrastructure quality measures for locomotives, wagons and coaches are constructed based on their depletion rates over the years assuming that quality infrastructure endures and therefore the depletion rate is lower than for poor quality infrastructure.

South Africa has the biggest rail company in the SADC region and even the African continent. It is also the 13th largest railway company in the world based on network size[34]. Table 5 shows the capacity of railways in the five SADC countries under study as at December 2018.

Table 5: Comparative Railway Capacity as at December 2018

Country	Route (km)	Locomotives	Wagons	Coaches	Employees
Botswana	888	27	1 309	37	703
Namibia	2 382	43	1 533	79	1 269
South Africa	20 953	3 618	57 640	1 141	25 721
Zambia	1791	27	1 721	39	2 772
Zimbabwe	3 127	61	3 169	58	5 079

Source: Researcher's construction based on company records and other sources.

Table 5 indicates that South Africa railways dominates in all aspects of capacity. South African Railways is greater than the railways in the other four countries combined in all aspects.

Table 6 shows the comparison of the total capacity for the four countries against that of South Africa.

[34] International Union of Railways

Table 6: Comparison of four country total capacity against South Africa

Country	Route	Locomotives	Wagons	Coaches	Employees
South Africa	20 953	3 618	57 640	1 141	25 721
BNZZ[35]	8 188	158	7 732	213	9 079
Total	**29 141**	**3 776**	**65 372**	**1 354**	**34 800**
%South Africa	71.9	95.8	88.2	84.3	73.9
%BNZZ	28.1	4.2	11.8	15.7	26.1
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: Researcher's calculations based on Table 5.

3.4.1 Capacity Indicators

3.4.1.1 Railway track

The length of the rail line defines the network size, the volume of cargo and passengers that can be transported given a set of locomotives and wagons. The bigger the network size the higher the capacity. Network sizes measured in route kilometres for the countries under study for the period 1940 to 2018 are shown in Figure 8.

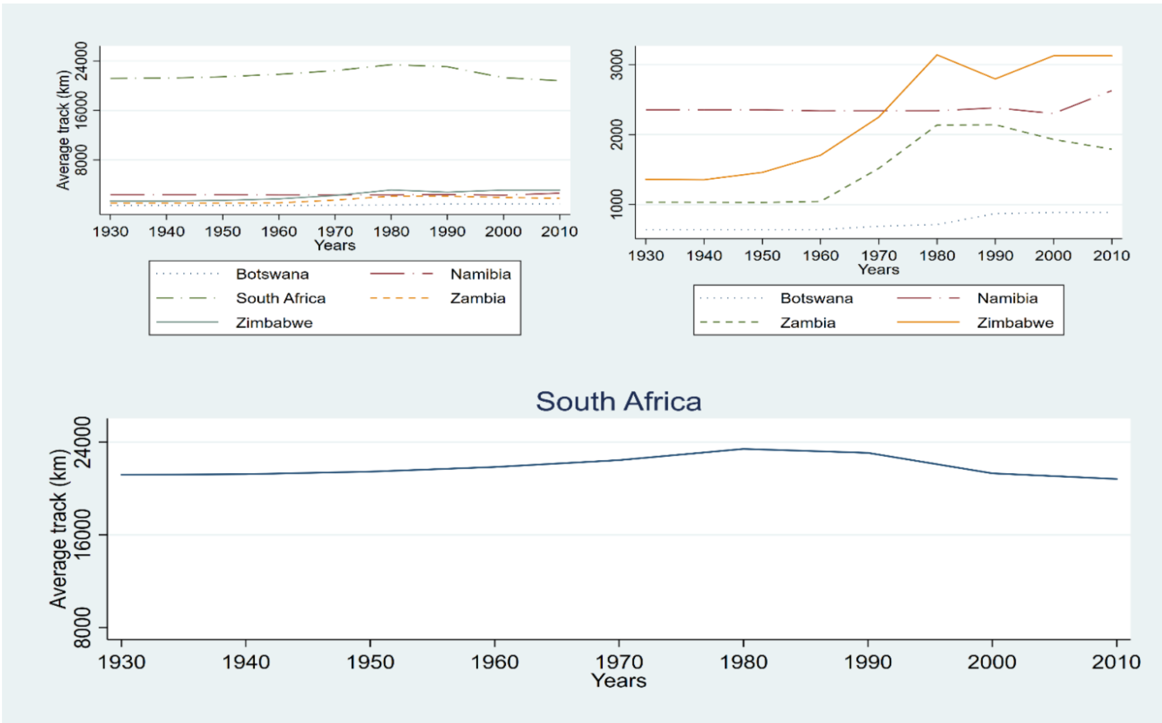
The total increase for the total rail route length of the five countries between 1940 and 2018 is 10.1% (2 684km). The increase was accounted for as follows; Botswana (247km), Namibia (275km), South Africa (-361km), Zambia (757km) and Zimbabwe (1 760km). Fedderke *et al* (2006) observe that South Africa did not expand its rail network after the 1930s.

Botswana's rail network remained relatively constant. It increased by 247km from 1940 to 2018 primarily due to mining activities. The increase was as a result of branch-lines to Selebi Phikwe (56.3km), Morepule (16km) and Sua Pan (174.5km) constructed in 1973, 1974 and 1992

[35] BNZZ-is the summation of Botswana, Namibia, Zambia and Zimbabwe.

respectively in response to mining developments. The line remained predominantly a transit route and fixed.

Figure 8: Rail route length by country (km)



Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years*.

Namibia's rail declined by 0.59% on average between and 1990. Post-independence, the network length declined by 3.4% between 1990 and 2000 due to decommissioning of the line between Aus and Lüderitz. Post-independence, the Namibian government invested in the new rail extension of the Northern Line from Tsumeb to Oshikango border with Angola (306km) and a 28km branch line from Ondangwa to Oshakati between 2006 and 2013. This represents a 10.4% increase between 1990 and 2018.

South Africa's core rail network was already in place by 1940. Additional routes post 1940 include the 580km Richards Bay coal line completed in 1976 and the 861km Sishen – Saldanha iron ore line completed in the same year (Transnet Freight Rail, 2010). South Africa has a vast network of branch lines some of which is used to handle high traffic volumes. For a big railway network such as the one of South Africa, a decline of 361km over five decades is small.

Zambia's rail route length grew from 1 034km in 1940 to 1 046km in 1970 in response to mining developments and started to decline thereafter. The rail route length stood at 916 km in 2018. The mainline remained intact and the decline is accounted for by closure of some branch lines for example the Mulobedzi timber branch line in the southern region.

Post-independence, an increase of 885km was recorded on the Zambian rail route length following the construction of the Tanzania Zambia Railway Authority (TAZARA) railway line in 1976. The concessioning of the Zambia Railways network to a private operator in 2004 saw the closure of inter-mine branch lines. The concession was cancelled in 2012 due to failure by the concessionaire to invest in infrastructure, declining service levels and high rail tariffs that pushed traffic to road.

Zimbabwe's rail route length increased by 571km from 2 188km in 1940 to 2 759km in 1990. Major additions came from the new links from Bannockburn through Chicualacuala (320km) to Maputo port in Mozambique opened in 1955; the link from Mbizi to Chiredzi (90km) sugar cane estates was opened in 1964 and extended by Rutenga to Beitbridge (139.6km) linking with South Africa opened in 1974. An additional 173km would come from the new line built on a Build Own and Transfer (BOT) arrangement[36] by Beitbridge Bulawayo Railways (BBR) in 1999 linking the existing rail line at West Nicholson to Beitbridge border with South Africa.

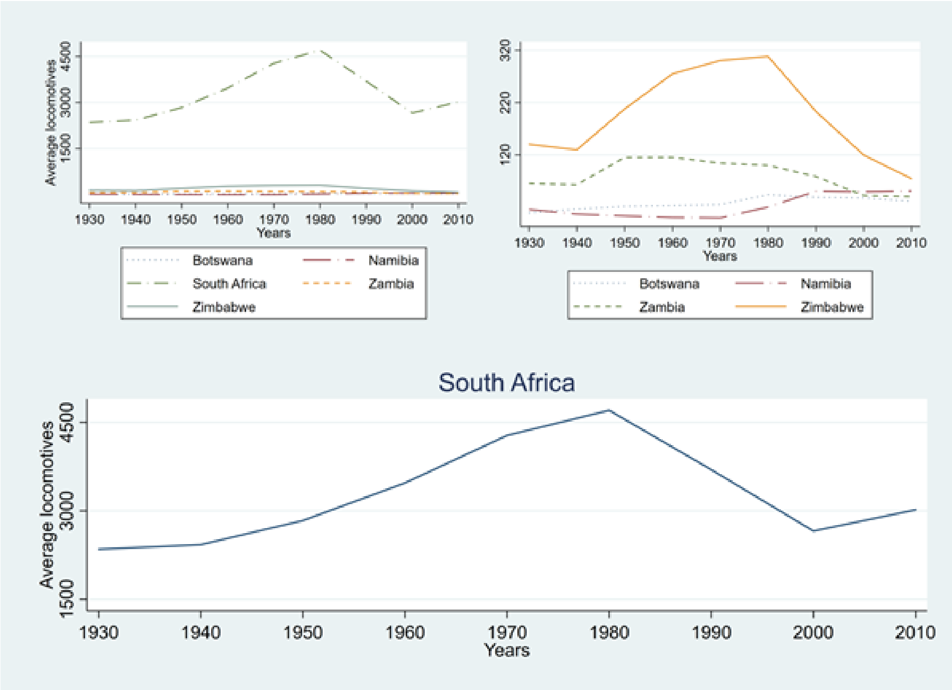
3.4.1.2 Locomotives

The total number of locomotives in the 5 countries declined over the past forty years due to lack of maintenance and investment in new stock. Some locomotives were scrapped on account of age and others were written off following major accidents without replacement. The trend for locomotives in use per country is as shown in Figure 9.

The average net increase in the total locomotive fleet of the five countries between 1940 and 2018 is 635 locomotives representing a 24.6% increase. The increase in the number of locomotives per country was as follows; Botswana (22), Namibia (35), South Africa (668), Zambia (-25) and Zimbabwe (-65). South Africa is the major contributor to the total fleet growth over the study period.

[36] The BBR line is the only new railway network section to be constructed after the independence of Zimbabwe in 1980 apart from existing lines reopened following the end of the war of liberation.

Figure 9: Number of locomotives in use by country



Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

The number of locomotives in use increased during the four decades from 1940 and 1980 when the fleet level reached its peak. Demand for railways services increased during World War II and rapid economic growth soon after necessitating expansion of rail capacity. Economic growth of the countries increased demand for rail transportation services hence the response in capacity. Transport is derived demand.

While the overall locomotive fleet shows an increase over the entire study period from 1940 to 2018, the continuous decline from 1980 onwards is cause for concern. South Africa responded to this capacity threat by adopting the Market Demand Strategy in 2012 to arrest the downward trend. The Market Demand Strategy's major thrust is on recapitalization of locomotives, wagons and rail infrastructure. South Africa has internal capacity to manufacture locomotives and wagons for its own use and export in the region through Transnet Rail Engineering, a sister company to Transnet Freight Rail.

The locomotive trend in the other four countries points to total collapse if nothing is done in the short to medium term.

For Namibia, the locomotive fleet should be viewed in the context of allocations being dependent on South Africa who were operating the railway network in Namibia until 1989. The allocations may not therefore reflect investment requirements for Namibia but operational requirements for South African Railways. The small number of locomotives, wagons and coaches possibly represent those South African Railways operating equipment stationed in Namibia. Traffic volumes for Namibia in the early 1980s to the point of separation suggest that more operating resources were in use in Namibia and between South Africa and Namibia. Diesel locomotives were introduced in Namibia in 1959 which eventually replaced steam locomotives which were problematic because of the unavailability of water in Namibia.

The decline in Namibia's locomotives from 1990 onwards was due to the unreliable Chinese locomotives which they purchased after independence which were very difficult to maintain. The locomotives were also found to be unsuitable for the desert environment of Namibia.

Rhodesia Railways introduced diesel locomotives and new wagons in the early 1950s being financed by loans from World Bank, AfreExim Bank and Anglo-American Cooperation (Tow, 1960). Additional resources were obtained from the Railways Contributory Pension Fund (Rhodesia Railways Annual Reports, various years). These also benefited Botswana and Zambia who were then part of Rhodesia Railways. Rhodesia was under international sanctions from 1965 following its Unilateral Declaration of Independence hence access to resources on the international market was restricted leading to dependence on South Africa for sanction busting. Depletion of Rhodesia Railways locomotive fleet started in 1980 due to lack of maintenance over the years. A new fleet of 30 new Electric locomotives was introduced in 1984 following the electrification of the network section between Harare and Dabuka in Gweru in 1982. This new fleet was depleted because of lack of spare parts following the closure of the company which manufactured them[37]. The NRZ ended up taking spares from other locomotives (cannibalism) in the fleet thereby reducing the numbers.

[37] A new company was specifically formed to manufacture and supply the locomotives to NRZ under World Bank funding. The order was delivered, and the manufacture closed thereafter. No other company could supply spare parts for the locomotives due to Original Equipment Manufacturers' restrictions on interchange of spares.

The steep decline in the number of locomotives from the late 1990s to 2018 was due to phasing out of steam locomotives, lack of investment in new locomotives and the collapse of the Zimbabwean economy following the land reform programme. The collapse of the economy resulted in:

(i) departure of qualified technical staff who sought employment opportunities in other countries;
(ii) Shortage of foreign currency to import spare parts; and
(iii) Lack of funding to invest in new equipment and infrastructure.

Investment in new locomotives, wagons and coaches and maintenance of same and the track were compromised. The number also declined due to scrapping of old locomotives and those extensively damaged without replacement. NRZ does not ensure its locomotives, wagons, coaches and track against accidents or any damage.

The problem was compounded by the imposition of economic sanctions on the state-owned National Railways of Zimbabwe which meant that the company could not buy spares for locomotives purchased from the European Union and United States of America Original Equipment Manufacturers like General Motors (GM), General Electric (GE) and Bombardier. The company had to purchase expensive spares through third parties, a situation which was not sustainable due to lack of funding and foreign currency.

The average number of locomotives in use in Botswana was dependent on the allocation from Rhodesia Railways until separation in 1987. While Botswana locomotive numbers were generally increasing in sympathy with the Rhodesia Railways fleet before separation, their numbers are estimates which show high variability because the allocations were made on a short-term basis by Rhodesia Railways in response to prevailing demand.

The locomotive fleet in use in Botswana increased from 10 in 1940 to a peak of 44 in 1980 and thereafter declining by 27.3% to 32 locomotives in 2018. It is critical to point out that locomotives operating in Botswana before 1956 belonged to Rhodesia Railways and South African Railways as these were the two operators of the network. Between 1967 and 1987, all the locomotives belonged to Rhodesia Railways (later NRZ). Botswana as a country did not own locomotives until 1987 when it purchased assets from National Railways of Zimbabwe. Given that locomotives are predominantly confined to geographical national boundaries[38], the decline may suggest an adjustment by Botswana to meet its local needs and also a response to the reduced traffic caused by diversion to NRZ following separation in 1987.

Zambia Railways separated from Rhodesia Railways in 1967. Zambia's locomotive fleet declined after separation from Rhodesia Railways due to immediate challenges of shortage of technical staff and maintenance facilities as they previously relied on Rhodesia Railways headquarters in Bulawayo. The allocation of locomotives and other operating equipment was arbitrarily done by non-independent Southern Rhodesia where the headquarters was domiciled. The distribution was therefore likely to be in favour of Rhodesia railways.

This possibility is supported by the fact that on one side Rhodesia Railways was instructed by the Government of Rhodesia not to increase the number of locomotives and rolling stock in Zambia beyond that which existed as at 27th May 1966, while on the Zambian side the Republican President assumed powers to control the movement of railway equipment and material out of Zambia (Rhodesia Railways Annual Report, 1967).

The locomotive fleet in use in Zambia increased from 66 in 1940 to 116 in 1960. These are estimated allocations from Rhodesia Railways. The total of locomotives in use decreased to an average of 105[39] in 1970 following the separation from Rhodesia Railways in 1967. The total locomotive fleet in use increased to 116 in 1980 reflecting part of the TAZARA locomotives introduced in 1976. However, the impact of TAZARA Chinese locomotives introduced in 1976 was short-lived as the locomotives were underpowered, prone to failure and lacked maintenance. The local technical staff were not properly trained, and the Chinese engineers left thereby making it difficult to maintain the equipment (Reichardt & Duncan, 1990). TAZARA locomotives in use declined from 100[40] in 1976 to 39 in 1990.

There was a continuous decline of Zambia's locomotive fleet from an average of 100 in 1980 to 41 in 2018. The decline from 1980 was due to economic challenges faced by Zambia which

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[38] Locomotives do not ordinarily cross borders due to operational and maintenance considerations which differs from country to country. Only wagon loads are exchanged at interchange points (mostly yards at border stations).
[39] Croxton (1973) provides an estimate of number of locomotives of Zambia Railways at the point of separation from Rhodes Railways to be 105.
[40] 48 locomotives were proportionally apportioned to Zambia on the basis distance.

resulted in shortage of foreign currency to procure maintenance spares and lack of funding to invest in new locomotives and maintenance of existing ones. Old locomotives were being scrapped over time without replacement.

3.4.1.3 Wagons

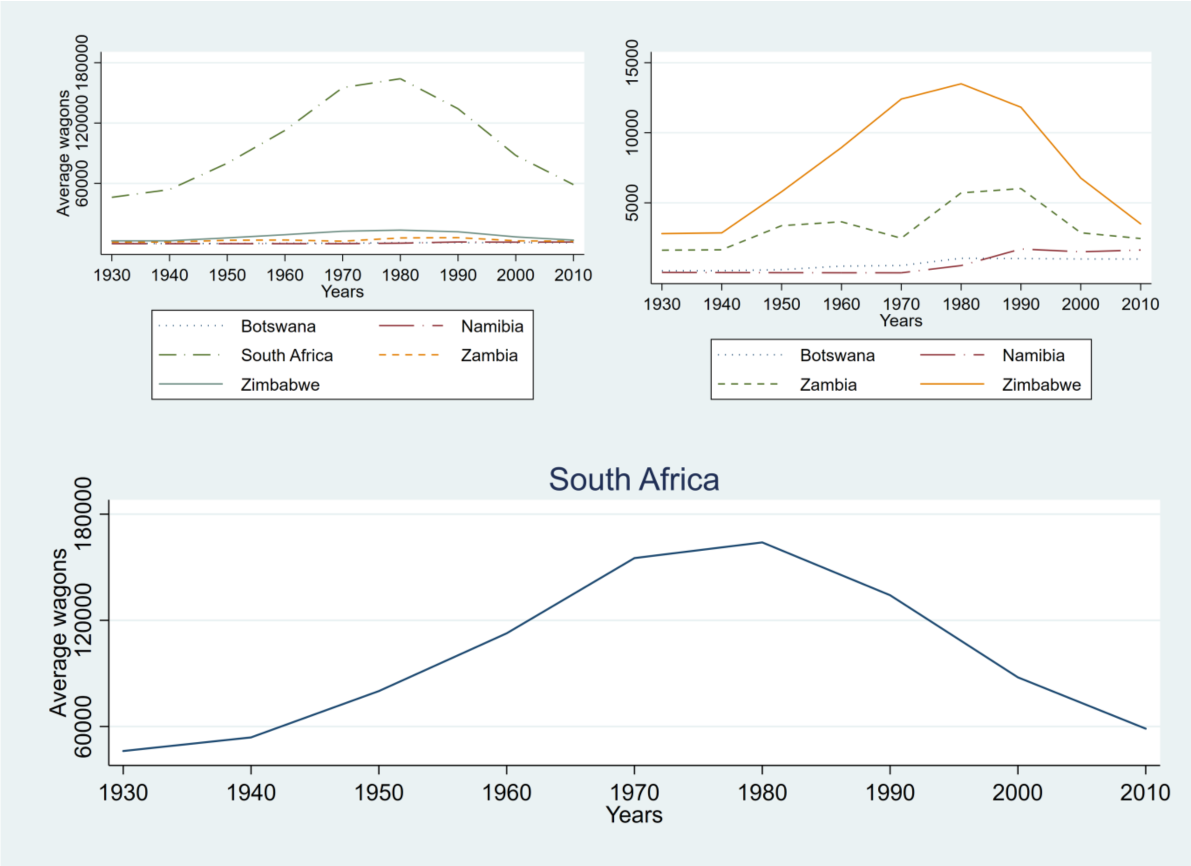
Wagons are an indicator of loading capacity of the railways. More wagons reflect more capacity to load traffic given the track, locomotives and human resources. Figure 5 below shows wagon endowment by country for selected years.

The net increase in the total wagon fleet of the five countries was 32.7% (16 596 wagons) between 1940 and 2018. The increase in the number of wagons per country during this period was as follows; Botswana (838), Namibia (1 600), South Africa (12 626), Zambia (835) and Zimbabwe (697). South Africa is the major contributor to the total fleet growth over the study period. Despite this positive growth over the entire study period, it is necessary to also interrogate the intervening period. To achieve this objective, the trend is analysed over two time periods of four decades each.

The total wagon fleet for the five countries grew rapidly over the four decades from 1940 to 1980 in response to business growth. A rapid decline ensued after 1980 due to lack of investment in new stock and maintenance. Wagons have an average design life of forty years therefore the accelerated depletion rate after a forty-year period is not surprising especially in the absence of scheduled maintenance or refurbishment to extend design life.

Figure 10 shows the number of wagons by country over time. South Africa remained the biggest contributor to the combined wagon fleet of the five countries. The combined SADC wagon fleet declined by a massive 63.3% between 1980 and 2018. In the case of South Africa, the decline was 64.2% reflecting its proportionate contribution the combined fleet. South Africa has the capacity to manufacture wagons for own use and export through Transnet Rail Engineering. Transnet Freight Rail also adopted the Market Demand Strategy in 2012 whose objective is to ensure recapitalization of the company in response to business demand.

Figure 10: Number of wagons per country



Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

Namibia did not own any wagons until 1990 following political independence. All wagons before then reflect the allocation from South African Railways that was possibly stationed in Namibia. Namibia's average wagon fleet decreased by 4.4% between 1990 and 2018. The decline has been primarily due to lack of maintenance of the wagon fleet over the years.

The number of wagons in use by Rhodesia Railways in Rhodesia (Zimbabwe) increased from 2 856 in 1940 to 8 943 in 1970 in response to growth in traffic and funding from World Bank, AfreExim, Anglo-American Cooperation and Railways Contributory Pension Fund (Tow, 1960; Rhodesia Railways Annual Reports, various years) to Rhodesia Railways in the 1950s. This was followed by another increase of 8.8% to reach its peak of 13 495 in 1980. The trend reversed post-independence and continued on the decline up to 2018. The decline between 1980 and 2018 was 74.1%.

No new acquisitions were made, and the existing stock suffered from severe lack of maintenance. The steep decline in the number of wagons between 1990 and 2018 was due to scrapping of life expired wagons, lack of investment in new wagons and failure to maintain the current fleet. The collapse of the Zimbabwean economy following the land reform program resulted in the departure of qualified technical staff, shortage of foreign currency to import spare parts and lack of funding to invest in new wagons.

Botswana as a country did not own any wagons until 1987 when it separated from the National Railways of Zimbabwe. The wagons before this period are a reflection of the volume of Rhodesia Railways transit traffic that passed through the Botswana rail network. Operating agreements among the railways in SADC demand that the railway from whose network traffic originates should provide wagons to load the traffic. For a transit country like Botswana whose rail traffic was predominantly transit, it was therefore possible for them to exist without wagons.

Wagons for Botswana increased from 153 in 1940 to 1 043 in 1980 followed by a decline of 1.8% between 1980 and 1990. The decline was caused by the separation from Rhodesia Railways which resulted in the latter diverting transit and export traffic *en*-route to South Africa to its network through Beitbridge where the distance was longer compared to only 113km between Bulawayo and the border with Botswana. NRZ would thus earn more revenue over the longer distance on its network than routing the traffic through Botswana.

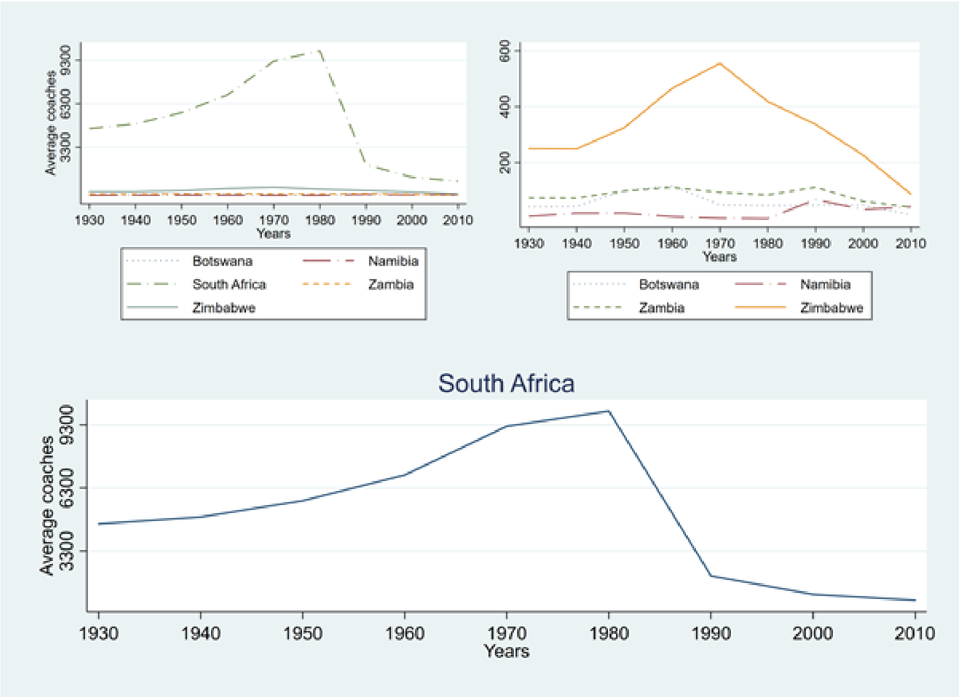
The wagons in use marginally increased between 1990 and 2000 (10.6%) before declining from 1025 in 2000 to 726 in 2013 following diversion of most of the transit line to the BBR line 1999 which had become the shortest route to and from South Africa. Botswana has however refurbished some old wagons, purchased new wagons for soda ash and acid tankers from Transnet Rail Engineering between 2010 and 2018 hence the evident increase in its wagon fleet.

Zambia's wagon fleet in use allocated by Rhodesia Railways increased by 128% from 1 607 in 1940 to 3 659 in 1960 in response to increased demand for rail services during and after World War II. The regional economies grew rapidly soon after the Second World War leading to high demand for rail capacity to support the economic growth. Zambia benefited from the loan funding from World Bank, AfreExim Bank and Anglo American to Rhodesia Railways for the purchase of locomotives and wagons. Post separation from Rhodesia Railways, there an increase between 1970 and 1990 as a result of joint use of Unitary Assets which jointly owned with Rhodesia Railways following the dissolution of the Federation of Rhodesia and Nyasaland. Wagons from TAZARA added to the fleet with effect from 1976. The fleet then declined by 36.7% between 2010 and 2018. The decrease was mainly due to lack of funding for maintenance and acquiring new stock.

3.4.1.4 Coaches

Coaches provide capacity for passenger services. Availability of coaches reflects capacity to provide passenger services given the track and locomotives. Evidence from the sample countries indicates a decline in coaching stock capacity. Figure 11 below shows the trend for coaches in use between 1970 and 2012 for the sample countries.

Figure 11: Number of coaches by country



Source: Own compilation using company Annual and Management Reports, National Statistics databases
Note: Each data point represents an average of ten succeeding years.

The combined coaching fleet for the five countries decreased by 77% between 1940 and 2018 although it had a rising trend during the first four decades. Business was booming during the first four decades because the railways were the major passenger transporter. This necessitated capacity expansion. The marked decline was due to lack of both investment in new coaches and maintenance of the existing fleet. Overall, coaches followed the same trend as locomotives and wagons during the study period. In cases where new coaches were acquired, they in most cases replaced the old ones hence their impact was often cancelled by the old coaches being scrapped.
The coaching fleet in use in Botswana increased from 42 in 1940 to 100 in 1960 under Rhodesia Railways. The number of coaches reached its peak of 117 in 1960 allocated by Rhodesia Railways before declining over time to 47 in 2000. Botswana railways sold off all its coaches in 2010 after deciding to do away with passenger services business because of the losses it generated. However, due to public pressure passenger services were re-introduced in 2016 following purchase of 37 new coaches from Transnet Rail Engineering of South Africa.

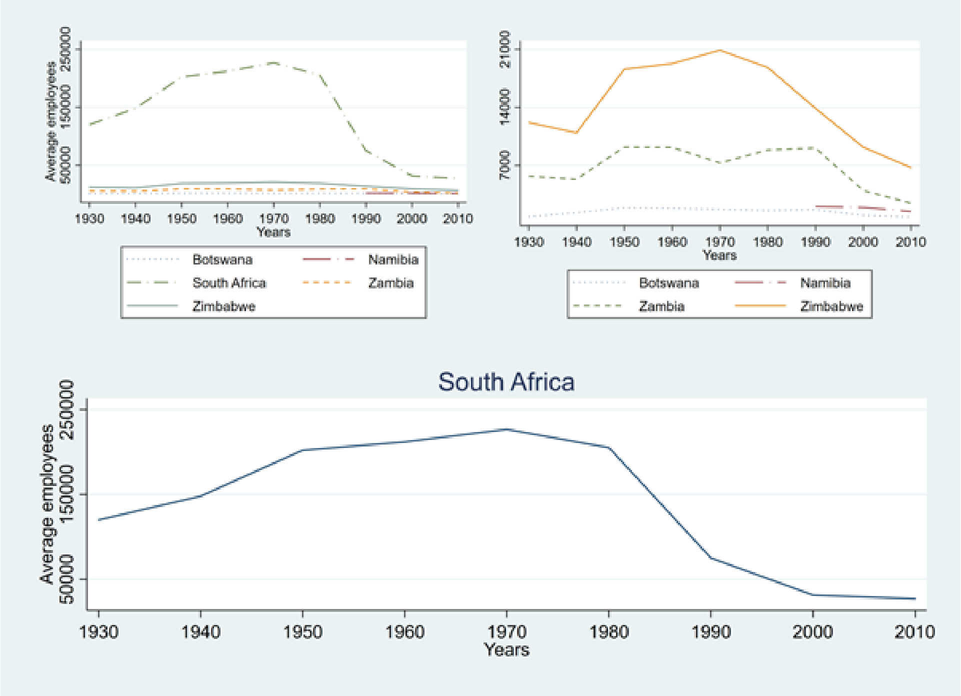
Namibia’s passenger coach fleet declined by 52.9% between 1990 and 2010 due to lack of investment in new coaches and lack of maintenance of faulty available coaches purchased from China. This was followed by an increase of 31.3% between 2010 and 2018. The increase followed the purchase of Diesel Multiple Unit (DMU) sets from China during the same period following the Northline Extension from Tsumeb to Ondangwa.

The average number of passenger coaches for Zimbabwe increased from 250 in 1940 to a peak of 555 in 1980 due to investment in new coaches in the 1950s in response to increased demand for railway transportation services and increased share following the separation of Zambia Railways from Rhodesia Railways. NRZ’s coaching stock was old having been inherited from Rhodesia railways except for the 100 coaches purchased from South Africa to mark the company’s centenary in 1997. The number of passenger coaches for Zimbabwe declined by 74.2% from 1990 to 2018. The sharp decline was due to lack of investment in new coaches and lack of maintenance resulting in obsolescence of the coaches. Old and accident damaged coaches were withdrawn from service without replacement.

3.4.1.5 Employees

Railways are considered among the major employers in most SADC economies. Ideally, the number of employees employed by railways should be based on business volume. However, railways have historically been notorious for overstaffing because of their ownership by government. The average level of employment in railways by country over the study period is shown in Figure 12 below.

Figure 12: Rail Employees by Country



Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

The average aggregate number of employees for the five countries grew from 138 741 in 1940 reaching a peak of 256 621 in 1980. The next four decades saw a sharp decline of 85% to 38 587 in 2018. A closer look at this decline shows that South Africa is the only country whose number of employees declined significantly by 78.6% from 226 734 to 27 148 when the tonnage increased by 23% from 174.9 to 215.1 million tonnes between 1980 and 2018. This may suggest a number of possibilities:

(i) Transnet Freight Rail (TFR) was initially overstaffed but forced by business environment to reduce the number and rationalized staff levels;

(ii) The company has improved managerial and operational efficiency;

(iii) There has been substitution of labour by equipment; and

(iv) Productivity of employees increased leading to less employees being required.

Considering other complementary performance indicators of the rail business, it would seem plausible to conclude that initial overstaffing followed by retrenchment, improved employee productivity and improved organizational efficiency could have jointly contributed to the decline in the number of employees over the years.

The other four countries show a decline in both tonnage and employees suggesting pressure on the railways to reduce the number of employees in sympathy with declining business levels. The percentage reduction in the number of employees is higher than that of tonnage for Botswana, Namibia and Zimbabwe. Zambia is the only country where the percentage reduction in tonnage is higher than the percentage reduction in the number of employees suggesting possible overstaffing.

3.5 Performance Indicators

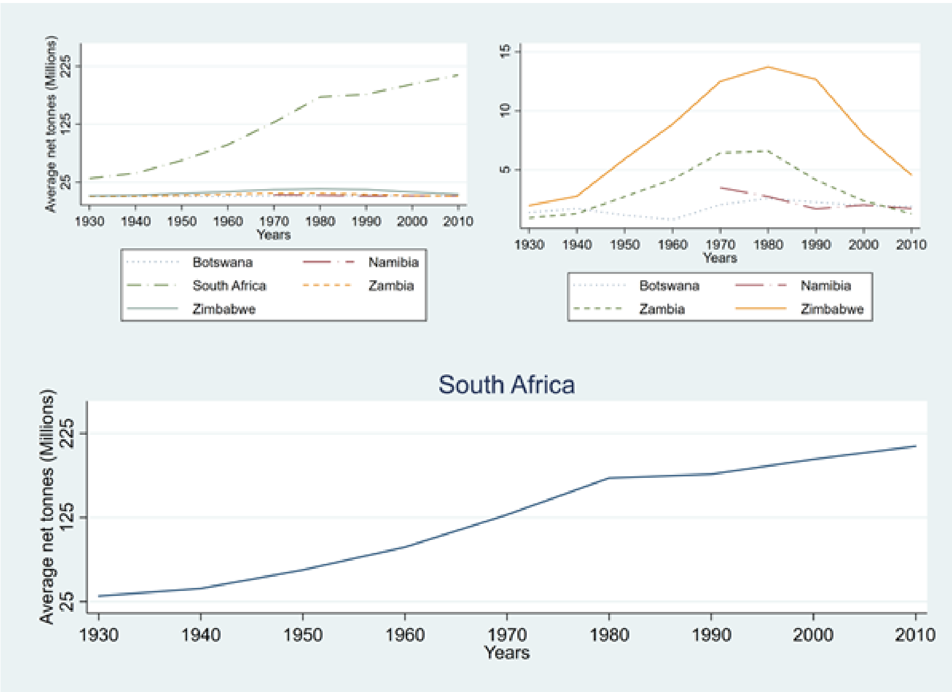
Freight tonnes transported are the main basis of measuring overall performance of any railway operator as the railways exist to move freight and passengers. It is through transportation of goods and passengers that railways contribute to the economy.

3.5.1 Tonnage

Tonnes transported are a good indicator of rail performance given that origins and destinations of railway traffic are relatively fixed over time. Various organisational performance indicators can be derived from tonnage. Figure 13 below shows annual tonnes carried by country.

South Africa has by far the largest rail transporter among the five countries contributing more than the combined tonnage of the other four countries under study. This has to be viewed in the context of the country size, location, economic sectors (mining, agriculture and manufacturing), and railway capacity (rail network size and operating equipment) as highlighted in Tables 1 and 2. Transnet Freight Rail (TFR) benefits from traffic generated by its big local economy. It is estimated that regional traffic constitutes between 7 and 10% of traffic handled by TFR annually[41]. A simple calculation indicates that Botswana, Namibia and Zambia's individual annual tonnage can be moved by South Africa (TFR) in two days while that for Zimbabwe will be done in five days at most!

Figure 13: Tonnes carried by country (000)



Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

Demand for rail transportation services grew rapidly during the Second World War and soon after as economies were booming (Tow, 1960; Jorgensen, 2010). Railways had the monopoly to transport most of the goods hence the rapid growth of traffic during the first two decades from 1940 to 1960. Regional economic growth was sustained beyond 1960 to about 1980. The decline thereafter can be attributed to increasing competition from road following liberalization of the transport sector and declining rail capacity due to lack of investment in new equipment and maintenance of existing equipment. Slow growth was experienced between 2007 to 2009 due to

[41] Transnet (2017).

the global financial crisis which affected demand for minerals and other raw material exports from the five countries.

Even though the tonnage follows the same trend among the five countries reflecting the economic outlook, South Africa's annual tonnage grew at a faster rate and volume when compared to the other four countries. South Africa is the only country that managed to sustain tonnage growth beyond 1990 despite the number of locomotives and wagons showing a general decline. The other four countries recorded a general decline in tonnage from 1980 to 2018 reflecting their failure to move available business due to declining capacity and increased competition from road.

There are however country specific factors that might have contributed to the decline in tonnage. For example, Zimbabwe's tonnage recorded a significant decline from 2000 following adoption of the land reform programme which led to the collapse of the economy. Little traffic was generated from Zimbabwe since then and capacity constraints incapacitate the railways from moving available business and effectively compete against road.

Zambia's average traffic levels were depressed between 1967 and 1970 partially due to the blockade imposed by Rhodesia. Croxton (1973) attributes the decline in Zambia's traffic volumes following the separation from Rhodesia Railways in 1967 to lack of:

(i) maintenance facilities;
(ii) skilled manpower to maintain the locos and wagons; and
(iii) qualified operating staff to run the trains.

In cases where figures were missing, the average haul was used to extrapolate the net tonne kilometres. Zambia's average traffic volume declined 42.8% between 1990 and 2000 due to capacity related challenges arising from lack of funds to invest in the track, locomotives and wagons. This prompted the government of Zambia to concession the railway network for Zambia Railways Limited to Railway Systems of Zambia (RSZ) in 2004 with the hope of securing funding to support investment in infrastructure and improved operations. The condition of the track worsened as no investment was made by the concessionaire.

Railway services further declined during the concession period as the concessionaire excluded some traditional rail traffic like inter-mine traffic and charged the most expensive tariffs along the

North South Corridor.[42] This resulted in the loss of traffic on the corridor to road transporters. All railways on the corridor were thus impacted negatively through the shift of traffic to road transport for the duration of the concession.

The concessionaire's failure to invest in the track, locomotives and wagons and deteriorating services prompted the Government of Zambia to prematurely cancel the concession in 2012 and resume operations as Zambia Railways Limited.

Average annual tonnage carried by TransNamib decreased by 16.1% between 2000 and 2018. The decline was due to capacity related challenges arising from unreliable Chinese locomotives which posed maintenance difficulties and failure to invest in new operating equipment.

Botswana tonnage declined beyond 2000 due to the diversion of transit traffic to the newly constructed BBR line in Zimbabwe linking Bulawayo with Beitbridge to South Africa which became operational in 1999. The BBR line became the shortest route for north and south bound transit traffic.

3.5.2 Net tonne-kilometres (000)

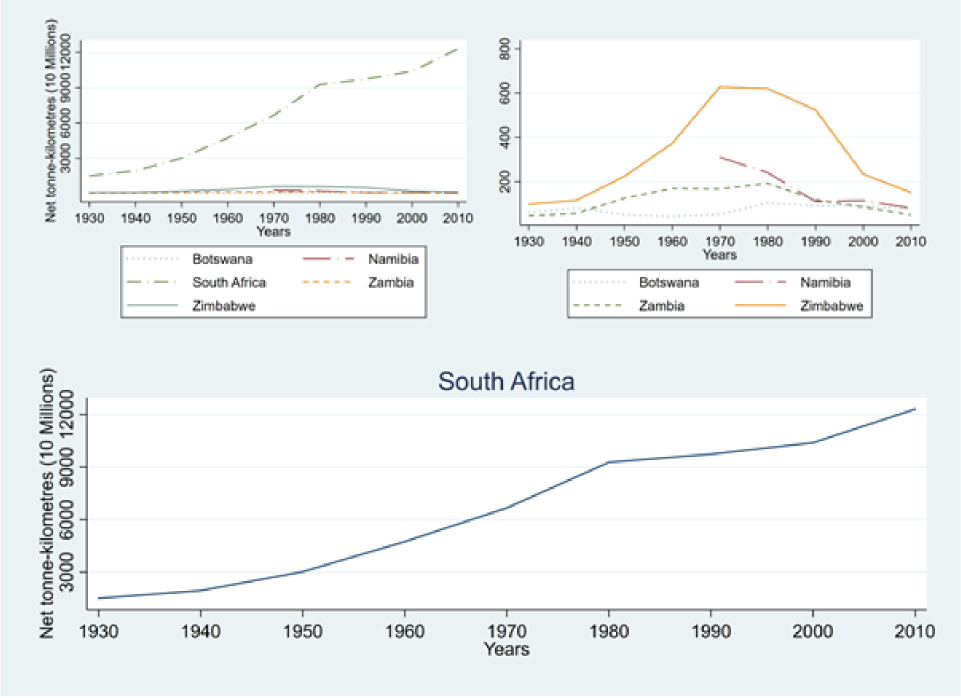
Net tonne-kilometres (NTKMs) are the main indicator of freight business performance of any given railway as they reflect the actual level of activity by taking into account actual tonnes carried and the distance over which they were carried. They are a derivative of net tonnes. The higher the net tonne-kilometres, the higher the level of railway activity and the more revenue the railway operator is expected to earn.

As the main performance indicator, NTKMs have implications on resource requirements and revenue to be generated. Management of railway companies use NTKMs as the primary measure of their performance whose trend should be closely monitored. NTKMs are achieved through the interaction of net tonnes, rail track, locomotives and wagons being coordinated by personnel. An increase in NTKMs ceteris paribus indicates superior performance.

[42] The North South Corridor includes South Africa, Botswana, Zimbabwe, Zambia and Democratic Republic of Congo (DRC).

South Africa's rail level of activity is more than twenty times that of Zimbabwe which is second in terms of size due to the size of the economy and network size. Mining dominates the freight transported. The use of South African ports by landlocked countries like Botswana, Democratic Republic of Congo, Eswatini (formerly Swaziland), Zambia and Zimbabwe also increases the business volumes handled by Transnet freight Rail in terms of traffic. Transit traffic contributes about 10% of total traffic.[43]

Figure 14: Net tonne-kilometres



Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

The similarity between Figures 13 and 14 for net tonnes and net tonne-kilometres respectively confirms that the origins and destinations of rail traffic are relatively fixed. The two Figures maintained the same shape despite the huge gap between units (scale) on the y-axis.

The overall productivity (measured by net tonne-kilometres) of TransNamib declined by 22.3% between 1970 and 1990 followed by a 26.4% decline between 1990 and 2018.

[43] Transnet (2017)

Zambia's net tonne kilometres declined over the years. The concession period of between 2000 and 2012 shows a marked decline.

Average net tonne-kilometres for Zimbabwe declined by 15.5% between 1980 and 2000 followed by a further decline of 55.3% between 2000 and 2010. The overall decline in NTKMs from 1980 to 2018 was 75.5%.

Reasons for changes in NTKMs are the same as for changes in net tonnes carried since NTKMs are a derivative of net tonnes.

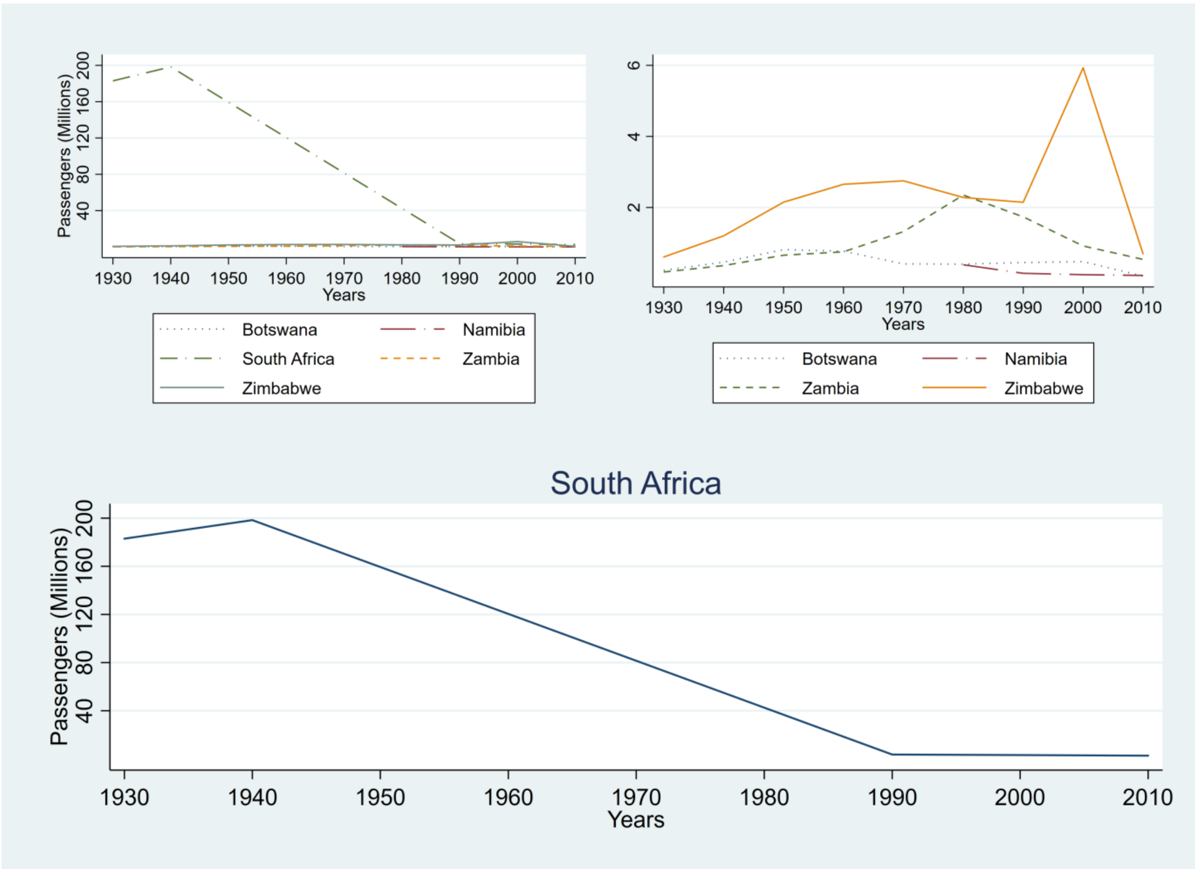
3.5.3 Passengers

Passenger traffic volume indicates the level of business in the passenger services rail sub-sector. Ordinary passenger and urban commuter services are usually loss making hence their classification as social service obligations. This implies that the higher the passenger volumes the higher the losses incurred by the company. While financial benefits from passenger services to the company may be negative, wider economic benefits could be enhanced through improved convenience to the public and employee productivity. Social service obligations should ideally be supported by the government to ensure sustained provision. Botswana Railways terminated its passenger services after selling its coaches in 2009 on the basis that passenger services were loss making. However, due to public pressure BR purchased new 37 coaches in 2016 and re-introduced passenger services.

Figure 15 below shows that passenger volumes for the four countries (Botswana, Namibia, Zambia and Zimbabwe) exhibit a positive trend from 1940 to about 1990 reflecting the early dominance and monopoly position held by the railways in a booming regional economy. The decline of passenger volumes beyond 1990 could have been due increasing competition from road where bigger, faster and luxurious buses were introduced on the market coupled with improvements and expansion of the road infrastructure network. Railways on their part remained slow, rigid, uncomfortable and faced with declining capacity.

South Africa exhibits a consistent and steeper decline of the volume of passengers transported by rail since 1940 reflecting that increased competition from road transport in South Africa started way before the other four countries. The road sector growth took place earlier in South Africa and has been growing ever since, effectively diluting the monopoly enjoyed by rail transport.

Figure 15: Passengers

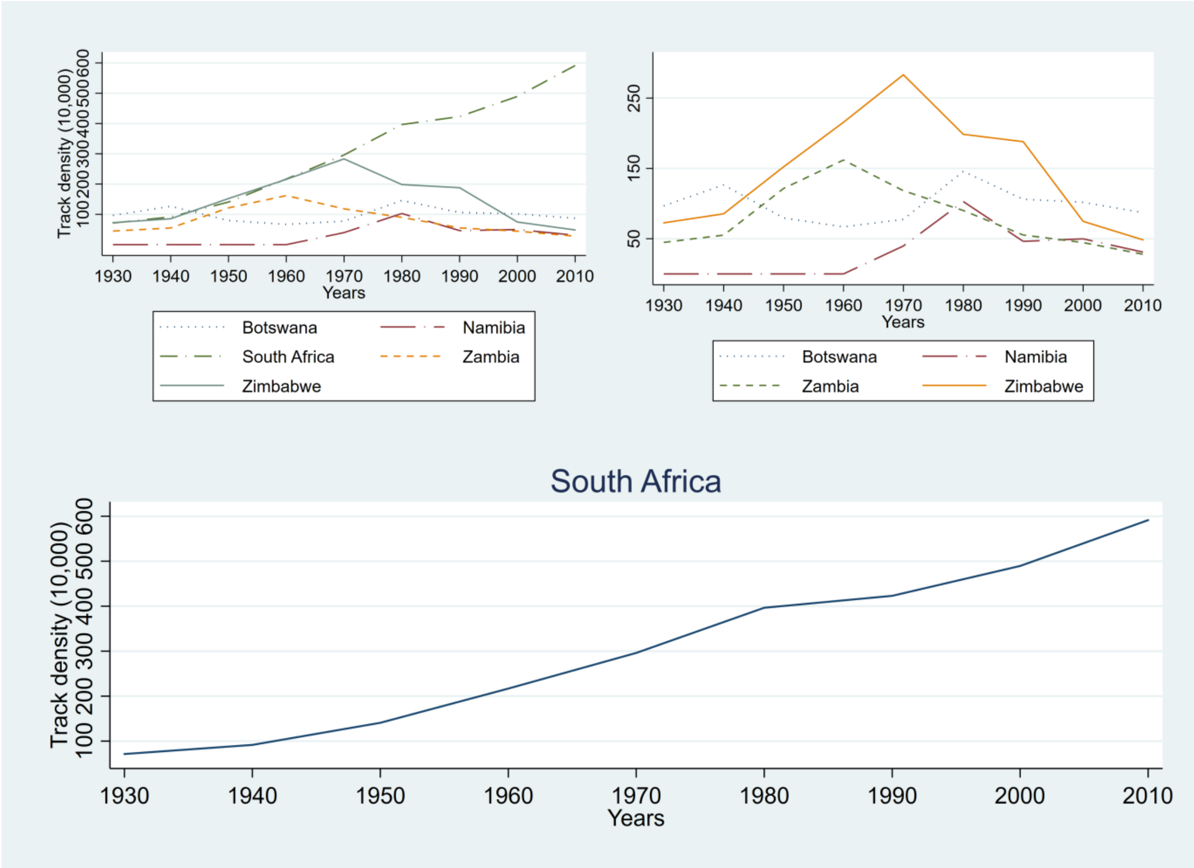


Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

3.5.4 Track Utilization

Utilisation of the rail track is measured by the volume of traffic that passes through the network. Net tonne kilometres per kilometre of track are used to measure the track utilization level. This is also called traffic density. The annual utilization levels for the countries under study are shown in Figure 16 below.

Figure 16: Traffic Density (000)



Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

Traffic density measures the productivity of the rail track. It is measured by net tonne kilometres per kilometre of track annually. This is calculated by dividing the total annual NTKMs by the route length. The higher the traffic density, the higher the utilization level and productivity of the rail track. South Africa maintained superior performance throughout the study period and also recorded continuous increases over the years. This may partially explain South Africa's ability to move more tonnage compared to the other four countries especially considering that its rail route is far bigger than for the other four.

The other four countries indicate an overall decline in traffic density over the years possibly due to capacity challenges arising from the poor condition of the track, locomotives and wagons which impact negatively on train speed. Traffic density may also be influenced by managerial competence and effort.

South Africa has a well-functioning Centralised Train Control (CTC) system introduced in 1955 (Transnet, 2010). The CTC improves capacity of the rail line by allowing more trains to be run at any given time, enhancing safety and operational efficiency. About 38.7%[44] of the rail route kilometres of South Africa is electrified therefore relatively heavier loads can be moved at any given time. Railway electrification in South Africa started as early as 1924 in Natal (Jorgensen, 2010; Transnet, 2010).

Botswana also has a modern CTC system installed in 2008 which improves its line capacity, safety and operational efficiency. Botswana could ideally have high traffic density in view of the CTC it owns and the straight-line configuration of its rail route. However, the traffic density of Botswana is restricted by its reliance on transit traffic. As a country, Botswana does not generate a lot of rail traffic and depends to a greater extent on transit traffic. This may suggest underutilization of the design capacity of the line due to factors beyond the control of management. Recent discovery of huge coal deposits at Mmamabula is likely to change this scenario.[45]

Zimbabwe used to have a CTC system which collapsed in the early 2000s. This could not be replaced due to lack of funding and shortage of foreign currency. The Zimbabwean economy was already struggling by this time. Traffic density for Zimbabwe compared favourably with that of South Africa until the collapse of its CTC system. Zimbabwe also had the 280km section between Dabuka in Gweru and Harare electrified in 1983 which also contributed to improved traffic density. However, all electrical wires and pylons were stolen through organized crime in 2011/2012. Available electric locomotives could not be used going forward. The condition of the track which started to deteriorate in the mid-2000s also contributed to the decline in the country’s traffic density. Lack of funding has made it difficult to maintain the track.

Zambia also had a CTC system at separation from Rhodesia Railways in 1967 which was replaced between 1986 to 1987 (ZRL Facts and Figures, 1987) and later decommissioned due to

[44] Transnet (2016).
[45] Known coal deposits for Botswana are estimated at 202billion tonnes (Botswana Ministry of Minerals, Energy and Water Resources).

obsolescence. This together with the poor condition of the track, locomotives and wagons contributed to the decline in transit density.

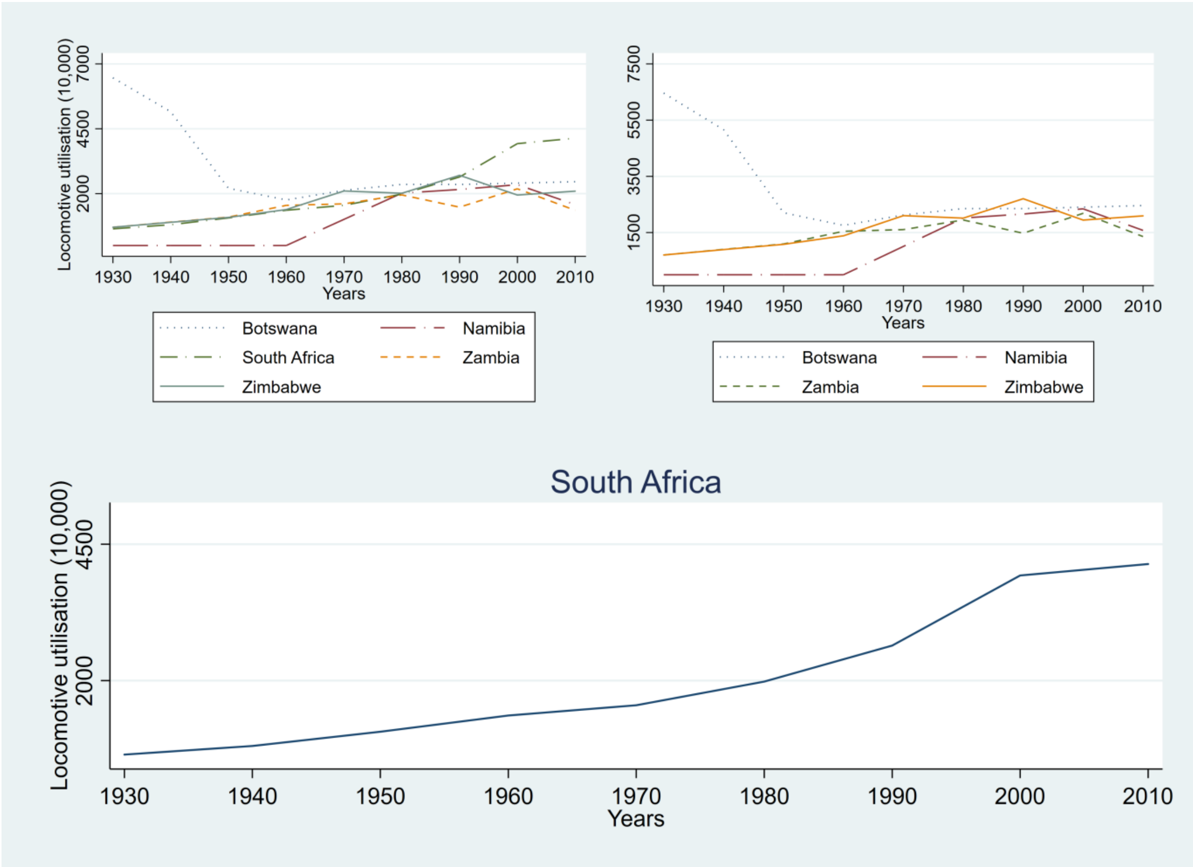
The utilization level of the rail track in Namibia declined by 54.5% between 1980 and 1990 and a further decline of 66.4% between 1990 and 2018. This can be attributed to the poor track and locomotive conditions which contributed to the decline in traffic volumes over the years.

3.5.5 Locomotive Productivity

Locomotives are key operating assets for any rail operator as they are the engines that haul traffic. The productivity level of locomotives is measured by the volume of traffic they carry over distance. This is measured by the net tonne kilometres made by a locomotive in a particular time frame. In this case locomotive productivity is being measured per annum. Locomotive productivity can also be measured using gross tonne kilometres per locomotive. However, where the interest is in revenue earning tonnes which affect the bottom line, net tonne kilometres per locomotive are preferable.

Locomotive productivity is within comparable range across countries over time. However, South Africa's locomotives maintain superior performance from 1990 onwards. The trend is unstable for most of the countries except for Namibia. Locomotive productivity for Namibia is clearly declining over the years due to unreliability of the locomotives. The decline in productivity of Botswana locomotives may be explained by the decline in business over the years due to the construction of new rail routes for Zimbabwe as follows; Rutenga to Maputo line (1955), Rutenga to Beitbridge (1972), Beitbridge Bulawayo Railway (1997). These developments provided alternative routes to and from sea ports for Zambia and Zimbabwe traffic. The separation of Botswana Railways from National Railways of Zimbabwe in 1987 also led to Zimbabwe preferring to use its own network at the expense of the Botswana network.

Figure 17: Net tonne-kilometres per locomotive (000)



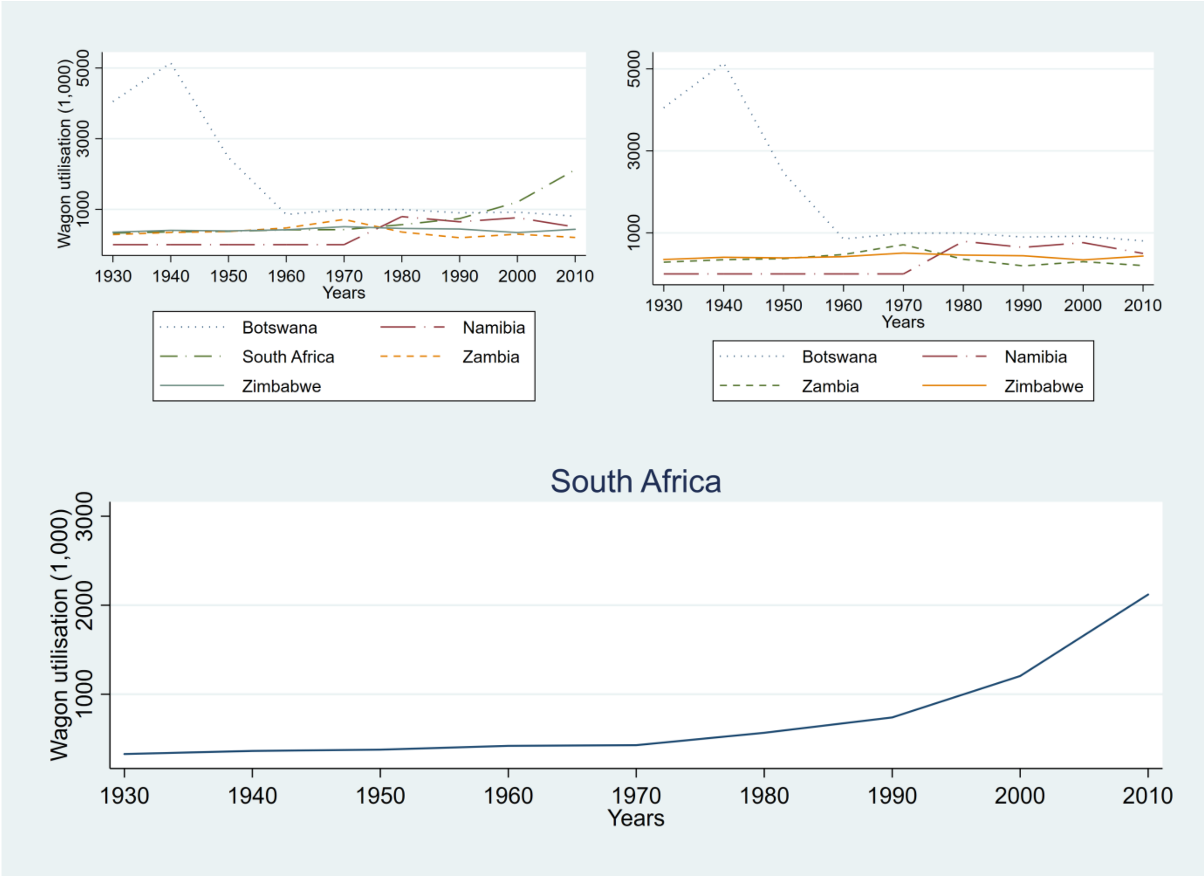
Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years*.

3.5.6 Wagon Productivity

South Africa's wagon productivity has been consistently increasing over the entire study period. South Africa's wagon productivity is superior to that of Botswana beyond 2000. Given that South Africa has a vast rail network and the largest number of wagons, among the five countries, it is plausible to conclude that its wagon productivity is superior.

Botswana has on average wagons with the highest productivity. This is explained by the fact that Botswana has few wagons and is a transit country therefore some of its net tonne kilometres are contributed by foreign wagons which traverse its lines. Its rail route is almost a straight line which requires minimum shunting.

Figure 18: Net tonne-kilometres per wagon (000)



Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

The decline in productivity of Botswana wagons may be explained by the decline in business over the years due to the construction of alternative routes to and from sea ports. The new rail routes for Zambia and Zimbabwe leading Mozambican and South African ports. The separation of Botswana Railways from National Railways of Zimbabwe in 1987 also led to Zimbabwe preferring to mostly use its own rail network at the expense of the Botswana rail route.

Zambia and Zimbabwe also handle transit traffic but have many wagons and relatively bigger railway networks. Their wagon productivity has been declining since 1980. However, Zimbabwe's wagon productivity for 2018 is the highest for the entire study period. This may suggest efficient management of the few wagons left given the more than 76.8% decline in wagon numbers between 1980 and 2018.

3.5.7 Number of Passengers Per Coach

Zambia has the highest number of passengers per coach suggesting increased use of rail passenger services in the country.

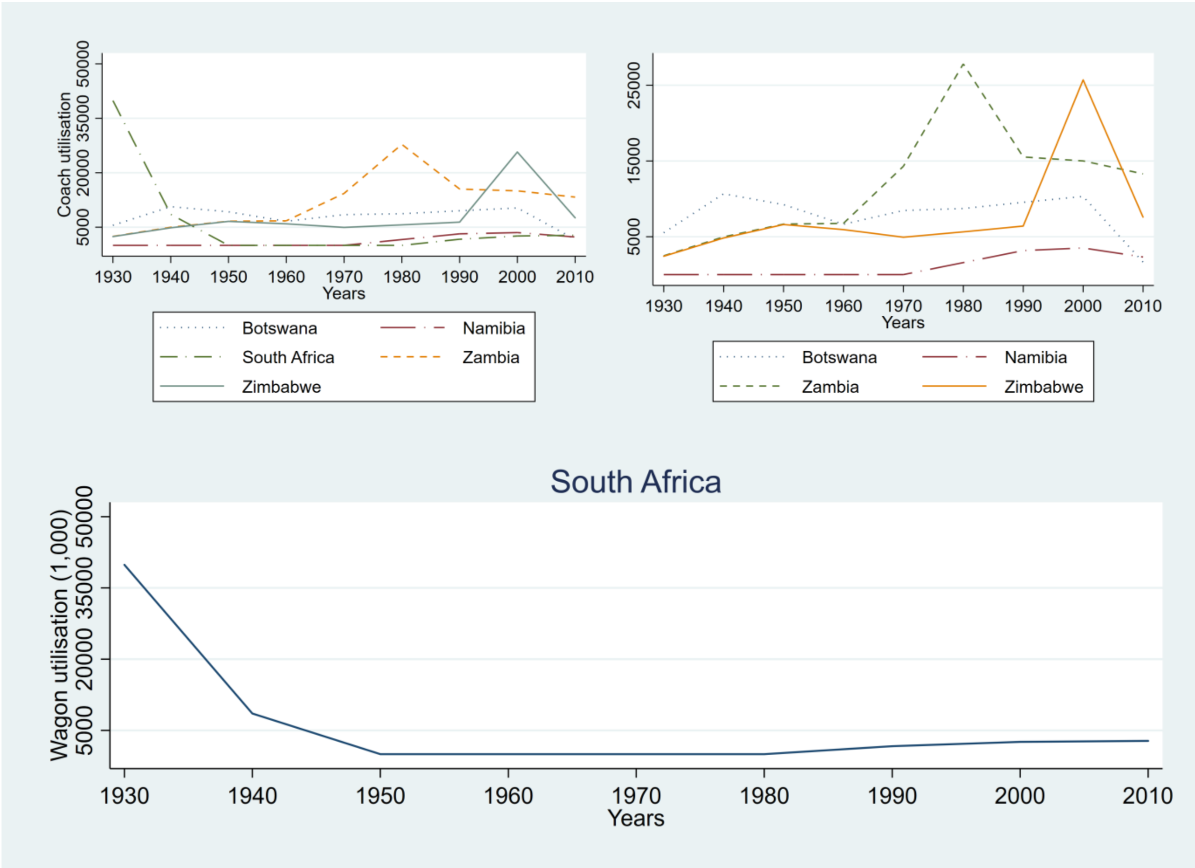
Botswana is second followed by Zimbabwe then South Africa and lastly Namibia. Given that Botswana has a relatively small population, the high coach occupancy may suggest popularity of the passenger train service. This is confirmed by the re-introduction of passenger services in 2016 due public pressure having been discontinued in 2010. The occupancy level in 2018 compares favourably with previous years.

The occupancy levels for Zimbabwe have been increasing with a steep increase of 265% between 1980 and 1990 followed by a decline of 40.3% decline 1990 and 2018. The decline is possibly due to increased competition from road and declining railway passenger services capacity.

South Africa is a big country with a well-developed network, modern luxury coaches on the road and very high connectivity so competition from road is likely to be the major cause of low coach occupancy. The bus and taxi services are more flexible and efficient.

Namibia’s passenger coach occupancy levels have been declining over the years due to increased competition from road and declining capacity.

Figure 19: Passengers per coach



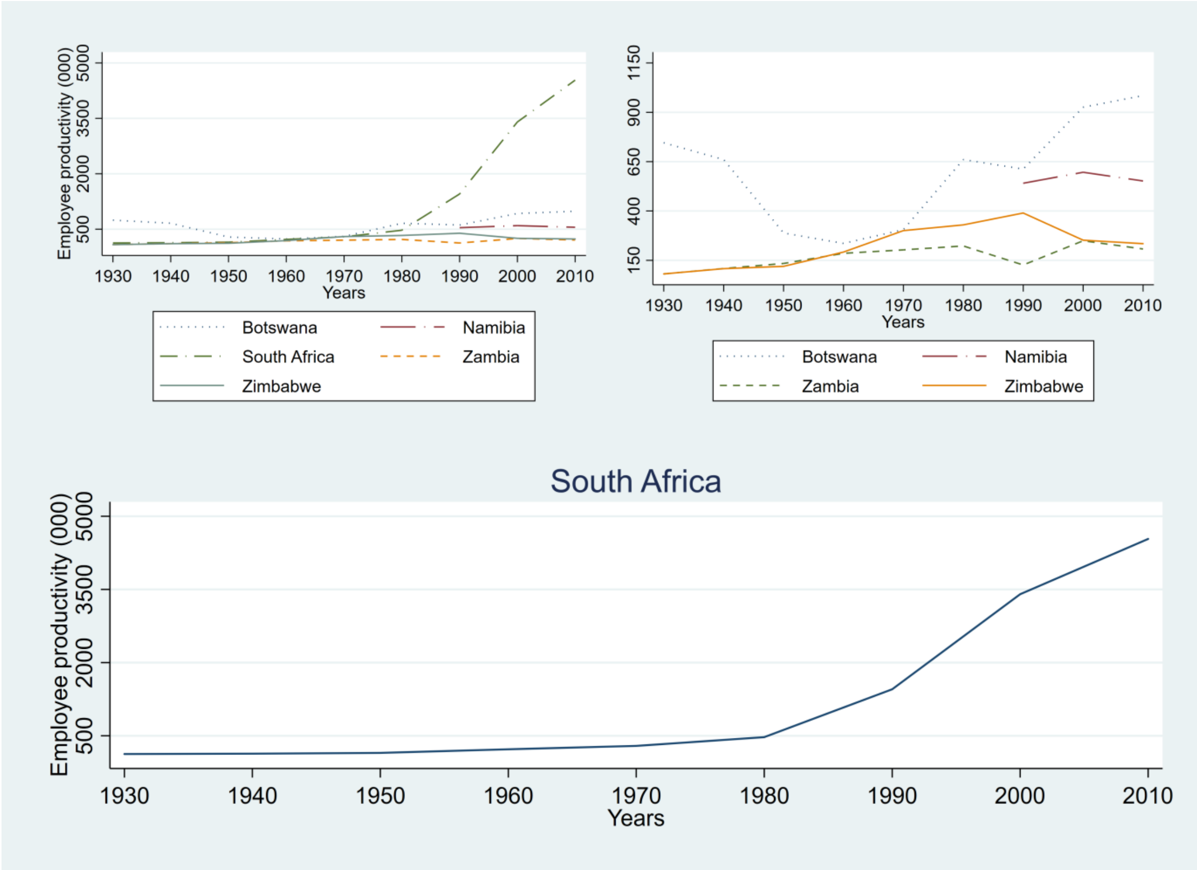
Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

3.5.8 Employee Productivity

Employee productivity is measured by net tonne-kilometres per employee per annum. Respective employee productivity for sample countries is shown in Figure 20 below. It is of concern to management due to its implications on staff levels and profitability.

South Africa has the highest employee productivity between 1990 and 2018. Its employee productivity is increasing throughout the study with a more than twelve-fold between 1980 and 2018. Staff productivity for the other four countries has not even doubled over the same period and is generally declining except for Botswana.

Figure 20: Net tonne-kilometres per employee (000)



Source: *Own compilation using company Annual and Management Reports, National Statistics databases*
Note: *Each data point represents an average of ten succeeding years.*

South Africa's number of employees has been declining when traffic is going up over the years. The country has also been investing in capacity and improving on operational efficiency as demonstrated by its traffic density.

The other four countries appear to have had challenges of declining capacity, declining business and operational challenges which affected employee productivity. Overstaffing could also have had a role to play in the decline of employee productivity.

While South Africa has more capacity than the other four countries in absolute measures, the distinction is less with respect to productivity measures.

3.6 Conclusion

The new rail infrastructure and operational data sets generated for the five SADC countries constitute an important and novel contribution to the understanding of infrastructure development in Southern Africa. Disaggregated data for each country provides opportunities to track and better understand railway developments in each individual country to inform future country specific policy and decisions. What emerges from the descriptive analysis of rail infrastructure capacity and performance trends is that economic, geostrategic, policy and institutional factors drive investment in rail infrastructure and railway operational performance. The finding concurs with the driving forces behind rail infrastructure development in Southern Africa as highlighted in the preceding chapter on Evolution of Railway Networks in Five Southern African Development Community Countries. This outcome highlights country specific issues that have economic, political, policy, managerial and implications. The country specific data sets also provide a basis for country specific interventions and can facilitate future research on the individual countries.

South Africa emerges as the best performer among the five countries under study based on infrastructure measures and performance indicators. South Africa's capacity was rising up to 1980 and declines thereafter, with a mirror image in terms of efficiency measures which fall to the 1980/90 period and then sharply rise. The story for Botswana, Namibia, Zambia and Zimbabwe is that of declining capacity and efficiency. Evidence provided by analysing data trends indicates a marked decline in railway capacity between 1940 and 2018 for Botswana, Namibia, Zambia and Zimbabwe. There has not been significant growth in the length of the rail track as measured by route kilometres.

Locomotives, wagons and coaches show a significant decline in four countries except for South Africa. Overall, rail capacity declined significantly suggesting lack of investment. Apart from the four countries benchmarking their rail investment policies and operations on South Africa, the analysis can form the basis for the identification of areas of possible cooperation among regional railways and the development of a regional rail strategy.

The decline in rail capacity and increased competition from road appear to have resulted in a decline in rail performance measured by various indicators. NTKMs which are the main indicator of rail performance declined despite the fact that the economies under study recorded significant growth in GDP over the years.[46] It would appear that investment in rail infrastructure did not respond to the growth of the economies beyond 1980. Given that rail transport has a number of advantages over road transport, the distribution of traffic between these two surface transport modes has implications on the competitiveness of regional products.

The brief literature survey helped to provide the context of rail infrastructure development and their performance. Shortcomings of current government policy were highlighted through the literature review. Rail challenges and their causes were identified and recommendations on the way forward suggested.

The experience of the five railways in the SADC region provides a challenge pertaining to the determinants of investment in rail infrastructure. Identification of the determinants of investment in rail infrastructure will guide policy makers in improving investment in the rail sector by creating an enabling environment. The next paper focuses on the determinants of investment in rail infrastructure.

[46] Zimbabwe's economic performance declined significantly from 2000 to 2018.

Appendix 3.1 **Data Dictionary**

VARIABLE	CAPACITY/BUSINESS MEASURES	Unit	Purpose
CAPACITY			
Rail Track	Route kilometres of railway track	km	Railroad
Locomotive	Engine which pulls wagons and coaches	Number	Motive power
Wagon	Truck where goods are loaded	Number	Rolling stock
Coach	Special type of wagon which carries people	Number	Rolling stock
Employees	Total number of rail workers in a year	Number	Labour
RAIL INFRASTRUCTURE			
Freight Rail Infrastructure -FI	Composite of Track, Wagon, and Locos	Index	Freight Business
Passenger Rail Infrastructure - PI	Composite of Track, Locos and Coach	Index	Passenger Business
Mixed RailInfrastructure - MI	Composite of Track, Wagon, Coach and Locos	Index	Mixed business
Track Infrastructure-TTI	Railroad length in kilometres	Number	Rail route length
BUSINESS VOLUME/PRODUCTIVITY			
Net tonnes – NT/nt	Total of tonnes of freight transported per year	Number	Volume of freight
Net tonne kilometres-NTKM/ntkm	Product of net tonnes and haulage distance	Number	Volume of freight business
Passengers -pax	People transported by train per year	Number	Volume of passengers

Passenger kilometres - PAXKM	Product of number of passengers and distance travelled	Number	Volume of passenger business
PERFOMANCE/PROUCTIVITY INDICATORS			
Traffic density	NTKM per kilometre of track (NTKMTRK)	Number	Efficiency measure
Locomotive Utilization	NTKM per locomotive (NTKMLOC)	Number	Efficiency measure
Wagon Utilization	NTKM per wagon (NTKMWG)	Number	Efficiency measure
Coach Utilization	Number of Passengers per coach (PAXCHA)	Number	Efficiency measure
Coach Utilization	Passenger coach kilometres (PAXCHAKM)	Number	Efficiency measure
Employee Productivity	NTKM per employee (NTKMEMPL)	Number	Efficiency measure

Appendix 3.2 **Data Sources**

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Appendix 3.3 Descriptive Statistics - Individual Countries Infrastructure Composite Indices

Botswana

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max	CV
FRII	80	0.56	0.35	0	1	62.21
PRII	78	0.55	0.33	0	1	60.40
MRII	78	0.54	0.38	0	1	70.68

Namibia

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max	CV
FRII	76	0.22	0.27	0	1	122.16
PRII	76	0.24	0.26	0	1	110
MRII	76	0.26	0.29	0	1	111.12

South Africa

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max	CV
FRII	80	0.40	0.31	**0**	1	77.49
PRII	80	0.40	0.28	0	1	70.11
MRII	80	0.40	0.29	0	1	72.80

Zambia

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max	CV
FRII	80	0.34	0.26	0	1	76.90
PRII	80	0.50	0.27	0	1	54.12
MRII	80	0.50	0.27	0	1	54.41

Zimbabwe

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max	CV
FRII	80	0.45	0.33	0	1	73.05
PRII	80	0.44	0.23	0	1	52.86
MRII	80	0.44	0.27	0	1	59.97

Appendix 3.4 **Individual Countries Descriptive Statistics**

Botswana

Variable	**No. of Obs.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**CV**
Track	80	744	110	641	888	15
Locos	80	30	11	8	51	35
Wagons	80	671	379	150	1309	57
Coaches	78	59	38	0	147	63
Employees	80	1474	432	682	2167	29
Tonnes	80	1781469	808993.4	397753.6	4374534	45.41
Passengers	78	494147.7	251790.8	0	1039045	50.95

Namibia

Variable	**No. of Obs.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**CV**
Track	80	2377	107	2192	2682	5
Locos	76	23	26	0	123	116
Wagons	76	664	838	0	3125	126
Coaches	76	24	29	0	169	119
Employees	29	1829	324	1269	2488	18
Tonnes	42	2137065	666670	1428833	3975000	31.20
Passengers	30	124087.7	63992.75	61000	388000	51.57

South Africa

Variable	**No. of Obs.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**CV**
Track	80	21955	1164	20247	24487	5
Locos	80	3377	807	2330	5273	24
Wagons	80	105661	41478	46145	176508	39
Coaches	80	5172	3362	817	10945	65
Employees	80	142167	80876	25051	252739	57
Tonnes	80	1.32e+08	6.25e+07	3.17e+07	2.64e+08	47.34
Passengers	28	2.35e+07	6.00e+07	1750000	2.03e+08	255.42

Zambia

Variable	No. of Obs.	Mean	Std. Dev.	Min.	Max.	CV
Track	80	1569	502	1007	2141	32
Locos	80	83	33	25	151	40
Wagons	80	3514	1747	1598	9263	50
Coaches	80	85	25	38	139	29
Employees	80	6966	2815	0	13023	40
Tonnes	80	3612004	2064328	728257.1	7076000	57.15
Passengers	80	1074629	684407.4	183743	2684202	63.69

Zimbabwe

Variable	No. of Obs.	Mean	Std. Dev.	Min.	Max.	CV
Track	80	2348	754	1344	3394	32
Locos	80	203	88	61	403	43
Wagons	80	8189	4010	2764	14189	49
Coaches	80	335	149	58	676	44
Employees	80	14859	5185	5079	21844	35
Tonnes	80	8536773	4043372	1661387	1.44e+07	47.36
Passengers	80	2474917	2074066	210000	1.19e+07	83.80

Appendix 3.5 **Ten Year Averages of Data Observations**

Railway length by country (km)

Year	(1) Botswana mean	(2) Namibia mean	(3) South Africa mean	(4) Zambia mean	(5) Zimbabwe mean	Total
1930	641	2354	21184	1034	1361	26574
1940	641	2354	21234	1033	1355	26617
1950	641	2354	21453	1030	1460	26938
1960	641	2339	21853	1045	1705	27583
1970	690	2340	22444	1518	2250	29242
1980	714	2340	23413	2137	3140	31744
1990	871	2382	23076	2141	2796	31266
2000	888	2302	21306	1931	3127	29554
2010	888	2629	20823	1791	3127	29258
Average	735	2377	21865	1518	2258	28753

Notes:

Average number of locomotives in use by country

Year	(1) Botswana mean	(2) Namibia mean	(3) South Africa mean	(4) Zambia mean	(5) Zimbabwe mean	Total
1930	10	16	2349	66	140	2581
1940	17	7	2425	63	130	2642
1950	22	4	2834	115	208	3183
1960	23	1	3472	116	275	3887
1970	25	0	4278	105	300	4708
1980	44	21	4703	100	308	5176
1990	39	51	3696	79	203	4068
2000	38	50	2657	43	120	2908
2010	32	51	3017	41	75	3216
Average	28	22	3270	81	195	3597

Notes:

Average number of wagons per country

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	153	33	46145	1622	2803	50756
1940	157	22	53839	1650	2856	58524
1950	231	14	80024	3371	5794	89434
1960	483	9	112667	3649	8943	125751
1970	526	5	155199	2476	12406	170612
1980	1043	521	164053	5711	13495	184823
1990	1024	1708	134204	6020	11821	154777
2000	994	1506	87792	2862	6766	99920
2010	991	1633	58771	2457	3500	67352
Average	623	606	99188	3313	7598	111328

Notes:

Average number of coaches per country

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	42	8	4588	74	250	4962
1940	43	19	4916	73	249	5300
1950	100	19	5690	99	325	6233
1960	117	7	6913	112	466	7615
1970	49	2	9232	94	555	9932
1980	46	0	9950	85	419	10500
1990	47	68	2116	112	337	2680
2000	48	32	1236	61	226	1603
2010	14	42	957	41	87	1141
Average	56	22	5066	83	324	5552

Notes:

Average number of employees per country

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	833		120021	5714	12173	138741
1940	1317		147974	5333	10936	165560
1950	1897		202225	9208	18605	231935
1960	1844		212047	9175	19277	242343
1970	1702		226734	7307	20878	256621
1980	1572		205336	8854	18811	234573
1990	1656	2053	75080	9098	13881	101768
2000	1010	1940	31508	3975	9193	47626
2010	786	1457	27148	2452	6744	38587
Average	1402	1817	138675	6791	14500	161973

Notes:

Average net tonnes

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	1379781		31700279	921115	1962508	35963683
1940	1699732		40586160	1274278	2756000	46316170
1950	1152444		62708525	2719827	5909901	72490697
1960	766120		89827066	4167601	8850269	103611056
1970	2038096	3478333	128340383	6423323	12482000	152762135
1980	2569927	2729100	172035320	6581600	13737900	197653847
1990	2245200	1669400	176613200	4128880	12663000	197319680
2000	1951300	2013200	194289936	2361362	7997200	208612998
2010	1878835	1689413	209803333	1274502	4550883	219196966
Average	1742382	2315889	122878245	3316943	7878851	137103026

Notes:

Average net tonne-kilometres (10 Millions)

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	62		1511	46	99	1718
1940	81		1946	57	116	2200
1950	51		3021	125	224	3421
1960	43		4741	169	373	5326
1970	52	310	6665	168	628	7823
1980	104	241	9273	193	620	10431
1990	92	110	9734	118	524	10578
2000	90	115	10392	85	234	10916
2010	77	81	12306	50	152	12666
Average	73	171	6621	112	330	7231

Notes:

Passengers (000)

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	232		182949	184	606	183971
1940	461		198381	364	1202	200408
1950	813			656	2149	3618
1960	768			752	2653	4173
1970	411			1319	2750	4480
1980	405	388		2349	2282	5424
1990	450	146	3620	1738	2146	8100
2000	476	109	3175	916	5932	10608
2010	68	87	2673	539	694	4061
Average	454	183	78160	980	2268	47205

Notes:

Traffic density

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	968645	0	713379	448700	726148	2856872
1940	1266254	0	916165	551141	855340	3588900
1950	796372	0	1407630	1215341	1522980	4942323
1960	669120	0	2168374	1619904	2156581	4457398
1970	776016	397672	2961287	1183346	2832166	8150487
1980	1458753	1028940	3965744	901715	1985045	9340197
1990	1061598	463566	4230769	553083	1880951	8189967
2000	1018694	498986	4895247	445624	747410	7605961
2010	871348	310624	5913828	279501	484529	7859830
Average	987422	299976	3019158	799817	1465683	6332437

Notes:

Locomotive utilization (000)

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	64615	0	6433	7036	7036	85120
1940	51583	0	8015	9030	8952	77580
1950	22061	0	10629	10950	10829	54469
1960	17566	0	13596	15471	13860	60493
1970	21274		15482	16069	21029	773854
1980	23552	20189	19817	19498	20147	103203
1990	23528	21603	26419	14776	27051	113377
2000	24049	23452	39277	21863	19453	128094
2010	24612	15783	41373	13595	20946	116309
Average	30316	10128	20116	14254	16589	168056

Notes:

Net tonne-km per wagon

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	4051572	0	327494	286029	352578	5017673
1940	5144030	0	362041	345680	406682	6258433
1950	2465717	0	376501	372677	390763	3605658
1960	854677	0	419473	473706	421384	2169240
1970	991851	0	426971	712616	508497	2639935
1980	997516	794657	565970	357606	459052	3174801
1990	900379	646720	738552	197470	443577	2926698
2000	920091	763206	1204105	298101	341961	3527464
2010	806126	499142	2120230	204998	435801	4066297
Average	1903551	300414	726815	360987	417811	3709578

Notes:

Coach utilization

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	5532	0	39876	2483	2423	50314
1940	10672	0	8561	4982	4835	29050
1950	9236	0	0	6667	6609	22512
1960	6644	0	0	6770	5939	19353
1970	8469	0	0	14305	4938	27712
1980	8725		0	27825	5642	42192
1990	9544	3171	1680	15527	6407	36329
2000	10322	3518	2585	15014	25710	57149
2010	1654	2321	2791	13301	7595	27662
Average	7866	1126	6166	11875	7789	34697

Notes:

Employee productivity (000)

	(1)	(2)	(3)	(4)	(5)	
Year	Botswana mean	Namibia mean	South Africa mean	Zambia mean	Zimbabwe mean	Total
1930	746		126	81	81	1034
1940	661		133	109	108	1011
1950	289		149	134	120	692
1960	236		223	186	192	837
1970	306		292	203	301	1102
1980	661		472	223	330	1686
1990	612	541	1453	127	390	3123
2000	926	596	3402	249	252	5425
2010	985	552	4535	208	234	6514
Average	602	563	1198	169	223	2381

Notes:

CHAPTER FOUR

DETERMINANTS OF RAIL INFRASTRUCTURE INVESTMENT IN FIVE SOUTHERN AFRICAN DEVELOPMENT COMMUNITY COUNTRIES

4.1 Introduction

This chapter seeks to identify economic, geostrategic and institutional determinants of investment in rail infrastructure in Botswana, Namibia, South Africa, Zambia and Zimbabwe. We justify the need for rail in the economy, analyze the surface transport policy context in the five countries and review the rail infrastructure investment challenges in the Southern African Development Community (SADC) region. This is followed by the estimation of the investment functions for rail infrastructure.

The preceding chapter on descriptive analysis of rail infrastructure and performance highlights the declining economic role of railways in the five SADC countries under study as a result of lack of investment. Lack of investment in rail infrastructure and deteriorating rail performance in Africa is a major concern to policy makers and users of rail transport[47] as it resulted in the decline of railway capacity and rail transport services leading to loss of market share to road transport. The shift of traffic from rail to road transport has negative cost implications on the economy and regional competitiveness as rail is cheaper than road and suitable for bulk carriage required by developing countries. Most of the SADC economies are mineral and agro-based making rail the ideal transport mode given the bulk nature of these commodities and the long distances to the markets and sea ports.

In view of the potential of rail to make a positive contribution to the national and regional economies due to its advantages as a transport mode, this chapter seeks to identify drivers of rail infrastructure investment to inform policy. We frame the determinants of rail infrastructure investment basing on economic, geostrategic and domestic institutional drivers as identified through the historical review in Chapter 2 and descriptive analysis of rail infrastructure and

[47]The concern is raised in for example, the Brazzaville Declaration of 2006 made by African Union Ministers responsible for rail transport.

operational performance in Chapter 3. To achieve this, we use a novel dataset on rail infrastructure of five countries in SADC for the 1960-2018 period to estimate the impact of economic, geostrategic and institutional factors on investment in rail infrastructure within a flexible accelerator framework. The investment functions for rail and road infrastructure are estimated using a cointegration approach based on a novel dataset of rail infrastructure measures constructed through principal component analysis. Separate infrastructure indices are constructed to represent capacity for freight, passenger and mixed business segments.

The preceding Chapter on the descriptive analysis of rail infrastructure and operational performance draws a very strong distinction between South Africa and the other four countries in the study sample. In view of this distinction, we employ the Bounds Test technique of Pesaran, Shin and Smith (2001) for time series analysis in the case of South Africa and the Pooled Mean Group (PMG) estimator for heterogenous panels of Pesaran, Shin and Smith (1999) on the panel comprising of Botswana, Namibia, Zambia and Zimbabwe. The distinction makes it easier to evaluate the different drivers of rail infrastructure investment in different contexts.

Panel cointegration tests confirm the existence of a long term relationship between rail infrastructure measures and economic and institutional measures. The existence of a stable long-run equilibrium relationship is investigated through the Pooled Mean Group (PMG) estimation technique for dynamic heterogeneous panels of Pesaran, Shin and Smith (1999). The strength of the PMG estimator is that it is consistent with both the underlying theory of a homogeneous long-run investment relationship and the possibly heterogeneous dynamic time-series nature of the data. The extended flexible accelerator model by Bond, Elston, Mairesse and Mulkay (1997) is used as the basis of empirical estimation. The model is augmented to incorporate economic, geostrategic and institutional variables to capture unique features of developing countries. The average adjustment coefficient of over 100% statistically significant at all levels in all empirical specifications for the four country and South African cases confirms rapid convergence and existence of a stable long-run relationship.

Research results suggest that economic, geostrategic and institutional factors matter for investment in rail infrastructure investment. Crucially, the results suggest systematic policy bias against rail infrastructure investment in favour of road infrastructure investment. Compared to rail, road infrastructure investment appears to have more resources from the fiscus due to the supportive institutional framework.

The contribution of this paper is four-fold. Firstly, the study contributes to existing literature by applying the PMG/MG and the Bounds Test estimation techniques using a novel dataset comprising of rail infrastructure capacity indices for the four SADC countries and South Africa respectively. The new dataset will be useful for further research on railways in these countries. Secondly, it is the first study to estimate rail infrastructure investment functions for the four SADC countries in a panel data setting. Thirdly, the analysis of rail efficiency measures provides new policy and managerial insights. Fourthly, the paper identifies the determinants of rail and road infrastructure investment in the five SADC countries. This is important for informing policy which may help to improve investment in rail infrastructure in these countries.

This chapter is structured as follows; section 4.2 provides a background to the study and policy context[48], followed by a review of literature in section 4.3 which covers theoretical and empirical perspectives of investment in infrastructure. We estimate the empirical model, interpret, and discuss results in section 4.4. Section 4.5 concludes by evaluating research findings, concluding and making recommendations.

4.2 Background and Policy Context

This section presents the potential benefits of using rail transport and sets out the policy context for rail and road transport as it relates to the institutional framework and funding in the five countries under study. It is observed that road transport has an elaborate funding institutional framework which supports road infrastructure development and maintenance. On the contrary, rail does not have a clearly defined institutional framework to support development and maintenance. Hence the challenges rail is facing. This section highlights important policy issues which will help in the interpretation of results of estimated rail and road infrastructure investment functions.

[48]Detailed background to rail infrastructure investment in the five SADC countries is contained in Chapter 3 on the Descriptive Analysis of Investment in Rail Infrastructure and Performance.

4.2.1 The case for rail transport

Africa has the highest transport costs compared to other continents due to inefficiency and use of road transport which is a relatively more expensive transport mode[49]. Competitiveness and economic growth are negatively impacted as a result. This challenge may be addressed through increased use of rail transport which is a relatively cheaper transport mode.

Fuel efficiency, environmental friendliness, relatively lower tariffs as well as lower external costs are desirable attributes of rail transport that can help reduce transportation costs. The advantages of rail compared to road transport are summarized below (OECD, 1997; Forkenbrock, 2001; Association of American Railroads, 2008; Australasian Railway Association, 2011; Maibach *et al*, 2008; Amos, 2009; Krohn, Ledbury & Schwarz; 2009).

(i) Fuel efficiency - rail is four times more fuel efficient than road measured on a tonne kilometre per litre basis. This is particularly important to SADC countries given that fuel is an imported finite resource whose price is rising. Increased use of rail will lead to fuel savings and alleviation of the fiscal burden that often confronts developing countries.

(ii) Lower cost per tonne kilometre – the lower average freight cost per tonne kilometre of rail of less than one fifth that of road positively contributes towards competitiveness through lower transportation costs.

(iii) Lower emission levels - transportation by rail will help to protect the environment due to lower emission levels which are one third those of road.

(iv) Lower external costs - external costs[50] of road transport are above three times those of rail (Maibach *et al*, 2008; Amos, 2009; ARA, 2011; OECD, 1997; Forkenbrock, 2001). Society stands to benefit through improved environment and welfare arising from increased use of rail.

(v) Reducing congestion on roads-a single train load equates to many road truck loads. A shift of traffic from road to rail transport reduces the number of trucks on the road and

[49]For example (UNCTAD, 2003; Agenor & Moreno-Dodson, 2006; Mbekeani, 2007; Naude & Matthee, 2007; Gwilliam, 2011) make this observation.

[50] These are measured in terms of accidents, air pollution, greenhouse gases and noise.

congestion. Consequently, demand for new roads, road maintenance costs and fuel consumption is reduced.

(vi) Mass transit - improved mobility can be achieved through mass transit solutions provided by rail in urban centres and reduced congestion on the roads.

(vii) Lower land requirements - construction of rail lines requires less land compared to road. This has a positive impact on the use of land which is a finite resource and less disturbance to the environment.

The forgoing suggests that rail can help address economic, financial, and environmental sustainability. Rail is therefore considered to be an appropriate surface transport mode to promote sustainable growth in most developing countries.

Historically, rail made a positive economic contribution on the African continent by facilitating trade, investment and creating an enabling environment (Luiz, 2010). Despite the relevance of rail, the challenge for Southern Africa is the lack of investment in rail infrastructure. This has led to loss of traffic from rail to road. Lack of investment in rail infrastructure has resulted in the decline in rail capacity and inability to move available traffic. The competitiveness of Southern Africa may be improved by a shift of traffic from road to rail transport through reduced transportation costs.

Inadequate infrastructure capacity has also resulted in African railways' failure to translate growth in GDP into increased volumes of freight traffic (Foster & Briceno-Garmendia, 2010; Ncube & Lufumpa, 2017). The loss of rail traffic in Southern Africa may also be attributed to war and natural disasters (Foster & Briceno-Garmendia, 2010). Angola, Democratic Republic of Congo (DRC) and Mozambique were affected by civil war, whereas Malawi together with Mozambique were affected by natural disasters specifically Cyclone Eline of year 2000. While these three countries are not part of the study sample countries, their railway networks are connected to the sample countries allowing for interchange of traffic and also Mozambique and Angola's seaports were used by the landlocked countries of mostly Zambia and Zimbabwe.

In the case of the European Union, policies were developed to shift traffic from road to rail (Thompson, 2007). Such deliberate policies will not achieve the intended results unless rail infrastructure capacity can accommodate new traffic. Zambia for example, introduced Statutory Instrument 7 (SI7) in 2018 which directed that at least 30% of freight should be transported by rail but failed to achieve the intended results because rail capacity in Zambia was inadequate to absorb the additional traffic.

4.2.2 Rail infrastructure investment challenge

Rail infrastructure investment is a global challenge that has been ascribed to failure of the current policy and institutional framework to address future rail infrastructure investment (Thompson, 2007). Evidence indicates that the share of rail infrastructure to global infrastructure has been declining over the years. For example, an analysis of the global infrastructure mix by Fay and Yepes (2003) revealed that rail infrastructure share of total global infrastructure dropped from 29% in 1960 to 6% in 2000 whereas for road the drop was from 47% to 44% during the same period.

Investment in infrastructure is one of the main responsibilities of government. Governments spend significant amounts of funds on infrastructure to support economic growth. In the African context, government’s annual spending on transport infrastructure constitutes about 60% of total infrastructure spending (Ncube & Lufumpa, 2017), with a huge chunk of transport infrastructure spending going to road. Fedderke *et al* (2006) and Foster and Briceno-Garmendia (2010) highlight the continued increase in investment in road infrastructure compared to the stagnant investment in rail infrastructure that has resulted in faster growth of road traffic.

The continued deterioration of rail infrastructure in the SADC region is in contrast to the expansion and quality improvement of road infrastructure. Policy makers, railway users and the public should be concerned about the decline in rail capacity. It is argued that existing rail infrastructure challenges in SADC negatively affect rail performance resulting in adverse effects on competitiveness and economic growth (Luiz, 2010). There is therefore a compelling need for investment in rail infrastructure and equipment to provide the enabling capacity for rail to be able to effectively support economic growth.

Poor government policies and lack of investment in rail infrastructure have contributed to capacity challenges currently affecting railways. Institutional failure in particular has been specifically identified as one of the major causes of the poor condition of railway infrastructure and performance in Sub-Saharan Africa (Kessides, 1993; World Bank, 1994; Thompson, 2007; Foster & Briceno-Garmendia, 2010).

Outside South Africa, most of the rail networks in Southern Africa are old as there has not been significant investment in the construction of new railways in the past eight decades (Foster & Briceno-Garmendia, 2010; Ncube & Lufumpa, 2017). The 1800km TAZARA rail line between Tanzania and Zambia completed in 1976 is an exception. While the length of the regional rail track has not changed significantly over the study period, the number of locomotives, wagons and coaches declined significantly.[51] The lack of investment in rail has been attributed to economic, policy, institutional and technological factors. (Bullock, 2005; Fedderke *et al,* 2006; Foster & Briceno-Garmendia, 2010; Nube & Lufumpa, 2017), policy and institutional factors (Kessides, 1993; World Bank, 1994; Donaldson, Sader & Wagle, 1997; Kessides, 2004; Thompson, 2007; Foster & Briceno-Garmendia, 2010; Gwilliam, 2011). Policy is part of institutional factors.

4.2.2.1 Economic factors

(i) Market size

The small size of most African economies restricts their ability to generate enough traffic volumes to support investment in rail infrastructure (Bullock, 2005). Competition from road reduces the volume of traffic available to rail. With a road freight market share of over 85%, road competition against rail is strongest in Southern Africa because the region has the largest trucks, the best roads in Sub-Saharan Africa and a liberal transport market structure[52].

(ii) Freight and passenger tariff regulation –

Rail tariffs have historically been controlled to the extent of being sub-economic in some cases (Kessides, 2004). The impact is two-fold; rail returns are lowered compromising the ability to reinvest and attractiveness to private investors eroded.

(iii) Social service obligations

Unprofitable rail passenger services and uneconomic branch lines negatively impact on profitability and ability to reinvest of rail business (Donaldson, Sader & Wagle, 1997; Kessides, 2004; Bullock, 2005; Thompson, 2007; Gwilliam, 2011). Unprofitable rail

[51] A detailed analysis is presented in Chapter 3.
[52] For example, Foster and Briceno-Garmendia (2010) and Gwilliam (2011) make this observation.

passenger services and branch lines tie down resources that could otherwise be used on profitable freight traffic.

4.2.2.2 Institutional Factors

(i) Ownership

Railways in Southern Africa have remained predominantly state owned over the past sixty years or more and enjoyed monopoly status until the rise of road transport in the 1950s and liberalization of the transportation market in the 1990s. All the major rail companies in the five countries under study are state-owned.

(ii) Road infrastructure funding

Governments allocate more funding for road development and maintenance annually through established road fund authorities or road development agencies.[53] Each of the five sample countries has these entities. This could be due to the fact that roads are cheaper and technically easier to construct relative to rail. Secondly, roads have broad coverage across the spectrum of voters therefore politicians may be trying to maximize votes. There is also an unproven suspicion that some policy makers own haulage trucks and therefore support road infrastructure development at the expense of rail which they consider a competitor. An empirical enquiry would help shed light on this matter.

(iii) Road user charges

Road user charges collected by governments are far below the full cost of construction and maintenance of roads. Road truckers are thus subsidized by government.

[53]The World Bank championed establishment of road funds and road development agencies through the Sub-Saharan Africa Transport Programme (SSATP).

(iv) Rail infrastructure funding

SADC countries do not have structured institutional frameworks to facilitate rail infrastructure investment. As such, railways do not have dedicated rail funds or development agencies as is the case with road. Railways incur the full cost of constructing and maintaining their infrastructure. Direct allocations from the fiscus are rare and unpredictable. Governments usually provide loan guarantees when railways borrow funds for infrastructure investment and maintenance.

(v) Management

Management of rail contributes to the poor performance of the railway sector[54]. Political appointments of rail management and the political interference in decision making result in political expedience taking precedence over sound business principles.

(vi) Unfavourable institutional and political environment

Foreign direct investment (FDI) is required to supplement government resources. However, the economic, institutional and political environment in most of the African countries is not favourable to FDI.

A number of initiatives have been pursued at regional and continental levels in an attempt to facilitate rail infrastructure development, maintenance and operations. For example,

- The Union of African Railways (UAR) was formed by the Organization of African Unity (OAU)[55] in 1973 to promote investment in rail infrastructure and operations on the continent. The agency failed to have a positive impact on the rail sector.
- The African Union's Brazzaville Declaration[56]of 2006 expresses concern on lack of investment in rail on the African continent and proposes setting aside a certain

[54] Foster & Briceno-Garmendia (2010)
[55]Now African Union
[56]The Declaration was made by African Union Ministers responsible for railways in Brazzaville, Republic of Congo.

percentage of GDP towards investment in rail infrastructure annually. However, the proposal did not materialize.

- At SADC level, the Southern African Railways Association (SARA) was formed in 1996 to lobby for investment in rail infrastructure and promote equitable surface transport policy (SARA, 2016). Through lobbying efforts of SARA, a landmark SADC decision was taken in 2010 to establish rail development funds to facilitate rail infrastructure investment and maintenance.[57] However, the decision was never implemented at national level.

If pursued, these initiatives may assist in resolving the rail sector challenges including investment in infrastructure.

4.2.2.3 Technological factors

Technology has been one of the major drivers of growth for some economic sectors. Rail in the SADC region made limited technological advances during the study period. Locomotives changed from steam, diesel and electric motive power. To date diesel and electric locomotives are widely used in the SADC region. The type of track, wagons and coaches have not changed significantly over the study period. South Africa is the only country which has managed to maintain well-functioning electrified and signalling systems throughout the study period. Botswana introduced a modern signalling system in 2008.

Zambia and Zimbabwe once had signalling systems which have since collapsed. Namibia never had a signalling system.

Resolving rail infrastructure investment challenges requires a broad framework that addresses these highlighted challenges.

4.3. Literature review

This section provides a survey of literature relating to infrastructure investment particularly focusing on the nexus between institutional and economic factors, and investment in rail

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[57]The decision was taken at the Meeting of SADC Ministers of Transport and Communications held in June 2010 in Pemba, Mozambique.

infrastructure anchored on theoretical and empirical perspectives. The review provides a highlight of key issues and the required context for the formulation of the empirical model to be estimated and the baseline for interpretation of study results.

4.3.1 Institutions and infrastructure investment dynamics

North (1990) defines institutions as humanly devised constraints that shape human interaction. The institutional environment shapes economic outcomes by defining rules of engagement, the incentive structure and constraints on economic actors (North, 1990; Aron, 2000; Rodrik & Subramanian, 2003; Bardhan; 2005; Engerman & Sokoloff, 2008). This reduces uncertainty, the cost of production and exchange.

The reduction in uncertainty and instability promotes investment (Rodrik *et al.*, 2004; Acemoglu, Johnson and Robinson, 2005; Benassy-Quere, Coupet & Mayer, 2007; Fedderke & Luiz, 2008). It is through enforcement of property rights that uncertainty and instability are reduced. With secure property rights, the incentive structure is defined and assured to guide economic behavior.[58]Barro (1990) equates an improvement in the security of property rights to marginal tax rate reductions which stimulate private investment resulting in economic growth. Good institutions can therefore help address challenges of investment in infrastructure experienced by developing countries by reducing risk.

Institutions can also be extractive in nature, promoting exploitation and inequality (Sokoloff & Engerman, 2000; Acemoglu *et al*, 2001). Extractive institutions increase risk through their potential to cause instability and expropriation as a result of power being concentrated in the hands of a few individuals who would want to maintain the status quo. Extractive institutions are therefore detrimental to investment. Countries with better quality institutions achieve higher private investment levels and higher productivity of investment hence higher economic growth rates (Gwartney, Holcombe & Lawson, 2006). However, rail infrastructure is publicly owned therefore the impact of this in

[58] This is emphasized in literature by for example Smith (1776), North (1990), Hall & Jones (1999), Aron (2000), Rodrik (2000), Rodrik & Subramanian (2003), Bardhan (2005), Acemoglu *et al* (2005), Calderon & Serven (2008), Engerman & Sokoloff (2008), Fedderke & Luiz (2008).

Strong political institutions enhance credibility of the promise to enforce property rights. Political freedom for example has a positive effect on the protection of property rights due to the checks and balances it provides (North, 1990; Jakobsen, 2006). According to North (1990) political freedom, bureaucratic efficiency and rule of law create a conducive investment climate by reducing uncertainty and transaction costs and also minimize opportunistic and rent-seeking behaviour. It is also argued by, for example Rodrik (2000), that participatory political regimes produce higher quality growth due to superior institutions that are more applicable to domestic conditions.

Unlike in developed countries where good institutions are in place to reduce uncertainty and transaction costs, literature suggests that institutions in many African countries are weak, unstable, unpredictable and non-existent in some cases (Aron, 2000; Ramamurti & Doh, 2004; Bardhan, 2005; Jakobsen, 2006; Luiz, 2009). This implies that risk and transaction costs are high in many African countries with a depressing effect on investment.

Literature further suggests that the risk of expropriation is very high in Sub-Saharan Africa (SSA) due to weak, underdeveloped and ineffective property rights (Donaldson, Sader & Wagle, 1997; Acemoglu & Johnson, 2005; Luiz, 2009). These weak institutions partly explain the failure to attract foreign direct investment (FDI) by some African countries and their poor economic performance (Fedderke and Gwenhamo, 2013).

Studies have also shown that institutions affect economic performance through national income[59] and that Africa is poorer compared to the rest of the world because of worse institutions. Countries with clearly defined property rights and regulatory systems perform better than those with weak institutions. (Rodrik, 2000; Eicher, Penalosa, & Teksoz, 2006; Luiz, 2009). Investors are risk averse and sensitive to weak institutional frameworks therefore institutional reforms are required to boost economic performance of countries with bad institutions.

Private investment in infrastructure is important for augmenting government resources and introducing management efficiency. Lack of financial resources to meet infrastructure inadequacies in developing countries makes it imperative to attract foreign direct investment to

[59]For example like Hall and Jones, 1999; Acemoglu et al, 2001; Eicher et al, 2006 and Luiz; 2009 extensively discuss this relationship.

augment local resources (Van de Walle, 1989; Aisedu, 2002, 2006). The ability of a country to attract FDI partly depends on institutions existing in that country. FDI will flow into those countries with stable economic and political environment and secure property rights.

Developing countries are not attractive to FDI because of the risk of expropriation, political and economic collapse (Ahlquist, 2006); weak, unstable and unpredictable institutions (Ramamurti & Doh, 2004; Jakobsen, 2006); and policy reversals (Jakobsen, 2006). For example, Jakobsen (2006) observes that obsolescing bargain[60] is high in countries with weak institutions and the likelihood of policy reversals is high in the absence of democracy due to discretionary interventions by government. Institutions have therefore an important role to play in ensuring that these risks are mitigated against, more so given that foreign direct investment is irreversible in most cases.

It is argued by for example, Gwilliam (2011) that railways are driven into bankruptcy by tariff controls and populist impositions by government. Price controls constitute a risk to investment as they affect profit levels. The discretionary power of the executive is therefore a major source of risk to investors.

FDI has been found to be more sensitive to institutional persistence as opposed to fiscal policies as observed by, for example Ahlquist (2006). However, high variability of political and institutional factors has been identified as a major cause of economic instability in developing countries.[61] Political and economic instability are indicators and sources of risk to investment. For investment in infrastructure in particular, the risk is even higher due to inherent high exit costs in the event of unfavourable shocks. This makes investment unattractive to the private sector hence the public investor is the main investor driven more by economic and political considerations rather than financial returns.

Pindyck (1991) argues that in the presence of irreversibility, stimulation of investment necessitates creation of an institutional framework that ensures stability and credibility as opposed to tax incentives or interest rates.

Inappropriate institutional frameworks have been identified as the cause of failure to promote infrastructure development and management in developing countries (World Bank, 1994).

[60] Shifting of bargaining power to the government once the foreign investor's asset base increases in a country-
[61] Rama (1993) for example makes this observation.

Railways in the SADC region are equally in a poor state due to unsupportive institutional structures (Kessides, 1993; Foster and Briceno-Garmendia, 2010).

Ndulu (2006) recommends that challenges that come with long-term infrastructure investments should be addressed through development of risk mitigating instruments over and above reducing risk induced by governance, policy distortions and politics.

The relationship between economic growth and institutions is not unidirectional. Although institutions affect economic growth, economic growth can also lead to good institutions making the relationship between the two bi-directional (Aron, 2000; Rodrik &Subramanian, 2003; Hsiao &Shen, 2003; Rodrik, Subramanian & Trebbi, 2004; Fedderke& Garlick, 2010).

4.3.2 Investment in Rail Infrastructure

Rail infrastructure conforms to standard characteristics of infrastructure of being lumpy, space specific, non-tradable, prone to market failure and subject to indirect consumption.[62] Investment in rail infrastructure requires high initial capital outlay which is recouped over long time horizons. The complexity and unattractiveness of rail infrastructure investment is due to the inherent risk arising from its characteristics which imply irreversibility and high exit costs coupled with long period to recoup initial investment. The scope for investors to add a risk premium as dictated by standard economic theory under such circumstances is not possible in view of infrastructure's vulnerability to market failure. Therefore, the government becomes the major investor in rail infrastructure.

High investment costs of rail infrastructure require high business volumes to justify investment expenditure. However, low demand due to low incomes in developing countries cannot support investment in rail infrastructure because the countries cannot generate enough traffic volumes to enable their railways to earn enough revenues to support the investment and earn a profit. Low traffic volumes make it difficult for the small railways to invest in new infrastructure or at least maintain the existing, more so given the initial capital requirements, the extent of deterioration of the existing rail infrastructure and constraints often imposed on the railways by governments

[62]Key features of infrastructure were highlighted by for example Ramamurti and Doh (2004), Prud'homme (2005) and Banerjee, Oertzel and Ranganathan (2006).

(Donaldson, Sader and Wagle, 1997; Bullock, 2005; Gwilliam, 2011). South Africa is an exception in this regard.

Government becomes the major investor in infrastructure in cases of market failure due to high risk levels beyond private sector tolerance (Henisz & Williamson,1999). However, there is a strand of literature which suggests that rail infrastructure investment is beyond the capacity of the private sector, for example Bullock (2005) and Pozzo di Borgo *et al* (2006). The contention is that the private sector relies in most cases on lending from government at concessional interest rates to fund rail infrastructure investment. This partly explains the prevalence of State-owned rail monopolies in the SADC region.

While government dominates investment in railways in Southern Africa today, it is pertinent to note that these railways were initially built by the private sector who also controlled the mining sector then (Wolfe, 1963; Katzenellenbogen, 1974; Croxton, 1982).

Rail transport has strong linkages with other sectors of the economy through provision of transportation services. Thus, rail transport is derived demand, a situation which further compounds the risky nature of railway infrastructure investment as it is dependent on demand conditions of other sectors of the economy whose future performance is not known with certainty.

To mitigate rail infrastructure investment challenges, Thompson (2007) suggests establishment of a framework which addresses the high cost of railway infrastructure relative to road, economic and financial forces that determine the incentive structure for infrastructure providers and freight operators, government policy and technology. There is therefore need to align institutional and economic factors to create a conducive investment climate within the historical, cultural and political context of the countries concerned.

4.3.3 Theoretical Perspectives

Instantaneous and costless adjustment of capital stock by firms assumed by early economic theory for example Jorgenson (1963), is not valid in the presence of irreversibility. Adjustment costs do exist and need to be factored in when analyzing investment behaviour. Effects of uncertainty and irreversibility on investment have been subjected to extensive theoretical enquiry in the fields of economics and finance. However, there is still ambiguity on how uncertainty affects investment due to inconclusive empirical results. The general conclusion, however, seems to support the view that high levels of uncertainty lead to lower investment.

Bernanke (1983) indicates the likelihood of cyclical variation of the uncertainty perceived by firms and emphasizes the importance of irreversibility effects in the understanding of cyclical behavior of aggregate investment. Irreversibility makes investment sensitive to other forms of risk like uncertainty over future product prices, operating costs, interest rates, exchange rates, investment costs and its timing, and regulatory policy (Pindyck, 1991). Decisions to invest are therefore influenced by irreversibility, uncertainty and timing as observed by Dixit and Pindyck (1994).

The objective of investment is to earn returns and it is attractive to invest when returns are high and assured. When risk is high, returns are not assured. Therefore, investors become sensitive to changes that can take place over time. The risk can be due to shocks induced by changes in prices, future interest rates, taxes, cost and timing of the investment, exchange rates, regulation, trade regimes and expropriation which can affect profitability and ownership in the worst case.

Risk increases where long-term irreversible investments are involved. Uncertainty about potential shocks on returns will have a negative effect on investment due to risk-aversion of investors (Serven, 1998; Fedderke, 2004; Fedderke & Luiz, 2008). These shocks are mitigated by stable and credible economic policies which insulate investors against risks (Pindyck, 1991).

Irreversibility has important implications on aggregate investment given that the behaviour of variables like price, costs and demand will be unknown over time. There is therefore need to apply dynamic as opposed to static optimization models. Dixit and Pindyck (1994) further observe that optimization over an infinite time horizon introduces uncertainty.

Uncertainty is found to increase the separation between the marginal revenue product of capital (MRPC) which justifies investment and the one which justifies disinvestment (Bloom, Bond & van Reenen, 2007). In between the two, there will be no investment as the firm chooses to wait for additional information. Investors become cautious under uncertainty. In this regard, Bertola (1998) and Fedderke (2004) observe that irreversibility drives a wedge between the cost of capital and its marginal contribution to profits.

Bloom *et al.* (2007) and Fedderke (2004) among others typify an investment model in a single partially irreversible capital with a Cobb-Douglas revenue function and demand conditions that follow a Brownian motion process with constant variance. The dynamic optimization objective is to maximize the expected present value of returns net of sunk cost given the starting value of capital stock and the starting value of the stochastic shift variable.

Fedderke (2004) notes that the threshold to invest is triggered when the expected marginal profit from an additional unit of capital exceeds the marginal cost of installation by a margin which increases in the drift and variance parameters of the Brownian motion as well as the rate of time discount. In the same vein, Bloom *et al.* (2007) indicate that investment only takes place when a firm's marginal revenue product of capital (MRPC) hits the upper threshold given by the traditional user cost of capital plus an option value of investment. Conversely, disinvestment occurs when the MRPC hits the lower threshold given by the user cost of selling capital less an option value for disinvestment.

Bernanke (1983) and Pindyck (1991) recommend the application of simulation models to test the implications of irreversibility and uncertainty. In line with this recommendation, Bloom *et al* (2007) developed a theoretical model which they tested using simulation based on UK firm-level data to establish the effects of irreversibility and uncertainty.

The theory of investment under uncertainty stresses the impact of uncertainty on investment while institutional theory hypothesizes that institutions are fundamental determinants of economic outcomes and income variations among countries. It is pertinent to understand the determinants of investment in rail infrastructure so that appropriate measures are put in place to improve the investment climate in the rail transport sub-sector.

4.3.4 Empirical model of investment

Literature suggests lack of consensus on investment model specification for developing countries (Blejer & Khan, 1984; Rama, 1993; Jorgenson, 1996; Ouattara, 2004). This is despite the existence of theoretical models on investment behaviour. Existing theoretical models on investment behaviour do not perfectly suit developing countries due to institutional and structural factors that render theoretical assumptions underlying the standard optimizing investment models inapplicable

(Blejer & Khan, 1984; Fielding, 1999; Ouattara, 2004). Further, data limitations have made it difficult to strictly adhere to models as provided for by theory when making empirical estimations.

Rama (1993) points out that investment models for developed countries are premised on income considerations and cost of variable inputs and proposes an integrative framework which captures the underlying structural features of developing countries. Rama (1993) contends that determinants of investment in developing countries differ from those for developed countries. The differences are attributed to differences in macroeconomic and institutional settings. By extension, this observation suggests heterogeneity among developing countries themselves as each has its own unique features hence the need for the model to respond to this reality.

4.4 Data and Methods

4.4.1 Data

The dataset is comprised of a panel of four SADC countries namely Botswana, Namibia, Zambia and Zimbabwe observed annually from 1960 to 2018 and time series for South Africa for the same period. While the data for infrastructure measures compiled dates back to 1939, other important economic, geostrategic and institutional data used in the models are available from 1960 onwards. The panel has T=59 and N=4. The large T allows for the application of dynamic panel techniques to estimate a long -run equilibrium relationship and modelling short-run dynamics for the investment function. South Africa has been excluded from the panel due to the huge differences it has with the other four countries under study as highlighted in the preceding Chapter on the Descriptive Analysis of Rail Infrastructure and Operational Performance.

Investment in rail and road infrastructure is measured in physical stock as opposed to investment flows to avoid the failure of investment expenditure to capture the multi-dimensional nature of infrastructure. Secondly, investment expenditure values may be distorted by government inefficiency and corruption. Thirdly, procurement practices that differ across countries may present comparison challenges. This is more relevant to rail and road infrastructure given that their investment is dominated by public sector hence its susceptibility to these factors. Unavailability of financial data and timing of monetary flows would also create challenges on the use of investment flows. In view of some technical terms used in the rail industry, a data dictionary was compiled and attached as *Appendix 3.1*.

Multiple sources were used to compile the dataset. Rail infrastructure data was collected from rail companies' annual and financial reports, government publications and the Southern African Railways Association (SARA) database. National road agencies annual reports and government publications provided data on roads. The World Development Indicators (WDI) database, United Nations Statistical Yearbook, country and government reports provided data on economic and social indicators. Published literature supplemented the data where gaps existed.[63]Details of data sources are indicated in *Appendix 3.2.*

The SADC region is selected for this study because it has the highest rail network connectivity and best roads in Sub-Saharan Africa (SSA)[64], yet rail is failing to effectively contribute to the economy due lack of investment in capacity (Foster & Briceno-Garmendia, 2010). This creates a suitable setting for the investigation of the determinants of investment in rail infrastructure. The selected five countries' rail networks are interconnected and share a common history in terms of historical development. South Africa has the 13th largest rail network in the world based on network size and commands about 70% of the rail network in SSA. The Southern Africa region's rail network constitutes 43% of the whole of Africa's rail network (Foster & Briceno-Garmendia, 2010; UNECA, 2009; Ncube & Lufumpa, 2017). The Transnet Freight Rail (TFR) network of South Africa accounts for 40% of the continental rail network and carries 70% of the continent's traffic.

Rail infrastructure measures are based on new annual composite indices generated through principal component analysis.[65] The annual composite infrastructure indices are premised on the consideration that rail infrastructure capacity is a combination of the track, locomotives, wagons and coaches.

Considering that the length of rail track has not changed significantly for the five countries during the study period, we focus on capacity and efficiency measures of rail infrastructure categories that have significantly changed over time. In recognition of the three rail business segments, the

[63]Details on data sources are contained in *Appendix 3.2.*
[64]Gwilliam (2011) makes this observation.
[65]Refer to Chapter 3 for more technical details on the construction of the indices.

infrastructure capacity measures relate to freight rail infrastructure (FI) based on a combination of the rail track, locomotives and wagons representing capacity for the freight business segment; passenger rail infrastructure (PI) based on the combination of the rail track, locomotives and coaches representing capacity for the passenger business segment and mixed rail infrastructure (MI) based on the combination of rail track, locomotives, wagons and coaches representing capacity for the mixed rail business segment where trains carry freight and passengers at the same time. However, for the purpose of comparison between the road and rail infrastructure, we also estimate the rail track infrastructure (TTI) representing rail route kilometres.

Road infrastructure (RI) is measured in kilometres of paved road. A constructed annual composite index for land transport infrastructure (RRI) comprising of kilometres of paved road and rail track is included to represent surface transport hard infrastructure.

The investment rate is the dependent variable influenced by a number of independent variables (determinants). Investment in rail infrastructure capacity is proxied by composite indices generated through principal component analysis (PCA) representing the three rail business segments of freight, passengers and mixed trains. Road infrastructure is proxied by length of paved road.

Determinants of rail and road infrastructure investment are framed on the basis of economic, geostrategic and institutional factors. Economic variables of interest were collected from various national and international databases.[66] Geostrategic factors are proxied by the length of colonial tenure. Domestic institutions are proxied by the Executive Constraints indicator (XCONST) since investment in rail and road infrastructure in the selected SADC countries is predominantly by government therefore institutional measures selected are those that relate to the constraints on the executive as opposed to property rights.

4.4.2 Model specification

This study employs the error-correction specification of the flexible accelerator model by Bond, Elston, Mairesse and Mulkay (1997) augmented by institutional, geostrategic and other economic determinants to estimate the rail infrastructure investment function for in four SADC countries (Botswana, Namibia, Zambia and Zimbabwe) in a panel setting. The rail infrastructure investment

[66]Refer to *Appendix 3.2* for more details on data sources.

function for South Africa is estimated separately employing time series techniques. The error correction approach allows modelling of the country's long-run demand for capital within a regression model permitting flexible specification for short-run investment dynamics to be estimated from the data (Bloom *et al*, 2007).

Although this model specification is for profit maximising firms, it can be also applicable to countries given that, firstly it incorporates income and cost of capital that are generally agreed determinants of investment. Cost matters to both firms and government. Secondly government resources are not adequate to meet competing needs hence the need to get the best out of available resources considering both financial and economic returns in order to maximise welfare. Welfare is measured on the basis of income levels.

Inclusion of income as a determinant of investment may be more relevant to rail infrastructure because of the latter's long-term nature and expensiveness. This may suggest that growth leads investment in rail infrastructure, as there should be justification for sinking expensive, irreversible and long-term investment. However, once infrastructure is in place it becomes an economic enabler and promotes further growth. The relationship between rail infrastructure investment and growth becomes "push and pull" type.

4.4.2.1 The Bond *et al.* (1997) model

The desired capital stock can be expressed as a log linear function of output and the cost of capital, assuming no adjustments as follows;

$$k_{it} = a_i + y_{it} - \sigma j_{it} \qquad (1)$$

Where:

k_{it} - *log of desired capital stock for country i in period t*

y_{it} - *log of output for country i in period t*

j_{it} - *log of the real user cost of capital*

a_i - *country-specific intercept*

Formulation of equation (1) is consistent with the following;

(i) Profit maximisation subject to constant returns to scale (CRS) and a constant elasticity of substitution (CES), with a possibility of having a fixed capital-output ratio (σ =0).

(ii) Cobb-Douglas production function when $\sigma = 1$ in the presence or absence of constant returns to scale.

(iii) The country specific intercept a_i could be a mark-up under monopolistic competition or a distribution parameter in the production function. This should be relevant to SADC railways that were monopolies for long periods. The railways were able to charge a mark-up on their services as dominant suppliers of transport services in their respective countries. From a production function perspective, the country specific intercept will affect input factor intensity and the output shares of the input factors.

Specification of equation (1) takes the form of a general dynamic regression model given the slow adjustment of actual capital stock to the desired capital stock level. If an autoregressive distributed lag specification of up to second order dynamics [ADL (2,2)] is considered, the following obtains;

$$k_{it} = \alpha_1 k_{i,t-1} + \alpha_2 k_{i,t-2} + \beta_0 y_{it} + \beta_1 y_{i,t-1} + \beta_2 y_{i,t-2} + d_t + \eta_i + v_{it} \qquad (2)$$

Time and country-specific effects, d_t and η_i respectively are included to control for changes in the user cost of capital and uncertainty. v_{it} is the error term.

The specification of equation (2) assumes;

(i) Proportionality of the country's desired capital stock under adjustment costs to desired capital stock without adjustment costs.

(ii) Stability of short-run investment dynamics over the period covered to be well approximated by distributed lags in the regression model.

The long-run unit elasticity of capital with respect to output implied by equation (1) necessitates imposition of the restriction

$$\frac{\beta_0 + \beta_1 + \beta_2}{1 - \alpha_1 - \alpha_2} = 1 \qquad (3)$$

Reparameterization of equation (2) in error-correction form and imposing the restriction represented by equation (3) results in equation (4) below.

$$\Delta k_{it} = (\alpha_1 - 1)\Delta k_{i,t-1} + \beta_0 \Delta y_{it} + (\beta_0 + \beta_1)\Delta y_{i,t-1} - (1 - \alpha_1 - \alpha_2)\left(k_{i,t-2} - y_{i,t-2}\right) + d_t + \eta_i + v_{it} \qquad (4)$$

If I_{it} represents gross investment, K_{it} the capital stock and δ_i the rate of depreciation then the investment rate can be obtained by

$$\Delta k_{it} \approx \frac{I_{it}}{K_{i,t-1}} - \delta_i \qquad (5)$$

Given equation (5), the empirical model to be estimated takes the following form;

$$\frac{I_{it}}{K_{i,t-1}} = \rho \frac{I_{i,t-1}}{K_{i,t-2}} + \gamma_0 \Delta y_{it} + \gamma_1 \Delta y_{i,t-1} + \phi\left(k_{i,t-2} - y_{i,t-2}\right) + d_t + \eta_i + v_{it} \qquad (6)$$

Considering that investment in rail infrastructure in SADC is dominated by government, the investment rate may be modified to express it in terms of investment over income as opposed to investment over capital as is the case in (6) above. This adjustment recognises the dominant role that income is likely to play in rail infrastructure investment both from the demand and supply sides. Government spending will therefore be included as one of the determinants of investment in rail infrastructure.

4.4.2.2 Extended Bond *et al.* (1997) model

Equation (6) is augmented by vectors of geostrategic and institutional variables, $\boldsymbol{W}_{i,t}$ and $\boldsymbol{Z}_{i,t}$ respectively because of the effect geostrategic factors and domestic institutions are supposed to have on investment. Geostrategic and institutional factors have been demonstrated to have influenced rail infrastructure development in Chapters 2 and 3 of this study. Institutions have been found to matter on investment but are classified as weak in Africa.[67] Developing countries also possess unique structural features that need to be controlled for (Rama, 1993). Including domestic institutions and geostrategic factors controls for unique structural features for our sample.

[67]Donaldson *et al,* (1997); Aron (2000); Ramamurti &Doh (2004); Acemoglu & Johnson (2005); Bardhan (2005); Luiz (2009) refer.

The augmented model is specified as follows;

$$\frac{I_{it}}{K_{i,t-1}} = \rho \frac{I_{i,t-1}}{K_{i,t-2}} + \gamma_0 \Delta y_{it} + \gamma_1 \Delta y_{i,t-1} + \phi\left(k_{i,t-2} - y_{i,t-2}\right) + \tau \boldsymbol{W_{i,t}} + \lambda_p \boldsymbol{Z_{i.t}} + \pi_2 DV_{i,t} + \pi_3 T_{i,t} + \pi_4\ FDI + \pi_5 GI + d_t + \eta_i + v_{it} \tag{7}$$

Vectors $\boldsymbol{W_{i,t}}$ and $\boldsymbol{Z_{i.t}}$ will comprise of geostrategic and institutional variables respectively. GI is gross fixed capital formation by public sector. FDI is the ratio of FDI to GDP. T is technology proxied by the residual of TFP. The definitions of the variables are as indicated in Tables 4.1 and 4.2 below. DV is development proxied by infant mortality rate (IMR). These are followed by explanations and the justification for inclusion of the variables in the models in section 4.4.2.3.1

4.4.2.3 Empirical analysis

Estimated equations for rail infrastructure investment are based on rail infrastructure measures generated through principal component analysis in Chapter 3. The infrastructure investment measures are for rail freight (FI), passenger rail (PI), mixed rail (MI), rail track (TTI), road (RI) and land transport (RRI). Table 7 shows the dependent variables and their proxies.

Table 7: Dependent variables: infrastructure investment measures

Infrastructure Variable	Notation	Proxy	Units
Freight	FI	Combination of locomotives and wagons	Index
Passenger	PI	Combination of locomotives and coaches	Index
Mixed	MI	Combination of locomotives, wagons and coaches	Index
Road	RI	Length of paved road	Kilometres
Land transport	RRI	Combination of road and rail	Index
Rail track	TTI	Length of rail track	Kilometres

The independent variables for the infrastructure investment functions are given in Table 8 below.

Table 8 : Independent variables: economic, geostrategic and institutional variables

Determinant	**Notation**	**Proxy**	**Units**
National income	GDP	Gross Domestic Product	Number
National income per capita	GDPcap	Gross Domestic Product per capita	Number
Government investment	GI	Ratio of GI to gross fixed capital formation	Ratio
Foreign direct investment	FDI	Ratio of FDI to GDP	Ratio
Technology	T	Residual of TFP	Ratio
Development	IMR	Infant mortality rate	Ratio
Geostrategic factors	CT	Length of colonial tenure	Years
Domestic institutions	XCONST	Executive constraints	Index

Geostrategic factors are in vector $W_{i,t}$ and institutional factors are in vector $Z_{i.t}$.

4.4.2.3.1 Justification of the variables

Gross Domestic Product (GDP)

Rail transport is derived demand therefore an expanding economy should demand more of railway transport services to carry inputs to production plants and output to markets. A positive relationship between GDP and investment in rail infrastructure is expected. This should particularly be the case for SADC given the bulk nature of commodities produced. GDP data was obtained from WDI and AfDB supplemented by national accounts. Central Bank reports, National Statistics agencies and World Bank Reports were also utilized.

Inclusion of income as a determinant of investment may be more relevant to rail infrastructure because of its long-term nature and expensiveness. This may suggest that growth leads investment in rail infrastructure, as there should be justification for sinking expensive, irreversible and long-term investment. However, once infrastructure is in place it becomes an economic enabler and promotes further growth. The relationship between rail infrastructure investment and growth becomes “push and pull” type. The level of economic activity for any country is ordinarily expected to grow over time and thus expected to drive investment in rail infrastructure upwards to support economic growth. Demand for rail transportation services is therefore expected to increase, more so for developing countries whose output is mostly bulk and semi-processed for which railways is the most suitable transportation mode. The accelerator effect is therefore expected to be significant in developing country investment model specification.

Foreign Direct Investment (FDI)

Foreign direct investment (FDI) plays a critical role in infrastructure development especially if it is resource seeking. Infrastructure will be required to support production and distribution. FDI affects investment in physical infrastructure as it augments local resources that are usually inadequate to undertake huge infrastructure projects like railways. The important role of FDI is well documented in literature. The ratio of FDI to GDP will be used to measure this variable. A positive relationship is expected.

Technology (T)

A variable to measure technological progress (T) is included in the model in order to assess the impact of technology on the rail sector given the profound global impact it has had on other business sectors. Technological advancement increases productivity of factors of production and induces investment.

The proxy for technology is derived within the Schumpeterian growth model by decomposing GDP into its capital and labour components, the residual being total factor productivity interpreted as technology. The coefficient of technology with respect to infrastructure investment should be positive *a priori* as technological progress induces investment. The following formula is used to derive the technology variable;

$$\frac{\frac{dy}{dt}}{Y} = \frac{(1-\propto).\frac{dK}{dt}}{K} + \propto \frac{\frac{dL}{dt}}{L} + T$$

The decomposition of GDP shows total factor productivity for capital, labour and the residual corresponding to the effect of technology on GDP. The model assumes homogeneity of degree 1, constant returns to scale.

Fedderke (2004) recommends the inclusion of the technological progress as a control variable on the grounds that technology may lead to the creation of new varieties of physical capital through innovation and may or may not affect other factors of production.

Development (DV)

Infant mortality rate is used as a proxy to capture the effects of economic development on investment in rail infrastructure. A positive relationship is expected between investment in rail infrastructure and economic development.

Executive Constraints (XCONST)

Domestic institutional factors are proxied by the Executive Constraints (XCONST) index sourced from Polity V dataset. Investment in rail and road infrastructure in the selected SADC countries is dominated by government therefore the institutional measure selected is that related to Executive accountability as opposed to property rights institutions which are more applicable to private investment.

Length of colonial tenure (CT)

The length of colonial tenure is used as a proxy for geostrategic factors which are included to capture the effect of past geostrategic priorities on rail infrastructure investment which has its roots linked to the colonial era. In view of the length of colonial tenure being a constant, we assign a 0 for the year 1960 (commencement of study period) and allow the number to increase by 1 annually up to the year of independence after which the figure becomes negative from -1 increasing by 1 annually as well until 2018 (end of study period). Pre-independence values are positive while post-independence values are negative.

4.4.3 Determinants of rail infrastructure investment in Botswana, Namibia, Zambia and Zimbabwe

We begin by analysing the data to establish its properties in order to inform the modelling process.

4.4.3.1 Basic Statistics

Table 9 shows descriptive statistics based on collected data. Apart from institutional variables, all other variables are expressed in levels.

Table 9: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
FI	222	0.001	0.039	-0.205	0.363
PI	222	-0.002	0.026	-0.113	0.175
MI	222	0.0005	0.037	-0.184	0.326
TTI	227	0.0003	0.002	-0.009	0.029
RI	225	0.003	0.008	-0.020	0.049
RRI	225	0.003	0.012	-0.063	0.078
LGDP	231	22.485	1.139	19.139	24.091
GI	221	20.137	3.052	12.027	25.307
lGDP cap	231	7.50	0.75	6.01	8.99
XCONST	176	4.398	1.754	1.000	7.000
CT	232	5.288	1.932	0.000	7.941
T	222	22.797	0.990	21.100	25.458
FDI	216	2.432	2.871	-10.775	15.594
IMR	236	67.059	25.13	29.000	124.597
TFP	176	0.111	0.266	-0.445	2.669

Unavailability of data in some years affected the number of observations which are expected to be 236 for each data series. The institutional variable (XCONST) is available from the year of independence for each of the four countries. Some data for Namibia is not available in some years. Summaries of country by country statistics are in *Appendices 3.3* and *3.4.*

4.4.3.2. Panel Unit Root Tests

Considering the fairly long duration of our panel, there is a possibility of non-stationarity among the panels which necessitates investigation of the order of integration to ensure that the variables are I(0) and I(1) consistent with the application of an ARDL model (Pesaran & Smith, 1995; Pesaran *et al*, 1999). We therefore examine the time series properties of the data through panel unit root tests. The Im, Pesaran and Shin (IPS) (2003) and Augmented Dickey Fuller-Fisher (ADF) tests are employed to test for non-stationarity against the alternative of trend stationary.

Table 10 reports results of unit root tests with the order of integration for each variable and the corresponding level of significance. The results suggest that FI, RI, FDI, DLGDP, DDLGDP, TFP, XCONST, NTKMLOC, NTKMWG and NTKMEMPL are stationary while PI, MI, TTI, RRI, GDP, LGDP CAP, GI, IMR, CT, T, NTKM and NTKMTRK are integrated of order 1. The order of integration provides a guide on the level at which variables enter the model.

Results of the panel unit root tests are reported in Table 10. Results presented in Table 10 suggest that all infrastructure investment rates (dependent variables), change in GDP (DLGDP), foreign direct investment, return on capital and institutional variable are I(0) at all levels of significance, while GDP, government investment, infant mortality and technology, are I(1) at all levels of significance and only the geostrategic variable is I(1) at the 5% level of significance.

Table 10: Panel Unit Root Tests Results

Variable	**IPS**		**ADF-Fisher**		
	Levels	First differences	Levels	First differences	Level of Integration
FI	(-2.67)***	(-11.87)***	4.10***	70.09***	I(0)
PI	(-1.17)	(-11.27)***	2.33***	69.32***	I(1)
MI	(-1.46)*	(-11.76)***	1.44*	70.09***	I(1)
RRI	-0,92	(-8.49)***	0,48	34.71***	I(1)
RI	(-9.19)***	(-11.95)***	43.92***	70.09***	I(0)
TTI	(-2.94)	(-8.33)***	(-2.90)	(-8.25)***	I(1)
DLGDP	(-9.60)***	(-11.61)***	50.30***	70.09***	I(0)
DDLGDP	(-9.50)***	(-11.47)***	49.62***	70.09***	I(0)
GDP	(-0.62)	(-9.60)***	-0,09	50.30***	I(1)
GI	0,81	(-8.37)***	(-0.41)	(35.30)***	I(1)
IMR	(-0,16)	(-7.03)***	0,15	24.56***	I(1)
T	(-0.37)	(-8.73)***	0,28	39.41***	I(1)
FDI	(-5.22)***	(-10.51)***	12.59***	62.20***	I(0)
XCONST	(2.07)**	(-8.14)***	3.01***	44.63***	I(0)
LGDP CAP	-0.46	-9.72***	0.05	52.05***	I(1)
CT	-0.57	-1.99**	-0.10	2.02**	I(1)
TFP	-7.64***	-10.54***	33.77***	62.21***	I(0)
NT	(-0.09)	(-8.83)***	(-0.36)	40.43***	I(1)
NTKM	(-1.71)**	(-8.80)***	1.53*	42.39***	I(1)
NTKMTRK	(-1.63)**	(-8.78)***	1.37*	42.17***	I(1)
NTKMLOC	(-3.62)***	(-9.25)***	7.47***	50.16***	I(0)
NTKMWG	(-2.06)**	(-8.75)***	2.50***	44.15***	I(0)
PAXCHA	0,59	(-8.28)***	(-0.36)	37.52***	I(1)
NTKMEMPL	(-2.49)***	(-8.47)***	4.39***	40.76***	I(0)

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Rail infrastructure efficiency measures are defined as follows:

Net tonnes – NT

Net tonne-kilometres – NTKM

Net tonnes per kilometre of track-NTKMTRK

Net tonne-kilometres per locomotive – NTKMLOC

Net tonne-kilometres per wagon – NTKMWG

Passengers per coach - PAXCHA

Net tonne-kilometres per employee – NTKMEMPL.

4.4.3.3 Testing for Cointegration

Pedroni (1999, 2004) and Kao (1999) panel cointegration tests are conducted to establish whether a long-term equilibrium relationship exists among the variables in the model. The Pedroni (1999, 2004) panel cointegration technique is preferred because it is robust to causality running in both directions and allows for both heterogeneous cointegrating vectors and short-run dynamics across countries (Canning & Pedroni, 2008).

The panel cointegration technique is based on the examination of the residual of the regression performed using I(1) variables. The residual should be I(0) if the variables are cointegrated (Das & Chowdhury, 2011). We test the null of no cointegration that the residual is I(1). We test whether rail and road infrastructure investment measures (dependent variables) are cointegrated with their determinants.

Variables of interest are the four rail infrastructure investment measures, the road infrastructure investment measure and the land transport infrastructure investment measure. These are expressed as rates of GDP_{t-1}. Specifically, the infrastructure variables of interest are freight rail infrastructure (FI), passenger rail infrastructure (PI), mixed rail infrastructure (MI), rail track infrastructure (TTI), road infrastructure (RI) and land transport infrastructure (RRI). Determinants of interest are economic, geostrategic (CT) and institutional measures (XCONST).

The panel cointegration tests were conducted on the following six models based on the six infrastructure investment measures. The variables are as previously defined in Tables 7 and 8.

(i) Freight: FI=f(DLGDP GI T FDI IMR CT XCONST)
(ii) Passenger: PI=f(DLGDP GI T FDI IMR RI CT XCONST)
(iii) Mixed: MI=f(DLGDP GI T FDI IMR RI CT XCONST)
(iv) Road: RI=f(DLGDP GI T FDI IMR CT XCONST)
(v) Land Transport: RRI=f(DLGDP GI T FDI CT XCONST)
(vi) Rail Track: TTI=f(DLGDP GI T FDI IMR RI CT XCONST)

Results of the Pedroni and Kao panel cointegration tests are presented in Table 11. Both Pedroni and Kao tests confirm existence of cointegration among the variables in all models at all levels of significance. These results confirm the existence of a long-run relationship between infrastructure investment rates, and the dependent variables including domestic institutions and geostrategic priorities in all the five model specifications.

Table 11: Pedroni and Kao Panel cointegration tests-infrastructure investment

Modified Phillip-Perron/Modified Dickey-Fuller

Model	**Pedroni Test**	**Kao Test**
FI	-5.9802***	-20.1076***
PI	-5.9112***	-23.3497***
MI	-5.0542***	-20.9913***
RI	-3.0467***	-18.2509***
RRI	-2.8860***	-17.9266***
TT1	-4.1143***	-21.6139***

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Given the presence of cointegration, we proceed by estimating the model by means of Pooled Mean Group (PMG) and Mean Group (MG) estimators for dynamic heterogenous panels of Pesaran *et al* (1999).

In view of the historical and economic links among the four countries, we test for cross-country dependence. Results for five of the six infrastructure investment models indicate that there is no cross-country dependence. However, the results for the determinants of infrastructure efficiency models suggest that there is cross-country dependence. The results are reported in *Appendix 4.2*.

4.4.3.4 Model estimation and discussion of results

The functional specification of the empirical model is expressed in log-linear format. The analysis for the four countries (Botswana, Namibia, Zambia and Zimbabwe) is based on panel data techniques whereas that of South Africa is based on time series analysis due to the clear differences between South Africa and the other four countries demonstrated in Chapter 3.

The PMG estimator is formulated by allowing the intercepts, short-run coefficients and error variances to differ freely across groups, but the long-run coefficients to be homogeneous. Group specific short-run coefficients and the common long-run coefficients are computed by the pooled maximum likelihood estimation. PMG estimation provides an intermediate case between the dynamic fixed effects (DFE) estimator which imposes the homogeneity assumption for all parameters except for the fixed effects, and the mean group (MG) estimator proposed by Pesaran and Smith (1995), which allows for heterogeneity of all parameters. It exploits the statistical power offered by the panel through long-run homogeneity, while still admitting short-run heterogeneity.

This methodology is applicable to the four of the five countries in this study in that the countries are likely to have different features in the short-run due to history, economic structure, politics, geography and homogeneous features in the long run due regional integration, technology, neighbourhood effects and competition.

The important advantage of employing the PMG estimation method is that it allows for explicit modelling of dynamics generally argued to be inherent in the investment process, while recognizing the presence of a long-run relationship underlying the dynamics (Fedderke, 2004).

Following the exposition by Pesaran, Shin and Smith (1999), consider the following unrestricted error-correction ARDL(p,q):

$$\Delta y_{it} = \phi_i y_{i,t-1} + \beta_i' x_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}' \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \quad (1)$$

Where i=1,2,….., N, t =1,2,….., T, denote the cross-section units and time periods respectively. y_{it} is a scalar-dependent variable, x_{it} (k x 1) a vector of (weakly exogenous) regressors for group i, and μ_i represents fixed effects. ε_{it}'s are independently distributed disturbances across i and t, with zero means and variances $\sigma_i^2 > 0$, and assume $\phi_i < 0$ for all i. There exists a long-run relationship between y_{it} and x_{it}:

$$y_{it} = \theta_i' x_{it} + \eta_{it},\ i = 1, 2, \ldots\ldots, N,\ t = 1, 2, \ldots.., T, \quad (2)$$

where θ_i=-$\beta_i'\phi_i$ is the k x 1 vector of the long run coefficients, and η_{it}'s are stationary with possibly non-zero means. Equation (1) can therefore be written as the error correction model:

$$\Delta y_{it} = \phi_i \eta_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}' \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \quad (3)$$

whereϕ_i is the error-correction coefficient measuring the speed of adjustment towards the long-run equilibrium.

This general framework provides the formulation of the PMG estimation, which allows the short-run coefficients and error variances to differ freely across groups, but the long-run coefficients to be homogeneous, where $\theta_i = \theta \; \forall \; i$. Group specific short-run coefficients and the common long-run coefficients are computed by pooled maximum likelihood estimation. Denoting the PMG estimators by $\widetilde{\phi}_i$, $\widetilde{\beta}_i, \tilde{\lambda}_{ij}$, $\tilde{\delta}_{ij}$and $\tilde{\theta}$, we obtain them by $\phi_{PMG} = \frac{\sum_{i=1}^{N} \widetilde{\phi}_i}{N}$, $\beta_{PMG} = \frac{\sum_{i=1}^{N} \widetilde{\beta}_i}{N}$, $\lambda_{jPMG} = \frac{\sum_{i=1}^{N} \widetilde{\lambda}_{ij}}{N}$, j = 1,…., p-1, and $\delta_{jPMG} = \frac{\sum_{i=1}^{N} \widetilde{\delta}_{ij}}{N}$, j = 0,…., q-1, $\theta_{PMG} = \tilde{\phi}$.

The model is estimated using the PMG estimator to establish the long-run equilibrium relationship between rail and road infrastructure investment measures, and economic, geostrategic and institutional variables. Rail infrastructure investment measures as defined earlier, are freight rail infrastructure (FI), passenger rail infrastructure (PI), mixed rail infrastructure (MI) and rail track (TTI). The road infrastructure measure is the paved road infrastructure (RI) and the surface transport infrastructure (RRI) is a composite of road and rail infrastructure. We therefore estimate six equations based on these infrastructure measures as dependent variables. Geostrategic and institutional factors are respectively proxied by length of colonial tenure (CT) and Executive constraints (XCONST). Efficiency measures of rail infrastructure and labour are constituted by net tonne kilometres (NTKM), net tonne kilometres per locomotive (NTKMLOC), net tonne kilometre per wagon (NTKMWG), passenger kilometres per coach (PAXCHA), net tonne kilometre per kilometre of track (NTKMTRK); and net tonne kilometre per employee (NTKMEMPL).

Infrastructure investment is defined as function of economic, geostrategic and institutional factors. The specific investment functions e estimated for each infrastructure category are as follows;

Freight: FI=f(DLGDP GI T FDI IMR CT XCONST)

Passenger: PI=f(DLGDP GI T FDI IMR RI CT XCONST)

Mixed: MI=f(DLGDP GI T FDI IMR RI CT XCONST)

Road: RI=f(DLGDP GI T FDI IMR CT XCONST)

Land Transport: RRI=f(DLGDP GI T FDI CT XCONST)

Rail Track: TTI=f(DLGDP GI T FDI IMR T2 RI CT XCONST)

The AIC lag orders are determined by ARDL. The results of the PMG and MG estimations of the infrastructure investment models for the four countries are reported in Tables 4.6 and 4.7 below respectively. We use the Hausman test to select the efficient and consistent estimates between PMG and MG estimators. Selection of the PMG estimator for the model leads us to accept the null of long-run homogeneity of coefficients and conclude that long run coefficients of infrastructure investment function are homogeneous for the five countries under study. This selection and comparison between PMG and MG estimates show how the empirical results of the infrastructure investment equations are sensitive to different model specifications and estimation techniques to some extent. We report results for both PMG and MG in cases where MG is selected by the Hausman test otherwise we report PMG only. This is motivated by the fact that the standard errors for PMG are smaller than those for MG in all models and PMG is generally considered superior compared to MG.

PMG results for the determinants of rail infrastructure investment in the four countries are presented in Table 12. The estimation results are reported by driver of infrastructure investment, i.e. economic, geostrategic and institutional determinants.

Table 12: PMG equations for infrastructure investment

	D.FI		D.PI		D.MI		D.RRI		D.RI		D.TTI	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Lag order	1, 0, 0, 0, 0, 0, 0, 1, 0		1, 0, 0, 0, 0, 0, 0, 0, 0, 0		1, 0, 0, 0, 0, 0, 0, 0, 1, 0		1, 0, 1, 0, 0, 1, 1, 0		1, 1, 1, 0, 0, 0, 0, 0, 0		1, 0, 1, 0, 0, 0, 1, 1, 0, 0	
DLGDP	-0.01675	(0.010)	-0.00606	(0.010)	-0.01684*	(0.010)	0.03074**	(0.014)			0.00163	(0.003)
XCONST	0.00129	(0.001)	0.00222***	(0.001)	0.00164**	(0.001)	0.00063	(0.001)	-0.00019	(0.001)	-0.00030	(0.000)
CT	0.00067***	(0.000)	0.00057***	(0.000)	0.00094***	(0.000)	-0.00037**	(0.000)	0.00005	(0.000)	-0.00001	(0.000)
GI	0.00029	(0.001)	0.00129*	(0.001)					0.00022	(0.000)		
T	-0.00589*	(0.003)	-0.01100***	(0.003)	-0.00213	(0.003)			-0.00087	(0.002)		
L.FDI	0.00148***	(0.000)			0.00117***	(0.000)						
FDI			-0.00121**	(0.000)			-0.00027	(0.000)	-0.00011	(0.000)	-0.00004	(0.000)
IMR	-0.00018**	(0.000)	0.00015*	(0.000)	-0.00015*	(0.000)			0.00001	(0.000)	0.00004**	(0.000)
RI			0.31414**	(0.166)	0.33288*	(0.176)					0.04906***	(0.017)
L.GI							-0.00076	(0.001)			-0.00016	(0.000)
L.T							-0.00386	(0.004)			0.00044	(0.001)
L.DLGDP									0.03057***	(0.009)		
SR												
EC	-1.27179***	(0.088)	-1.42206***	(0.169)	-1.25036***	(0.188)	-0.91117***	(0.082)	-1.02703***	(0.174)	-0.98994***	(0.029)
D.DLGDP	0.04536*	(0.024)	-0.02589	(0.037)	0.03653	(0.045)	0.01580	(0.023)	0.02830**	(0.014)	0.00328	(0.003)
D.XCONST	-0.01349	(0.014)	0.00742	(0.006)	-0.01051	(0.014)	0.00033	(0.001)	-0.00026	(0.001)	0.00021	(0.000)
D.CT	-0.00699	(0.007)	-0.00611	(0.006)	-0.00454	(0.005)	0.00162	(0.001)	0.00207	(0.001)	0.00011	(0.000)
D.GI	0.00153	(0.015)	-0.00233	(0.004)			0.00134	(0.004)	-0.00405	(0.003)	0.00125	(0.001)
D.T	0.00474	(0.025)	0.03263***	(0.013)	0.00813	(0.016)	-0.00572	(0.032)	-0.00064	(0.003)	-0.00245	(0.005)
D.FDI	0.00152***	(0.000)	0.00091***	(0.000)	0.00123***	(0.000)	-0.00048	(0.000)	0.00013	(0.000)	-0.00013	(0.000)
D.IMR	0.00073	(0.001)	-0.00147	(0.002)	0.00118	(0.002)			-0.00024	(0.000)	-0.00015*	(0.000)
D.RI			0.17557	(0.283)	-0.19481	(0.395)					-0.00586	(0.017)
Cons	0.00646	(0.008)	-0.06597***	(0.011)	-0.08574***	(0.014)	-0.01051***	(0.002)	-0.04898***	(0.007)	-0.02377***	(0.001)
Iterations	6		5		6		4		5		5	
H test	160.10(0.00)		18.76(0.03)		30.75(0.00)		60.58(0.00)		84.86(0.00)		193.52(0.00)	
Null	pmg mg		pmg mg		pmg mg		pmg mg		pmg mg		pmg mg	
Llhd	482.37		498.86		475.95		583.14		716.96		888.47	
N	170		170		170		172		172		172	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient; SE = Standard error.

Economic drivers

Gross Domestic Product:

Results indicate that GDP is an insignificant determinant of freight infrastructure investment (FI), passenger infrastructure investment (PI) and rail track infrastructure investment (TTI). GDP has a negative impact on mixed rail infrastructure investment (MI) with a coefficient of -0.01684 significant at the 10% level. This finding may be a reflection of the fact that most of the traffic in the countries under study is moving by road. Second, rail infrastructure capacity for freight (FI), passenger (PI) and mixed rail (MI) has been declining despite persistent growth in GDP in the sample countries.

In contrast, GDP is a significant determinant of investment in land transport infrastructure investment (RRI), a composite of road and rail track infrastructure with a coefficient of 0.031 significant at the 5% level. Land transport infrastructure investment (RRI) is dominated by road infrastructure investment in terms of network size (route kilometres), given that the road network in the four countries is by far longer than the rail network.

The lag of GDP (L.DLGDP) has a positive impact on road infrastructure investment with a coefficient of 0.031 significant at all levels. This result is expected because the road network expanded over the years in response to the growth of the economies. Road also commands a market share of over 85% of freight and passenger traffic in the four countries under study. The result suggests that a 1% increase in GDP is associated with a 0.31% increase in the length of road or land transport infrastructure network *ceteris paribus.* This finding is consistent with the accelerator theory of investment which postulates that investment is driven by growth in GDP. Growth in GDP also provides funding for land transport infrastructure investment. This indicates that GDP is a major driver of land transport infrastructure investment in the four countries.

Foreign Direct Investment:

The lag of foreign direct investment (L.FDI) has a positive impact on investment in freight rail (FI) and mixed rail (MI) with coefficients of 0.00148 and 0.00117 respectively, both significant at all levels. The impact appears to be minimal as the coefficients are close to zero. The channel through which FDI affects investment in rail is likely to be through GDP growth as governments are the major investors in these infrastructure categories.

In contrast, FDI has a negative impact on investment in passenger rail infrastructure investment (PI) with a coefficient of -0.00121 significant at the 5% level. Passenger services are not attractive to private investors hence the negative relationship.

FDI has an insignificant determinant of road infrastructure investment (RI), land transport infrastructure investment (RRI) and rail track infrastructure investment (TTI) possibly due to the unattractive small traffic volumes against the huge capital outlay required.

Government Investment:

Government investment (GI) has an insignificant impact on investment in all rail infrastructure categories, road and surface transport infrastructure except in the case of passenger rail infrastructure investment where it has a positive impact with a coefficient of 0.00129 significant at the 10% level. This result is a reflection of funding support extended to passenger services by government. Government investment may also be directed to those sectors that do not have significant impact on rail infrastructure investment.

Technology:

Results indicate that technology (T) is a significant negative determinant of freight (FI) and passenger (PI) rail infrastructure investment with coefficients of -0.00589 and -0.011 respectively significant at the 10% and 1% levels. This could be due to the fact that there were no significant technological developments in rail during the study period. The negative impact of technology on passenger infrastructure investment (PI) is possibly a reflection of competition from road. Diesel and electric locomotives were introduced before 1960. Apart from the size of the locomotives, little change took place. Wagons and coaches remained the same over the study period.

The impact of technology is insignificant for investment in road (RI), mixed (MI, land transport infrastructure (RRI) and rail track (TTI) infrastructure. The finding of an insignificant impact of technology on road infrastructure investment is surprising in view of the growth in demand for road transport services induced by technology and also that technology has reduced the cost of road construction. The result possibly reflects that technological levels in the four countries are low and may also be directed to those sectors that harm road and rail infrastructure investment.

Road infrastructure investment

Road infrastructure investment (RI) is included as one of the determinants in the rail infrastructure models to establish the relationship between the two transport modes which compete against and also complement each other. Results indicate that road infrastructure investment (RI) has positive coefficients of 0.314, 0.333and 0.049 in models of passenger, mixed and rail track infrastructure investment respectively. These are also respectively significant at the 5%, 10% and 1% levels suggesting that road infrastructure has a positive impact on rail infrastructure investment. This finding further suggests that investment in rail infrastructure could be driven by opportunities by feeder services availed by road transport. The two transport modes will then complement each other in this case. Investment in both road and rail will therefore benefit the economies.

Geostrategic drivers

Geostrategic factors are proxied by length of colonial tenure (CT). Results indicate that geostrategic factors have a positive impact on investment in FI, PI and MI with coefficients of -0.00067, 0.00057 and 0.0009 respectively significant at all levels. This finding suggests that geostrategic priorities adopted in the past positively impact on investment therefore should be reinforced. It is often argued that colonial governance, particularly long colonial governance led to the development of infrastructure. Results also indicate that geostrategic factors have a negative effect on land transport infrastructure (RRI) and insignificant on road infrastructure investment (RI).

Geostrategic factors have emerged as strong drivers of investment in rail infrastructure, consistent with findings from the historical review and descriptive analysis of rail infrastructure development in Chapters Two and Three.

The insignificant impact on road infrastructure investment may indicate lack of social and economic inclusivity of colonial policies where many areas in the countries under study were not accessible by road during colonial times.

Institutional drivers

Results indicate that domestic institutions are proxied by the Executive Constraints (XCONST) indicator have a significant impact on investment in passenger and mixed rail infrastructure investment (PI and MI) with coefficients of 0.0022 and 0.00164 respectively significant at the 1% and 5% levels. The finding suggests that domestic institutions support investment in passenger and mixed rail infrastructure. Passenger services receive subsidies from the government. Passenger rail transport receives subsidies from government as social service obligations since rail passenger services are not viable to attract private investors.

Further, the results indicate the impact of institutions on freight railroad, land transport and rail track infrastructure investment is insignificant suggesting the failure of institutions in these countries to support transport infrastructure investment. This result may suggest that domestic institutions in these countries have not matured enough to exert a positive impact transport infrastructure investment.

These results suggest that, while important, existing institutions have mixed effects on investment in rail and road infrastructure investment, but the negative impact dominates. The result may further suggest that sector specific institutions are non-existent, weak or have been in existence for a short period.

Error Correction Coefficient

The error correction coefficients of the six infrastructure investment models range from 91.1% to 142.2% with an average of 114.5%. The average of the error correction coefficient (ϕ) which represents the speed of convergence is 114.5% and has the expected negative sign and significant at all levels. This provides sufficient evidence of rapid speed of convergence to long-run equilibrium relationship for all dynamic specifications for all the four countries under study.

4. 4.4 Determinants of rail infrastructure efficiency in Botswana, Namibia, Zambia and Zimbabwe

We investigate the determinants of efficiency of the following rail infrastructure; locomotives, wagons, rail track and rail coaches. The measures of efficiency investigated are net tonne kilometres per locomotive (NTKMLOC), net tonne kilometre per wagon (NTKMWG), net tonnes per kilometre of track (NTKMTRK) and passenger coach kilometres (PAXCHAKM)/ passengers per coach (PAXCHA) respectively. The productivity of labour is also investigated based on net tonne kilometres per employee (NTKMEMPL).

The general infrastructure efficiency function is defined as:

Infrastructure Efficiency = f(Economic factors, geostrategic factors, institutional factors).

The following specific models for infrastructure efficiency measures are estimated;

(i) Locomotives: NTKMLOC = f(DLGDP,T, NTKM, TTI, XCONST, CT)

(ii) Wagons: NTKMWG = f(DLGDP,T, NTKM,TTI, XCONST, CT)

(iii) Coaches: PAXCHAKM = f(DLGDP,T, NTKM, TTI, XCONST, CT)

(iv) Track: NTKMTRK = f(DLGDP,T, NTKM, XCONST, CT)

(v) Employees: NTKMEMPL = f(T, NTKM, XCONST, CT)

Estimation results are reported by driver of efficiency, that is, economic, geostrategic and institutional. The PMG results are presented in Table 13.

Table 13: PMG estimated equations for determinants of rail infrastructure efficiency

	D.NTKM		D.NTKMLOC		D.NTKMWG		D.PAXCHAKM		D.NTKMEMPL		D.NTKMTRK	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Lag order	1, 1, 0, 0, 0, 0		1, 0, 0, 0, 0, 0, 0		1, 1, 1, 1, 0, 0, 0		1, 0, 0, 0, 0, 0		1, 1, 0, 0, 0		1, 0, 0, 0, 0	
L.FI	40.61970***	(15.948)										
DLGDP	8.12509**	(4.226)	1.56072***	(0.760)			-2.28870*	(1.389)	0.44176	(0.475)	4.05296*	(2.437)
XCONST	0.25559	(0.245)	0.12706****	(0.049)	0.25536***	(0.100)	-0.06851	(0.077)			0.20131	(0.169)
CT	-0.02679	(0.054)	-0.00057	(0.008)	0.00822	(0.015)	-0.05282***	(0.012)	-0.00058	(0.005)	-0.03352	(0.030)
T	-0.20389	(0.925)	-0.10404	(0.151)	-0.15032	(0.262)	-0.83636***	(0.221)	0.51382***	(0.107)	-0.95463*	(0.505)
TTI			-35.41664	(22.327)			103.50606**	(45.117)				
NTKM			0.52611***	(0.090)								
L.TTI					30.57024	(37.367)						
L.NTKM					0.25577**	(0.115)			0.88212***	(0.072)		
L.DLGDP					2.41149**	(1.252)						
SR												
EC	-0.06606	(0.048)	-0.37102**	(0.166)	-0.16160**	(0.082)	-0.28351***	(0.048)	-0.12809***	(0.021)	-0.15523***	(0.047)
D.FI	2.62268***	(1.039)										
D.DLGDP	-0.24577	(0.494)	-0.23504	(0.256)	0.09191	(0.179)	0.62994	(0.711)	0.05238	(0.042)	-0.32960	(0.273)
D.XCONST	0.04250	(0.076)	0.01169	(0.015)	0.01797	(0.043)	0.01062	(0.022)			-0.03046	(0.024)
D.CT	0.09073	(0.099)	-0.00054	(0.012)	0.06592	(0.064)	0.16738	(0.165)	0.13843	(0.137)	0.04603	(0.057)
D.T	-0.06841	(0.052)	-0.03005	(0.090)	-0.13249***	(0.040)	0.17549	(0.176)	-0.03872	(0.029)	0.11747	(0.116)
D.TTI			10.75817	(9.038)	-0.34576	(3.723)	-7.48087	(7.485)				
D.NTKM			0.71908***	(0.157)	0.84237***	(0.168)			1.00592***	(0.017)		
_cons	1.60680	(1.178)	2.83320**	(1.245)	1.74309**	(0.880)	9.80959***	(1.629)	-2.11038***	(0.462)	5.20472***	(1.560)
Iteration	14		8		6		10		18		9	
H test	6.05(0.30)		7.95(0.16)		28.68(0.00)		0.60(0.99)		7.63(0.11)		10.92(0.03)	
Null	mg pmg		pmg mg		pmg mg		mg pmg		mg pmg		mg pmg	
Llhd	77.17		113.78		154.69		27.73		244.26		42.85	
N	171		172		172		165		196		172	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient; SE = Standard error.

Economic Drivers

Gross Domestic Product

Gross domestic product (GDP) has a positive significant impact on net tonne kilometres (NTKM), net tonne kilometres per locomotive (NTKMLOC) and (NTKMTRK) with coefficients of 8.125, 1.561 and 4.053 respectively. These are respectively significant at the 5%, 10% and 1% levels. The lag of GDP (LDLGDP) has a positive impact on wagon efficiency (NTKMWG) with a coefficient of 2.411 significant at the 5% level. A 1% increase in GDP is respectively associated with 8.125%, 1.561% and 4.053% improvement in efficiency. These findings may indicate that infrastructure becomes efficient and more productive as business volume increases and may suggest that current infrastructure is underutilised given their elasticities in relation to GDP growth.

On passenger coach kilometres (PAXCHAKM), the effect of GDP is negative (-2.289) and weakly significant at the 10% level. When GDP grows, disposable incomes increase resulting in increased use of road passenger transport which is more efficient at the expense of passenger rail transport.

GDP growth presents opportunities for transportation of more traffic by rail. The impact of GDP growth is more pronounced in the case of net tonnes per kilometre of track (NTKMTRK) because the rail track length is relatively fixed. The huge impact on the efficiency of the rail track (NTKMTRK) may suggest under-utilization of rail track infrastructure. Both wagons and the rail track have the potential to be more productive in the presence of high traffic volumes.

Technology

Technology (T) is a significant determinant of labour efficiency (NTKMEMPL) with a coefficient of 0.51382 significant at all levels. Higher productivity is realized in the case of technological advancement where tasks are completed faster and at lower cost in most cases. The finding implies that the four countries can boost the productivity of their labour by investing in technology. More investment in technology will accelerate economic growth through improved factor productivity and efficiency.

Results further indicate that technology has a negative impact on passenger coach efficiency (PAXCHAKM) and rail track efficiency (NTKMTRK) with coefficients of -0.836 and -0.9546 significant at the 1% and 10% levels. The negative impact of technology on passenger coach kilometres (PAXCHAKM) may be explained by the fact that changes in technology over the years were embraced more by the road transport sector where passenger luxury coaches flooded the market resulting in passengers preferring to use more of road transport which is more convenient and efficient compared to passenger rail transport. Rail passenger services therefore lost market share due to failure to embrace technological advancement. Some of the rail passenger coaches that were in use in the 1950s are still in use to this day in some of the countries under study.

The negative impact of technology on NTKMTRK is expected given the long life span of rails of up to 100 years and notable lack of technological advancement with respect to rail tracks in the four countries. Rail track infrastructure remained relatively fixed during the study period without incorporation of technological advancements. Business available to the track was also reduced due to technological advances on the part of road transport, giving the latter a competitive edge.

The effect of technology on net tonne-kilometres per wagon (NTKMWG) and passenger coach kilometres (PAXCHA) is negative with coefficients of -0.564 and -0. 460 significant at the 1% and 5% levels respectively. The negative effect of technology on NTKMWG may be a reflection of the fact that railway wagons in the countries under the study remained predominantly the same during the study period. In contrast, major technological changes have taken place in the road sector where the size of trucks has increased significantly resulting in their ability to carry bigger loads (from 7 tonnes to over 60 tonnes in some cases). Second, the loading and offloading technology for road trucks has improved significantly over the years resulting in improved convenience to shippers. Technology has thus benefited the road transport sector at the expense of the rail transport sector. The coefficients reflect a huge impact suggesting that most of the traffic will shift to road transport if rail transport does not embrace technology.

Technology has an insignificant negative coefficient of -0.096 on net-tonne kilometres per kilometre of rail.

Net Tonne Kilometres

Net tonne-kilometres (NTKM) have a positive effect on net tonne kilometres per locomotive (NTKMLOC) with a coefficient of 0.526 significant at all levels. The result means that a 1% increase in net ton kilometres will be associated with a 0.53% increase in net tonne-kilometres per locomotive, other things being equal. This result indicates that locomotives can be more productive if traffic volumes are high since the NTKMs represent the volume of business.

In the same vein, the lag of NTKM (L.NTKM) is a significant determinant of net tonne-kilometres per wagon (NTKMWG) and net tonne-kilometres per employee (NTKMEMPL) with coefficients of 0.2558 and 0.882 respectively significant at the 5% and 1% levels. The finding means that a 1% increase in net tonne-kilometres will be associated with a 0.26% increase in the net tonne-kilometres per wagon (NTKMWG), and a 0.88% increase in NTKMEMPL *ceteris paribus.* This may also suggest current underutilization of wagons and labour. It is therefore productive to invest in additional locomotive and wagon capacity especially in view of inadequate capacity that has persisted over the years. In essence, business volume justifies investment in both locomotives and wagons.

Overall, net tonne-kilometres (NTKMs) are a measure of business volume on which the infrastructure and labour are utilized. The positive relationship is therefore expected. NTKMs can therefore be used as a barometer for rail performance both at aggregate organisational level and efficiency of various rail infrastructure categories.

Geostrategic Drivers

The coefficients of geostrategic factors proxied by the length of colonial tenure (CT) are insignificant for all efficiency measures except for PAXCHAKM where the coefficient of CT is -0.05282 significant at all levels. This finding suggests that passenger rail efficiency is a victim of geostrategic priorities adopted in the past. More effort would therefore be required in order to improve passenger rail efficiency.

Institutional Drivers

Domestic institutions in the four countries are significant positive determinants of rail infrastructure efficiency. Results indicate that institutions have a positive effect on net tonne-kilometres per loco (NTKMLOC) with a coefficient of 0.127 significant at all levels, and net tonne-kilometres per wagon (NTKMWG) with a coefficient of 0.255 significant at all levels. These results suggest that domestic institutions have been supportive to railway operations and utilization of operating resources. This provides strong justification for developing or improving institutional frameworks to support railways in these four countries, more so given that rail infrastructure capacity in these four countries has been declining over the years. However, the descriptive analysis in Chapter 3 shows a persistent decline in rail infrastructure efficiency in the four countries.

Overall, we conclude that domestic institutions are important determinants of rail infrastructure efficiency and therefore should be accorded due attention. Based on the research findings, we conclude that rail infrastructure investment and efficiency in the four countries are driven by a mix of economic, geostrategic and domestic institutions whose impact on investment depends on the context and time.

The MG estimated results for the determinants of rail infrastructure efficiency in the four countries are presented in Table 14.

Table 14: MG estimated equations for determinants of rail infrastructure efficiency

	D.NTKM		D.NTKMLOC		D.NTKMWG		D.PAXCHAKM		D.NTKMEMPL		D.NTKMTRK	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
L.FI	27.718*	(15.517)										
DLGDP	3.369	(3.241)	2.088	(1.555)			-0.207	(2.758)	-1.909	(6.077)	1.600	(3.995)
XCONST	-0.105**	(0.044)	0.047	(0.038)	0.097**	(0.049)	-0.083	(0.128)	0.356	(0.304)	-0.139	(0.114)
CT	0.124	(0.468)			-0.083	(0.239)	0.165	(0.272)	-1.541	(1.416)	-0.022	(0.483)
T	-0.548	(0.410)	0.020	(0.193)	-0.143	(0.100)	-0.301	(0.223)	1.988	(1.416)	-0.654	(0.476)
TTI			-4.960	(24.862)			21.859	(66.027)				
NTKM			0.626***	(0.129)								
L.CT			0.100	(0.204)								
L.TTI					23.482	(33.468)						
L.NTKM					0.355*	(0.216)			1.511***	(0.450)		
L.DLGDP					1.721*	(1.026)						
SR												
EC	-0.251***	(0.060)	-0.712***	(0.179)	-0.438**	(0.186)	-0.573***	(0.211)	-0.230	(0.149)	-0.292***	(0.083)
D.FI	3.680***	(1.482)										
D.DLGDP	-0.648	(0.593)	-0.368**	(0.180)	0.091	(0.104)	-0.395	(0.993)	0.044	(0.483)	-0.689	(0.512)
D.XCONST	0.066	(0.079)	0.015	(0.016)	0.032	(0.048)	0.071	(0.103)	-0.005**	(0.002)	-0.000	(0.041)
D.CT	0.054	(0.408)	0.000	(0.550)	-0.049	(0.176)	-0.121	(0.786)	0.039	(0.128)	0.100	(0.501)
D.T	-0.070	(0.110)	-0.001	(0.187)	-0.069	(0.101)	0.008	(0.121)	-0.055	(0.044)	-0.046	(0.122)
D.TTI			4.919	(9.351)	6.296	(5.884)	15.292	(17.680)				
D.NTKM			0.415**	(0.182)	0.829***	(0.170)			0.893***	(0.116)		
_cons	7.076***	(1.639)	2.204	(4.737)	1.718	(1.793)	10.475***	(2.651)	-4.987	(4.932)	6.171***	(1.940)
h test	0.34(1.00)		3.02(0.81)		3.54(0.74)		0.76(0.98)		2.04(0.73)		1.00(0.91)	
N	164		164		164		157		162		164	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient; SE = Standard error.

4.4.5 Determinants of Investment in Rail Infrastructure in South Africa

The distinction between South Africa and the other four countries rendered its inclusion in the panel inappropriate. Analysis for South Africa is therefore done separately from the other four countries employing the Bounds Test time series technique of Pesaran *et al* (2001). The lags are based on Akaike Information Criteria (AIC) and the lag order is determined by ARDL.

4.4.5.1 Basic statistics

The basic statistics of South Africa are presented in table 4.10 below.

Table 15: Summary statistics

Variable	**Obs.**	**Mean**	**Std. dev.**	**Minimum**	**Maximum**
FI	58	0.000	0.008	-0.027	0.023
PI	58	0.000	0.009	-0.026	0.025
MI	58	-0.001	0.009	-0.023	0.019
TTI	58	0.000	0.001	-0.004	0.007
RI	52	0.002	0.004	-0.001	0.027
RRI	52	0.004	0.020	-0.050	0.100
LGDP	59	26.087	0.459	25.094	26.786
LGDPCAP	59	8.745	0.121	8.439	8.934
GI	59	24.694	1.763	21.932	27.510
XCONST	59	3.780	17.339	-88.000	7.000
CT	59	6.00	17.176	-23.000	35.00
T	59	25.351	0.552	24.519	26.456
FDI	59	0.685	1.146	-0.841	5.983
IMR	59	63.357	27.006	28.500	117.740
HCI	58	2.044	0.305	1.739	2.809
TFPK1	39	0.066	0.013	0.034	0.097
NTKM	59	25.149	0.338	24.339	25.626
NTKMTRK	59	15.144	0.348	14.354	15.697
NTKMLOC	59	16.969	0.439	16.263	17.805
NTKMWG	59	13.515	0.585	12.857	14.717
PAXCHA	59	11.900	0.954	10.791	13.399
NTKMEMPL	59	13.707	1.187	12.085	15.432

The summary indicates that most of the data for South Africa is available.

4.4.5.2 Model estimation and discussion of results

In the time series case of South Africa, we employ the Bounds Test technique of Pesaran, Shin and Smith (2001) to conduct cointegration tests. When compared to other cointegration techniques, the superiority of the ARDL cointegration approach as observed by for example, Odhiambo (2009, 2010) lies in;

(i) Its robustness in the cases where the sample size is small.

(ii) Non-imposition of the restrictive assumption that all the variables under study must be integrated of the same order and therefore applicable when the underlying regressors are I(0) and I(1).

(iii) Unbiasedness of the long-run model estimates and validity of t-statistics, even in the presence of endogeneity among some of the regressors.

The Bounds Test is appropriate in this case of South Africa considering that the data sample size is small (59 observations) and the variables have different orders of integration (Table 4.11 refers). The Akaike Information Criterion (AIC) is used to determine the optimal lag length.

4.4.5.3 Unit Root Tests

We perform the ADF-Fisher and Phillips-Perron unit roots test for the time-series data in the case of South Africa. Test results are reported in Table 16.

Table 16: ADF-Fisher (ADF) and Phillips-Perron Unit Root Test Results

Variable	**ADF-Fisher (ADF)**		**Phillips-Perron**		
	Levels	First differences	Levels	First differences	Level of Integration
FI	-4.54***	-10.61***	-4.57***	-12.78***	I(0)
PI	-4.78 ***	-10.81***	-4.77***	-13.82***	I(0)
MI	-3.95 **	-10.26***	-3.88**	-12.61***	I(0)
RRI	-11.45***	-16.76***	-11.58***	-22.86***	I(0)
RI	-27.03***	-22.77***	-24.18***	-42.95***	I(0)
TTI	-8.27***	-12.89***	-8.35***	-17.06***	I(0)
GDP	-3.07	-4.70***	-2.87	-4.68***	I(1)
GI	-2.58	-7.123***	-2.52	-7.132***	1(1)
IMR	-0.95	-3.26*	-1.12	-3.16*	I(1)
T	-2.079	-7.313***	-2.023	-7.301***	1(1)
FDI	-6.14***	-11.81***	-6.13***	-16.00***	I(0)
XCONST	-4.278**	-7.725***	-4.384***	-7.349***	1(0)
LGDP CAP	-1.95	-4.27***	-2.07	-4.23***	I(1)
CT	-1.619	-7.446***	-1.626	-7.445*	1(1)
TFP	-2.88	-6.85***	-2.78	-6.93***	I(1)
NT	-2.50	-7.02***	-2.70	-6.85***	I(1)
NTKM	-2.36	-8.22***	-2.43	-8.16***	I(1)
NTKMTRK	-2.87	-8.67***	-2.94	-8.58***	I(1)
NTKMLOC	-2.41	-8.73***	-2.46	(-8.47***	I(1)
NTKMWG	-1.64	-7.00***	-1.67	-7.05)***	I(1)
PAXCHA	-1.02)	-6.09***	-0.52	-6.07***	I(1)
NTKMEMPL	-1.53)	-6.28***	-1.49	-6.37***	I(1)
LGDPCAP	-2.074)	-4.234***	-1.946	-4.266***	I(1)
TFPK1	-2.775)	-6.934***	-2.879	-6.85***	I(1)

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Results in Table 16 indicate that all infrastructure measures, XCONST and FDI are I(0). The rest of the variables are I(1).

Time series data is susceptible to a number of challenges which may render estimates spurious or inefficient. These challenges include serial corelation, heteroskedasticity and skewness. The Breusch-Godfrey Serial Correlation test indicate the presence of serial correlation in the data series for TFP and Direct Infrastructure Impact models. There is no serial correlation in the total infrastructure impact models. The challenges posed by serial correlation may be mitigated by the selected optimal lag length. While increasing the lag order would mitigate serial corelation challenges, the concern is that higher lag orders would reduce the number of observations and lead to small sample bias. Transport issues are persistent therefore serial correlation may not be avoidable in data series. The lag length is therefore considered sufficient to minimise the adverse effects of serial correlation. Non-stationarity and absence of cointegration are much more serious and therefore need to be investigated.

We estimate investment equations for freight (FI), passenger (PI), mixed (MI), track (TTI), road (RI) and surface transport (RRI) infrastructure investment as is the case for the panel context of the other four SADC countries. The following specific infrastructure investment equations are estimated;

(i) Freight: FI=f(DLGDP F2 XCONST CT GI T)

(ii) Passenger: PI=f(DLGDP P2 XCONST CT GI T)

(iii) Mixed: MI=f(DLGDP M2 XCONST CT GI)

(iv) Surface Transport: RRI=f(RR2 DLGDP GI XCONST CT T)

(v) Road: RI=f(R2 GI XCONST IMR T)

(vi) Rail Track: TTI=f(T2 DLGDP RI CT T)

4.4.5.4 Cointegration Tests

In order to establish the existence of a long-term equilibrium relationship among the variables in the model, cointegration tests are conducted using the Bounds Test technique to cointegration to establish if rail infrastructure investment is cointegrated with GDP, domestic institutions, geostrategic priorities, government investment, technology and development.

The Bounds Test technique is based on the joint F-statistic to cointegration analysis where the asymptotic distribution of the F-statistics is non-standard under the null hypothesis of no cointegration between the variables in the model. The decision criteria is based on the position of the F-statistic in relation to the range defined by the lower and upper bound critical values for a given level of significance.[68]The null hypothesis is rejected if the F-statistic is greater than the upper bound critical value. If the F-statistic is below the lower bound critical value, the null

[68] The critical values and approximate p values are as reported by Kripfganz and Schneider (2018).

hypothesis of no cointegration cannot be rejected. The cointegration test is inconclusive if the F-statistic falls within the bounds.

Results for the Bounds Test for cointegration for the determinants of rail and road infrastructure investment in South Africa are reported in Table 17.

Table 17: Bounds Test cointegration results for infrastructure investment

Dependent variable	**AIC lags**	**F-statistic**	**LB CV at 5%**	**UB CV at 5%**	**Decision**
FI (DLGDP F2 XCONST CT GI T)	(1,1,0,0,0,0,0)	4.47	2.70	4.03	Cointegration
PI (DLGDP P2 XCONST CT GI T)	(1,0,0,0,0,0,0)	7.70	2.70	4.02	Cointegration
MI (DLGDP M2 XCONST CT GI)	(1,0,0,2,1,1,2)	7.27	2.67	4.08	Cointegration
RRI (RR2 DLGDP GI XCONST CT T)	(1,1,0,0,0,1,1)	14.55	2.75	4.17	Cointegration
RI (R2 DLGDP XCONST IMR CT T)	(1,1,0,2,1,1,0)	26.79	2.74	4.20	Cointegration
TTI (T2 DLGDP RI CT T)	(1,0,0,2,2,1)	18.22	2.90	4.31	Cointegration

Notes: LBCV-Lower bound critical value; UBCV-Upper bound critical value.

Based on the results, we reject the null of no cointegration and conclude that the variables are cointegrated. The result allows us to proceed with the estimation of the determinants of rail infrastructure investment in South Africa using the ARDL Bounds Test technique to establish the long run relationship.

The Bounds Test estimation results for the models are presented in Table 18.

Table 18: Determinants of rail infrastructure investment in South Africa

Equation						
	D.FI	D.PI	D.MI	D.RI	D.RRI	D.TTI
Lag order	1, 1, 0, 0, 0, 0, 0	1, 0, 0, 0, 0, 0, 0	1, 0, 0, 2, 1, 1, 2	1,1,0,2,1,0	1, 1, 0, 0, 0, 1, 1	1, 0, 0, 2, 2, 0
	Coef	Coef	Coef	Coef	Coef	Coef
ECT	-0.711***(0.13)	-0.847***(0.14)	-0.789***(0.13)	-1.022***(0.09)	-1.613***(0.16)	-1.326***(0.13)
DLGDP	-0.08(0.08)	-0.1832***(0.07)	-0.1947*** (0.06)	-0.005(0.00)	0.0423(0.06)	-0.005(0.01)
XCONST	0.00004(0.00)	0.0001 (0.00)	-0.0002(0.00)	-0.00004***(0.00)	0.0010(0.00)	
GI	-0.0085*** (0.00)	-0.0075*(0.00)	-0.0047(0.00)		0.00001(0.00)	
CT	0.00005(0.02)	-0.0003(0.00)	-0.0005**(0.001)	0.00001(0.00)	-0.0004(0.00)	0.00001(0.00)
T	0.0017(0.01)	-0.0062(0.01)		0.021***(0.00)	-0.0017(0.01)	0.0001(0.00)
IMR			0.00007(0.00)	0.0001(0.00)		
RI						0.6515***(0.24)
T2						-0.001(0.00)
F-statistic	6.52(0.0000)	5.52(0.0000)	6.97(0.0000)	16.2(0.0000)	2.91(0.0000)	2.75(0.0000)
Adj.R^2	0.44	0.45	0.49	0.82	0.72	0.71
Llhd	213.34	204.54	222.68	302.39	149.27	271.41
RMSE	0,01	0,01	0,01	0,001	0,01	0,001
SR						
XCONST						
DL			0.0002**(0.00)	0.00002***(0.00)		
LD			0.0003***(0.00)	0.00003*** (0.00)		
GI						
DL						
LD						
RI						
D1						-0.845*** (0.25)
LD						0.071(0.04)
CT						
DL			0.0007*(0.00)	-0.00007**(0.00)	0.0005(0.00)	0.00004(0.00)
LD						0.0001*(0.00)
T						
D1					0.0385(0.03)	
LD						
IMR						
D1			-0.0007(0.00)	0.0001(0.00)		-0.128(0.32)
LD			0.012(0.00)			0.106***(0.04)
cons	-0.1565 (0.12)	-0.0305(0.17)	0.070 (0.07)	-0.084*(0.04)	-0.3374 (0.34)	0.0266*(0.02)
N	57	57	57	48	48	48

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient; SE = Standard error.

The adjusted R^2 for the four rail infrastructure investment models averages 52%. This result suggests average explanatory power of the models. The adjusted R^2 for the road infrastructure investment model of 82% suggests strong explanatory power of the model. The low Root Mean Square Error (RMSE) averaging 0.007 suggests a good fit between the data and the model indicating good prediction power of the model. The F-statistic which is significant at all levels confirms that the models are well specified.

Adjustment Coefficient

The adjustment coefficients of the six rail infrastructure investment models range from 71.1% to 161.3% with an average of 120.2%. The average of the adjustment coefficient which represents the speed of convergence is 105% with the expected negative sign and significant at all levels. This provides sufficient evidence for rapid speed of convergence to long-run equilibrium relationship for all dynamic specifications for the country under study.

The results are presented and analyzed on the basis of the categories of determinants i.e. economic, geostrategic and institutional.

Economic factors

Gross domestic product

Results indicate that there is a negative relationship between gross domestic product (GDP) rail passenger infrastructure investment (PI) and mixed infrastructure investment (MI) with coefficients of -0.1832 and -0.1947 respectively significant at all levels. Rail transport in South Africa has not been benefiting from the growth in GDP but actually lost out. This is explained by the fact that over 85% of freight traffic has been transported by road. The impact is large.

The relationship between GDP; rail freight (FI) and rail track infrastructure investment (TTI) is insignificant. This may be due to the fact that rail infrastructure investment in South Africa has not been growing in sympathy with GDP growth. This is so given that the core rail network for South Africa was already in place in the 1930s before our study period.

The impact of GDP on road infrastructure investment (RI) is surprisingly insignificant given the over 85% freight and passenger transport market share commanded by road transport in South Africa. The road network in South Africa may not have grown significantly over the years even though GDP grew significantly.

Government investment

The results indicate that the impact of government investment (gi) is negative on freight rail infrastructure (FI) and passenger rail infrastructure (PI) with coefficients of -0.0085 and -0.0075 significant at the 1% and 5% levels respectively. This finding suggests that the two are not benefiting from government investment. The fact that the impact is negative may further suggest that the South African government could be investing in those sectors that do not benefit the railways but possibly competing with rail transport interests in some cases. The impact of government investment on rail passenger infrastructure is negative even though rail passenger transport receives subsidies from government which appears to be inadequate based on the result. The impact on mixed rail infrastructure (MI) investment is insignificant.

The impact of government investment on land transport infrastructure investment is insignificant. This finding suggests that when combined, rail and road infrastructure investment is not benefiting from government investment which could be through direct funding or indirect through investment in other sector that promote land transport infrastructure investment.

Technology

The impact of technology (T) on rail infrastructure investment is insignificant. This result may be due to the rail sector's failure to embrace technological advancements. No major technological changes were introduced in rail transport in South Africa during the study period. The rail track did not change much, and diesel and electric locomotive traction were already in place prior to the study period except those introduced into service during the study period, some of which were of bigger sizes. The decline in rail infrastructure demonstrated in Chapter 3 implies little or no replacement of infrastructure, a situation which did not provide opportunities for introducing new technology. The long life span of rail infrastructure and its huge capital requirements compounded this problem as replacement would have serious financial implications.

In contrast, the impact of technology on investment in road infrastructure is positive with a coefficient of 0.021 significant at all levels suggesting that technology drives investment in road infrastructure. This could be through the demand side where production and processing techniques increase the demand for road transport, or through improved capacity of road haulage trucks and also through technologically advanced methods of road construction which make it cheaper to build new roads.

Geostrategic factors

Estimation results indicate that geostrategic factors proxied by length of colonial tenure (Ct) have an insignificant impact on freight, passenger and rail track infrastructure investment. The impact is negative on mixed rail infrastructure investment with a coefficient of 0.0005 significant at the 5% level.

Geostrategic factors also have an insignificant impact on road (RI) and land transport infrastructure investment (RRI). This finding suggests that road and land transport infrastructure investment in South Africa did not benefit from geostrategic initiatives adopted in the past.

Overall, the results suggest that geostrategic priorities adopted in the past did not benefit the transport sector in South Africa.

Institutional factors

Results indicate that domestic institutions proxied by the Executive Constraints (XCONST) indicator have an insignificant impact on all the infrastructure measure except for road infrastructure investment where it is negative with a coefficient of -0.00004 significant at all levels. However, the impact is minimal given that the coefficient is close to zero. The finding suggests that domestic institutions in South Africa are not supportive to rail infrastructure investment.

4.4.6 Determinants of rail infrastructure efficiency in South Africa

The efficiency of rail infrastructure is important as it determines productivity. Improved efficiency of infrastructure implies less resource requirements. The identification of the determinants of rail infrastructure investment will help address rail infrastructure challenges if the determinants are considered and managed. However, it is not only rail infrastructure availability which matters, but also how efficient the infrastructure is. Rail infrastructure efficiency will determine the productivity of and the requirements for infrastructure. We therefore seek to identify the determinants of rail infrastructure efficiency to provide insights on how the efficiency can be improved.

4.4.6.1 Cointegration test

Cointegration tests are conducted using the Bounds Test technique to cointegration to establish the existence of long-term equilibrium relationship among the variables in the models. We specifically seek to establish if rail infrastructure efficiency is cointegrated with GDP, domestic institutions, geostrategic priorities and technology.

*Table 19: **Bounds Test cointegration results for infrastructure efficiency measures***

Dependent variable	AIC lags	F-statistic	LB CV at 5%	UB CV at 5%	Decision
NTKMLOC (NTKMEMPL NTKM GI XCONST CT T)	(1,1,0,0,0,0,0)	4.71	2.65	4.10	Cointegration
NTKMWG (LOCKM XCONST CT T)	(1,0,0,0,0,0,0)	5.88	3.06	4.38	Cointegration
NTKMTRK (NTKMLOC NTKMEMPL GI XCONST CT T)	(1,0,0,2,1,1,2)	6.45	2.56	3.94	Cointegration
PAXKMCHA (LOCKM TK XCONST CT)	(1,1,0,0,0,1,1)	11.22	3.06	4.38	Cointegration
NTKMEMPL (LOCKM NTKM GI XCONST T)	(1,1,0,2,1,1,0)	4.77	2.85	4.16	Cointegration

Notes: Kripfganz and Schneider (2018) critical values and approximate p-values; LBCV-Lower bound critical value; UBCV-Upper bound critical value.

Given the presence of cointegration, we reject the null of no cointegration and conclude that the variables are cointegrated and proceed with the estimation of the determinants of rail infrastructure efficiency in South Africa using the ARDL Bounds Test technique to establish the long run relationship.

4.4.6.2 Model estimation and discussion of results

Having established existence of cointegration, we proceed to estimate the full models by means of the Bounds Test estimation technique. The Bounds Test estimation results for the determinants of rail infrastructure efficiency in South Africa are presented in Table 4.15.

The adjusted R^2 averaging 67.8% for the five models suggests moderate explanatory power of the models. The low Root Mean Square Error (RMSE) averaging 0.06 suggests a good fit between the data and the model indicating good prediction power of the model. The F-statistic which is significant at all levels in the four models, indicates the joint significance of the variables and that the models are well specified.

Adjustment Coefficient

The adjustment coefficients of the six rail infrastructure investment models range from 5.6% to 73% with an average of 36.5%. The average of the adjustment coefficient which represents the speed of convergence is 36.5% with the expected negative sign and significant at all levels except one at the 5% level. This provides sufficient evidence of convergence to long-run equilibrium relationship for all dynamic specifications for the country under study though slow.

Table 20: Determinants of rail infrastructure efficiency in South Africa

Equation					
	NTKMLOC	NTKMWG	NTKMTRK	PAXKMCHA	NTKMEMPL
Lag order	1, 1, 2, 1, 2, 0, 2	2, 0, 1, 0, 2	1, 0, 1, 1, 0, 1, 0, 0	2, 0, 0, 2, 1	1, 0, 1, 0, 1, 0
	Coef	Coef	Coef	Coef	Coef
ECT	-0.421***(0.10)	-0.73***(0.13)	-0.484***(0.08)	-0.056**(0.02)	-0.135***(0.04)
NTKM	-0.076(0.16)		1.1287***(0.02)		1.7301***(0.64)
XCONST	0.0048***(0.00)	-0.004*** (0.00)	-0.003*(0.00)	0.1055*(0.06)	-0.0134*(0.01)
GI	0.0887()		-0.0047(0.01)		0.6515***(0.14)
CT	0.0099***(0.00)	0.0109***(0.00)	0.0008***(0.00)	0.1164**(0.08)	
T	-0.2822*** (0.13)	0.8245*** (0.03)	0.0082(0.01)		
NTKMLOC		0.88*** (0.173)			
NTKMWG					
LOCKM		0.0000(0.00)	-0.00001***(0.00)	-0.0009***(0.00)	0.00004***(0.00)
NTKMEMPL	0.4759***(0.09)		-0.0498***(0.01)		
DLGDP					
TTI				88.4964** (43.52)	
F-statistic	432.67(0.0000)	690.63(0.0000)	20464.50(0.0000)	690.32(0.0000)	2402.45(0.0000)
Adj.R^2	0.78	0.34	0.99	0.80	0.48
Llhd	112.76	89.87	228.03	63.52	81.98
RMSE	0.040	0.06	0.01	0.09	0.06
SR					
XCONST					
D1	-0.017***(0.00)	0.0025***(0.000)	0.001*(0.000)	-0.0036**(0.000)	0.0021***(0.00)
LD	-0.0008*(0.00)			-0.0161***(0.00)	
NTKM					
D1	1.0156***(0.13)		0.4731***(0.09)		0.6295***(0.15)
LD	-0.2198**(0.11)				
NTKMLOC					
D1					
PAXKMCHA					
LD				0.2222(0.14)	
NTKMWG					
D1		0.3526**(0.14)			
LD					
LOCKM					
D1			-5.94e-06***(0.00)		
CT					
D1				-0.0449***(0.01)	
LD					
NTKMEMPL					
D1	-0.1708(0.11)				
T					
D1	0.2092***(0.08)	-0.3455***(0.13)			
LD	0.2237***(0.08)	-0.3640*** (0.13)			
CONS	7.2499***(1.56)	-5.1090***(1.03)	-5.6506***(0.99)	-43.731***(10.54)	1.9929(1.42)
N	57	57	58	58	57

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient; Standard error in parenthesis.

The determinants are analyzed on the basis of the three driver categories of economic, geostrategic and institutional factors as before.

Economic Factors

Net tonne-kilometre

The net tonne-kilometre (NTKM) has appositive impact on the efficiency of the rail track and labour with coefficients of 1.1287 and 1.7301 respectively significant at all levels. NTKMs measure the level of business done by railways. High business volume would improve utilization and productivity of the rail track and employees.

Government Investment

Government investment in South Africa has an insignificant impact on locomotive (NTKMLOC) and rail track (NTKMTRK) efficiency. This reflects lack of support to fund rail infrastructure and equipment by government.

In contrast, government investment has a positive impact on the efficiency of labour. Government investment has a coefficient of 0.6515 significant at all levels suggesting that government is investing in those sectors which promote employee productivity like training and mechanization, for example.

Technology

Technology has a positive impact on wagon efficiency with a coefficient of 0.8245 significant at all levels. The finding suggests that wagons benefited from technological developments. The impact of technology on the efficiency of the rail track insignificant reflecting the fixed nature of the rail track and long life span. No major technological changes relating to the rail track in South Africa took place during the study period.

The impact of technology is negative on locomotive (NTKMLOC) and labour (NTKMEMPL) efficiency with a coefficient of -0.2822 significant at the 5% level. Locomotives might have not benefited from technological developments as the changes in traction power (steam, diesel and electricity) had already taken place in South Africa before our study period.

Regarding labour efficiency, a lot depends on the infrastructure at the disposal of employees as they carryout their duties. Lack of major technological advancement in the domain of railways negatively affected the efficiency of labour.

Net tonne kilometre per locomotive (NTKMLOC) and net tonne kilometre per wagon (NTKMWG)

Locomotives, wagons and the rail track provide rail freight transportation services jointly therefore their efficiencies are dependent on each other. The locomotive provides the motive power to pull the wagons over the rail track. The locomotive kilometres (LOCKM) have a negative impact on NTKMTRK, PAXKMCHA and NTKMEMPL with coefficients of -0.00001, -0.0009 and -0.00004 significant at the 1%, 5% and 1% levels respectively. These findings confirm the relationships among the various rail infrastructure classes which provide transportation services jointly. It is worth noting that the efficiency of locomotives and wagons for example will also depend on the quality of the track.

Geostrategic factors

Geostrategic factors proxied by length of colonial tenure (CT) have a significant positive effect on net tonne kilometres per locomotive (NTKMLOC) with a coefficient of 0.0099 significant at all levels. In contrast, geostrategic factors have a negative impact on the efficiency of wagons (NTKMWG) and net tonnes per kilometre of track (NTKMTRK) with coefficients of -0.0109 and -0.00080 respectively and significant at all levels. This may mean that South Africa needs to put more effort on improving the efficiency of these two classes of rail infrastructure.

The effect is insignificant on the efficiency of passenger coaches (PAXCHA) possibly due to the long life of passenger coaches which results the use of old coaches over long periods. Worth noting however, is the fact that despite the inefficiency and poor performance of passenger train services government has continued to provide support. This may suggest that passenger train services are a necessity.

Institutional factors

Results indicate that domestic institutions in South Africa have a positive effect on net tonne-kilometres per locomotive (NTKMLOC) and passenger coaches (PAXCHA) with coefficients of 0.0048 and 0.1055 respectively significant at the 1% and 10% levels. This finding may reflect South Africa’s ability to maintain its own locomotives through Transnet Rail Engineering and subsidies extended to passenger services by government.

The impact of domestic institutions is negative on net tonne kilometres per wagon (NTKMWG), net tonnes per kilometre of track (NTKMTRK) and net tonne-kilometres per employee (NTKMEMPL) with coefficients of -0.004, -0.0003 and -0.0134 respectively significant at the 1%, 10% and 10% levels. This result suggests that domestic institutions in South are not supportive to rail track, wagon and labour efficiency. The support could be through improved funding to support new investment and maintenance so as to improve the quality of the rail track for safe and faster speed of trains.

Domestic institutions are in fact harmful to the efficiency of these categories of rail infrastructure and rail freight business in general. The channel of the impact of domestic institutions may be indirect through their failure to support rail infrastructure efficiency improving sectors.

Overall, the results suggest that technology, geostrategic and domestic institutional factors are significant determinants of rail infrastructure efficiency in South Africa. Geostrategic and domestic institutional factors need to be correctly aligned for them to support efficiency improvement. Keeping pace with, and investment in technology is required in order to boost infrastructure efficiency and productivity.

4.5. Evaluation, conclusions and recommendations

Our estimation results confirm that the determinants of investment in rail infrastructure and efficiency can be classified as economic, geostrategic and institutional drivers.

4.5.1 Determinants of investment in rail infrastructure

4.5.1.1 Economic factors

GDP, government investment and technology are the main economic factors considered.

Gross Domestic Product - The finding of an insignificant or negative effect of GDP on rail infrastructure investment in the five SADC countries is plausible considering that most of the traffic is moving by road transport. The finding suggests that rail transport failed to benefit from the growth in GDP from two perspectives. First, the insignificant relationship is due to the fact that rail transport lost business to road transport as GDP was growing indicating a decline in the demand for rail transport due to inefficiency occasioned by inadequate and declining capacity. Second, rail infrastructure did not benefit from funding opportunities presented by the growth of national incomes of the countries under study hence the decline of rail infrastructure investment when GDP was growing.

The contrasting finding in the case of road infrastructure investment, where the impact of GDP is positive in the four-country case is expected considering that road transport moves most of the traffic in these countries. Road transport infrastructure investment responded to the growth in GDP consistent with the accelerator theory of investment. Road infrastructure investment could have also benefited from funding opportunities that come with growth in national income. The insignificant effect of GDP on road infrastructure investment in the case of South Africa may be due to the fact that the road infrastructure network in South Africa did not grow significantly as GDP was growing. This could also be due to the fact that the core road network was already in place prior to 1960, the starting of the study period. Fedderke and Bogetic (2009) show that road kilometres were going down on the main routes and efficiency improvements were due to widening and straitening of the roads.

Government investment – The finding of an insignificant impact of government investment on rail infrastructure investment in the four case and a negative impact in the case of South Africa may suggest that the governments in the five countries are investing in other sectors not rail. This finding supports the results from the descriptive analysis of rail infrastructure in Chapter 3 which show a persistent decline in rail infrastructure investment. The negative impact in the case of South Africa further suggests that government investment is directed to sectors competing against rail transport.

In contrast, the impact of government investment on road infrastructure investment is positive. This finding indicates that government investment in these countries is directed towards those sectors that support road infrastructure investment and road infrastructure investment itself. More government investment could be directed to road compared to rail transport. This could partly explain the insignificant or negative impact on rail infrastructure investment. In the case of South Africa, government investment has a significant positive impact on land transport infrastructure.

This finding indicates that's government investment could have been directed to land transport or indirectly to land transport infrastructure through those sectors that promote land transport. Considering the earlier results indicating a negative impact of government investment on rail infrastructure investment in South Africa, we can conclude that the positive impact of government investment on land transport infrastructure investment is through its impact on road infrastructure investment.

Overall, the allocation of government investment cannot be separated from domestic institutional frameworks and prevailing institutional factors.

Technology – The finding of a significant negative impact of technology on some rail infrastructure investment measures (freight and passengers) and an insignificant impact on the rest of the infrastructure measures including road and land transport infrastructure in the four-country case point to the differences across sectors regarding access to technology and its use. In the case of South Africa technology has a positive impact on road infrastructure investment only. Diesel and electric locomotives were already in use by 1960 even though steam locomotives were gradually phased out during the study period, without replacement in some cases hence the decline in the number of locomotives. No significant technological changes were made to wagons during the study period in four country case. If anything, wagons lost traffic carrying opportunities due to technological developments in road transport and also production and distribution processes. However, there were some technological improvements on wagons in South Africa in terms of the size of the wagons, braking system and use of roller bearings which allowed longer trains to hauled.

The finding of a negative impact of technology on road infrastructure investment in the four-country case and a positive impact in the case of South Africa may indicate South Africa's technological superiority over the other four countries. The positive impact of technology on road infrastructure investment in South Africa could be through improved road construction technology which lowers the cost of road construction, increased demand and use of road transport due to better service offering or technologically advanced production and distribution processes that lead to technologically induced demand for road transport services.

4.5.1.2 Geostrategic factors

The mixed impact of geostrategic factors on rail infrastructure investment reflects the peculiarities among rail infrastructure measures. Geostrategic factors have a negative impact on freight, passenger and mixed rail infrastructure investment, and a positive impact of rail track infrastructure investment. The positive impact on rail track infrastructure investment is a reflection of the fact that most rail lines in these countries were constructed during the colonial era. The countries can build on existing rail track infrastructure to expand their track capacity.

The negative impact on freight, passenger and mixed rail infrastructure investment may suggest that geostrategic priorities of the past did not favour investment in these rail infrastructure categories and therefore the countries have to work harder to catch-up. The contrasting finding of a positive impact of geostrategic factors on rail infrastructure investment in South Africa indicates that South Africa's rail infrastructure benefited from geostrategic priorities adopted in the past. There is therefore a sound infrastructure base to build on.

The negative effect of geostrategic factors on road infrastructure investment in the four-country case possibly indicates the lack of wider coverage and accessibility during the colonial era. This suggests that the four countries will need to work harder to improve their road networks. In the case of South Africa, geostrategic factors have a positive impact on land transport infrastructure investment, suggesting the importance of geostrategic priorities of the past benefited land transport.

4.5.1.3 Domestic institutions

The insignificance of the impact of domestic institutions on freight, mixed and track ail infrastructure investment in the four countries indicates the failure of domestic institutions to support investment in rail infrastructure investment in these countries. It may also suggest that the institutions are not mature enough to influence investment in rail infrastructure investment or they do not exist at all. Institutional development and reform will be required in this case.

In contrast, domestic institutions have a positive impact on passenger and mixed rail infrastructure investment and insignificant on road infrastructure investment in the four-country case but the impact is negative on road infrastructure investment in the case of South Africa and insignificant for the rest of the investment measures. This result is expected as it reflects the impact of the funding support (subsidies) extended to rail passenger services by government in the five countries. This may reflect voting power of passengers and lack of voting power of business where lobbying is not effective.

Results for South Africa also indicate a positive impact of domestic institutions on mixed rail infrastructure investment. This suggests that domestic institutions in South Africa support other rail infrastructure investment apart from passenger rail infrastructure. Second, the finding may also suggest that domestic institutions in South Africa are relatively more developed compared to those in the four countries.

Overall, and based on findings the above, we conclude that domestic institutions are important determinants of rail infrastructure investment in the SADC five countries under study. However, elaborate institutional frameworks are required for their full impact on rail infrastructure investment to be realised.

4.5.2 Determinants of investment in rail infrastructure efficiency

4.5.2.1 Economic factors

Gross Domestic Product - The finding of a significant positive impact of GDP on the efficiency of rail wagons, locomotives and track in the four-country case indicates that these classes of rail infrastructure can be productive in the presence of high business volume. It may also be that GDP supports infrastructure and efficiency improving sectors of the economy possibly through funding. Considering the declining rail infrastructure capacity demonstrated in Chapter 3, the positive impact of GDP may indicate sweating of the rail infrastructure which is in short supply.

Technology – Technology has a positive impact on labour efficiency in the four-country case, and a negative impact on rail track and passenger coach efficiency. The positive impact on locomotive and employee efficiency is expected from both theoretical and practical perspectives. Bigger locomotives were introduced in some cases resulting in increased tractive power. The negative impact on wagons may simply indicate that the wagons did not change during the study period despite the technological advancement realised over the past six decades. Worth mentioning though is the fact that there were attempts to replace plain bearings by roller bearings on wagons. Funding remained a challenge therefore not all wagons were upgraded. In contrast, the loading capacity of road trucks increased significantly over the same period giving road transport a competitive edge. The negative impact of technology on the efficiency of passenger coaches is a reflection of increased competition from road passenger transport which is more efficient and comfortable as a result of embracing technology.

As is the case in the four-country case, technology has a positive impact on wagon efficiency. The difference is on the impact of technology on the efficiency of wagons which is positive in the case of South Africa and insignificant in the four-country case. Three reasons may explain the positive impact of technology on wagon efficiency in South Africa. First, the size of wagons has increased significantly especially those carrying coal and iron ore, second most of the wagons have roller bearings which allow for higher speed, stability and ability to carry heavy loads. Third, the braking system of the wagons has been modernised such that relatively longer trains can be run.

The insignificance of the impact of technology on the efficiency of the rail track is expected given the fixed nature of the rail track and its long lifespan.

4.5.2.2 Geostrategic factors

Results indicate that geostrategic factors have a positive impact on all rail efficiency measures in the case of South Africa whereas the impact is insignificant for all efficiency measures in the four-country case except for passenger coach efficiency where the impact is negative. The mixed effects of geostrategic factors on different rail infrastructure categories may indicate how these infrastructures were separately affected by history. Irrespective of the direction of the impact, we conclude that geostrategic factors are significant determinants of rail infrastructure efficiency.

4.5.2.3 Institutional factors

In the four-country case, the positive impact of domestic institutions on the efficiency of locomotives and wagons points to the importance of the former in determining infrastructure productivity. This finding is however surprising considering that earlier findings in Chapter 3 indicated declining efficiency for these countries. Domestic institutions may therefore be helping to minimize the extent of the decline in rail infrastructure efficiency.

The insignificance of domestic institutions in determining rail track infrastructure efficiency may indicate that domestic institutions are not supportive of rail track infrastructure investment and maintenance to enhance efficiency. The fixed nature of rail track may also contribute to this result as its efficiency will depend on the efficiency of other rail infrastructure.

The contrasting finding in the case of South Africa is that domestic institutions have a positive impact on the efficiency of passenger coaches with a coefficient of 0.1055 significant at the 10% level.

Overall, domestic institutions emerge as significant determinants of rail infrastructure efficiency with varying direction and degree of impact depending on the context.

4.5.3 Conclusions

A number of conclusions are drawn from our research findings:

(i) Rail infrastructure investment is not responsive to GDP growth in the five SADC countries due to lack of capacity and inefficiency of rail transport. Rail capacity did not expand as GDP grew over the years but declined instead hence the lack of significance of GDP as a determinant.

(ii) Government investment in the five countries does not benefit rail infrastructure reflecting its pro-road transport infrastructure bias. Investment in road infrastructure has been receiving funding resources due to the supportive institutional framework and systematic funding from the State. As a result, surface transport is dominated by road. Future relevancy of rail in the economy is doubtful unless governments take effective measures to expand and maintain rail capacity.

(iii) Rail infrastructure realized limited technological advancement during the period under study. The impact of technology is negative on passenger and track rail infrastructure respectively due to competition from road transport and the fixed nature of rail track infrastructure.

(iv) Road infrastructure investment benefited from technology in the case of South Africa whereas the impact of technology on road infrastructure investment in the four countries has been negative. South Africa is more advanced technologically when compared against the other four countries.

(v) Geostrategic factors matter for rail and road infrastructure investment, with their impact being positive or negative depending on the circumstances. Geostrategic factors' impact on rail and road infrastructure investment is distinctly positive in the case of South Africa and mixed in the case of the four countries.

(vi) Domestic institutions support passenger rail infrastructure investment in the five SADC countries due to the subsidies from government. While domestic institutions appear to matter for investment in rail infrastructure, they do not support investment in other categories of rail infrastructure in the four countries in contrast with South Africa which has relatively more developed domestic institutions.

(vii) Economic factors particularly technology; geostrategic and institutional factors determine rail infrastructure efficiency.

(viii) Technology has a positive impact on the efficiency of labour.

The overall conclusion is that rail infrastructure investment and efficiency are dependent on a mix of economic, geostrategic and domestic institutional factors. The effect and direction of impact of these drivers of rail infrastructure investment and efficiency in the five SADC countries differs in some cases due to context.

4.5.4 Recommendations

(i) Rail capacity needs to be expanded through deliberate policies which support rail infrastructure investment to promote use of rail transport;

(ii) A supportive institutional framework similar to that for road should developed to facilitate investment in rail infrastructure. Institutional reforms should be undertaken where institutional frameworks already exist in order to make them more effective in facilitating rail infrastructure investment;

(iii) Rail transport should embrace new technology in order to improve on service delivery; and

(iv) Geostrategic factors should be considered when investing in rail and transport infrastructure in general.

(v) Countries should invest in technology in order to improve their productivity and efficiency.

Appendix 4.1 **Basic Statistics for Individual Countries**

Botswana

Variable	Obs.	Mean	Std. Dev.	Min	Max
FI	58	0.002	0.035	-0.150	0.132
PI	58	-0.002	0.025	-0.094	0.108
MI	58	0.003	0.032	-0.131	0.118
TTI	58	0.0003	0.001	0.000	0.010
RI	58	0.006	0.011	-0.001	0.049
RRI	58	0.003	0.008	-0.001	0.055
LGDP	59	21.817	1.432	19.139	23.619
GI	55	21.069	2.543	16.989	24.772
XCONST	53	6.019	0.909	5.000	7.000
CT	58	5.549	2.082	0.000	7.864
T	55	22.230	0.745	21.100	23.531
FDI	59	2.763	3.543	-10.775	15.594
IMR	59	57.300	23.875	30.000	115.600

Namibia

Variable	Obs.	Mean	Std. Dev.	Min	Max
FI	48	0.007	0.068	-0.205	0.363
PI	48	0.001	0.037	-0.113	0.175
MI	48	0.005	0.061	-0.184	0.326
TTI	53	0.0001	0.001	-0.004	0.004
RI	53	0.003	0.008	-0.020	0.033
RRI	53	0.003	0.017	-0.063	0.063
LGDP	54	22.031	1.231	19.140	23.432
GI	48	21.579	1.868	18.572	24.636
XCONST	29	5.000	0.000	5.000	5.000
CT	58	4.919	1.685	0.000	6.868
T	49	22.240	0.563	21.365	23.365
FDI	39	3.475	2.982	-0.061	10.912
IMR	59	58.331	23.911	29.000	124.597

Zambia

Variable	Obs.	Mean	Std. Dev.	Min	Max
FI	58	-0.002	0.021	-0.048	0.084
PI	58	-0.003	0.022	-0.079	0.101
MI	58	-0.003	0.025	-0.064	0.100
TTI	58	0.0004	0.004	-0.008	0.029
RI	56	0.002	0.003	-0.004	0.017
RRI	56	0.003	0.012	-0.024	0.078
LGDP	59	22.988	0.498	22.236	24.091
GI	59	18.556	4.498	12.027	25.307
XCONST	55	3.255	1.868	1.000	5.000
CT	58	5.694	2.096	0.000	7.941
T	59	23.391	1.010	21.950	25.458
FDI	59	2.989	2.690	-1.909	9.605
IMR	59	90.815	24.442	40.400	122.200

Zimbabwe

Variable	Obs.	Mean	Std. Dev.	Min	Max
FI	58	-0.002	0.018	-0.084	0.093
PI	58	-0.002	0.017	-0.053	0.106
MI	58	-0.002	0.020	-0.073	0.120
TTI	58	0.001	0.002	-0.009	0.009
RI	58	0.002	0.006	-0.010	0.031
RRI	58	0.004	0.011	-0.033	0.037
LGDP	59	23.066	0.467	22.047	23.673
GI	59	19.676	0.976	17.903	21.540
XCONST	39	3.359	1.063	2	5
CT	58	4.990	1.760	0.0	7.22
T	59	23.196	0.923	22.04	24.79
FDI	59	0.854	1.112	-0.45	6.94
IMR	59	61.790	13.560	33.90	92.80

Appendix 4.2 Investment Models Diagnostics: Cross-Country Dependence

Determinants of Infrastructure Investment

Breusch-Pagan LM test for independence

Model	LM test statistic	Probability	Decision
FI	13.29	0.04	Yes
PI	5.86	0.44	No
MI	11.69	0.07	No
RI	9.52	0.15	No
RRI	11.84	0.07	No
TTI	4.70	0.58	No

Determinants of Infrastructure Efficiency

Breusch-Pagan LM test for independence

Model	LM test statistic	Probability	Decision
NTKM	22.05	0.001	Yes
NTKMLOC	4.36	0.63	No
NTKMWG	15.73	0.02	Yes
PAXCHAKM	15.76	0.02	Yes
NTKMEMPL	24.38	0.00	Yes
NTKMTRK	27.21	0.00	Yes

Appendix 4.3 Determinants of rail infrastructure investment in South Africa

Serial Correlation: Breusch-Godfrey Test

Interest Variable		χ2	p-value	Decision
Freight	FI	1.433	0.238	No
Passenger	PI	0.466	0.4985	No
Mixed Rail	MI	0.771	0.3847	No
Road	RI	1.749	0.1944	No
Road-Rail	RRI	0.146	0.7046	No
Track	TTI	1.899	0.1777	No

Heteroskedasticity: White Test

Interest Variable		χ2	p-value	Decision
Freight	FI	0.17	0.678	No
Passenger	PI	49.65	0.0977	No
Mixed Rail	MI	41.33	0.0816	No
Road	RI	38.96	0.4715	No
Road-Rail	RRI	48	0.4321	No
Track	TTI	45	0.4298	No

Skewness

Interest Variable		χ2	p-value	Decision
Freight	FI	19.21	0.0837	No
Passenger	PI	13.23	0.211	No
Mixed Rail	MI	12.27	0.1984	No
Road	RI	6.72	0.7514	No
Road-Rail	RRI	7.51	0.6768	No
Track	TTI	6.72	0.7514	No

Kurtosis

Interest Variable		χ2	p-value	Decision
Freight	FI	4.62	0.0316	Yes
Passenger	PI	2.97	0.0848	No
Mixed Rail	MI	3.69	0.0548	Yes
Road	RI	4.64	0.0312	Yes
Road-Rail	RRI	1.57	0.2105	No
Track	TTI	2.27	0.1323	No

Appendix 4.4 Determinants of rail infrastructure efficiency in South Africa

Serial Correlation: Breusch-Godfrey Test

Interest Variable		χ^2	p-value	Decision
Locomotives	NTKMLOC	1.113	0.2976	No
Wagons	NTKMWG	5.55	0.0236	Yes
Passenger coaches	PAXCHA	0.004	0.9509	No
Rail track	NTKMTRK	0.637	0.4289	No

Heteroskedasticity: White Test

Interest Variable		χ^2	p-value	Decision
Locomotives	NTKMLOC	53.77	0.2014	No
Wagons	NTKMWG	54	0.436	No
Passenger coaches	PAXCHA	44.09	0.0051	Yes
Rail track	NTKMTRK	40.87	0.0707	No

Skewness

Interest Variable		χ^2	p-value	Decision
Locomotives	NTKMLOC	18.99	0.0612	No
Wagons	NTKMWG	21.13	0.0705	No
Passenger coaches	PAXCHA			
Rail track	NTKMTRK	14.2	0.0477	Yes

Kurtosis

Interest Variable		χ^2	p-value	Decision
Locomotives	NTKMLOC	2.56	0.1098	No
Wagons	NTKMWG	0.39	0.5329	No
Passenger coaches	PAXCHA	4.84	0.0279	Yes
Rail track	NTKMTRK	1.93	0.1652	No

CHAPTER FIVE

PRODUCTIVITY GROWTH IMPACT OF RAIL INFRASTRUCTURE INVESTMENT IN FIVE SADC COUNTRIES

5.1. Introduction

Productivity growth generates numerous economic benefits including increased output, reduced costs, improved competitiveness, higher incomes, and overall economic growth, among others. In this regard, the impact of investment in infrastructure on productivity has been a major subject of empirical enquiry. Ample theoretical and empirical research has explored the underlying drivers of productivity growth within and across countries. However, not much is known regarding the impact of investment in transport infrastructure on productivity growth in low-income countries especially in the Southern African Development Community (SADC).

This chapter examines the contribution of investment in transport infrastructure on productivity growth in five Southern African Development Community (SADC) countries namely, Botswana, Namibia, South Africa, Zambia, and Zimbabwe. We focus on the SADC region primarily because it has the highest rail network connectivity and best road infrastructure in Sub-Saharan Africa (Gwilliam, 2011). Moreso, we concentrate on the five countries as noted earlier because they share a common history in terms of development, and their rail networks are interconnected.

Specifically, we investigate the impact of investment in rail and road transport infrastructure on economic growth. Transport infrastructure constitutes a critical component of the core infrastructure of the economy which supports production, distribution, and mobility. Thus, a lucid understanding of the transport infrastructure-economic growth nexus is essential for policy development especially in developing countries where the potential and need for economic growth is very high. Moreover, establishing the contribution of investment in various classes of transport infrastructure to GDP growth is necessary to inform policy particularly relating to resource allocation under conditions of uncertainty by the government. Investment in rail and road infrastructure is mostly undertaken by the government whose resources are often limited due to other competing national priorities.

GDP per capita is used to measure productivity growth in this study. We apply new measures of rail infrastructure generated through principal component analysis (PCA) namely freight rail infrastructure (FI) for freight services, passenger rail infrastructure (PI) for passenger services and mixed rail infrastructure (MI) for mixed rail services, rail track infrastructure (TTI) and land transport infrastructure (RRI), a combination of rail and road infrastructure.[69]

Our empirical approach builds on the Barro (1990) framework of endogenous growth theory in which we conduct panel cointegration tests of Pedroni (1999, 2004) and Kao (1999) and the Pooled Mean Group (PMG) estimator for dynamic heterogeneous panels of Pesaran, Shin and Smith (1999) to estimate the productivity growth impact of investment in rail and road infrastructure in Botswana, Namibia, Zambia and Zimbabwe using an augmented Cobb-Douglas production function. The Bounds Test technique of Pesaran, Shin and Smith (2001) is applied in the time series context of South Africa to conduct cointegration tests and ARDL estimation of the productivity growth impact of road and rail infrastructure investment. To the best of our knowledge, this is one of the first studies to examine the productivity impact of transport infrastructure (rail and road) in the context of SADC countries that share common historical development.

The empirical results from the regression models for Botswana, Namibia, Zambia and Zimbabwe, suggest that the long-run *direct* impact of rail infrastructure investment on GDP growth is insignificant, except for rail track infrastructure investment whose impact on productivity growth is positive and significant. The results further indicate that rail infrastructure investment has a negative *indirect* impact on GDP growth through depressing total factor productivity (T). Further, the results also suggest that there is positive long run relationship between growth in GDP and growth in land transport infrastructure investment implying road infrastructure investment as well.

The results also indicate that the impact of domestic institutions on productivity growth in the four countries is negative while that of geostrategic factors is mixed.

Geostrategic factors and domestic institutional factors are found to have a long-run negative relationship with total factor productivity (T). Domestic institutions have an insignificant impact

[69] Details on the generation of the infrastructure indices are contained in Chapter 3.

on productivity growth when the *direct* impact of infrastructure on productivity growth is considered. Geostrategic factors have a mixed impact on productivity growth when the direct productivity impact of infrastructure investment is considered. The impact is positive for models including mixed rail, road, land transport and rail track infrastructure investment measures, and negative for models including freight and passenger rail infrastructure investment measures. Regarding the productivity impact of rail infrastructure efficiency, results suggest that their impact is mixed. The impact of rail track efficiency is positive for, negative for wagon and passenger coach efficiency, and insignificant for locomotive and labour efficiency.

The PMG estimation results suggest strong association as indicated by convergence of the model and significant long-run coefficients of infrastructure, geostrategic and institutional variables, and efficiency measures. The results confirm the importance of investment in transport infrastructure, geostrategic and domestic institutional factors, and efficiency in promoting productivity growth in the four countries. The finding that growth in rail and road transport infrastructure investment drives GDP growth in the four SADC countries suggests the need to promote these two modes of transport particularly rail transport which has the potential to provide cheaper transport services and also complement road transport.

The results for South Africa suggest that investment in rail infrastructure has a significant negative direct impact on productivity growth and also a negative impact on total factor productivity (T) indicating an overall negative impact. Government investment is found to have a negative direct impact on productivity growth and a positive indirect impact through enhancing total factor productivity. Human capital formation is also found to be a significant economic driver of productivity growth in South Africa.

Results on the productivity growth impact of rail infrastructure efficiency measures suggest that the impact of locomotive efficiency only is significantly positive and that of the rest of the rail infrastructure efficiency measures is negative except for the passenger coach efficiency which has an insignificant impact.

Our contribution to the previous literature is five-fold. First, we create and use a unique and novel dataset comprising of five SADC countries with data from 1960 to 2018.This dataset was compiled from multiple sources including the World Development Indicators (WDI) database, government documents/reports, published literature, country and company reports. Second, we estimate and compare the productivity growth impact of investment in rail and road infrastructure on GDP growth to capture the specific effects of each of the two transport modes for policy insights on land transport in the five SADC countries. Third, we create a composite land transport infrastructure index (road and rail infrastructure index-RRI) to examine the combined impact of investment in rail and road infrastructure on GDP growth to generate policy insights on the contribution of hard transport infrastructure on productivity growth. Fourth, we develop a framework for analysing the infrastructure-growth relationship (The EGI framework of analysis – **E**conomic, **G**eostrategic and **I**nstitutional framework) which can also be applied in other contexts. Fifth we also estimate the productivity growth impact of economic, geostrategic and institutional factors on the GDP of the five SADC countries in view of the hypothesized role of these factors in determining economic performance across the five countries. Fifth, policy insights based on our findings may trigger policy debate, reflection and review of infrastructure investment policy on land transport and rail transport in particular.

This chapter is structured as follows: Section 2 provides background to the study followed by a brief literature review in Section 3 focusing on existing literature on the nexus between infrastructure growth in general, transport infrastructure and growth in particular and the role of institutions in promoting productivity growth. Section 4 covers the theoretical framework and empirical model. In Section 5 we present the empirical strategy, estimate and discuss research results. Section 6 provides an evaluation of the findings, conclusion and recommendations.

5.2. Background

The huge income gap between developed and developing countries can be attributed to differences in factor productivity (Agénor & Dodson, 2006). Developing countries need to achieve high levels of productivity in order to narrow the income gap and reduce poverty among their citizens. Productivity growth improves competitiveness and leads to growth in national incomes. Productivity growth results in less inputs being required to produce the same amount of output thereby reducing the cost of production. Productivity improvement has been cited as one of the most important determinants of sustained economic growth, see for example, Hall and Jones (1999), and Easterly and Levine (2001).

Policy makers are interested in understanding how investment in infrastructure can impact economic growth (Aschauer, 1989; Esfahani & Ramírez, 2003; Calderón & Servén, 2004; Canning & Pedroni, 2004). Aschauer (1989) found a strong impact of infrastructure on aggregate total factor productivity (TFP) as was the case for many papers that ensued. Validity of results from these early studies were however questioned for overstating the impact of infrastructure on growth and failure to address key methodological issues.[70]

Identifying drivers of economic growth and understanding the channels through which they impact on economic growth is necessary for informing policy on resource allocation. While increased investment in public infrastructure has been identified as a major driver of economic growth, infrastructure in developing countries is in poor condition. Low productivity of developing countries is often attributed to poor or inadequate infrastructure that fails to support other factors of production and promote investment including foreign direct investment (FDI). Infrastructure investments with higher productivity impact on GDP growth is preferred especially where resources are inadequate and subject to rationing due to competing needs.

Broad channels through which public infrastructure impacts economic growth are identified in literature by for example, Agénor and Dodson (2006) and Straub (2008). These are classified as conventional and new channels. Conventional channels include impact on productivity of private inputs, complementary effect on private investment and crowding-out effects. New channels include indirect effect on labour productivity, effect on adjustment costs associated with private investment, impact on durability of private capital, effect on education and health outcomes. Fedderke and Bogetic (2009) reclassify the channels into those that impact GDP growth through capital accumulation and those with an indirect impact through total factor productivity gains.

[70] For example by Holtz-Eakan (1994) and Baltagi & Pinnoi (1995).

As part of core infrastructure, investment in transport infrastructure has the potential to contribute to GDP growth through the channels identified above. Specifically, investment in transport infrastructure can impact GDP through the following ways:

(i) Reduction in transport costs;
(ii) Reduction in firm's input costs;
(iii) Lower production and distribution costs which foster competition;
(iv) Agglomeration effects, and
(v) Improved connectivity of markets.

The seminal paper by Aschauer (1989) investigating the productivity of infrastructure ignited a debate which has attracted a lot of interest and empirical investigation. Many other studies followed in this regard including among others Munnell (1990), Démurger (2001), Pereira and Andraz (2005), Boopen (2006), Fedderke, Perkins and Luiz (2006), Fedderke and Bogetic (2009). Empirical measurement of the impact of investment in public infrastructure on GDP growth particularly transport has produced controversial and sometimes conflicting results. The differences in results have been attributed to methodological, data, context and measurement issues.[71] Banister and Berechman (2001); Lakshmanan (2011); Deng (2013) and Pradhan and Bagchi (2013) contend that the nexus between investment in transport infrastructure and economic growth nexus is not clear in terms of its nature and magnitude due to the multidimensional interconnectedness between transport infrastructure and other sectors of the economy.

Road and rail constitute the major surface transport modes for the SADC region (Luiz, 2010). Each of the modes has unique transport characteristics which define their potential impact on GDP growth. The productivity growth impact of each transport mode needs to be investigated in order to guide policy on resource allocation.

Transport infrastructure in the SADC region is mostly financed by the government therefore political and institutional factors are actively at play. The scenario in the SADC region shows that more resources are being dedicated to road infrastructure investment compared to rail (Kessides, 2004; Gwilliam, 2011). Road capacity has therefore been expanding over the years whereas that of railways has been declining. Road managed to attract freight from rail resulting in declining rail

[71] For example, Fedderke & Bogetic (2009), Deng (2013), Melo, Graham & Brage-Ardao (2013) proffer these reasons.

market share. Rail freight current market share in the SADC region is about 10% (SADC, 2017). At this rate, rail's contribution to GDP is minimal.

There has been a universal decline in the performance of railways since the 1950s as observed by for example Kessides (2004) and Luiz (2010). In the Sub-Saharan context and SADC region in particular, the decline in railway performance has been attributed to a poor institutional framework which favours road infrastructure investment in the SADC region (Kessides, 2004; Foster & Bricerno-Garmendia, 2010). Policy has thus failed to equitably allocate infrastructure investment resources between road and rail.[72]

Road transport is relatively more expensive than rail implying that GDP growth is being supported by an expensive transport mode, a situation which may compromise regional competitiveness due to high freight costs. Rail may be the most suitable mode for bulk commodities like minerals and agricultural products which dominate freight in the SADC region. A comparison of the productivity impact of the investment in road and rail infrastructure will guide policy on the allocation of resources between the two transport modes. The allocation of resources will have implications on modal capacity expansion and freight market share.

5.3. Literature review

Chapter 4 dealt with determinants of investment in rail infrastructure. The infrastructure measures are the dependent variables, and the determinants are economic, geostrategic and institutional factors. This chapter addresses the productivity impact of rail infrastructure investment where the rail infrastructure investment measures are now the determinants among economic, geostrategic and institutional factors. While the discussion on institutions in Chapter 4 was in the context of their impact on rail infrastructure investment, the focus of the discussion in this Chapter is on the nexus between institutions and growth. Institutions are treated as a determinant of rail infrastructure investment in Chapter 4 as well as a determinant of rail infrastructure investment's impact on productivity growth Chapter 5.

[72] Refer to Chapter 3 for a detailed discussion.

5.3.1 Productivity and economic growth

Productivity growth is one of the drivers of economic growth. As such, it will be logical to discuss the concept of productivity within the broader context of economic growth. The Solow-Swan growth model postulates that growth is determined by changes in physical capital, labour and total factor productivity which is considered exogenous. The model has been augmented with technological progress through research and development as a determinant of long-run growth to address limitations imposed by the assumption that TFP is exogenous.[73]

Other studies include human capital as a determinant of productivity and economic growth for example Lucas (1988) and Rebelo (1991). The main determinants of productivity are infrastructure, market efficiency, institutions, education and innovation as identified by Kim and Loayza (2019).

National income is an aggregation of firm-level output therefore detailed insights may be obtained if analysis of productivity starts at firm level. The insights will not be different from those at macro level. Technology is one of the factors that contribute to productivity growth whose impact can be analyzed at firm level.

Acemoglu and Zilibotti (2001) contend that the productivity differences between the developed and developing countries is due to the mismatch between the skills in the developing countries and the technology imported from the developed countries. They further argue that technologies supplied by the developed countries affect the relative productivities due to local conditions in the developing countries like institutions, climate and tastes which may render the technology inappropriate.

[73] Romer (1987, 1990), Grossman and Helpman (1991), and Aghion and Howitt (1992) for example, provide an account of endogenous technological progress.

5.3.2 Infrastructure and growth

The relationship between infrastructure investment and productivity growth has been a major focus of empirical studies. Basing on theory, investment in infrastructure is expected to boost productivity and output (Barro, 1990; Aghion & Howitt, 1998; Canning, 1999; Barro & Sala-i-Martin, 2004; Straub, 2008). However, there is ambiguity on the effect, impact, and direction of causality of the relationship between the two as observed by for example, Fedderke and Bogetic (2009) and Deng (2013) among others. The ambiguity is often ascribed to methodological, context and data related issues. The consensus however suggests that infrastructure investment leads growth.

Infrastructure affects output as an input to the production process. It is an important element of the aggregate production function. The level of output depends on the inputs employed and their productivity. Infrastructure has a direct as well as an indirect impact on output (Dawson, 1998; Fedderke & Bogetic, 2009). The direct productivity channel captures the impact of an increase in the quantity of infrastructure capital on output. Indirectly, more or better infrastructure will positively impact on the productivity of private capital, adjustment costs, economies of scale and scope, human development and productivity of labour (Agénor & Dodson, 2006).

A good road network will, for example; facilitate safe and improved transit times of freight and passengers, improves utilization of resources (haulage trucks and drivers) through quick turnaround, and increases durability of trucks as they are not exposed to hazards posed by bad road networks. The same will apply in the case of a good railway network. These in turn positively impact on productivity.

It is the growth in the productivity of various factors of production that positively impacts on GDP growth. In this context, productivity growth can be measured by a shift in the production function where more output is produced with the same amount of inputs, or a shift in the cost function where the same output is produced is produced at a lower cost.

Aghion and Schankerman (1999) and Fedderke, Perkins and Luiz (2006) observe that infrastructure investment is an enabler of private capital stock productivity growth which influences the level of production by improving the average production efficiency and lowering transaction costs in the economy. Infrastructure has a complementary role to other factors of production and stimulates factor accumulation and aggregate demand (Fedderke & Garlick, 2008).

Effects of public infrastructure investment on economic growth are transmitted through enhancing productivity of private inputs, complementary effect on private investment, indirect effect on labour productivity, effect on adjustment costs and effect on the durability of private capital (Agénor & Dodson, 2006). Infrastructure has pervasive effects on the economy and human welfare hence the perpetual need for investment in economic infrastructure in pursuit of economic growth and development.

Sound infrastructure creates an enabling environment which attracts entry by new firms. Entry by new firms increases competition hence improved efficiencies and cost reduction. Prud'homme (2005) suggests that provision of infrastructure for power, communication and transportation can lead to substantial lowering of input costs.

Infrastructure reduces costs faced by enterprises, enlarges and integrates markets (Krugman, 1991; Eichengreen, 1995; Lakshmanan & Chatterjee, 2005; Ndulu, van Nierkerk & Reinikka, 2005; Boopen, 2006; Ndulu, 2006). However, it is observed by for example, Calderon and Serven (2008), and Luiz (2010) that Sub-Saharan Africa's infrastructure is inadequate in terms of quantity, quality and accessibility and therefore impedes economic growth.

Empirical studies suggest a positive long run effect of infrastructure on output, productivity and growth.[74] The crowding-in effect of public investment on private capital leads to more investment and more output. Countries with good infrastructure attract foreign direct investment over and above local private investment. This boosts output, employment and promotes technological and skills transfer which further enhance output.

The relationship between infrastructure investment and growth can be bi-directional given that infrastructure investment on one hand supports growth in national income and higher income levels can also support investment in public infrastructure through expanded tax revenue base or profitability in the case of private investment. A number of empirical studies have confirmed the

[74]Studies by Aschauer (1989), Easterly and Rebelo (1993), Mittnik and Neumann (2001); Fedderke *et al*, (2006); Calderon and Serven (2008), Canning and Pedroni (2008); Calderon (2009), Fedderke and Bogetic (2009), Lin and Doemeland (2012) for example confirm this relationship.

bi-directional nature of the relationship for example Fedderke *et al,* (2006), Canning and Pedroni (2008) and Fedderke and Bogetic (2009).

Fedderke and Bogetic (2009) attribute the empirical ambiguity to non-linearity of the relationship between public capital and output, crowding in/out effects of public investment on private investment, endogeneity of infrastructure measures, nature of the impact (direct or indirect) and effects of aggregation of different types of infrastructures which mask the productivity impact of infrastructure at a more disaggregated level. In view of these important observations, there is need to control for feedback effects from output to infrastructure during empirical modelling as suggested by for example, Dawson (1998), Canning and Pedroni (2008), Fedderke and Bogetic (2009), Calderon, Moral-Benito and Serven (2011).

5.3.3 Transport Infrastructure and Growth

According to Fedderke *et al.* (2006) and Fedderke and Garlick (2008) different types of infrastructure exert different types of influence on the economy at different times. Transport infrastructure is one type of infrastructure which is core to the operations of the economy. It integrates markets, improves accessibility, reduces transportation costs, improves productivity of other factors of production and hence growth (Radelet & Sachs, 1998; Limao & Venables, 2001; Kessides, 2004; Boopen, 2006; Lakshmanan, 2011; Deng, 2013).

The need to produce and distribute output means that transportation services will always be required for the transportation of inputs to production centres and output to markets. Pradhan and Bagchi (2013) observe the agglomeration effects of transportation infrastructure, its role of promoting mobility and structuring space. Transport infrastructure is therefore an absolute necessity in a modern economy. As with other types of infrastructure, measurement of the impact of transport infrastructure in the economy has not been without ambiguity. A number of explanations have been given to explain the differences including measurement of infrastructure, proxies used, time periods covered and methodological differences. Although empirical studies have resulted in differences on the impact of transportation investment on, there is common agreement on the positive relationship between the two (Demurger, 2001; Berechman, Ozmen & Ozbay, 2006; Deng, 2013).

Public investment in transportation infrastructure crowds-in private investment and employment and result in increases in long-term labour productivity in the economy (Pereira & Andraz, 2005). Empirical studies suggest a positive and significant output elasticity of transportation infrastructure for example Demurger (2001), Pereira and Andraz (2005), Boopen (2006), Hong, Chu and Wang (2011), Sahoo, Dash and Nataraj (2012), Yu, De Jong, Storm and Mi (2012). Literature suggests a positive impact of railway infrastructure on economic growth (Eichengreen, 1995; Fedderke *et al,* 2006; Donaldson, 2018). However, Canning (1999) found the impact of transport infrastructure (road and rail route per worker) to be small and insignificant but aggregate investment, which includes transport infrastructure had a positive and significant effect on output.

Pereira and Andraz (2005) also raised the issue of reverse causality between transport infrastructure and output by pointing out that output can also lead to investment in transport infrastructure. Transport services are derived demand therefore a rise in aggregate output is expected to result in increased demand for transportation services and transport infrastructure.

The transport infrastructure investment - economic growth nexus is not clear in terms of its nature and strength due to the multidimensional nature of the link between transport infrastructure and other sectors of the economy (Banister & Berechman, 2001; Lakshmanan, 2011; Pradhan & Bagchi, 2013). Use of general equilibrium modelling would possibly capture the broader effects of transport infrastructure in the economy but data challenges in most developing countries may render this methodological framework difficult to implement especially given the long-time spans over which growth impact studies have to cover to improve statistical power. However, Donaldson (2018) successfully applied a general equilibrium model to measure the productivity impact of rail infrastructure investment in India as the data was available.

Infrastructure affects trade through reducing transportation costs (World Bank, 1994; Eichengreen, 1995; Limao & Venables, 2001; Ndulu *et al,* 2005). This is achieved through improved connectivity, utilization of and productivity of resources, transit times, safety and flow of trade. The impact of infrastructure on GDP can be indirect through trade. The export-led growth hypothesis suggests that exports can be an engine for growth, increasing income in the exporting country, efficiency of resource allocation and achieving economies of scale.

It has been observed from empirical studies that the output elasticity of investment in infrastructure is generally positive and significant but there is high variation in terms of its magnitude attributed to methodological issues[75]. Previous studies are often criticized for their failure to address simultaneity bias arising from reverse causality between transport infrastructure and output, and model specification resulting in omitted variables and failure to address non-stationarity of time series data. The elasticity values tend to be significantly higher for less developed countries, possibly suggesting lack of infrastructure in these countries.

A comprehensive study specific to growth effects of investment in railway infrastructure was carried out by Donaldson (2018) for colonial India. The study found that investment in rail infrastructure reduced trade costs, increased trade, increased income and reduced income volatility, and improved welfare. The conclusion from the study is that transportation infrastructure can make significant improvements on welfare through exploitation of gains from trade.

Some empirical studies focused on the phenomenal growth of China investigating the impact of transport infrastructure on economic growth (for example, Demurger, 2001; Hong, Chu & Wang, 2011; Sahoo, Dash & Nataraj, 2012; Yu, De Jong, Storm & Mi, 2012) and concluded that transport infrastructure exerts a significant impact on economic growth. Railways in particular contributed significantly to economic growth. Zou, Zhang, Zhuang and Song (2008) observed the complexity and non-linearity of the relationship between transport infrastructure and economic growth. Although Zou *et al*, (2008) found both road and rail to exhibit a very significant effect on growth, the growth impact of railway infrastructure declined after a certain point implying diminishing returns to scale of railway infrastructure. The study also found evidence of complementarity between road and rail transport in the case of China. In terms of causality, the study found bi-directional causality between railway infrastructure and growth and uni-directional causality from road infrastructure to growth.

[75]Calderon *et al*, (2011), Melo, Graham and Brage-Ardao (2013), Pereira and Andraz (2013) identify these limitations.

5.3.4 Productivity and Institutions

Literature is replete with studies which accord institutions the important role of influencing economic performance.[76] Institutions are hypothesized to account for the difference in economic performance across countries. Dawson (1998) and, Aghion and Schankerman (1999) observe that institutions promote growth and productivity.

Institutions affect macroeconomic growth through infrastructure investment and enhancing total factor productivity. In this regard, Henisz (2002) argue that economic and institutional environments affect the pattern of infrastructure investment across countries over time. However, Foster and Briceno-Garmendia (2010) point out that Africa's institutions responsible for infrastructure are weak.

One of the channels through which infrastructure influences economic performance is by enhancing factor productivity. High productivity will result in high income. Productivity is influenced by a number of factors. Eicher, Penalosa and Teksoz (2006) argue that institutions indirectly affect growth through factor accumulation and productivity. `This is reinforced by for example, Fedderke and Garlick (2010) who observe that institutions affect productivity of labour and capital through incentive effects and resource allocation. This observation is however more relevant to private capital where profit is the primary focus. The effect will be different in the case of public capital which is driven more by economic rather than profit motives.

It is argued that Africa is poorer compared to the rest of the world because of the worse institutions. In particular, the gap between the economic performance of developed and developing countries is due to institutional factors (Rodrik, 2000; Eicher *et al,* 2006; Luiz, 2009; Zoega, 2015). Zoega (2015) observes that countries with high productivity are characterized by less corruption, a better legal system, superior enforcement of contracts, a lower cost of starting a business and lower tariffs. Institutions in many African countries are weak and non-existent in some cases (Aron,

[76] For example, North (1990), Dawson (1998), Rietveld and Sough (2004), Eicher, Penalosa and Teksoz (2006), Acemoglu, Johnson and Robinson (2002), Collier and O´Çonnell (2007), World Bank (2010).

2000; Bardan, 2005; Luiz, 2009). The challenge of developing countries may therefore be ascribed to lack of Executive accountability.

Institutions may help to narrow the income gap between developed and developing countries, including SADC countries as demonstrated by studies by for example, Hall and Jones (1999), Acemoglu, Johnson and Robinson (2001), Eicher *et al*, (2006) and Luiz (2009). Kodongo and Ojah (2016) found institutions to be among the determinants of economic growth that had a consistent and significant positive impact on growth in the case of Sub-Saharan Africa.

High-quality institutions are associated with productivity (Hall & Jones 1999; Easterly & Levine 2003; Acemoglu, Johnson & Robinson, 2004; Rodrik, Subramanian & Trebbi, 2004). For example, quality of governance demonstrated by political stability, rule of law, bureaucratic quality, absence of corruption among others is positively related to total factor productivity and economic growth as suggested by Barro (1991) and Zoega (2015). Countries with better quality institutions achieve higher investment levels and higher productivity of investment hence higher economic growth rates (Gwartney *et al*, 2006). Institutions, for example enforcement of property rights induce people to improve in terms of their work effort, investment and productivity (Fedderke & Garlick, 2008).

The macroeconomic environment of which institutions are part, is important in the determination of economic growth. A number of intertwining factors will be at play in defining economic growth. In this regard, Hall and Jones (1999) conclude that long-run economic performance depends on policies that define the business environment within which investment, production and innovation takes place, a view shared by Engerman and Sokoloff (2008) who observe that growth must be explained from both economic and institutional perspectives. Kim and Loayza (2019) identifies institutions together with innovation, education, market efficiency and infrastructure as the main determinants of economic productivity. While being fundamental to the determination of economic growth, institutions are one among many of the determinants of economic growth.

Although institutions influence economic growth, there is academic consensus that the causality between the two is bi-directional (Aron, 2000; Rodrik & Subramanian, 2003; Rodrik *et al,* 2004; Fedderke & Garlick, 2010). Growth can also lead to strong institutions.

5.4. Theoretical framework and empirical model

5.4.1 Theoretical Framework

We define a labour-intensive production function based on the Cobb-Douglas production technology and homogeneity of degree one in a closed economy. The utility of the Cobb-Douglas production function in various contexts is observed by Chiang (1984). The Cobb-Douglas production function specification and its variants have been widely applied in empirical research[77]. Extensive application of the Cobb-Douglas production function is due to the following reasons:

(i) It is flexible to accommodate extensions involving increasing or decreasing economies of scale.

(ii) Consistency with steady state growth under technological progress that is not exclusively labour augmenting (Barro & Sala-i-Martin, 1995)

(iii) It is close to the true production function because there is no tendency for growth rates to increase or decrease on a continuous basis (Esfahani & Ramirez, 2003).

The study follows the theoretical exposition by Fedderke *et al*., (2006) which is nested in the framework of Barro (1990), as follows;

$$q = Tg^{\propto}k^{1-\propto} \qquad (1)$$

where: $0 < \propto < 1$

q = output per worker

T = level of technology, where $T > 0$

g = productive government expenditure per worker with no congestion effects

k = private capital (all forms of capital i.e. financial, human and physical)

The marginal productivity of government expenditure and private capital are respectively;

$$\frac{dq}{dg} = \propto Tg^{\propto-1}k^{1-\propto} \qquad (2)$$

$$= \propto T\left(\frac{k}{g}\right)^{1-\propto} > 0$$

$$\frac{dq}{dk} = (1-\propto)Tg^{\propto}k^{-\propto} \qquad (3)$$

[77]For example, Aschauer, 1989; Khan and Kumar, 1997; Canning, 1999; Esfahani and Ramirez, 2003; Boopen, 2006; Fedderke *et al*., 2006; Canning and Pedroni, 2008.

$$= (1 - \propto) T \left(\frac{g}{k}\right)^{\propto} > 0$$

The positive derivatives show the positive effect of infrastructure on the marginal product of physical capital.

We further define a utility function for a household which seeks to maximise total utility based on a given consumption function. The balanced budget constraint tax rate will be given by $^{g}/_{q}$ which will allow us to derive the steady state growth rate, γ. The steady state growth rate, γ will respond to policy interventions. It will increase due to an increase in $^{g}/_{k}$ and will decrease due the tax effect on $^{g}/_{q}$. The changes in the steady growth rate with respect to changes in $^{g}/_{q}$ will lead to growth consequences that we will explore.

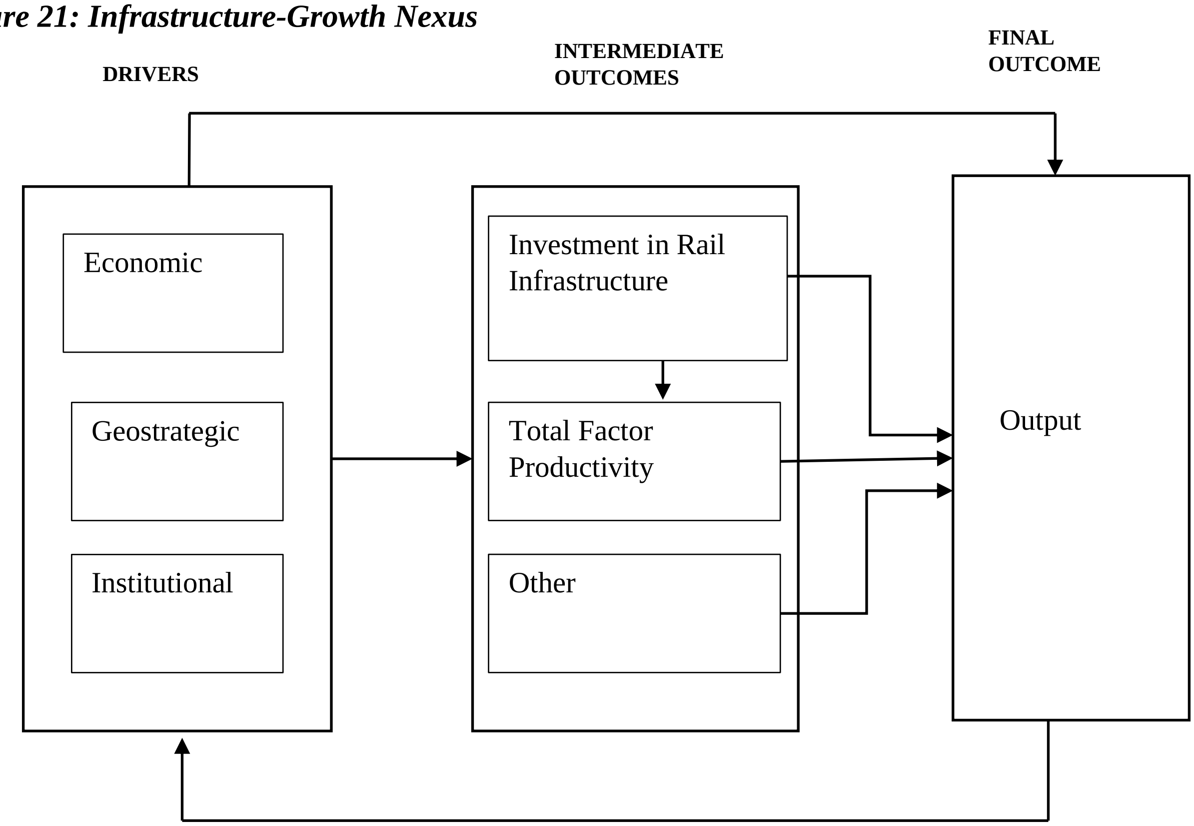
5.4.2 Conceptual Framework

Based on the literature review, a conceptual framework is developed. The conceptual framework shows the interaction among economic, geostrategic and institutional variables as they impact on investment and economic growth. The conceptual framework provides the premise for the formulation of the empirical model. It is important to separate the direct and indirect effects of infrastructure investment on growth in the modelling process as the two may have different policy implications which may be hidden if the two are lumped together. For example, infrastructure with large direct impact on output may attract financing from the private sector in view of the high returns. On the other hand, indirect impact through total factor productivity may influence location of industries.

While the focus of this chapter is on the nexus between rail infrastructure investment and productivity growth, the conceptual framework provides a holistic picture of factors at play leading to output growth based on the evolving rail narrative under this study. The conceptual framework integrates findings from the previous three core chapters (Chapters Two, Three and Four) and literature review to establish the basis of the empirical strategy for the study.

The study considers economic, geostrategic and institutional factors as the main joint drivers of intermediate outcomes namely, investment in rail infrastructure; productivity of other factors of production (TFP) for example, private capital and labour; and other socio-economic and political outcomes like capital flows, education, technology and innovation, foreign direct investment and health. These intermediate outcomes will jointly impact on output as depicted in Figure 21 below.

Figure 21: Infrastructure-Growth Nexus



Source: Researcher's construction

Economic, geostrategic and institutional factors affect output through their combined impact on investment in rail infrastructure, total factor productivity and other socio-economic and political outcomes like capital flows, education, technology and innovation, foreign direct investment and health. The economic, geostrategic and institutional factors also affect output directly. The output itself will also have a direct impact on economic, geostrategic and institutional factors.

A favourable economic environment will promote investment in rail infrastructure, total factor productivity, other socio-economic and political outcomes and ultimately output growth. Favourable geostrategic factors and good institutions particularly Executive constraints will also have a positive impact on investment in rail infrastructure, total factor productivity, other socio-economic and political outcomes and output growth given the public nature of rail infrastructure investment in the SADC region.

This study focuses on the joint impact of economic, geostrategic and institutional factors on investment in rail infrastructure which will also affect final national output. On the other hand, output directly affects institutions and economic determinants. There is therefore possible reverse causality between final output and initial determinants. National output also affects investment through the accelerator effect. While the effect of institutions and economic determinants on output is indirect through investment, reverse causality from output to institutions and economic determinants is direct. Issues of reverse causality have methodological implications that will be dealt with using appropriate econometric techniques.

5.4.3 Empirical model

The theoretical model (equation 1) demonstrates that factor productivity can be increased through increased productive expenditure by government and private capital expenditure as suggested by positive marginal productivity (equations 2 and 3).

Guided by the theoretical framework, the empirical model is based on an extended Cobb-Douglas aggregate production function. Given that output is a function of inputs and their productivity, the model is specified follows:

$$Y_t = A_t K_t^{\beta_1} L_t^{\beta_2} \qquad (4)$$

where:

Y_t = GDP per capita

A_t = Total factor productivity

K_t= Physical capital stock

L_t = Labour

t = time

β_i are constant elasticity coefficients of output with respect to inputs.

We posit that investment in infrastructure, technology and institutions affect total factor productivity whose function is specified as follows;

$$A_t = f(G_t, R_t, S_t, T_t, C_t) = G_t^{\beta_3} R_t^{\beta_4} S_t^{\beta_5} T_t^{\beta_6} C_t \quad (5)$$

Where;

G_t = railway infrastructure stock

R_t = road infrastructure

S_t = institutions

T_t = technology

C_t = other exogenous factors

Equation (4) is extended by incorporating other potential determinants of growth that are of particular interest in this research including railway infrastructure stock (G_t), road infrastructure (R_t), institutions (S_t), technology (T_t) and other exogenous factors (C_t).

A combination of equations (4) and (5) yield the extended model, equation (6).

$$Y_t = C_t\, K_t^{\beta_1}\, L_t^{\beta_2}\, G_t^{\beta_3}\, R_t^{\beta_4} S_t^{\beta_5} T_t^{\beta_6} \quad (6)$$

Linearizing equation (6) by taking natural logs yields equation (7) below.

$$lnY_t = lnC_t + \beta_1 lnK_t + \beta_2 lnL_t + \beta_3 lnG_t + \beta_4 lnR_t + \beta_5 lnS_t + \beta_6 lnT_t + e_i \quad (7)$$

Railway infrastructure stock at a given time (G_t) represents route kilometres of rail, number of operational locomotives, wagons and coaches. Composite rail infrastructure indices for freight (FI), passenger (PI) and mixed (MI) rail business, and rail track infrastructure (TTI) generated in Chapter 3 on Descriptive Rail Infrastructure Analysis and Performance are used in place of G_t to represent railway infrastructure for each rail business segment. Road (RI) and land transport (RRI) infrastructure are respectively represented by length of paved road in kilometres and the composite measure for road and rail as compiled in Chapter 3. Separate equations are estimated for each of the classes of infrastructure.

5.5. Productivity growth impact of rail infrastructure in Botswana, Namibia, Zambia and Zimbabwe

5.5.1 Data

The data set used in this Chapter is composed of five SADC countries namely Botswana, Namibia, South Africa, Zambia and Zimbabwe observed annually from 1960 to 2018. The SADC region is selected for this study because it has the highest rail network connectivity and best roads in Sub-Saharan Africa (SSA)[78], making it a suitable setting for the investigation of the productivity impact of investment road and rail infrastructure on GDP growth. The selected five countries share a common history in terms of historical development and their rail networks are interconnected. South Africa has the 13th largest rail network in the world and commands about 70% of the rail network in SSA measured in route kilometres.

Investment in infrastructure is measured by physical stock of rail infrastructure. Our study uses physical stocks and efficiency measures to circumvent investment flows' failure to capture the multi-dimensional nature of infrastructure and avoid shortcomings of investment flow values arising from inefficiency, corruption, government procurement practices that differ across countries. This is more relevant to rail and road infrastructure given that their investment is dominated by public sector hence its susceptibility to these factors.

Unavailability of monetary data on rail and road infrastructure investment, and use of different currencies by the sample countries would also create challenges on the use of investment flows. The issue of currency would be particularly a major challenge in the case of Zimbabwe for example, where multiple exchange rates are in use during the same time period in some instances and the exchange rate is subject to controls.

The dataset was compiled from multiple sources. Data relating to rail infrastructure was collected from company annual and financial reports, government publications and the Southern African Railways Association (SARA) database. National road agencies annual reports and government publications provided data on roads. The World Development Indicators (WDI) database, United

[78]Gwilliam (2011) makes this observation.

Nations Statistical Yearbook, country and government reports provided data on economic and social indicators. Published literature supplemented the data where gaps existed.[79]

The data set used in this chapter is classified into four broad categories based on the evolving railway story. These categories are:

(i) Infrastructure measures;
(ii) Economic variables;
(iii) Institutional variables; and
(iv) Geostrategic variables.

Infrastructure investment measures for rail are based on annual composite indices generated through principal component analysis.[80] These relate to freight rail infrastructure (FI), passenger rail infrastructure (PI) and mixed rail infrastructure (MI). Rail track infrastructure (TTI) is also captured separately. Road infrastructure (RI) is measured in kilometres of paved road. An annual composite index for land transport infrastructure (RRI) comprising of kilometres of paved road and rail track is included to represent land transport hard infrastructure.

Domestic institutional factors are proxied by the Executive Constraints (XCONST) indicator sourced from Polity V dataset. Investment in rail and road infrastructure in the selected SADC countries is predominantly by government therefore the institutional measure selected is that related to Executive accountability as opposed to property rights institutions. Geostrategic factors are proxied by length of colonial tenure (CT) for the five sample countries. Economic variables of interest were collected from various national and international databases.[81] Considering the distinct differences between South Africa and the other four countries demonstrated in Chapter 3, we analyze the other four countries as a panel and separately employ time series analysis in the case of South Africa.

[79] Details on data sources are annexed to Chapter 3.
[80] Refer to Chapter 3 for more technical details on the construction of the indices.
[81] Refer to *Appendix 3.2* for more details on sources.

5.5.2 Estimation and discussion of results

The heterogeneous panel has T=59 and N=4. The large T provides opportunities to employ dynamic panel methods to estimate a long-run equilibrium relationship and modelling short-run dynamics.

5.5.2.1 Analysis of Data

The long duration of our panel time-series (59 years) allows us to test for unit root and cointegration to determine the order of integration and the long-run relationship between variables. A number of tests and estimators have been developed and applied in varying circumstances relating mostly to the nature of the data. Data properties are explored using standard analytical tools to guide the modelling process.

Variables used in estimating the empirical model are in levels to benefit from the information that is contained in levels data as we seek to capture the impact of growth in infrastructure on GDP. Empirical studies have shown that it is infrastructure spending and increments in access to infrastructure not infrastructure stock or access to infrastructure that influence economic growth in environments with low infrastructure endowments by for example, Kodongo and Ojah (2016).

Table 21 shows the notation of variables in levels.

Technology (T) is measured by the residual of TFP as defined in Chapter 4. Total Factor productivity (TFP) is proxied by the Solow residual (T). The infant mortality rate (IMR), the number of children per 1 000 who die before the age of 1 year proxies development.

Table 21: Notation of variables

Variable	**Level**
GDP	Y
Freight rail infrastructure	FI
Passenger rail infrastructure	PI
Mixed rail infrastructure	MI
Rail track infrastructure	TTI
Paved road infrastructure	RI
Land transport infrastructure	RRI
Technology	T
Government Investment	GI
Foreign Direct Investment	FDI
Infant mortality rates	IMR
Domestic institutions	XCONST
Geostrategic factors	CT
Total factor productivity	TFP

Table 22 shows descriptive statistics based on collected data. Apart from institutional and geostrategic variables, all other variables are expressed in levels.

Unavailability of data in some years affected the number of observations to be below 236 (based on N=4 and T=59). While availability of data on some variables is due to non-availability of records, the institutional variable (XCONST) is available from 1966 to 2018. Among the four countries in the panel, Namibia is the most affected in terms of data availability. Summaries of country by country statistics are in *Appendix 4.1*

Table 22: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
FI	222	0.001	0.039	-0.205	0.363
PI	222	-0.002	0.026	-0.113	0.175
MI	222	0.0005	0.037	-0.184	0.326
TTI	227	0.0003	0.002	-0.009	0.029
RI	225	0.003	0.008	-0.020	0.049
RRI	225	0.003	0.012	-0.063	0.078
LGDP	231	22.485	1.139	19.139	24.091
GI	221	20.137	3.052	12.027	25.307
LGDP cap	231	7.50	0.75	6.01	8.99
XCONST	176	4.398	1.754	1.000	7.000
CT	232	5.288	1.932	0.000	7.941
T	222	22.797	0.990	21.100	25.458
FDI	216	2.432	2.871	-10.775	15.594
IMR	236	67.059	25.13	29.000	124.597

5.5.2.2 Panel Unit Root Tests

Considering the fairly long duration of our panel, there is a possibility of non-stationarity among the panels which necessitates investigation of the order of integration to ensure that the variables are I(0) and I(1) consistent with the application of an ARDL model (Pesaran & Smith, 1995; Pesaran *et al*, 1999). We therefore examine the time series properties of the data through panel unit root tests. The Im, Pesaran and Shin (IPS) (2003) and Augmented Dickey Fuller-Fisher (ADF) tests are employed to test for non-stationarity against the alternative of trend stationary.

Table 23 reports results of unit root tests with the order of integration for each variable and the corresponding level of significance. The results suggest that FI, RI, FDI, TFP AND XCONST are stationary while PI, MI, TTI, RRI, GDP, GI, IMR, CT AND T are integrated of order 1. The order of integration provides a guide on the level at which variables enter the model.

Table 23: Im, Pesaran and Shin (IPS) and ADF-Fisher (ADF) unit root test results

Variable	**Im, Pesaran and Shin(IPS)**		**ADF-Fisher (ADF)**		
	Levels	First differences	Levels	First differences	Level of Integration
FI	-2.67***	-11.87***	4.10***	70.09***	I(0)
PI	-1.17	-11.27***	2.33***	69.32***	I(1)
MI	-1.46*	-11.76***	1.44*	70.09***	I(1)
RRI	-0,92	-8.49***	0,48	34.71***	I(1)
RI	-9.19***	-11.95***	43.92***	70.09***	I(0)
TTI	-2.94	-8.33***	-2.90	-8.25***	I(1)
GDP	-0.62	-9.60***	-0,09	50.30***	I(1)
GI	0,81	-8.37***	-0.41	35.30***	I(1)
IMR	-0,16	-7.03***	0,15	24.56***	I(1)
T	-0.37	-8.73***	0,28	39.41***	I(1)
FDI	-5.22***	-10.51***	12.59***	62.20***	I(0)
XCONST	2.07**	-8.14***	3.01***	44.63***	I(0)
LGDP CAP	-0.46	-9.72***	0.05	52.05***	I(1)
CT	-0.57	-1.99**	-0.10	2.02**	I(1)
TFP	-7.64***	-10.54***	33.77***	62.21***	I(0)

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level.

5.5.2.3 Testing for Cointegration

In order to establish the existence of a long-term equilibrium relationship among the variables in the model, panel cointegration tests are conducted using the Pedroni (1999, 2004) and Kao (1999) panel cointegration tests to establish if GDP growth is cointegrated with rail, road and land transport infrastructure, government investment, total factor productivity (TFP), technology, geostrategic factors and domestic institutions. The advantage of the Pedroni (1999, 2004) panel cointegration test arises from its robustness to bi-directional causality and its accommodation of heterogeneous cointegrating vectors and short-run dynamics across countries (Canning & Pedroni, 2008). The panel cointegration test is premised on the analysis of the residual of the spurious regression performed using I(1) variables where a finding of the residual being I(0) indicates that the variables are cointegrated. The Pedroni panel cointegration technique tests the null of no cointegration against the alternative of all panels being cointegrated. In essence, the null of no cointegration is that the residual is I(1).

Our variables of primary interest are GDP per capita, freight rail infrastructure (FI), passenger rail infrastructure (PI), mixed rail infrastructure (MI), rail track infrastructure (TTI), road transport infrastructure (RI), land transport infrastructure (RRI), geostrategic factors (CT) and domestic institutions (XCONST). Other variables of interest are government investment (GI), total factor productivity (TFP) and technology (T).

Six (6) productivity growth models with GDP per capita as the dependent variable are formulated, each containing one of the following rail and road infrastructure measures; FI, PI, MI, TTI, RI, RRI as defined above among the independent variables. The other independent variables are XCONST, CT, GI, T and TFP.

5.5.2.4 Model Estimation

Panel cointegration establishes whether there is a long-run equilibrium relationship or not. It does not indicate the extent of the long-run relationship. Following establishment of a long-run cointegrated relationship between GDP growth and growth in infrastructure and other control variables, we proceed to conduct econometric estimation of the model to get conclusive results about the long-run relationship to guide policy.

Considering the historical ties, geographical proximity and rail network connectivity of the four countries, we employ the Pesaran CD test to test for cross-country dependence. The results suggest that there is no cross-country dependence when considering rail infrastructure investment measures. Two factors may explain this finding. First, Zambia Railways separated from Rhodesia Railways in 1967 following its attainment of independence in 1964. Our data analysis for this study is from 1960 to 2018 which means that Zambia Railways was part of Rhodesia Railways for only seven years of the study period. Second, Namibia's railway network is not directly connected to any of the other three countries except through South Africa which is excluded from the panel.

The Pesaran CD test indicates presence of cross-country dependence in the case of road infrastructure investment. This finding may be due to the fact that main paved road routes connect to the neighbouring countries. However, road infrastructure is not a major focus of our study so we proceeded without making any transformation to this data series.

We investigate the direct and indirect impact of rail infrastructure investment on productivity growth in Botswana, Namibia, Zambia and Zimbabwe by estimating the *direct* impact of rail infrastructure investment where GDP per capita is the dependent variable and rail infrastructure measures, road infrastructure, land transport infrastructure geostrategic factors, institutions, and government as the independent variables. Following Fedderke and Bogetic (2009), the Solow residual (T) is used as the dependent variable proxying total factor productivity (TFP) in conducting the indirect infrastructure test. The determinants of T in the model are the infrastructure investment measures for rail, road and land transport. Other determinants are geostrategic factors, domestic institutions and government investment.

TFP is proxied by the Solow residual (T). Consideration was given to the use of labour productivity, but non-availability of data would not permit this line of investigation.

The Pooled Mean Group (PMG) estimator of dynamic heterogeneous panels by Pesaran *et al* (1999) is employed to analyze the data. The following section covers our model estimation based on the Pooled Mean Group (PMG) and Mean Group (MG) estimators.

The PMG estimator is formulated by allowing the intercepts, short-run coefficients and error variances to differ freely across groups, but the long-run coefficients to be homogeneous. Group specific short-run coefficients and the common long-run coefficients are computed by the pooled maximum likelihood estimation. PMG estimation provides and intermediate case between the dynamic fixed effects (DFE) estimator which imposes the homogeneity assumption for all parameters except for the fixed effects, and the mean group (MG) estimator proposed by Pesaran and Smith (1995), which allows for heterogeneity of all parameters. It exploits the statistical power offered by the panel through long-run homogeneity, while still admitting short-run heterogeneity.

This methodology is applicable to this study in that the countries under study are likely to have different features in the short-run due to history, economic structure, politics, geography and homogeneous features in the long run due regional integration, technology, neighbourhood effects and competition.

Following the exposition by Pesaran, Shin and Smith (1999), consider the following unrestricted error-correction ARDL(p,q):

$$\Delta y_{it} = \phi_i y_{i,t-1} + \beta_i' x_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}' \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \quad (1)$$

Where i=1,2,….., N, t =1,2,….., T, denote the cross-section units and time periods respectively. y_{it} is a scalar-dependent variable, x_{it} (k x 1) a vector of (weakly exogenous) regressors for group i, and μ_i represents fixed effects. ε_{it}'s are independently distributed disturbances across i and t, with zero means and variances $\sigma_i^2 > 0$, and assume $\phi_i < 0$ for all i. There exists a long-run relationship between y_{it} and x_{it}:

$y_{it} = \theta_i' x_{it} + \eta_{it}$, i= 1, 2, ……, N, t = 1, 2, ….., T, (2)

where θ_i=-$\beta_i'\phi_i$ is the k x 1 vector of the long run coefficients, and η_{it}'s are stationary with possibly non-zero means. Equation (1) can therefore be written as the error correction model:

$\Delta y_{it} = \phi_i \eta_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij}\, \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}' \Delta x_{i,t-j} + \mu_i + \varepsilon_{it}$ (3)

where ϕ_i is the error-correction coefficient measuring the speed of adjustment towards the long-run equilibrium.

This general framework provides the formulation of the PMG estimation, which allows the short-run coefficients and error variances to differ freely across groups, but the long-run coefficients to be homogeneous, where $\theta_i = \theta \; \forall \; i$. Group specific short-run coefficients and the common long-run coefficients are computed by pooled maximum likelihood estimation. Denoting the PMG estimators by $\tilde{\phi}_i$, $\tilde{\beta}_i, \tilde{\lambda}_{ij}$, $\tilde{\delta}_{ij}$and $\tilde{\theta}$, we obtain them by $\phi_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\phi}_i}{N}$, $\beta_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\beta}_i}{N}, \lambda_{jPMG} = \frac{\sum_{i=1}^{N} \tilde{\lambda}_{ij}}{N}$, j = 1,…., p-1, and $\delta_{jPMG} = \frac{\sum_{i=1}^{N} \tilde{\delta}_{ij}}{N}$, j = 0,…., q-1, $\theta_{PMG} = \tilde{\phi}$.

The model is estimated using the PMG estimator to establish the long-run equilibrium relationship between GDP growth and growth rail and road infrastructure investment and estimate the short-run dynamics among the variables. While a number of variables are included in the model, primary focus is on rail and road infrastructure investment, geostrategic and institutional factors. As defined earlier, rail infrastructure investment variables are for freight rail infrastructure (FI), passenger rail infrastructure (PI), mixed rail infrastructure (MI) and rail track infrastructure (TTI). Road infrastructure investment is composed of paved road infrastructure (RI). Land transport infrastructure (RRI) is an infrastructure measure for the combination of rail and road. Domestic institutional factors are proxied by the Executive Constraints (XCONST) indicator and geostrategic factors are proxied by length of colonial tenure (CT).

The Hausman test is used to select the efficient and consistent estimates between PMG and MG estimators. We report results of the PMG estimation in all cases as it is considered superior to the MG estimator. MG results are reported and compared with PMG results only for models where the MG is selected by the Hausman test and some coefficients are significant. The optimal lag length is determined by ARDL based on the Akaike Information Criteria (AIC).

5.5.3 Direct productivity growth impact of rail infrastructure investment

We estimate six (6) equations of productivity growth with GDP per capita as the dependent variable. Each of the equations includes one of the rail infrastructure investment measures for freight (FI), passenger (PI), mixed (MI), track (TTI); road infrastructure investment (RI); and land transport infrastructure investment (RRI) as the determinants. Other determinants are government investment (GI), foreign direct investment (FDI), domestic institutions (XCONST) and geostrategic factors (CT).

The following productivity growth models are estimated:

Equation I: GDP per capita = f(FI XCONST GI FDI CT)

Equation II: GDP per capita = f(PI XCONST GI FDI CT)

Equation III: GDP per capita = f(MI XCONST GI CT)

Equation IV: GDP per capita = f(RI XCONST GI CT)

Equation V: GDP per capita = f(RRI XCONST GI FDI CT)

Equation VI: GDP per capita = f(TTI XCONST GI CT)

5.5.3.1 Testing for Cointegration

In order to establish the existence of a long-term equilibrium relationship among the variables in the model, panel cointegration tests are conducted using the Pedroni (1999, 2004) and Kao (1999) panel cointegration tests to establish if GDP growth is cointegrated with rail, road and land transport infrastructure, government investment, total factor productivity (TFP), technology, geostrategic factors and domestic institutions. The advantage of the Pedroni (1999, 2004) panel cointegration test arises from its robustness to bi-directional causality and its accommodation of heterogeneous cointegrating vectors and short-run dynamics across countries (Canning & Pedroni, 2008). The panel cointegration test is premised on the analysis of the residual of the spurious regression performed using I(1) variables where a finding of the residual being I(0) indicates that the variables are cointegrated. The Pedroni panel cointegration technique tests the null of no cointegration against the alternative of all panels being cointegrated. In essence, the null of no cointegration is that the residual is I(1).

Panel cointegration tests are performed on equations I to VI, each containing one of the six infrastructure investment measures. Results of the panel cointegration tests for the productivity growth models are reported in Table 24.

Table 24: Pedroni and Kao Panel Cointegration tests -direct productivity growth impact

	Augmented Dickey-Fuller t	
Test/Model	**Pedroni Test**	**Kao Test**
LGDPcap = f(FI XCONST GI FDI CT)	(3.03)***	(-1.95)**
LGDPcap = f(PI XCONST GI FDI CT)	(2.95)***	(-1.88)**
LGDPcap = f(MI XCONST GI CT)	(2.99)***	(-1.97)**
LGDPcap = f(RI XCONST GI CT)	(2.55)***	(-2.37)***
LGDPcap = f(RRI XCONST GI FDI CT)	(2.70)***	(-1.93)**
LGDPcap = f(TTI XCONST GI CT)	(3.06)***	(-1.94)**

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level.

The Pedroni test confirms existence of cointegration in all models significant at all levels. Results from the Kao test results also confirm presence of cointegration in all the models significant at the 5% level except in the model for road infrastructure investment where the significance is at the 1% level. Although the level of significance differs between the two tests, the Kao test serves to confirm the robustness of the results. The same conclusion is arrived that the panels are cointegrated even though the restrictions imposed under the two cointegration testing techniques are different.

The results lead us to reject the null of no cointegration against the alternative of cointegration. Therefore, the results confirm the existence of a long-run relationship between GDP growth and growth in infrastructure variables and the control variables in the models. Knowledge of this relationship is crucial for guiding policy to promote GDP growth. It would therefore be instructive to uncover the short-run and long-run effects of this established long-run relationship stated in Table 25.

5.5.3.2 Estimated results

Having established that the variables are bound together in the long run, we proceed to estimate the productivity growth models using the PMG estimator to establish the long-run equilibrium relationship. Results of the PMG estimation are presented in Table 25 below.

Table 25: Direct productivity growth impact of rail infrastructure investment

	D.LGDPcap		D.LGDPcap		D.LGDPcap		D.LGDPcap		D.LGDPcap		D.LGDPcap	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Lag order	1,0,0,1,0,0		1,0,0,1,0,0		1,0,0,1,0		1,0,0,1,0		1,0,0,1,0,0		1,0,0,1,0	
FI	2.50745	(2.359)										
XCONST	-0.13918	(0.093)	-0.11258	(0.097)	0.05646	(0.049)	0.05262	(0.066)	0.05085	(0.052)	0.04180	(0.053)
L.GI	0.12019**	(0.050)	0.11073**	(0.050)	0.22649***	(0.070)	0.27802***	(0.073)	0.23947***	(0.061)	0.25136***	(0.055)
FDI	-0.01211	(0.008)	-0.00901	(0.007)					0.02159	(0.019)		
CT	-0.01207*	(0.007)	-0.01395**	(0.007)	0.01694***	(0.006)	0.01725**	(0.008)	0.01861**	(0.006)	0.01461**	(0.007)
PI			-0.78408	(1.160)								
MI					0.79085	(3.338)						
RI							27.03490**	(11.687)				
RRI									6.71305**	(3.331)		
TTI											47.63375**	(22.368)
SR												
EC	-0.10932	(0.069)	-0.12213	(0.080)	-0.08845*	(0.046)	-0.08691***	(0.031)	-0.10114**	(0.042)	-0.12013***	(0.043)
D.FI	-0.75564*	(0.465)										
D.XCONST	0.00856	(0.009)	0.00670	(0.006)	0.00119	(0.006)	0.00082	(0.008)	-0.00076	(0.007)	0.00005	(0.008)
D.GI	0.05856***	(0.023)	0.05681***	(0.022)	0.04566***	(0.017)	0.05643***	(0.023)	0.03848**	(0.017)	0.04144**	(0.017)
D.FDI	0.00423**	(0.002)	0.00289**	(0.001)					0.00122	(0.001)		
D.CT	-0.00578	(0.011)	-0.00650	(0.010)	-0.00763	(0.007)	-0.00853	(0.007)	-0.00801	(0.007)	-0.00642	(0.008)
D.PI			-0.33398	(0.549)								
D.MI					-0.58126	(0.592)						
D.RI							-0.62640**	(0.289)				
D.RRI									0.03087	(0.224)		
D.TTI											-1.95012	(1.874)
_cons	0.67172	(0.442)	0.75382	(0.512)	0.26471**	(0.123)	0.16953***	(0.057)	0.27866***	(0.104)	0.30995***	(0.107)
Iteration	4		9		5		6		6		7	
h test	0.18(0.99)		5.67(0.34)		40.90(0.00)		3.75(0.44)		11.04(0.05)		3.98(0.41)	
Null	mg pmg		mg pmg		mg pmg		mg pmg		mg pmg		mg pmg	
Llhd	315.31		314.95		310.67		317.05		317.98		313.52	
N	171		171		171		172		172		172	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient; SE = Standard error.

The estimation results of the direct impact of rail and road infrastructure on productivity growth in Botswana, Namibia, Zambia and Zimbabwe are reported by thematic focus of the determinants viz; economic, geostrategic and institutional factors.

Economic Factors

Rail infrastructure

Results suggest that among the rail infrastructure investment measures, only rail track infrastructure (railroad) investment has a significant positive direct impact on productivity growth in Botswana, Namibia, Zambia and Zimbabwe with a coefficient of 47.63 significant at the 5% level.

Road infrastructure

The direct impact of road infrastructure investment is positive with a coefficient of 27.03 significant at the 5% level. This finding is consistent with the important role of road transport which commands more than 80% of the transport market share.

Land transport infrastructure

The direct impact of land transport infrastructure investment (RRI) is positive with a coefficient of 6.71 significant at the 5% level. The finding reflects the importance of land transport infrastructure which is dominated by road.

Government investment

Government investment has a positive impact on productivity growth significant at the 5% level in models including freight and passenger infrastructure investment, and significant all levels in other four models. The average coefficient for equations I, II, III and VI which include rail infrastructure measures is 0.18 significant at the 5% level for models including freight and passenger infrastructure investment and significant at all levels for models including mixed and rail track infrastructure investment. The coefficients in equations IV and V for road infrastructure and land transport are 0.28 and 0.24 respectively significantly at all levels. The overall average coefficient is 0.21. The results confirm the important role of government investment in promoting economic growth.

Foreign direct investment

The results indicate that foreign direct investment (FDI) has an insignificant impact on GDP growth. While this result relates to total FDI, an insignificant impact is also expected from the rail sector FDI given that there is little or no foreign direct investment in rail which is principally funded by government. There is minimal or little participation of private sector in the rail sector.

Geostrategic Factors

Geostrategic factors proxied by length of colonial tenure (CT) have a negative impact on productivity growth in equations including freight and passenger rail infrastructure investment with coefficients of -0.01 significant at the 5% and 1% levels respectively. In contrast the coefficients in equations including mixed and rail track infrastructure investment are positive at 0.02 and 0.01 significant at the 1% and 5% levels respectively.

Geostrategic factors also have positive coefficients of 0.02 significant at the 5% in equations which include road and land transport infrastructure investment. The contrasting finding possibly reflects that various transport sub-sectors might have been subjected to different treatment during the colonial era and also that countries with a bad history need to work hard to catch up.

Institutional factors

Results suggest that domestic institutions proxied by Executive Constraints (XCONST) have an insignificant impact on productivity growth. Institutions in the four countries might be immature and are therefore not able to impact growth directly as a result.

Overall, the results presented in Table 5.6 show a positive long run relationship between GDP growth and; rail track infrastructure investment, growth in road infrastructure investment, land transport infrastructure investment and government investment. The coefficients of the infrastructure measure appear to be too high which may simply reflect the importance of these infrastructure investments. Given that rail track infrastructure investment did not increase significantly while other variables were changing over the study period, its impact is likely to be direct. The long run elasticity of GDP growth with respect to growth in land transport infrastructure is estimated at 6.7% suggesting that a 1% increase in land transport infrastructure investment will result in a 6.7% in GDP per capita other things being equal. In the case of government investment, the average elasticity is 0.20% implying that a 1% increase in government invest will lead to a 0.20% increase in GDP per capita.

With respect to geostrategic factors, the results show a mixed impact in terms of direction. The results suggest existence of a negative long run relationship between GDP growth and geostrategic factors in scenarios including; freight and passenger rail infrastructure investment. These infrastructure measures predominantly represent mobile infrastructure whose life span is shorter than that of rail track infrastructure. Investments could have been made post-independence reflecting underinvestment in these infrastructure classes during the colonial period. In contrast, there is a long run positive relationship between GDP per capita and; rail track, road and land transport infrastructure investment.

The error correction coefficient which represents the speed of convergence ranges from 9% to 12% significant at all levels in scenarios involving road and rail track infrastructure investment, and also significant at the 5% level for the land transport infrastructure investment model. The error correction coefficient for the mixed rail infrastructure investment is significant at the 10% level. The PMG estimation gives an average speed of convergence of 10.45% over the period from 1960 to 2018. This provides sufficient evidence of convergence to long-run equilibrium relationship for all dynamic specifications for all the four countries under study. However, this represents a slow convergence rate to long-run stable path in case of any deviation in the previous period.

5.5.4 Determinants of Total Factor Productivity

We estimate six (6) total factor productivity (T) models where T is the dependent variable. Each of the equations includes one of the rail infrastructure investment measures for freight (FI), passenger (PI), mixed (MI), track (TTI); road infrastructure investment (RI); and land transport infrastructure investment (RRI) as the determinants. Other determinants are government investment (GI), domestic institutions (XCONST), geostrategic factors (CT).

The following equations are estimated:

Equation VII: T = f(FI XCONST GI CT HCI IMR)

Equation VIII: T = f(PI XCONST GI CT HCI IMR)

Equation IX: T = f(MI XCONST GI CT HCI IMR)

Equation X: T = f(RI XCONST GI CT HCI IMR)

Equation XII: T = f(RRI XCONST GI CT HCI IMR)

Equation XIII: T = f(TTI XCONST GI CT HCI IMR)

5.5.4.1 Cointegration results

Pedroni and Kao Panel Cointegration tests are also performed for T models. Results of the tests are presented in Table 26.

Table 26: Pedroni and Kao Panel Cointegration Tests-TFP

	Augmented Dickey-Fuller t	
Test/Model	Pedroni Test	Kao Test
T = f(FI XCONST GI CT HCI IMR)	(1.27)*	(-1.49)*
T = f(PI XCONST GI CT HCI IMR)	(1.29)*	(-1.48)*
T = f(MI XCONST GI CT HCI IMR)	(1.37)*	(-1.48)*
T = f(RI XCONST GI CT HCI imr)	(1.29)*	(-1.54)*
T = f(RRI XCONST GI CT HCI IMR)	(2.06)**	(-1.37)*
T = f(TTI XCONST GI CT HCI IMR)	(1.99)**	(-1.46)*

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Both tests confirm existence of weak cointegration among the variables in all models significant at the 10% level and lead us to reject the null of no cointegration against the alternative of cointegration. The results confirm the existence of a long-run relationship between T growth and growth in infrastructure measures and the control variables in the models.

5.5.4.2. Estimated results

Results of the PMG estimation are presented in Table 27 below.

Table 27: Determinants of total factor productivity among selected SADC countries

	D.T		D.T		D.T		D.T		D.T		D.T	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Lag order	1, 0, 0, 1, 0, 0		1, 0, 0, 1, 0, 1		1, 0, 0, 1, 0, 0, 0		1, 0 ,0, 1, 0		1, 0, 0, 1, 0, 1		1, 0, 0, 1, 0, 1	
FI	-1.938**	(0.987)										
XCONST	-0.103	(0.077)	-0.206***	(0.045)	-0.115	(0.079)	-0.225***	(0.078)	0.018	(0.060)	-0.315**	(0.129)
L.GI	0.136***	(0.047)	0.204***	(0.020)	0.171***	(0.042)	0.208***	(0.042)	0.348***	(0.074)	0.299**	(0.123)
CT	-0.066***	(0.012)			-0.055***	(0.014)	-0.037***	(0.007)	-0.049***	(0.007)	-0.022	(0.016)
HCI	-0.890***	(0.264)	1.106***	(0.202)	-0.654**	(0.328)						
PI			2.167	(2.711)								
L.IMR			-0.004*	(0.003)					0.012	(0.008)	0.000	(0.004)
IMR					0.002	(0.003)						
MI					-1.109	(1.013)						
RI							-1.949	(6.939)				
RRI									5.035	(3.126)		
TTI											-150.158***	(52.475)
SR												
EC	-0.225***	(0.058)	-0.157**	(0.066)	-0.242***	(0.056)	-0.206**	(0.088)	-0.205*	(0.124)	-0.117***	(0.042)
D.FI	0.599	(0.647)										
D.XCONST	-0.023	(0.037)	-0.012	(0.027)	-0.013	(0.041)	-0.014	(0.032)	-0.019	(0.038)	-0.010	(0.040)
D.GI	0.225***	(0.032)	0.202***	(0.009)	0.214***	(0.020)	0.218***	(0.037)	0.227***	(0.034)	0.225***	(0.034)
D.CT	-0.000	(0.009)			0.004	(0.012)	0.001	(0.006)	0.006	(0.006)	0.006	(0.005)
D.HCI	1.224	(1.617)	1.549	(1.328)	1.796	(1.426)						
D.PI			0.008	(0.337)								
D.MI					0.297	(0.438)						
D.IMR					0.005	(0.009)			0.024	(0.018)	0.001	(0.007)
D.RI							0.298	(1.376)				
D.RRI									-1.515	(1.201)		
D.TTI											8.106	(8.763)
_cons	4.654***	(1.153)	2.835**	(1.223)	4.752***	(1.044)	3.874**	(1.596)	3.013	(1.886)	2.057***	(0.695)
Iteration	15		19		25		16		18		17	
h test	5.63(0.34)		1.94(0.59)		1.92(0.75)		1.07(0.78)		6.17(0.10)		5.10(0.16)	
Null	mg pmg		pmg mg		mg pmg		pmg mg		pmg mg		pmg mg	
Llhd	185.54		177.24		188.46		176.19		201.68		201.99	
N	168		168		168		172		172		172	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient; SE = Standard error.

Table 28: MG Results

	D.T		D.T		D.T		D.T		D.T		D.T	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
ec												
FI	9.579	(7.084)										
XCONST	-0.090	(0.062)	-0.265**	(0.135)	-0.052	(0.041)	-0.142**	(0.062)	-0.054	(0.034)	-0.085*	(0.051)
L.GI	0.127	(0.091)	0.230***	(0.044)	0.114	(0.116)	0.161	(0.149)	0.219**	(0.093)	0.232***	(0.087)
CT	-0.046***	(0.015)			-0.046***	(0.019)	-0.048***	(0.013)	-0.037**	(0.018)	-0.039***	(0.015)
HCI	0.620	(0.826)	2.577*	(1.427)	3.472	(3.619)						
PI			4.561***	(1.335)								
L.IMR			0.006	(0.011)					0.002	(0.006)	0.004	(0.005)
IMR					0.034	(0.031)						
MI					4.526	(2.918)						
RI							-8.791	(20.709)				
RRI									-7.107	(9.454)		
TTI											-30.063	(68.624)
SR												
EC	-0.294***	(0.035)	-0.262***	(0.048)	-0.406***	(0.026)	-0.284***	(0.065)	-0.322***	(0.073)	-0.306***	(0.075)
D.FI	-0.800**	(0.346)										
D.XCONST	-0.022	(0.028)	-0.004	(0.029)	-0.008	(0.027)	-0.016	(0.031)	-0.020	(0.030)	-0.010	(0.033)
D.GI	0.219***	(0.024)	0.232***	(0.022)	0.208***	(0.013)	0.219***	(0.035)	0.218***	(0.023)	0.207***	(0.015)
D.CT	0.002	(0.010)			0.004	(0.011)	0.007	(0.006)	-0.001	(0.003)	-0.000	(0.005)
D.HCI	0.998	(1.327)	0.605	(1.314)	0.908	(1.492)						
D.PI			-0.533***	(0.190)								
D.MI					-1.022*	(0.605)						
D.IMR					0.015	(0.013)			0.024	(0.017)	0.022	(0.015)
D.RI							-0.012	(1.403)				
D.RRI									-0.619	(0.599)		
D.TTI											-3.644***	(1.256)
_cons	5.547***	(0.938)	3.423***	(1.145)	5.038*	(2.627)	5.761***	(1.709)	5.750***	(1.172)	5.416***	(1.235)
N	168		168		168		172		172		172	

Economic Factors

Rail Infrastructure

Results suggest that freight rail infrastructure investment (FI) and rail track infrastructure investment (TTI) have a negative impact on total factor productivity (T) with coefficients of -1.94 and -150.16 significant at the 5% and 1% levels respectively. This result suggests that these infrastructure categories have a significant but negative impact on T. All the other rail infrastructure investment measures have an insignificant impact on total factor productivity. This finding suggests that rail infrastructure investment (FI and TTI) will have a negative *indirect* impact on productivity growth through total factor productivity.

Rail track infrastructure investment (TTI) is an insignificant determinant of TFP, possibly due to the fact that rail track infrastructure has been relatively fixed during the study period. This finding suggests that its impact on productivity growth may only be direct. We conclude that, overall, rail infrastructure investment has a negative impact on total factor productivity.

Road Infrastructure

Results suggest that road infrastructure investment (RI) has an insignificant impact on TFP. This finding implies that road infrastructure investment may only have a direct impact on productivity growth.

Government investment

Government investment (GI) has coefficients of 0.136, 0.204, 0.171, 0.208, 0.348 and 0.299 in equations which include freight (FI), passenger (PI), mixed (MI), road (RI), land transport (RRI) and rail track (TTI) infrastructure investment respectively significant at all levels except for the coefficient of TTI which is significant at the 5% level. Results suggest that the lag of government investment (L.GI) has a positive impact on total factor productivity. This result may point to the fact that government is investing in areas that impact positively on T, in which case productivity growth is promoted.

Human capital index

The human capital index has mixed results, but negative impact appears to dominate. This may point to low skills levels in the four countries.

Geostrategic Factors

The lag of length of colonial tenure (CT) has coefficients of -0.066, 0.055, -0.037 and -0.049 significant at all levels in equations including freight (FI), mixed (MI), road (RI) and land transport (RRI) infrastructure investment respectively. The results suggest that geostrategic factors in the four countries impact negative determinants of total factor productivity.

Colonial history has a negative impact on T suggesting that geostrategic priorities pursued during the colonial era did note promote total factor productivity. Geostrategic factors will therefore have an indirect negative impact on productivity growth through depressing T.

Institutional Factors

Institutions (XCONST) have coefficients of -0.206, -0.225 and -0.315 in the equations including passenger infrastructure investment (PI), road infrastructure investment (RI) and rail track infrastructure investment significant at all levels for the PI and RI models, and 5% level for the TTI model. The rest of the coefficients are insignificant. The finding suggests that domestic institutions harm total factor productivity. Domestic institutions in Botswana, Namibia, Zambia and Zimbabwe will have a negative indirect impact on productivity growth through depressing total factor productivity.

Overall, the results show a positive long run relationship between T and government investment; a negative long run relationship between T and; rail infrastructure investment, road infrastructure investment, geostrategic factors and domestic institutions.

The error correction coefficient ranges from 11.7% to 24.2% significant at the 10% at least. The PMG estimator gives an average speed of convergence of 19.2% over the period from 1960 to 2018 which suggests slow convergence. This provides sufficient evidence of convergence to long-run equilibrium relationship for all dynamic specifications for all the four countries under study.

5.6 Productivity growth impact of rail infrastructure efficiency in four SADC countries

We also investigate the impact of rail infrastructure efficiency on productivity growth in Botswana, Namibia, Zambia and Zimbabwe by estimating models where GDP per capita is the dependent variable and rail efficiency measures included among the determinants. Rail infrastructure efficiency measures considered are net tonnes per kilometre of track (NTKMTRK), net tonne-kilometre per locomotive (NTKMLOC) net tonne-kilometre per wagon (NTKMWG), passenger per coach (PAXCHA) and net tonne-kilometre per employee (NTKMEMPL) as presented in Chapter 3. The other determinants are domestic institutions (XCONST), geostrategic factors (CT) and government investment (GI).

Our variables of major interest are therefore NTKMTRK, NTMLOC, NTKMWG, PAXCHA AND NTKMEMPL.

5.6.2 Estimated Results

Estimated results are reported in Table 29 below.

Table 29: Productivity Growth Impact of Rail Infrastructure Efficiency-PMG

	D.LGDPcap		D.LGDPcap		D.LGDPcap		D.LGDPcap		D.LGDPcap	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Lag order	1,0,0,1,0		1,0,0,0,1,0		1,0,0,0,1,0		1,0,0,0,1,0		1,0,0,0,0,1,0	
NTKMTRK	0.33713***	(0.061)	0.38408***	(0.086)	0.43027***	(0.062)	0.14557	(0.104)	0.36521***	(0.096)
XCONST	0.04488**	(0.023)	0.05651**	(0.027)	0.06889***	(0.023)	-0.05452	(0.044)	0.06383***	(0.022)
L.GI	0.16478***	(0.035)	0.15789***	(0.041)	0.16272***	(0.031)	0.07655	(0.042)	0.16162***	(0.028)
CT	-0.00259	(0.005)	-0.00452	(0.006)	-0.00518	(0.004)	-0.00573	(0.006)	-0.00327	(0.004)
NTKMLOC			-0.13261	(0.131)						
NTKMWG					-0.27713****	(0.104)			-0.32770***	(0.090)
PAXCHA							-0.32076***	(0.106)		
NTKMEMPL									0.10902	(0.121)
SR										
EC	-0.17930*	(0.098)	-0.17854**	(0.086)	-0.22157***	(0.108)	-0.09946	(0.077)	-0.24375**	(0.119)
D.NTKMTRK	-0.03341	(0.022)	-0.08718**	(0.044)	-0.09234*	(0.055)	-0.00361	(0.009)	-0.11635*	(0.069)
D.XCONST	0.00005	(0.006)	-0.00085	(0.005)	-0.00252	(0.004)	0.00862	(0.008)	-0.00229	(0.004)
D.GI	0.03843**	(0.016)	0.04072**	(0.018)	0.04096***	(0.017)	0.03094**	(0.015)	0.04190**	(0.017)
D.CT	-0.00507	(0.009)	-0.00510	(0.009)	-0.00389	(0.010)	-0.00518	(0.008)	-0.00278	(0.010)
D.NTKMLOC			0.06362	(0.041)						
D.NTKMWG					0.08030*	(0.047)			0.07006*	(0.041)
D.PAXCHA							0.01161	(0.009)		
D.NTKMEMPL									0.04001	(0.026)
_cons	-0.12804	(0.126)	0.17814***	(0.069)	0.36588**	(0.151)	0.66795	(0.506)	0.46182**	(0.197)
Iteration	8		6		7		10		13	
h test	16.78(0.00)		8.27(0.08)		42.75(0.00)		227.81(0.00)		18.58(0.00)	
Null	mg pmg		pmg mg		mg pmg		mg pmg		pmg mg	
Llhd	316.65		319.11		318.61		308.44		318.07	
N	172		172		172		165		170	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient; SE = Standard error.

Table 30: Productivity Growth Impact of Rail Infrastructure Efficiency-MG

	D.LGDPcap		D.LGDPcap		D.LGDPcap		D.LGDPcap		D.LGDPcap	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
ec										
NTKMTRK	1.56836	(1.197)								
XCONST	0.27532*	(0.149)	-0.57725	(0.693)	0.07345	(0.058)	0.13127	(0.212)	0.30129*	(0.173)
L.GI	-0.19253	(0.290)	-0.03550	(0.284)	-0.04357	(0.217)	-0.26546	(0.368)	-0.03436	(0.118)
CT	-0.11184*	(0.066)	0.06651	(0.111)	-0.03193	(0.028)	-0.04464	(0.037)	-0.03346	(0.030)
NTKMLOC			-3.10861	(3.479)						
NTKMWG					0.33622	(0.253)				
PAXCHA							-0.16293	(0.180)		
NTKMEMPL									1.14873	(1.039)
HCI									0.67768	(0.732)
SR										
EC	-0.18836*	(0.099)	-0.12195*	(0.069)	-0.12730***	(0.046)	-0.13064***	(0.053)	-0.31768**	(0.146)
D.NTKMTRK	-0.04749*	(0.025)								
D.XCONST	-0.00476	(0.004)	-0.00083	(0.005)	0.00203	(0.003)	0.00509	(0.007)	-0.00198	(0.005)
D.GI	0.03211**	(0.015)	0.03646**	(0.017)	0.03728***	(0.015)	0.02254**	(0.010)	0.03526**	(0.018)
D.CT	-0.00428	(0.013)	-0.00568	(0.012)	-0.00586	(0.012)	-0.01134	(0.009)	0.00199	(0.016)
D.NTKMLOC			-0.00648	(0.018)						
D.NTKMWG					-0.00677	(0.013)				
D.PAXCHA							0.01200	(0.011)		
D.NTKMEMPL									-0.02155	(0.021)
D.HCI									0.08285	(0.535)
_cons	-0.03737	(0.493)	-0.29788	(0.371)	0.14535	(0.467)	1.17887***	(0.425)	0.54927	(0.925)
N	172		172		172		165		167	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient; SE = Standard error.

Results indicate that the efficiency of rail track infrastructure measured net tonnes per kilometre of track (NTKMTRK) has a positive coefficient averaging 0.38 significant at all levels suggesting a positive impact on GDP growth per capita. This finding suggests that rail track efficiency promotes productivity growth and highlights the importance of adopting efficiency enhancing measures in rail to promote economic growth.

The productivity growth impact of wagon efficiency, net tonne-kilometre per wagon (NTKMWG) is negative with a coefficient of -0.28 significant at all levels suggesting a negative impact on GDP per capita. This result may be due to the old age of wagons, lack of maintenance and underutilization.

The coefficient for passengers per coach (PAXCHA) is negative (-0.32) and significant at all levels possibly due to the subsidies rail passenger services receive from government and the old age of the coaches coupled with lack of maintenance.

The impact of efficiency of locomotives measured by net tonne-kilometres per locomotive (NTKMLOC) and net tonne-kilometres per employee (NTKMEMPL) on GDP per capita is insignificant possibly due to the old age of the locomotives and lack of maintenance.

The error correction coefficient ranges from 18 – 24%. The average speed of convergence of 21% over the period from 1960 to 2018 provides sufficient evidence of convergence to long-run equilibrium relationship for all dynamic specifications for all the four countries under study. The convergence rate to long-run stable path in case of any deviation in the previous period slow.

5.7 Summary of findings

The results from the panel context of Botswana, Namibia, Zambia and Zimbabwe suggest that freight, passenger and mixed rail infrastructure investment has a negative *indirect* impact on productivity growth. Rail track infrastructure investment has a direct positive impact on productivity growth but a negative indirect impact.

The results also suggest that road and land transport infrastructure investment have a positive direct impact on productivity growth. Government investment has a positive impact on productivity growth in the four countries.

The findings also suggest that the impact of rail infrastructure efficiency has mixed results with only the efficiency rail track being positive and significant, while negative and significant for wagons and coaches, and insignificant for locomotives and employees.

With respect to domestic institutions, the results suggest that they are insignificant determinants of productivity growth. Domestic institutions have a negative impact on productivity growth through the negative impact on total factor productivity. While significant, the impact of geostrategic factors is mixed in that the impact is positive in some cases and negative in some cases. However, the impact of geostrategic factors on TFP is negative indicating that they also have an indirect impact.

5.8 Productivity Impact of Rail Infrastructure Investment in South Africa

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We follow the deductive approach used in the panel setting in the previous sections where we first estimate two (2) sets of six (6) equations for the direct productivity growth impact of rail infrastructure investment and the determinants of total factor productivity (T) in the time-series context of South Africa. GDP per capita and T are the dependent variables, and each of the equations includes one of the rail infrastructure investment measures (FI, PI, MI, TTI), the road infrastructure investment (RI) and land transport infrastructure investment (RRI). Other determinants are government investment (GI), domestic institutions (XCONST), geostrategic factors (CT) and human capital index (HCI).

5.8.1 Summary statistics and unit root tests

The summary statistics and unit root tests were reported in Tables 15 and 16 respectively.

5.8.2 Direct productivity impact of infrastructure investment in South Africa

The direct productivity growth impact models have GDP per capita as the dependent variable and excludes TFP from the determinants. The following equations are estimated:

Equation XXV: LGDPcap=f(FI XCONST GI CT HCI)

Equation XXVI: LGDPcap=f(PI XCONST GI CT HCI)

Equation XXVII: LGDPcap=f(MI XCONST GI CT HCI)

Equation XXVIII: LGDPcap=f(RI XCONST GI CT HCI)

Equation XXIX: LGDPcap=f(RRI XCONST GI CT HCI)

Equation XXX: LGDPcap=f(TTI XCONST GI CT HCI)

5.8.2.1 Cointegration Tests

The Bounds Test technique is based on the joint F-statistic to cointegration analysis where the asymptotic distribution of the F-statistics is non-standard under the null hypothesis of no cointegration between the variables in the model. The decision criteria is based on the position of the F-statistic in relation to the range defined by the lower and upper bound critical values for a given level of significance.[82]The null hypothesis is rejected if the F-statistic is greater than the upper bound critical value. If the F-statistic is below the lower bound critical value, the null hypothesis of no cointegration cannot be rejected. The cointegration test is inconclusive if the F-statistic falls within the bounds.

Results for the Bounds Test for cointegration for the direct productivity growth impact of rail and road infrastructure investment in South Africa are reported in Table 31 below.

Table 31: Bounds Test cointegration results

Dependent variable	AIC lags	F-statistic	LB CV at 5%	UB CV at 5%	Decision
LGDPcap (FI XCONST GI CT HCI)	(2,0,0,1,0,2)	6.46	2.84	4.20	Cointegration
LGDPcap (PI XCONST GI CT HCI)	(1,0,0,1,0,2)	11.02	2.85	4.19	Cointegration
LGDPcap (MI XCONST GI CT HCI)	(2,2,0,1,0,2)	5.53	2.83	4.24	Cointegration
LGDPcap (RI XCONST GI CT HCI)	(1,0,0,0,0,0)	6.63	2.91	4.21	Cointegration
LGDPcap (RRI XCONST GI CT HCI)	(1,1,0,0,0,0)	7.52	2.91	4.25	Cointegration
LGDPcap (TTI XCONST GI CT HCI)	(1,0,0,0,0,2)	8.23	2.86	4.18	Cointegration

[82] The critical values are as reported by Pesaran and Pesaran (1997) and Pesaran *et al* (2001).

Based on the results, we reject the null of no cointegration and conclude that the variables are cointegrated. This result allows us to proceed with the estimation of the productivity growth impact models using the ARDL Bounds Test technique to establish the long-run relationship.

5.8.2.2 Estimation results

Estimated results of the *direct* productivity growth impact of rail infrastructure investment in South Africa based on the ARDL Bounds Test technique are presented in Table 32 below.

The adjusted R^2 averaging 47.8% for the six models suggests an average explanatory power of the models. The low Root Mean Square Error (RMSE) averaging 0.02 suggests a good fit between the data and the model indicating good prediction power of the model. The F-statistic which is significant at all levels indicates the joint significance of the variables and that the models are well specified.

Table 32: Direct productivity growth impact of rail and road infrastructure investment in South Africa

Equation	XXV	XXVI	XXVII	XXVIII	XXIX	XXX
	LGDPcap	LGDPcap	LGDPcap	LGDPcap	LGDPcap	LGDPcap
Lag order	2, 0, 0, 1, 0, 2	1, 0, 0, 1, 0, 2	2, 2, 0, 1, 0, 2	1, 0, 0, 0, 0, 0	1, 1, 0, 0, 0, 0	1, 0, 0, 0, 0, 2
	Coef	Coef	Coef	Coef	Coef	Coef
ECT	-0.115*** (0.04)	-0.097**(0.04)	-0.146***(0.04)	-0.092**(0.04)	-0.134*** (0.05)	-0.118*** (0.04)
FI	-8.668* (4.71)					
XCONST	0.003** (0.00)	0.0043** (0.00)	0.0032***(0.00)	0.0027(0.00)	0.0022* (0.00)	0.0035**(0.00)
GI	-0.156*** (0.06)	-0.163** (0.07)	-0.0995** (0.05)	-0.0776* (0.04)	-0.091*** (0.03)	-0.0713*(0.04)
CT	-0.001(0.00)	-0.0059(0.01)	-0.0001(0.00)	-0.0072(0.01)	-0.0029(0.00)	-0.0030(0.00)
HCI	0.433	0.108(0.35)	0.2613(0.24)	0.2446(0.37)	0.4866** (0.22)	-0.0855(0.36)
PI		-9.648* (5.73)				
MI			-2.0059(4.45)			
RI				-11.2717(9.62)		
RRI					3.3434(2.22)	
TTI						16.3259(15.03)
F-statistic	195.91(0.0000)	219.20(0.0000)	175.07(0.0000)	234.54(0.0000)	245.36(0.0000)	208.38(0.0000)
Adj.R^2	0.52	0.52	0.55	0.40	0.44	0.44
Llhd	155.39	155.01	156.10	135.34	132.61	150.05
RMSE	0.0168	0.0168	0.0162	0.0183	0.0177	0.0181
SR						
LGDPcap						
Dl	0.2141(0.13)					
LD			0.2204(0.14)			
D.XCONST						
DL						0.001** (0.00)
GI	0.0195(0.01)					
DL		0.02(0.01)	0.0161(0.01)			
CT						
DL			0.023** (0.01)			0.02* (0.01)
MI						
D1			-0.9321* (0.53)			
LD			-0.4983(0.37)			
RRI						
D1					-0.2040(0.15)	
HCI						
DL	0.2351(0.63)	0.02(0.62)	0.4674(0.63)			-0.0941(0.66)
LD	1.0098(0.68)	1.2162* (0.67)	0.9649(0.67)			1.4002*(0.72)
cons	0.321*** (0.35)	1.2016*** (0.35)	1.5312*** (0.38)	0.9508***(0.36)	1.3429***(0.40)	1.2320*** (0.38)
N	56	56	55	51	49	56

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient. Standard errors are in parenthesis.

The results are presented and discussed under economic, geostrategic and institutional drivers.

Economic Factors

Rail, Road and Land Transport Infrastructure

Estimation results indicate that the direct productivity growth impact of freight (FI) and passenger (PI) is negative with coefficients of 8.87 and 7.65 respectively significant at the 10% level. The impact of mixed rail (MI), road (RI), rail track (TTI) and land transport (RRI) is found to be insignificant leading us to conclude that investment in these rail and road transport infrastructure categories does not have a significant direct impact on productivity growth in South Africa.

Government investment

Government investment (GI) has significant negative coefficients in all scenarios suggesting that government investment in South Africa is not supportive of those sectors that promote economic growth. Government investment could be crowding-out the private sector. Media reports of state capture of Transnet if true, might have had a negative impact on the performance of rail in South Africa. The insignificant productivity growth impact of rail infrastructure investment could have been partly due to transparency and accountability issues which in essence are institutional in nature.

Geostrategic Factors

Results indicate that geostrategic factors proxied by length of colonial tenure (CT) have an insignificant impact on GDP growth. Geostrategic factors are therefore insignificant determinants of productivity growth. Geostrategic priorities adopted during the colonial era might be having a neutral impact on productivity growth in South Africa.

Institutional Factors

Institutions proxied by Executive Constraints indicator (XCONST) are significant positive determinants of productivity growth in the case of South Africa. We conclude that domestic institutions are supportive to economic growth.

The results show a positive long run relationship between GDP growth and domestic institutions; a negative long run relationship between GDP growth and; government investment and transport infrastructure investment. The long run relationship between GDP growth and geostrategic factors is insignificant.

Adjustment coefficient

The adjustment coefficient which represents the speed of convergence ranges from 9.2-14.6% significant at least at the 5% level with an average of 11.7%. This provides sufficient evidence of convergence to long-run equilibrium relationship, though the convergence rate is low.

5.8.3 Determinants of Total Factor Productivity in South Africa

Total factor productivity (TFP) is the channel through which infrastructure can impact productivity growth indirectly. We seek to establish whether rail and road infrastructure measures affect TFP as we investigate the possibility of an indirect impact of these infrastructure investment measures. Six TFP models are estimated each including one of the rail infrastructure investment measures (FI, PI, MI, TTI), the road infrastructure investment (RI) and land transport infrastructure investment (RRI) as the determinants. Other determinants are government investment (GI), technology (T), domestic institutions (XCONST) and geostrategic factors (CT).

The following equations are estimated:

Equation XXXI: T=f(FI XCONST GI CT HCI)
Equation XXXII: T=f(PI XCONST GI CT HCI)
Equation XXXIII: T=f(MI XCONST GI CT HCI)
Equation XXXIV: T=f(RI XCONST GI CT HCI)
Equation XXXV: T=f(RRI XCONST GI CT HCI)
Equation XXXVI: T=f(TTI XCONST GI CT HCI)

Proxies for development (infant mortality rate-IMR) and quality of labour (human capital index-HCI) are also included in some of the equations as they are considered important determinants of TFP.

5.8.3.1 Cointegration tests

Results of the Bounds Test for cointegration for the TFP models in South Africa are reported in Table 33 below.

Table 33: Bounds Test cointegration results

Dependent variable	AIC lags	F-statistic	LB CV at 5%	UB CV at 5%	Decision
T (FI XCONST GI CT HCI)	(1,1,1,1,0,1)	6.94	2.84	4.20	Cointegration
T(PI XCONST GI CT HCI)	(1,0,0,1,1,0)	5.38	2.85	417	Cointegration
T (MI XCONST GI CT HCI)	(1,1,1,1,0,1)	6.28	2.84	4.20	Cointegration
T (RI XCONST GI CT HCI)	(1,1,0,1,1,1)	6.79	2.89	4.29	Cointegration
T (RRI XCONST GI CT HCI)	(1,1,0,1,0,1)	5.73	2.90	4.28	Cointegration
T (TTI XCONST GI CT HCI)	(1,1,0,1,0,1)	5.16	2.85	4.19	Cointegration

Based on the results, we reject the null of no cointegration for all the models and conclude that the variables are cointegrated. This result allows us to proceed with the estimation of the TFP models using the Bounds Test technique as there is sufficient evidence that the variables are bound together in the long run.

5.8.3.2 Estimation results

The Bounds Test estimated results of the determinants of TFP in South Africa are presented in Table 34.

The adjusted R^2 below 50% in five (5) of the six models and 50% in one (1) of the six models suggests a below average explanatory power of the models. The low Root Mean Square Error (RMSE) averaging 0.069 suggests a good fit between the data and the model indicating good prediction power of the model. The F-statistic, which is significant at all levels, indicates the joint significance of the variables and that the models are well specified.

Economic Factors

Rail, Road and Land Transport Infrastructure

Estimation results indicate that freight (FI), mixed (MI) and road (RI) infrastructure investment have a significant negative impact on TFP with coefficients of -6.17, 5.38 and 44.61 significant at the 5%, 10% and 1% respectively. Passenger (PI), track (TTI) and land transport (RRI) infrastructure investment are insignificant determinants of TFP. This finding suggests that investment in transport infrastructure harms TFP or has no significant impact in South Africa.

Government investment

Government investment (GI) has an average positive coefficient of 0.186 significant at all levels. Results suggest that government investment (GI) has a positive impact on TFP and therefore promotes TFP growth in South Africa. The government investment in South Africa could have been focused on sectors which promote TFP.

Table 34: Determinants of total factor productivity in South Africa

Equation	XXXI	XXXII	XXXIII	XXXIV	XXXV	XXXVI
	D.T	D.T	D.T	D.T	D.T	D.T
Lag order	1, 1, 1, 1, 0, 1	1, 0, 0, 1, 1, 0	1, 1, 1, 1, 0, 1	1, 1, 0, 1, 1, 1	1, 1, 0, 1, 0, 1	1, 1, 0, 1, 0, 1
	Coef	Coef	Coef	Coef	Coef	Coef
ECT	-0.72***(0.15)	-0.56***(0.12)	-0.69***(0.16)	-0.76***(0.15)	-0.53***(0.13)	-0.52***(0.13)
FI	-6.17**(2.84)					
XCONST	0.0035***(0.00)	0.002*(0.00)	0.0035***(0.00)	0.0022**(0.00)	0.0016(0.00)	0.0020(0.00)
GI	0.1442***(0.03)	0.178***(0.03)	0.1475***(0.03)	0.1610*** (0.02)	0.1645***(0.04)	0.1786***(0.03)
CT	-0.0051**(0.00)	0.003(0.00)	0.0042**(0.00)	0.0038**(0.00)	0.0037(0.00)	0.0036(0.00)
HCI	1.7165***(0.19)	1.592***(0.20)	1.6690***(0.19)	1.6469***(0.16)	1.8243***(0.27)	1.5544***(0.21)
PI		1.750(2.34)				
MI			-5.3781**(3.10)			
RI				-44.61***(18.88)		
RRI					2.8021(2.52)	
TTI						-16.5680(20.46)
F-statistic	331.23(0.0000)	377.91(0.0000)	314.99(0.0000)	280.86(0.0000)	302.03(0.0000)	353.31(0.0000)
Adj.R^2	0.48	0.42	0.45	0.50	0.49	0.46
Llhd	78.05	75.76	76.67	67.89	66.47	76.31
RMSE	0.067	0.070	0.069	0.069	0.070	0.068
SR						
FI						
D1	3.0047**(1.493)					
D.XCONST						
DL	-0.0012(0.00)		-0.0012(0.00)			
GI						
DL	0.1161**(0.06)	0.1362**(0.06)	-0.065***(0.02)	0.0768(0.06)	0.136**(0.06)	0.1472***(0.06)
CT						
DL	-0.075***(0.02)		0.078***(0.02)	-0.0051*(0.00)		
LD	-0.067***(0.02)		-0.070***(0.02)			
HCI						
DL	-9.265***(2.06)	-8.267(2.08)	-8.967***(2.07)	-12.477***(2.61)	-10.1535***(2.56)	-7.2446***(2.21)
MI						
DL						
RI						
DL				4.3921(2.68)		
RRI						
DL					-1.1035*(0.60)	
TTI						
D1						11.8969**(6.67)
Cons	13.26***(2.76)	-1.51***(0.36)	12.80***(0.19)	13.957***(2.76	9.39***(2.36)	9.370***(2.34)
N	56	57	56	49	49	56

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient. Standard errors are in parenthesis.

Geostrategic Factors

Geostrategic factors proxied by the length of colonial tenure (CT) have a negative coefficient of -0.005 significant at the 5% level in the equation including freight (FI) and positive coefficients of 0.0042 and 0.0038 significant at the 10% and 5% in models including mixed (MI) rail and road infrastructure investment respectively. The coefficients of geostrategic factors in equations containing passenger, land transport infrastructure and rail track are insignificant. The results suggest that geostrategic factors have a significant impact on total factor productivity on the overall. However, the mixed results may suggest that different geostrategic priorities which had different implications for TFP were taken in the past.

Institutional Factors

Domestic institutions (XCONST) have a positive significant impact on TFP in four of the six models. The impact is insignificant in the two models involving land transport and rail track infrastructure investment. The finding suggests that domestic institutions are important determinants of TFP in South Africa.

In the case of South Africa, overall results indicate existence of a positive long run relationship between TFP and government investment; and TFP and domestic institutions. Results further indicate existence of a mixed long run relationship between TFP and geostrategic factors. The results also show a negative long run relationship between TFP and transport infrastructure investment in South Africa.

The adjustment coefficient ranges from 52% to 76% significant at all levels with an average of 63%. This provides sufficient evidence of quick convergence to long-run equilibrium relationship.

5.9 Productivity growth impact of rail infrastructure efficiency in South Africa

The impact of rail infrastructure efficiency on productivity growth in South Africa is investigated by estimating models where GDP per capita is the dependent variable and one rail efficiency measures are among the independent variables. The same rail infrastructure efficiency measures as for the panel case of Botswana, Namibia, Zambia and Zimbabwe are considered.

The following models are estimated:

Equation XLIII: lGDPcap =f(NTKMTRK NTKMLOC XCONST GI CT HCI)

Equation XLIV: lGDPcap =f(NTKMTRK NTKMLOC NTKMWG XCONST GI CT HCI)

Equation XLV: lGDPcap =f(NTKMLOC NTKMWG XCONST GI CT HCI)

Equation XLVI: lGDPcap =f(NTKMTRK NTKMLOC NTKMWG NTKMEMPL XCONST GI CT HCI)

Equation XLVII: lGDPcap =f(NTKMTRK NTKMLOC PAXCHA XCONST GI CT HCI)

Equation XLVIII: lGDPcap =f(NTKMTRK NTKMLOC PAXCHA XCONST GI CT)

5.9.1 Cointegration tests

We test for cointegration for models with rail efficiency measures in the same way as for the rail infrastructure measures using the Bounds Test technique. The Bounds Test cointegration results are presented in Table 35 below.

Table 35: Bounds Test cointegration results-Output growth and rail infrastructure efficiency

Dependent variable	AIC lags	F-statistic	LB CV at 5%	UB CV at 5%	Decision
lGDPcap (ntkmtrk ntkmloc xconst gi Ct hci)[83]	(1,0,0,0,1,0,0)	6.88	2.70	4.03	Cointegration
lGDPcap (ntkmtrk ntkmloc ntkmwg xconst gi Ct hci)	(2,0,0,0,0,0,0,0)	3.59	2.59	3.94	Inconclusive
lGDPcap (ntkmloc ntkmwg xconst gi Ct hci)	(2,0,0,0,0,0,0)	4.20	2.71	4.04	Cointegration
lGDPcap (ntkmtrk ntkmloc ntkmwg ntkmempl xconst gi Ct hci)	(1,1,0,0,1,0,0,0,0)	6.87	2.48	3.87	Cointegration
lGDPcap (ntkmtrk ntkmloc paxcha xconst gi Ct hci)	(1,0,0,1,0,0,0,0)	7.23	2.58	3.93	Cointegration
lGDPcap (ntkmtrk ntkmloc paxcha xconst gi Ct)	(1,0,0,1,1,0,0)	8.09	2.69	4.03	Cointegration

Based on the results presented above, the null of no cointegration is rejected for all the models except the one with NTKMWG which is inconclusive. We therefore proceed to estimate the models using the ARDL Bounds Test technique having established that the variables are bound together in the long run.

5.9.2 Estimation results

As before, our variables of interest are the efficiency measures namely, NTKMTRK, NTMLOC, NTKMWG, PAXCHA AND NTKMEMPL. Estimation results are presented in Table 5.21 below.

The results indicate that the impact of NTMLOC is positive and significant in all the six models. This result suggests that locomotive efficiency promotes growth in South Africa. The impact of NTKMTRK, NTKMWG, PAXCHA AND NTKMEMPL is significantly negative with

[83] Acronyms in lower case for space economy purposes.

coefficients of -0.0084, -0.59, -0.31 and -0.33 significant at the 10%, 10%, 10% and 1% levels respectively suggesting that the efficiency levels of the rail track, wagons, coaches and employees are impacting negatively on growth in South Africa. This points to the need to devise efficiency improvement strategies for rail transport to promote economic growth.

The adjustment coefficient ranges from 7.1% to 16.4% with an average of -0.31 significant at all levels. The rate of 31% provides sufficient evidence of convergence to long-run equilibrium relationship.

Table 36: ***Productivity growth impact of rail infrastructure efficiency in South Africa***

Equation	XLIII		XLIV		XLV		XLVI		XLVII		XLVIII	
	lGDPcap		lGDPcap		lGDPcap		lGDPcap		lGDPcap		lGDPcap	
Lag order	1,0,0,0,1,0,0		2, 0, 0 ,0, 0, 0, 0		1,0, 0, 1, 0, 0, 0, 0		2, 0, 0, 0, 0, 0, 0, 0		1, 1, 0, 0, 1, 0, 0, 0, 0		1, 0, 0, 1, 1, 0, 0	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Adj	-0.094**	0.05	-0.161***	0.05	-0.101**	0.04	-0.16***	0.06	-0.164***	0.06	-0.071**	0.03
XCONST	0.0029	0.00	0.0020**	0.00	0.0046**	0.00	0.002*	0.00	-0.0017	0.00	0.0025	0.00
GI	-0.2356	0.01	-0.0948*	0.05	-0.1702**	0.08	-0.0954	0.06	-0.0557	0.06	-0.1919	0.11
CT	-0.0046	0.01	-0.0021	0.00	-0.0082	0.01	-0.0021	0.00	-0.0082*	0.00	-0.017**	0.01
NTKMTRK	-0.3675	0.38			-0.1860	0.29	-0.0084*	0.20	0.1223	0.17	-0.3036	0.42
NTKMLOC	0.9105*	0.50	0.4786***	0.18	0.8523*	0.45	0.4845**	0.23	1.1038***	0.34	1.3151*	
NTKMWG			-0.5297*	0.27			-0.5259*	0.29	-0.7112**	0.29		
PAXCHA					-0.1622	0.11					-0.3129*	0.17
NTKMEMPL									-0.3277***	0.12		
HCI	0.4324	0.33	1.0135***	0.31	0.3535	0.31	1.0100***	0.33	1.1347***	0.30		
SR												
LGDPCAP												
Dl			0.2283*	0.13								
LD							0.2259	0.15				
XCONST												
DL											0.0003	0.0002
GI												
DL	0.0220	0.01										
PAXCHA											0.0438***	0.02
DL	0.100***	0.04			0.0512***	0.02						
NTKMTRK												
DL									-0.1037**	0.05		
NTKMWG												
DL												
NTKMEMPL												
D1									0.0935**	0.04		
T1												
D1												
Cons	0.363	0.37	1.303**	0.51	0.263	0.37	1.293**	0.57	0.227	0.53	-0.022	0.33
F-statistic	264.71(0.0000)		247.17(0.0000)		257.27(0.0000)		215.04(0.0000)		215.93(0.0000)		278.24(0.0000)	
Adj.R^2	0.42		0.47		0.47		0.45		0.48		0.48	
Llhd	152.13		151.34		155.21		151.33		157.14		159.00	
RMSE	0.0183		0.02		0.0175		0.0173		0.0161		0.0172	
N	57		56		57		57		37		58	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level. Coef = coefficient.

The impact of NTKMTRK is insignificant suggesting that rail efficiency in South Africa may not have reached threshold levels to be able to contribute significantly to economic growth. The efficiency of locomotives in South Africa (NTMLOC) has a positive and significant impact on productivity growth with an average coefficient of 0.85. The impact efficiency of wagons (NTKMWG), passenger coaches (PAXCHA) and employees (NTKMEMPL) on productivity growth is negative with average coefficients of -0.59, 0.31 and 0.33 respectively. This points to the need to devise efficiency improvement strategies for rail transport to promote economic growth.

The adjustment coefficient ranges from 7% to 16% with an average of -0.31 significant at least at the 5% level. The rate of 12% provides sufficient evidence of convergence to long-run equilibrium relationship. The adjusted R^2 averages 46% for the six (6) models suggesting below average explanatory power of the models. The low Root Mean Square Error (RMSE) averaging 0.02 suggests a good fit between the data and the model indicating good prediction power of the model. The F-statistic which is significant at all levels in all the models indicates the joint significance of the variables and that the models are well specified. Results for the three scenarios are summarized in Table 37 below.

Table 37: Direction of impact summary

	Four Country case					
	Rail Infra.	Road Infra.	Govt Invest.	Land Transport	Geostrategic	Institutions
GDPcap (direct)	+/0	+	+	+	+/-	0
T	-	0	+	0	-	-
GDPcap (indirect)	-	+	+	+	-	-
	South Africa					
GDPcap (direct)	-	0	+	0	+	0
T	-	+	-	0	+/-	+
GDPcap (indirect)	0	0	-	0	+	+

Notes: + positive impact; -negative impact; +/- mixed impact; 0 - insignificant.

Source: Researcher's own construction based on research results.

5.10. Evaluation and recommendations

5.10.1 Evaluation

5.10.1.1 Economic factors

Rail Infrastructure investment

The research finding that only rail track infrastructure investment has a *direct* impact on GDP growth in the case of Botswana, Namibia, Zambia and Zimbabwe indicates the importance of rail infrastructure investment as a factor of production. Further, the finding that the productivity growth impact of freight, passenger and rail track infrastructure investment is *indirect* through enhancing total factor productivity (T) points to the importance of rail infrastructure investment and the importance of T itself in promoting growth. Absence of a direct impact from these categories of rail infrastructure may be due to their inadequacy in terms of quantity and quality. This suggests the importance of investing in rail infrastructure to promote growth.

Our research findings particularly on rail track infrastructure from the panel case of the four countries concur with findings of other studies. Results of Eichengreen (1995), Fedderke *et al*, (2006) and Donaldson (2018), focusing on developing countries, South Africa and colonial India respectively for example, suggest a positive impact of rail infrastructure investment on economic growth. In the case of China, findings by for example Demurger (2001), Hong *et al*, (2011) and Zou *et al* (2008) indicate that land transport infrastructure is a significant determinant of GDP growth. Zou *et al*, (2008) found rail infrastructure investment to be a significant determinant of economic growth.

The finding of an insignificant impact on output of other rail infrastructure measures apart from the rail track concurs with that of Canning (1999) which suggests that infrastructure in developing countries is inadequate to impact growth. The fact that the impact of rail track infrastructure investment on output has remained positive despite declining rail capacity over the years[84]suggests that there are benefits of using rail transport. Additional investment in rail infrastructure should therefore positively impact growth in the four countries.

[84] The decline in railway capacity is clearly demonstrated in Chapter 3.

In the case of South Africa, the research finding of a negative and significant impact on productivity growth by some rail infrastructure investment measures (freight and passenger) while the others (mixed and rail track) are insignificant points to the declining economic role of rail transport due to competition from road. This result may also be due to the fact that rail infrastructure did not grow significantly during the study period in sympathy with GDP[85] and loss of market share from rail to road transport. However, this finding contradicts the finding by Fedderke *et al,* (2006) possibly due to the differences in the study periods covered and the construction of infrastructure measures used. The finding of a stagnant growth of rail infrastructure investment over the study period is in line with the observation by Fedderke *et al,* (2006) that the rail network in South Africa did not grow significantly beyond the 1930s.

The other possible reason for this finding in the case of South Africa may be that GDP growth could have been the one driving growth in rail transport infrastructure investment where higher GDP levels will need supporting transport infrastructure consistent with the Accelerator Theory of Investment. Perkins *et al,* (2005) found forcing long-run relationships from GDP to rail track and coaches; and potential simultaneity between GDP and locomotives and wagons in the case of South Africa. Fedderke *et al,* (2006) also found potential simultaneity between output and various rail infrastructure measures in the case of South Africa. The other possible cause of the finding could be that the South African rail network reached the threshold beyond which any additional investment would not have a positive impact given that its core railway network was already in place by the 1930s.

Road infrastructure investment

The finding of a positive *direct* productivity growth impact of road infrastructure investment in the four countries is plausible given that road transport commands over 80% of freight and passenger market in these countries. This finding is similar to findings of other studies for example, Zou *et al,* (2008) who found road infrastructure investment to have a positive impact on economic growth in the case of China. The growth in GDP is therefore supported by road transport. Our

[85] Fedderke *et al* (2006) observe that the rail network in South Africa did not grow significantly beyond 1930s.

finding that the impact of road infrastructure investment on TFP is insignificant confirms that the impact of road infrastructure investment on output is indeed direct. This is further confirmed by the fact that both road infrastructure investment and TFP have positive impact on productivity growth coefficients in the same model suggesting that the two are complements in promoting output growth.

The contrasting finding of an insignificant *direct* impact of road infrastructure investment in the case of South Africa is surprising given that South Africa has a relatively bigger road network compared to the other four countries and that over 80% of freight and passenger traffic in the country is moved by road transport. This result may possibly be due to two reasons. First, road infrastructure investment could have been driven by GDP growth in line with the finding by Fedderke *et al*, (2006). Second, there could be a case of oversupply of road infrastructure leading to diminishing returns. Fedderke and Bogetic (2009) show that road kilometres declined on the main routes and any efficiency gains would be due to widening and straightening of the roads. It would be instructive to further investigate these possibilities in order to guide policy accordingly. However, road infrastructure investment has a positive indirect impact on productivity growth through enhancing total factor productivity.

Regarding transport infrastructure in general, other studies elsewhere by for example, African countries (Boopen, 2006), China (Demurger, 2001; Hong *et al*, 2011; Sahoo *et al*, 2012; Yu *et al*, 2012) and Portugal (Pereira & Andraz, 2005) suggest a positive and significant output elasticity of transportation infrastructure.

Government investment

The positive productivity growth impact of government investment found in the four-country case as well as in the case of South Africa in the case of total factor productivity, indicates the importance of government investment to support growth especially in infrastructure and those sectors that promote production and enhance T. In this regard, the finding of a positive impact of government investment on T in the case of South Africa suggests that more government investment is directed towards those sectors that enhance T like for example, infrastructure, technology and human capital. The finding is of a negative impact of government investment suggests that government investment is possibly crowding out the private sector. This calls for the interrogation of government investment and prioritization of investment in those sectors that promote productivity growth in order to accelerate economic growth.

5.10.1.2 Geostrategic Factors

The importance of geostrategic considerations is confirmed by the finding of their significant productivity growth impact in both the four-country case and South Africa. The finding that the impact of geostrategic factors is mixed (negative and positive) in both the four-country case and South Africa suggests the impact of colonialism differed across sectors resulting in positive as well as negative contribution. The positive contribution should be reinforced, and the negative ones addressed through additional effort.

The contrasting finding of differences in the direction of the impact among models with different infrastructure investment measures in the four-country case may indicate differences in geostrategic priorities across economic sectors. The positive impact of geostrategic factors in models including rail track (railroad) and road infrastructure may be due to the fact that these infrastructures were constructed mostly during the colonial era. The negative impact in the models involving freight and passenger rail infrastructure investment measures may possibly indicate the negative contribution of past geostrategic priorities and suggests that more effort is required in these areas for the countries to catch up.

The finding of a negative effect of geostrategic factors on T in the four-country case suggests that geostrategic priorities adopted in the past impact negatively on economic growth through depressing TFP. More effort will be required to align the geostrategic priorities to promote growth in these countries.

In contrast, the positive impact of geostrategic factors on TFP when freight rail, passenger rail and road infrastructure investment measures are considered in the case of South Africa suggests that freight rail, passenger rail and road infrastructure investment benefited from geostrategic positioning of the past given that major trade routes were constructed during the colonial era and that the market share for road transport has been rising rapidly over the years.

Overall, geostrategic factors have proved to be significant throughout although the direction of impact is different in some cases. This implies that geostrategic factors matter for economic growth. In essence, geostrategic considerations cannot be separated from socio-economic considerations.

5.10.1.3 Institutional factors

The finding that domestic institutions have an insignificant *direct* impact on productivity growth and a significant negative impact on T in the four-country case indicates that domestic institutions harm economic growth through depressing total factor productivity. This result is consistent with the observation by for example, Aron (2000), Bardan (2005) and Luiz (2010) that institutions in Sub-Saharan Africa are weak and non-existent in some cases resulting in their failure to support economic growth. This finding further suggests the need for institutional development and reforms for domestic institutions to promote economic growth.

The finding of a positive impact of domestic institutions on productivity growth and T in the case of South Africa suggests that domestic institutions are promoting economic growth in this country. Further, South African institutions are superior to those of the other four countries.

It is important to observe that the impact of economic, geostrategic and institutional factors on productivity growth is not mutually exclusive. They impact jointly on growth with varying degrees and direction of the impact. This observation demonstrates the interconnectedness of various sectors of the economy and suggests the need for a holistic approach incorporating other economic sectors in the growth strategy apart from transport infrastructure investment.

5.11 Recommendations

The study findings of this Chapter provide some policy insights to promote GDP growth. Based on our results and analysis, the following recommendations are proposed:

(i) Botswana, Namibia, Zambia and Zimbabwe should invest in physical infrastructure including transport infrastructure to enhance total factor productivity (T) and promote economic growth. South Africa should undertake targeted rail and road transport infrastructure investment given their insignificant impact on overall productivity growth;

(ii) Government investment should be prioritized in the five SADC countries in view of its positive impact on economic growth.

(iii) Investment in technology should be undertaken in order to promote economic growth;

(iv) Countries need to support the road sector in terms of infrastructure and policies to sustain its positive contribution to GDP growth.

(v) The five SADC countries should pay particular attention to geostrategic factors as they significantly impact productivity growth and total factor productivity; and

(vi) Develop institutions and undertake institutional reforms to ensure that they mature to thresholds where they can positively impact productivity growth.

(vii) Academia should investigate infrastructure investment thresholds for rail transport to positively contribute to growth and the limits of positive contribution thereof.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents conclusions from the findings of the thesis and discusses implications of the findings before making recommendations based on the conclusions. The second part presents contributions and limitations of the study, and recommendations for future research.

6.1 Findings

This thesis addresses two key issues: firstly, the thesis addresses the determinants of investment in rail infrastructure in Botswana, Namibia, South Africa, Zambia and Zimbabwe based on novel time series datasets on infrastructure measures constructed as part of this research. Secondly, it estimates the productivity growth impact of rail infrastructure in the five SADC countries. The key argument of this thesis is that rail infrastructure investment in the five SADC countries was driven by a mix of economic, geostrategic and domestic institutional factors with different relative importance of the three forces depending on time and context.

An important contribution of this thesis is the data set for the period 1939 to 2018 generated which can benefit rail transport policy makers, managers and other researchers. Based on the analysis of data from 1960 to 2018, the research findings confirm that rail infrastructure investment and efficiency are driven by economic, geostrategic and institutional factors in the panel context of Botswana, Namibia, Zambia and Zimbabwe, and also in the time-series context of South Africa. These three major drivers of rail infrastructure investment are initially identified through a historical review of the development of railways in the five SADC countries under study followed by a descriptive data analysis and finally econometric model estimation.

The descriptive analysis of rail infrastructure investment and efficiency which follows the historical review shows a persistent decline of rail infrastructure capacity and performance for Botswana, Namibia, Zambia and Zimbabwe over the period from 1940 to 2018. In the case of South Africa, rail capacity was rising up to 1980 and then declined thereafter, with a mirror image in terms of efficiency measures which fall to the 1980/90 period, and then sharply rise. The trend of infrastructure capacity and efficiency in the different countries is also attributed to economic, geostrategic and institutional factors impacting jointly or individually at different intervals in the five countries.

Botswana, Namibia, Zambia and Zimbabwe's core rail networks construction was influenced by economic and geostrategic considerations. The extent of the impact of these factors differed across countries depending on geographical location and rail transportable business generated.

Namibia, Zambia and Zimbabwe have significant mining sectors and as result economic factors were major drivers of rail network development especially rail lines to the mines. Botswana is principally a transit route with low levels of internal traffic therefore the influence of economic factors on rail network development was minimal.

Agriculture also led to the construction of rail lines to the sugar estates and some farming areas in Zimbabwe. Construction of the Beitbridge Bulawayo Railways in Zimbabwe was due to business considerations by the private sector.

Access to the sea was a priority for Botswana, Zambia and Zimbabwe that are landlocked. As a result, geostrategic factors played a significant role in the rail network development especially in the case of Zambia and Zimbabwe leading to the construction of alternative rail routes leading to the seaports. Botswana did not construct any alternative route to the sea because it is not a major producer or consumer of rail transportable traffic. It served mainly as a transit route. Namibia did not construct alternative rail routes to the sea once the core network was in place since it is a coastal country.

The rail companies in the four countries are predominantly State owned and therefore funded by the government. There is, however, no elaborate institutional framework for sustainable rail infrastructure funding in these countries as is the case for road. Policy inconsistency had a negative impact in the case of Zimbabwe and Zambia which resulted in railways' failure to invest in infrastructure.

Passenger services in the four countries are loss-making and funded by the government as social service obligations. These receive subsidies from the government.

South Africa is a big economy with strong mining, agriculture and manufacturing sectors and as a result economic considerations were a major driver of rail network development. Geostrategic positioning arising from Afrikaner-British rivalry led to the construction of an alternative rail route from Pretoria to Maputo seaport and the routing of the Rhodesia Railways rail network via Botswana.

The railways in South Africa are predominantly State owned and the institutional framework for funding rail infrastructure is also not as elaborate as for road infrastructure funding.

Results of the estimation of the productivity growth impact of rail infrastructure investment based on GDP per capita growth indicate that the contribution of rail infrastructure investment is positive and significant for rail track infrastructure investment, and insignificant for the rest of the rail infrastructure investment measures in the panel context of Botswana, Namibia, Zambia and Zimbabwe. The impact of rail infrastructure investment on total factor productivity (T) is negative and significant in the case of freight and track rail infrastructure, and insignificant in the case of passenger and mixed rail infrastructure. Therefore, rail infrastructure investment has a direct positive impact on productivity growth and an indirect negative impact through depressing (T).

The productivity growth impact of road infrastructure is significantly positive but lower than that of rail infrastructure investment. The impact of road infrastructure on T is insignificant indicating that the productivity growth impact of road infrastructure investment is only direct as a factor of production.

In the time series case of South Africa, our research results suggest that investment in rail infrastructure has a negative significant impact on productivity growth.

Other significant determinants of productivity growth include government investment, domestic institutions, length of colonial tenure (geostrategic factors) and human capital formation. Significant determinants of T are infrastructure investment (except in the case of South Africa), domestic institutions, length of colonial tenure (geostrategic), government investment and human capital formation.

The finding that GDP is an insignificant determinant of rail infrastructure investment is consistent with the reality that rail infrastructure investment has not been growing despite the growth in GDP of the sample countries. The insignificance of government investment in rail infrastructure investment in Botswana, Namibia, Zambia and Zimbabwe may indicate that government investment is sectors that do not impact on railways and or the government investment levels are low. Government investment has a negative impact rail infrastructure investment in the case of South Africa possibly due to the South African government investing in sectors that impact negatively on railways.

The importance of economic drivers of rail infrastructure investment is consistent with standard economic theory which places importance on the conducive economic environment to attract investment. Further, since rail transport is derived demand, performance of other sectors of the economy will matter to investment in rail transport infrastructure. The road sector in particular is important because road transport competes and at times complements rail transport in the provision of transportation services. Road and rail infrastructure investment also compete for funding from the fiscus.

The finding that institutions are important drivers of investment in rail infrastructure, infrastructure efficiency and productivity growth supports institutional theory which emphasizes the importance of institutions in determining investment and growth. Countries with good institutions will attract more investment and consequently realize high growth rates.

The finding that geostrategic factors are significant determinants of rail infrastructure investment, and its productivity growth impact is consistent with the historical development of most rail networks in the countries under study. Countries need to have guaranteed control of the flow of their material supplies for production and consumption and also their exports hence the need for geostrategic positioning to avoid hostile territories.

Overall, our research findings suggest that the mix of economic, geostrategic and institutional factors pervade the entire rail transport sector through their impact on infrastructure investment, efficiency and productivity.

The contribution of this thesis is fourfold: first, the thesis provides a compact review of the evolution of rail infrastructure in Southern Africa particularly for Botswana, Namibia, South Africa, Zambia and Zimbabwe. This synthesis of literature on rail infrastructure development will facilitate better understanding of rail transport and helps to advance the infrastructure debate. The literature gap on railway infrastructure development is thus narrowed.

Second, time-series rail infrastructure datasets are compiled for the sample countries for the period from 1940 to 2018. Such datasets did not exist except in the case of South Africa. Third, novel rail infrastructure measures generated by this research will contribute towards better understanding of rail infrastructure development and management and also through further research. The new datasets are therefore an important enabler for rail transport policy development, rail infrastructure management and further research on rail transport. The data sets will thus deepen the understanding of rail infrastructure and advance the debate thereof. This will be an important starting point for supporting revival of the rail transport sector for the benefit of economies of the sample countries.

Fourth, the thesis identifies the drivers of investment in rail infrastructure and efficiency, and productivity growth as economic, geostrategic and institutional factors. This finding will assist in guiding policy development to promote investment in rail infrastructure and its management and also contribute to the broader growth strategy of the countries under study. The decline in rail infrastructure investment may be resolved through addressing the identified driving forces when developing policy for infrastructure development and management.

The findings of this study will be useful to policy makers, railway managers and researchers particularly as they relate to rail transport and rail infrastructure development. The debate on infrastructure development is therefore advanced.

6.2 Implications

A number of implications emerge from the research findings.

Economic factors

The significance of economic factors in determining investment in rail infrastructure and productivity growth points to the need for the creation of a conducive economic environment for investment in rail infrastructure. The economic factors are technology, road infrastructure investment and foreign direct investment (FDI). For road infrastructure investment, significant economic factors also include GDP and government investment. Government investment is also a significant negative determinant of rail infrastructure investment in the case of South Africa and insignificant in the four-country case. In view of the finding that investment in rail infrastructure has a positive direct impact on productivity growth and a negative indirect impact on productivity growth through depressing T, more investment in rail infrastructure in terms of new developments and maintenance is required if countries are to accelerate their economic growth.

The significance of T in determining productivity growth implies the need to pay particular attention to those factors which promote its growth like, technology, domestic institutions, length of colonial tenure, government investment, human capital formation and infrastructure investment. Technology acquisition and training will contribute positively to growth through T growth. Most of the factors affecting productivity growth also affect T growth so their management can be undertaken at the same time.

The continuous decline of rail capacity and efficiency of Botswana, Namibia, Zambia and Zimbabwe implies that rail services in these countries will continue to deteriorate and rail market share will also continue to decline until after investment in additional capacity. The desired shift of traffic from road to rail is therefore not currently possible and the potential benefits associated with increased use of rail transport will be lost in the mean-time. In view of the inadequate rail infrastructure capacity, development of policies to support the shift of traffic from road to rail should be preceded by investment in rail infrastructure capacity in order to achieve the desired objectives. South Africa's rising rail efficiency provides opportunities for benchmarking by the other four countries.

Geostrategic factors

The need to ensure uninterrupted flow of national imports and exports makes geostrategic considerations vital. Considering that economic and political relations among neighbouring and transit countries may change over time leading to a shift in geostrategic priorities, new alternative rail routes may be constructed in the future in response to the changing geostrategic priorities among the countries under study. Secondly, the positive impact of geostrategic factors (proxied by length of colonial tenure) on productivity growth through T in the case of South Africa, their mixed impact in four country case implies that countries that have had a bad colonial history need to work extra hard to catch up on economic growth. The finding contributes to the debate on colonial history. Colonial history can be good as in the case of South Africa, and bad in the case of the four countries. There is therefore no general answer, depends on how it was done.

Institutional factors

The finding that domestic institutions matter for investment in rail infrastructure in the case of the four countries against the need to use more of rail transport necessitates institutional and policy reforms in the SADC countries under study to support rail funding. Rail infrastructure investment stands to benefit from the establishment of institutions and development of polices that specifically address rail infrastructure development and operations.

Overall, the preceding observations suggest that the mix of economic, geostrategic and institutional factors needs particular and continuous alignment to ensure their appropriateness and relevancy to specific contexts which evolve over time. This way, investment in rail infrastructure, rail infrastructure efficiency and productivity growth will be promoted.

6.3 Conclusions

The following conclusions follow from the findings and implications highlighted for the countries under study:

(i) Investment in rail infrastructure promotes economic growth as it enhances production capacity and productivity of other factors of production.

(ii) Rail infrastructure investment is dependent on a mix of economic, geostrategic and domestic institutional factors. Countries should therefore place importance on these factors to promote investment in rail infrastructure investment.

(iii) Institutions matter for economic growth through their impact on investment in rail infrastructure and productivity growth.

(iv) Geostrategic factors matter for investment in rail infrastructure, its efficiency and impact on productivity growth.

6.4 Recommendations

Recommendations following from the research findings, implications and conclusions highlighted above are that;

(i) Countries should invest in rail infrastructure in order to promote economic growth.

(ii) Countries need to create a conducive economic environment for investment in rail infrastructure by paying particular attention to the mix of economic, geostrategic and domestic institutional factors.

(iii) Domestic institutions supportive to rail infrastructure funding need to be established where they do not exist, and reforms are required where the institutions already exist.

(iv) Government investment should be upscaled and sector focused to promote economic growth.

(v) Countries should invest in infrastructure, new technology and human capital in order to promote productivity growth.

(vi) Investment in adequate rail infrastructure capacity should be undertaken before developing policies to promote the shift of traffic from road to rail for the railways to be able to handle additional traffic.

(vii) Further research should consider extending the scope of the study to cover more SADC countries to improve understanding of rail infrastructure issues in the Southern Africa region. Secondly, consideration should be given to the development of datasets for rail infrastructure quality measures which will contribute towards advancing the infrastructure debate. A study on the determinants of road infrastructure development and generation of road infrastructure quality measures will also provide more insights on surface transport in the SADC region. Such a study will be particularly important for road transport considering that it is the major transporter of freight and passenger traffic.

Transport infrastructure is one of the key pillars of economic growth and therefore needs to be given priority in any country's development agenda. The mix of the determinants of rail infrastructure investment, efficiency and productivity growth requires a multi-sectoral approach with a strong coordination framework to ensure continuous alignment. It is only the government who can lead in ensuring that the alignment is achieved therefore the fate of rail transport is in the hands of government.

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