

Investigating the use of data analytics towards improved logistics performance for South African imports

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ABSTRACT

This thesis undertakes a comprehensive exploration of logistics performance within the context of South African imports, emphasising the pivotal role of efficient logistics in socio-economic development. Adding to the existing literature and evidence indicating an intricate connection between sustained economic growth, reliant on international and domestic trade, and the effective operation of global value chains, the study employs a meticulous, bottom-up, process-driven framework to improve logistics performance. This framework, centred on the perspective of freight forwarders, investigates logistics performance based on time, cost, and service reliability.

The primary objective is to contribute to the measurement of the national-level logistics system's performance, focusing on all actors from the freight forwarder's standpoint, with an emphasis on reducing international trade time and cost. By employing data analytics, the thesis systematically assesses existing scholarly works on import flow logistics performance, elucidating potential areas for enhancement in operational and detailed dimensions. The freight forwarder, as the central orchestrator in the logistics system, becomes the focal point for developing an operational framework and a bottom-up diagnostic tool. This tool aims to identify specific areas for improvement based on internationally recognised metrics of time, cost, and service reliability.

This study also utilises a Total Economic Cost (TEC) model to convert time delays and variability in time delays into monetary values. Results gleaned from the study illuminate substantial opportunities for enhancing logistics performance from the freight forwarder's viewpoint. Key segments in the end-to-end logistics chain, notably trade lane combinations and customs clearance processes, emerge as critical areas for improvement. The ANOVA analysis showed the various combinations of factors and their influence on time delays, and indicated that several factors have a statistically significant influence on logistics time delays and cost, as different cargo categories, using these factors as categorical variables, display time delays that are different from the population. These included (in order of significance based on the influence of the respective process segments) country of origin, shipping line, and port of loading.

In practice, cargo owners manage the impact of time delay variability through buffer stock strategies. Insights into the relationship between buffer stock strategies and various cost components, such as interest cost on inventory and total time delay cost, underscore the complexity of logistics optimisation. Ultimately, the results from the TEC model identify the ocean freight transport leg as the most impactful factor in time delays, emphasising the crucial role of optimal supplier-shipping trade lane selections. Port performance, both waterside and landside, significantly influences delays. Inbound road transport has a minimal impact, but delays in the

96th percentile suggest potential inefficiencies in the short haul–long haul inbound strategy. Optimal buffer stock strategies are shown to be essential to minimise the cost impact of time delays, emphasising the need for strategic planning. Variations in TEC due to time delays among top countries and shipping lines underscore the importance of informed decisions for freight forwarders, regarding the selection of sources of cargo and of service providers to optimise logistics performance.

The thesis underscores the importance of concentrating improvement efforts on segments entirely within the freight forwarder's control, such as documentary processes and customs clearance. The framework created serves as both a diagnostic tool and a contribution to the intricate field of logistics performance research, and the study appeals to a diverse audience, including national policymakers, multilateral agencies, economic actors, and logistics service providers.

In recommending future research directions, the research suggests extending the framework to investigate logistics performance across different industries and countries. Additionally, expanding the logistics system to encompass the entire supply chain and conducting detailed analyses on factors with significant performance variability, such as the choice of supplier and service provider, offers avenues for further exploration. The thesis envisions an ongoing exploration of data analytics applications in improving logistics performance across various roles and levels of analysis, emphasising the limitless potential for investigation in this dynamic field.

Key terms: *logistics performance, data analytics, logistics and supply chain management, South Africa, imports, international trade, process analysis.*

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LIST OF ABBREVIATIONS

3PL	=	Third-Party Logistics
4IR	=	Fourth Industrial Revolution
4PL	=	Fourth-Party Logistics Service Provider
ACOC	=	Air Cargo Operators Committee
ACSA	=	Airports Company South Africa
AEMLI	=	Agility Emerging Markets Logistics Index
AfCFTA	=	African Continental Free Trade Area Agreement
ANC	=	African National Congress
ANOVA	=	Analysis of Variance
ARIA	=	African Rail Industry Association
ATA	=	Actual Time of Arrival
AU	=	African Union
BASA	=	Banking Association of South Africa
BMA	=	Border Management Authority
BUSA	=	Business Unity South Africa
CAGR	=	Compound Annual Growth Rate
C-BRTA	=	Cross-Border Road Transport Agency
CIA	=	Central Intelligence Agency
CPPI	=	Container Port Performance Index
CSIR	=	Council for Scientific and Industrial Research
DOT	=	Department of Transport

DTIC	=	Department of Trade, Industry, and Competition
EC	=	European Commission
ECI	=	Economic Complexity Index
EDI	=	Electronic Data Interchange
EODB	=	Ease of Doing Business
ETA	=	Estimated Time of Arrival
EU	=	European Union
EWO	=	Enterprise-Wide Optimisation
FDM	=	Freight Demand Model
FESARTA	=	Federation of East and Southern African Road Transport Association
GCI	=	Global Competitiveness Index
GDP	=	Gross Domestic Product
GFC	=	Global Financial Crisis
GVCs	=	Global Value Chains
HDI	=	Human Development Index
ICC	=	International Chamber of Commerce
ICT	=	Information and communications technology
IMF	=	International Monetary Fund
IRC	=	Infrastructure Report Card
ISO	=	International Organisation for Standardisation
ITC	=	International Trade Centre
LPI	=	Logistics Performance Index
LSCI	=	Liner Shipping Connectivity Index

LSCM	=	Logistics and Supply Chain Management
MNCs	=	Multinational Corporations
NFFM	=	National Freight Flow Model
OECD	=	Organisation for Economic Co-operation and Development
OGA	=	Other Government Agency
PPP	=	Purchasing Power Parity
RFA	=	Road Freight Association
RFID	=	Radio Frequency Identification
SAAFF	=	The South African Association of Freight Forwarders
SAASOA	=	South African Association of Ship Operators and Agents
SAEPA	=	South African Express Parcel Association
SAICE	=	South African Institution of Civil Engineering
SANRAL	=	South African National Roads Agency Limited
SAPO	=	South African Port Operations
SARS	=	South African Revenue Service
SERVQUAL	=	Service Quality
SMEs	=	Small to Medium Enterprises
SOB	=	Shipped on Board
TAB	=	Trading Across Borders
TEC	=	Total Economic Cost
TEU	=	Twenty-foot Equivalent Unit
TFA	=	Trade Facilitation Agreement
TFR	=	Transnet Freight Rail

TNPA	=	Transnet National Ports Authority
TPT	=	Transnet Port Terminals
TRS	=	Time Release Study
TSPA	=	Technical Service Providers Association of South Africa
UK DIT	=	United Kingdom Department for International Trade
UK	=	United Kingdom
UN	=	United Nations
UNCTAD	=	United Nations Conference for Trade and Development
UNECE	=	United Nations Economic Commission for Europe
UNFPA	=	United Nations Population Fund
US	=	United States
VAT	=	Value-Added Tax
WB	=	World Bank
WEF	=	World Economic Forum
WITA	=	Washington International Trade Association
WTO	=	World Trade Organisation

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CHAPTER 1: INTRODUCTION

1.1 Background to the study

Efficient logistics is a critical factor in socio-economic development (Liu, 2009; Munim & Schramm, 2018; Lan *et al.*, 2017), *ceteris paribus*. Socio-economic development is highly dependent on sustained economic growth (Niaz, 2022), which in turn is highly dependent on international and domestic trade and the effective functioning of global value chains (GVCs) (see, for example, Kim & Lin, 2009; and Frankel & Romer, 2017). Improved logistics performance increases the efficiency of international trade by reducing the time and cost to trade (Arvis *et al.*, 2018), which could then result in an increase in the volume of trade (see, for example, Hausman *et al.*, 2013) and ultimately spills over into economic growth and socio-economic development (Müller *et al.*, 2012).

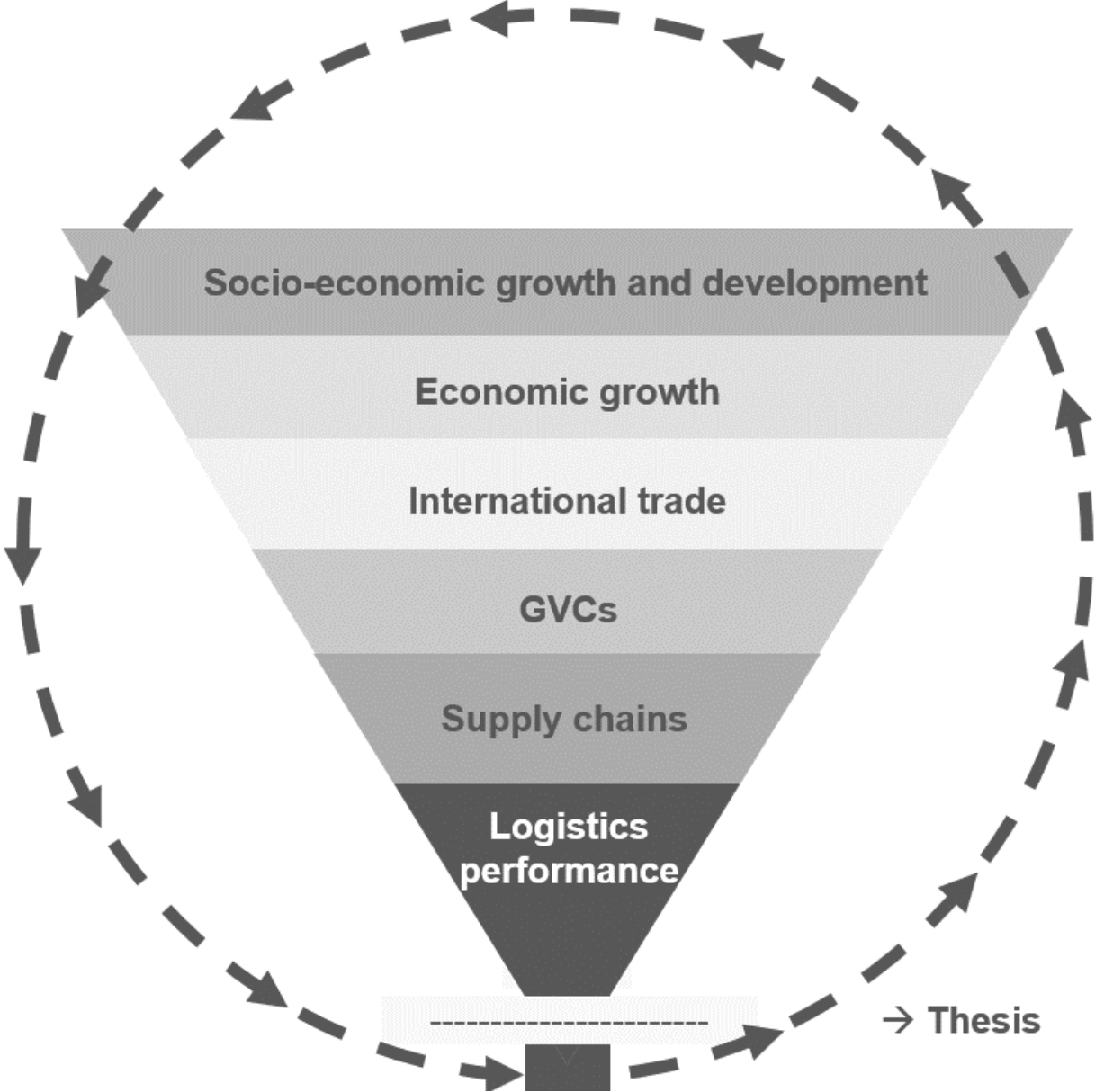
The relationship between efficient logistics and socio-economic development is widely accepted – implicitly and explicitly – from national policymakers to multilateral agencies, economic actors, and logistics service providers¹ (see, for example, Quium, 2019). This has been particularly the case since the 1980s–1990s, which corresponded with the acceleration of globalisation (see *the KOF indices in Figure 9-1 and Figure 9-2 in the annexure*). Although trade as a percentage of GDP peaked in 2008 according to World Bank (WB) data (see Figure 2-3 in Chapter 2), talks of de-globalisation, particularly in the context of the so-called trade wars, the global COVID-19 pandemic, and the Russia-Ukraine war, have yet to manifest into a durable inversion of both this relationship (i.e., between efficient logistics and socio-economic development) the widespread international commitment to trade (Chowdhury *et al.*, 2021), and the free movement of people and information.

Academic research conceptually and empirically confirms both the direct and indirect relationship between socio-economic development and logistics performance. The importance of the performance of logistics systems has been amply documented from several levels of analysis (local, country, regional, and global) and performance measurements (time, cost, service reliability, volume, and other performance elements). Logistics performance has a direct, measurable impact on socio-economic growth and development (see Munim & Schramm, 2018; and Lan *et al.*, 2017).

¹ The term “logistics service provider” can relate to any actor offering a service within the wider logistics network. The primary logistics service provider in this research concerns the freight forwarder. Therefore, the term “logistics service provider” can include the freight forwarder; however, the term “freight forwarder” will be used exclusively to relate to the primary actor orchestrating the flow of international trade.

The following illustration shows the conceptual framework of this thesis:

Figure 1-1: Conceptual framework



Source: Author's own compilation.

1.1.1 The South African socio-economic landscape

South Africa is a relatively small², open economy, where imports (as shown by the average negative trade balance over the last two decades) play a crucial and increasing role (trade as a percentage of GDP) in the socio-economic development of the country. Exports, on the other

² South Africa is ranked 38th according to the latest World Bank data (WB, 2023), where SA's share of global GDP is around 0.40% and has been decreasing.

hand – despite a notable decline in the share in GDP of the tradeable sector (see *South Africa’s manufacturing share as a percentage of GDP* in Figure 9-5 in the annexure) – particularly industrial and manufacturing goods (Andreoni & Tregenna, 2020) – have shown some resilience (see *South Africa’s exports of miscellaneous manufactured goods* in Figure 9-6 in the annexure).

Improving the flow of goods into and out of the country should positively influence trade competitiveness (Marti *et al.*, 2014) and, as a consequence, add to the economic growth and development of the country (Saidi *et al.*, 2020). This is particularly important, given the fact that South Africa has been stuck in a low growth, poor efficiency trap for more than a decade.

Following intense debates in the early 1990s, the ANC assumed power in 1994 and committed to opening the South African economy, which had previously been isolated by sanctions and had become exclusive and inefficient. Trade, investment, and financial flow barriers were lifted, South Africa joined the WTO on 1 January 1995, and subsidies to the domestic industries were halted (see a comprehensive overview of subsidies in Southern Africa in Cassim *et al.*, 2003). Growth, employment, and other performance indicators turned positive after the expected initial economic shock³ (OECD, 2008:9). Growth peaked in 2006 at 5.7%, averaging a meaningful 4.3% between 2000 and 2007, and lifting GDP per capita from R60 383 to R75 920⁴ during this period (see *GDP per capita* in Figure 9-3).

Despite some positive macro-economic performance, the economic reality in the 2000s made doing business even more challenging for local manufacturers, who were already struggling to compete with cheap imports from nations like China and India (OECD 2008:115). Moreover, as global commodity prices continued to rise, artificial currency appreciation ensued, which led to a dependence on commodity exports. Consequently, South Africa suffered from Dutch disease⁵. Some scholars and analysts argued that the country was also affected by the resource curse⁶ in various forms, as mineral wealth not only failed to benefit much of South Africa’s population but harmed some sections of society (Elbra, 2013:549), especially the manufacturing sector. For example, Rodrik remarked in 2006 that “*the disappointing growth and employment trajectory of the South African economy since its democratic transition is best understood as a consequence*

³ An economic survey by the OECD in 2008 summarised South Africa’s economic performance since 1994 as “impressive”: “... public finances were stabilised, inflation was brought down, foreign capital was attracted in growing amounts, and economic growth, after lagging for a time, improved.” (OECD, 2008:9).

⁴ GDP per capita (constant LCU) according to the WB development indicators (WB, 2023).

⁵ The Dutch disease theory concerns a three-sector small open economy and suggests that a resource boom causes both direct and indirect de-industrialisation (Corden & Neary, 1982).

⁶ The resource curse, also known as the paradox of plenty or the poverty paradox, is a phenomenon where countries with an abundance of natural resources, such as oil, gas, and minerals, experience less economic growth, less democracy, or worse development outcomes than countries with fewer natural resources.

of the under-performance of its non-resource tradable sector, and of manufacturing in particular” (2006:795).

In 2008, the global economic recession halted the “high-growth” economic cycle. The recession also corresponded with political and policy changes in government, intended to correct some of the negative consequences of that cycle, including de-industrialisation, poverty, unemployment, and lack of socio-economic growth and development. Accordingly, South Africa set out to create a developmental state similar to Japan, South Korea, and Taiwan (De Baissac, 2009:4). The ANC’s policies, which were based on state-led industrialisation, included socio-development (especially for the poorest), education, health, and fighting crime and corruption, among other matters, as outlined by the ANC’s manifesto (ANC, 2009).

Developmental policies of localisation (which are still ongoing – see the DTIC’s 2021 policy statement on “*Localisation for Jobs and Industrial Growth*”) and protectionism were seen as the solutions. These policies have broadly not been successful to date. They have yet to manifest themselves into growth drivers, as well as invert the long-term, structural decline of the country’s primary and secondary sectors. For example, mining as a share of GDP has decreased from 10.6% in 1990 to 8.4% in 2020 (Jones, 2003; Minerals Council, 2020:12). By the same token, the share of agriculture⁷ has decreased from 3.8% in 1990 to 2.5% in 2020 (WB, 2023c). These policies also failed to change the structural composition of the country’s share of exports (which was then, as it is now, dominated by raw materials and intermediate goods – see *product categories as a percentage of exports* in Figure 9-7 *the annexure*). Indeed, South Africa’s share of capital (13% in 2011, 13% in 2020) – and consumer goods (18% in 2011, 19% in 2020) trade as a percentage of exports – as measured by the WB – has hardly increased in ten years. The country is still predominantly exporting raw materials and intermediate goods.

Taking the ANC Manifesto’s own benchmark provides incontrovertible proof of the extent of the country’s counter-performance post the Global Financial Crisis (GFC). Growth averaged a meagre 1.6% between 2011 and 2019, resulting in a stagnant GDP per capita that barely moved from R78 174 to R78 918 during this period. Unemployment went up from 22.8% to 28.5% between 2011 and 2019 (see *South African unemployment* in Figure 9-9 *in the annexure*), and South Africa’s rank in health and primary education remained stagnant and moved from 117th in 2007 to 121st in 2017 (WEF⁸, 2018). At the same time, South Africa’s rank in tertiary education

⁷ Agriculture, forestry, and fishing, value added (% of GDP), as measured by the WB.

⁸ The World Economic Forum’s (WEF) Global Competitiveness Index (GCI) methodology changes significantly in 2018 with the introduction of GCI 4.0. Prior to that, the methodology had changed marginally between 2006 and 2018, hence, most of the pillars cited refer to South Africa’s ranking of 2017 (which was published in 2018 before the significant changes occurred). The report was

and training declined from 56th in 2007 to 85th in 2017. During this time, crime and corruption soared, as South Africa's *Corruption Perceptions Index* rank moved from 43rd in 2007 to 72nd in 2022 (Transparency International, 2023). Moreover, among the countries not at war, it has experienced the most prolonged rise in fragility (De Baissac, 2009:3), dropping from the 25th to the 50th percentile rank in the *Fragile States Index* between 2006 and 2023 (The Fund for Peace, 2023).

Besides the poor performing socio-economic indicators, the prevailing policies increased the dependence on imports and created a structural crisis typified by escalating debt (which is now as much as 70% of GDP in 2021, up from 24% in 2007, according to the International Monetary Fund (IMF) – see *South Africa's central government debt as a percentage of GDP* in Figure 9-10 in the annexure), currency devaluation, dependence on commodity exports, and uncompetitive crisis (as shown by the overall WEF rank which moved from 44th in 2008 to 57th in 2019 – the last version of the *WEF Global Competitiveness Report* before it was discontinued). The structural crisis is highlighted on several occasions in the NPC's National Development Plan 2030, most notably, “*several structural weaknesses must be overcome if Africa is to translate rapid growth and higher demand for commodities into rising employment and living standards*” (NPC, 2012:22).

1.1.2 Trade and logistics in South Africa

The country's increasing dependence on trade in the context of the enduring structural crisis signifies that it is critical to meaningfully and durably improve the performance of the logistics systems, *ceteris paribus*. In fact, per the introductory statement in Section 1.1, the global consensus and demonstrated academic literature thus far presented, the performance of the logistics system should have a significant impact on improving South Africa's trade and economic competitiveness (Arvis *et al.*, 2011; Hoffman *et al.*, 2020). South Africa's socio-economic growth and development crisis has been amply documented, along with the share of trade in capital and consumer goods (as a percentage of exports), which has not increased. Thus, the country has been experiencing a stagnation in the volume of international goods traded, the country's participation in GVCs (especially in higher-value-added goods), as well as regional and international integration. Furthermore, as the WB recorded, other structural challenges have also increased in the transport and logistics industry, which have deteriorated due to weak management, theft, and sabotage of the state-owned enterprise Transnet, constraining South Africa's export capacity (WB, 2023a).

discontinued after the 2018-2019 edition; therefore, the latest available rankings refer to 2019 (Olczyk *et al.*, 2022:119).

In the last 20 years, South Africa's exports have grown by an average of 1.6%. During the same time, imports have grown by 4%, according to the latest available WB data (WB, 2023c). Furthermore, during the same period, container traffic volume has shown no growth. In fact, there has been a negative change of -0.2% compound annual growth rate (CAGR) between 2009 and 2022 (see Figure 9-11 *in the annexure*). Moreover, the WB's liner shipping connectivity index (LSCI) for South Africa has shown no growth since 2013, compared to peer countries such as Brazil, China, and India which have increased their connectivity by 2.5% on average during the same period (WB, 2023c – see Figure 4-3). Lastly, South Africa's global connectedness ranking has moved from a high of 42nd in 2006 to a current position of 54th in 2022, as measured by the DHL Global Connectedness Index (Altman & Bastian, 2023:60).

As a result of both South Africa's economic decline and stagnation in measures of international trade and cooperation in GVCs, the relationship between socio-economic growth and development and logistics performance (as explained in Section 1.1) would anticipate that the performance of South Africa's logistics system would also be experiencing either stagnation or decline. Indeed, in some instances available data and limited literature on the performance of South Africa's logistics system confirm stagnation and decline. For instance, South Africa saw its ranking in the WB's Logistics Performance Index (LPI) decline from 24th in 2007 to 33rd in 2018. However, there has been a welcome and unexpected improvement to 25th out of 139 countries in 2023 (Arvis *et al.*, 2023).

In 2014, South Africa's logistics costs amounted to R429 billion, equivalent to 11.2% of its GDP or 51.5% of transportable GDP (Havenga *et al.*, 2016:5). While this cost is lower than that of emerging markets like Russia, China, and Brazil, which range from 15% to 20% of GDP, Havenga *et al.* (2016) note that it is considerably higher than in developed countries such as Denmark, Sweden, and the United States, where logistics costs represent only 6.1% to 7.9% of GDP (2016:6). Furthermore, estimates presented by Havenga *et al.* (2016:5) indicated projected logistics costs to increase. Given South Africa's reliance on international trade, managing and reducing logistics costs is of significant importance. Moreover, the analysis of logistics cost management issues provides an important empirical foundation for the improvement of logistic processes in supply chains and synthesises scientific literature in the field of logistics cost modelling (Muha, 2019:102), which is especially critical given South Africa's projected increase in logistics cost.

To further illustrate instances of stagnation and decline, a quick correlation has been constructed between key international indicators of socio-economic growth and development and logistics; i.e., on the economic side the WEF's Global Competitiveness Index, on the social side the Human Development Index (HDI), and on the logistics side, the LPI. The reason why the social side (i.e.,

measuring human development) is included is well explained by Guner and Coskun (2012) since, very often and as their results indicated, the performance of logistics will be more connected to the social side than the economic side (see *the correlation results in Table 9-1 of the annexure*). The results show that, on average, the LPI performance correlated by 48% with the WEF index and by 58% with the HDI between 2014 and 2018 – largely as expected by the aforementioned work by Guner and Coskun (2012).

In summarising this section on trade and logistics in South Africa, it is evident that South Africa’s logistics system is also experiencing either stagnation or decline. However, the current body of literature on logistics performance in South Africa is limited to country-level assessments (such as the WB LPI, DHL Connectedness Index, and others outlined in detail in Chapter 4) and the investigation of specific elements of the country’s logistics system, which includes: logistics cost (Botes *et al.*, 2006; Havenga, 2010; Havenga *et al.*, 2016, Hoffman, 2019; Hoffman *et al.*, 2023), customs operations (Hoffman *et al.*, 2016; Hoffman *et al.*, 2018; Maree, 2020), transport flow modelling (Shakantu *et al.*, 2008; Havenga 2007), cross-border freight management (Hoffman & Bhero, 2013), and infrastructure (Van Dyk & Maspero, 2004). Similar limitations exist in the literature on logistics performance in other countries.

1.1.3 Defining logistics and logistics performance

At this junction, it is critical to clearly define logistics and distinguish between several concepts revolving around logistics and accompanying logistics performance processes (or elements⁹) (i.e., as captured by the literature outlined above). The *European Committee for Standardisation* (CEN) defines logistics as “*the planning, execution and control of the movement and placement of people and/or goods, and of the supporting activities related to such movement and placement, within a system organised to achieve specific objectives*” (ELA, 2005:54).

The term “system” is to be understood as a dynamic unit of interconnected elements and sub-systems linked with each other in specific relations. These elements and sub-systems form the system structure and – by virtue of their interaction with each other – result in the system’s behaviour. As such, a system’s overall performance depends both on its aggregate performance as well as the performance of critical elements and sub-systems. Linear and hub-and-spoke systems tend to be sensitive to single-point disruptions and/or failures in critical elements and sub-systems.

⁹ Within the context of this research, a logistics “element” is interchangeable with a logistics “process”, as the various logistics elements (such as procurement, transport, storage, and the like) are important process steps in the entire logistics systems’ process as a whole.

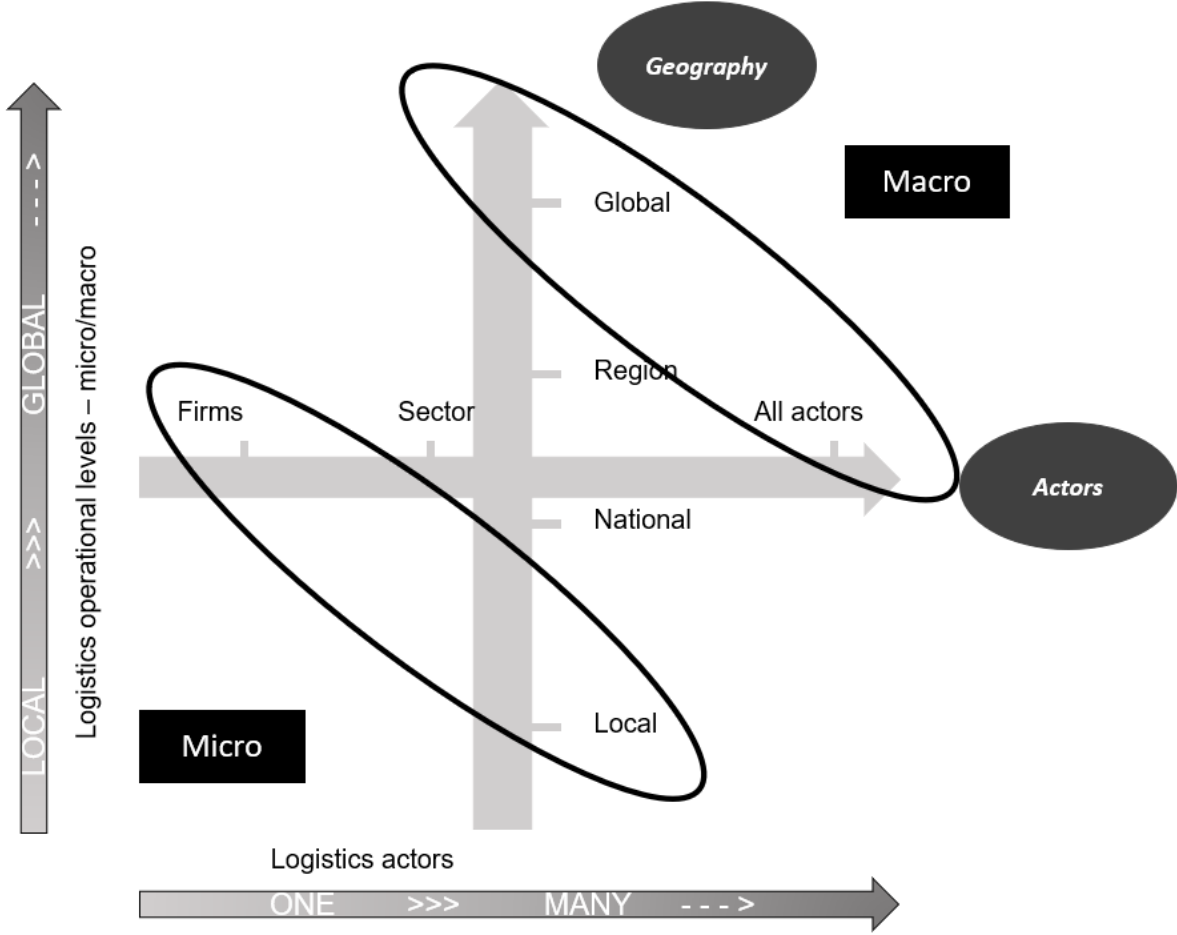
Logistics systems operate at different, intersecting and/or aggregative organisational and geographic levels, encompassing critical actors. At the most basic, a logistics system is as simple as an individual consumer ordering a product sourced locally. At the most complex, a logistics system encompasses all actors at all geographic levels. Firms represent a dominant actor in the system as the consumers of logistics.

Christopher (2011:2) defines a logistics system at the firm level as:

“the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organisation and its marketing channels in such a way that current and future profitability are maximised through the cost-effective fulfilment of orders”. Jacyna (2013:198), for their part, defines it as *“a system of technical and organisational means and people necessary for the flow of goods and accompanying information, which is specifically organised and integrated within a given business area”*.

At scale, a logistics system includes a greater number of actors, including those involved in the design, development, and operation of, for instance, a national logistics system. Moreover, a logistics system at that scale connotes elaborated planning and trade-off considerations (Banomyong *et al.*, 2015:24). These considerations are critical, as national logistics systems are the providers of infrastructures and spatial connectivity, whereas business logistics systems are the users. As a result, national logistics systems focus on developing and providing infrastructures, whereas business logistics systems focus on optimising supply chain decisions based on the infrastructures provided by national logistics systems.

Figure 1-2: Overview of logistics systems (actors and levels)



Source: Author’s own compilation.

The WB’s LPI index defines logistics as “a network of services that support the physical movement of goods, trade across borders, and commerce within borders. It comprises an array of activities beyond transportation, including warehousing, brokerage, express delivery, terminal operations, and related data and information management” (Arvis et al., 2018:1). The LPI is derived from an annual global survey of logistics experts, which can be biased towards a subjective view of different countries’ logistics systems – potentially leading to skewed ratings (see Beysenbaev & Dus, 2020 for a complete overview).

The LPI, like the DHL’s *Global Connectedness Index*, measures the performance of logistics systems at the national level because countries are the sovereign constituents of the global economic system, responsible for regulation, taxation, infrastructure development, and setting the rules of the international trade system.

The LPI analyses the performance of national logistics systems through six indicators (WB, 2020):

1. The efficiency of customs and border management clearance.
2. The quality of trade- and transport-related infrastructure.
3. The ease of arranging competitively priced international shipments.
4. The competence and quality of logistics services.
5. The ability to track and trace consignments.
6. The frequency with which shipments reach consignees within the scheduled or expected delivery time.

The aggregate-level definition includes logistics elements that can be divided into two main categories:

- Areas for policy regulation, indicating main inputs to the supply chain (customs, infrastructure, and services) and
- Supply chain performance outcomes (corresponding to LPI indicators of time, cost, and service reliability).

Jacyna further defines a logistics system as consisting of the following sub-systems: *supply sub-system, production servicing sub-system, distribution sub-system, transport sub-system, warehouse sub-system, and relations between them* (Jacyna, 2013:198).

For whichever actor, and at whichever scale, individual and aggregate, the efficiency of the system is the outcome of the performance of that system, measured in time, cost, and service reliability, as noted in the LPI analysis (Arvis *et al.*, 2018:8).

Therefore, the logistics system performance – whether at individual and/or local (actors) and collective and/or global levels (scales) – relates to the *overall, aggregate performance of the interconnected elements [processes] and sub-systems connected with each other in specific relations, as measured in terms of time, cost, and service reliability*. This derived definition will form the basis for investigating logistics system performance throughout this thesis.

The primary actor orchestrating the functioning of the logistics system is the freight forwarder. The freight forwarder offers amalgamated logistics solutions incorporating air freight, truck, sea and other modes of transportation (Baharmanda *et al.*, 2017). They also act as an intermediary between parties, often providing a host of services such as, among other things, freight forwarding, packaging, labelling, recording of inventory, distribution, brokerage, customs clearance, warehousing, and handling customer returns (Rushton *et al.*, 2010:59). The services of freight forwarders can be scaled and customised to the needs of customers, and in that capacity represents much of the volume and the processes in the end-to-end logistics chain.

As such, the freight forwarder at individual, local (actors), collective and global levels (scales) represents a proxy for measuring the performance of the system, as well as serving as a pivotal cog in improving logistics performance.

1.1.4 Logistics performance from the perspective of the freight forwarder

The freight forwarding industry turns over \$8 trillion¹⁰ in gross-revenue (approximately 28% of the trading industry's value, measured at \$28.5 trillion in 2021, according to UNCTAD data) and orchestrates approximately 90% of world freight (Singh, 2022). Furthermore, as this study will demonstrate, the freight forwarder is typically involved in 39 of the 44 process steps in the end-to-end logistics chain, providing the most comprehensive overview of the logistics process available and a proxy for logistics performance. Consequently, logistics performance could be measured by using operational data from the point of loading at origin to the final delivery at destination – and each data point in-between.

The opportunity to measure the performance of the logistics system has been created owing to the advancements of modern technology, especially in terms of the immense generation and flow of readily available data (Davenport & Patil, 2012:71) and the consequent management thereof. Due to the emergence of data in supply chain management, Waller and Fawcett (2013:77) have indicated that many opportunities exist to use data science, predictive analytics, and big data in supply chain management. Data analytics is essential since the accumulation and storage of data are useless unless it is shared horizontally and vertically in the supply chain and used to make better operational decisions. Furthermore, every new system, application, and operation generates enormous volumes of data, driving intelligence that supply chain management can use effectively (Hazen *et al.*, 2014:73).

Some further examples, notably on data analytics and supply chain modelling, include Wang *et al.* (2016) exploring several applications of big data analytics in logistics and supply chain management (LSCM), including market trends, customer behaviours, and maintenance cycles. These insights can lead to cost reduction and more informed decision-making (2016:98). The authors also propose further research to develop a model that links supply chain analytics and big data business analytics to organisational and supply chain performance, to be empirically validated through data collected from supply chain partners (2016:101). However, the researchers identified several limitations in the current literature, most notably that most studies have focused on predictive rather than descriptive analytics, often relying on theoretical rather

¹⁰ All dollar (\$) references denote US\$.

than operational-level data. They stress the importance of balancing both strategic and operational aspects in LSCM.

Other potential benefits of investigating the use of data analytics within LSCM also exist, including increased information availability, enhanced supply chain visibility, improved efficiency, greater collaboration, innovation opportunities, and optimised inventory management practices (Kache & Seuring, 2017). A Delphi study by Roßmann *et al.* (2018) further suggested that big data analytics can reduce uncertainty in supply chain operations by improving forecast accuracy, reducing inventory levels, and enhancing supplier management by utilising vast data for analysis (data analytics and supply chain modelling will be discussed further in greater detail in Section 3.5). Ultimately, data means nothing unless it can be effectively analysed to transfer numbers into knowledge at a rate fast enough to spot threats early enough to act on them (Prokop, 2017:21).

However, despite the significant opportunities to use data analytics, there appears to be no academic work that uses data analytics to explicitly and comprehensively document logistics performance on a detailed, operational level for South African imports. Comparable constraints are evident within the body of research pertaining to logistics performance in other countries. However, since detailed, low-level data is becoming available (in an industry which has many data generators but a low level of technological uptake – see, for example, Heinbach *et al.*, 2022), it is crucial to capitalise on the availability of data and accompanying tools to test whether logistics performance can be improved for South African imports from a freight forwarder's perspective. As shown by Pienaar (2009), data analytics have been shown to speed up the flow of information and lead to better services, diminished logistics costs, and rapid communication between suppliers and their clientele.

1.2 Limitation of available literature

As outlined in the previous section, most literature relating to logistics performance is presented at a macro level and based on survey data (such as the WB's LPI) – failing to capture the essence of the main economic actors in moving goods, namely the freight forwarders. Moreover, the literature presented at a micro level is limited towards investigating specific processes of the country's logistics system and not the performance of the system as a whole. Where logistics systems have been studied, the literature has focused on vertical industries, such as the automotive industry (see Dörnhöfer *et al.*, 2016, and Caplice & Sheffi, 1995), IT industry (Caplice & Sheffi, 1995) and military (Barad & Sapir, 2003).

Furthermore, while both the literature and empirical evidence provide *prima facie*, high-level evidence that demonstrates the declining performance of the logistics system in South Africa

specifically, the current literature falls short of providing a diagnosis of where the system fails and how its performance can be improved. The following table summarises the available literature on both micro and macro analysis, where micro denotes one or more logistics components investigated within the confines of South Africa’s trade borders, and macro denotes aggregate level logistics performance vis-à-vis against international peers).

Table 1-1: Summary of available literature on logistics performance from a South African perspective

Level	Author(s)/study	Theme/subject
Micro	Botes <i>et al.</i> (2006)	Logistics cost
	Chasomeris (2005)	Shipping cost
	Grater & Chasomeris (2022)	Port authority pricing
	Havenga (2010)	Logistics cost
	Havenga <i>et al.</i> (2016)	Logistics cost
	Havenga <i>et al.</i> (2022)	Logistics cost and freight flow modelling
	Hoffman (2019)	Total economic cost
	Hoffman <i>et al.</i> (2023)	Total economic cost
	Hoffman <i>et al.</i> (2016)	Customs operations
	Hoffman <i>et al.</i> (2018)	Customs operations
	Maree (2020)	Customs risk management
	Shakantu <i>et al.</i> (2008)	Transport flow modelling
	Havenga (2007)	Transport flow modelling
	Hoffman & Bhero (2013)	Cross-border freight management
	Van Dyk & Maspero (2004)	Infrastructure
Macro	WB LPI	Six components of logistics, ranging from the efficiency of customs to delivery times
	WB Ease of Doing Business (EODB) – Trading Across Borders (TAB)	Time and cost of national logistics procedures – documentary compliance, border compliance and domestic transport
	WB Container Port Performance Index (CPPI)	Container port performance
	WEF GCI – Burden of customs procedures	Customs procedures
	DHL GCI	Depth and breadth of international trade, capital, information, and people flows
	AEMLI	Logistics market development

Source: Author’s own compilation based on key subject literature on logistics performance.

In essence, the available literature and evidence do not demonstrate empirical, quantitative, and bottom-up measurements of the performance of a logistic system in South Africa, measured in time, cost, and service reliability. The lack of empirical operational-level work on logistics performance is valid for the case of South Africa, as it is true globally.

In theory, the relationship between socio-economic growth and development on the one hand and logistics performance (and vice versa) on the other, could, *ceteris paribus* and on a prima facie

basis, be empirically tested¹¹. As indicated above, no systematic, empirical analysis of this relationship exists for all actors at global, regional, national, and local levels. Moreover, as the preceding paragraphs stated, existing research at both the international level and in South Africa fails to provide a systematic, detailed, accurate, chronologically consistent diagnosis of the performance of the logistics system, in a manner that provides insights into the connection between that performance and socio-economic growth and development.

This reality outlined above presents two significant gaps in the academic literature. The first is understanding the operational performance of logistics systems at the national level across all actors. The second is in the allocation of performance in those systems between domestic and external factors. Both are essential to documenting and improving performance at whichever level the diagnostics determine. Moreover, improving logistics performance at the operational level should positively impact logistics performance at the aggregate level, with *ceteris paribus*, positive implications on socio-economic growth and development.

1.3 Problem statement

The overarching problem addressed in this thesis is the lack of a comprehensive, systematic, and empirically grounded analysis of logistics performance based on time, cost, and service reliability for import flows, both globally and within the context of South Africa. This problem is identified at multiple levels: global, regional, national, and local, leading to a critical gap in academic literature.

Despite being increasingly integrated into the global economy, South Africa faces socio-economic challenges, including escalating debt, currency devaluation, and dependence on commodity exports, partly due to a loss of global competitiveness and insufficient attention to improving logistics performance to act as a vehicle driving trade which could ultimately develop into much-needed socio-economic growth and development.

Addressing this problem necessitates the development of a comprehensive research framework that systematically evaluates logistics performance and its connection to global competitiveness, as well as the positive spillover effects on socio-economic growth and development. This research framework entails empirical analyses at various scales, encompassing all actors involved in logistics systems and distinguishing between domestic and external factors affecting logistics performance. Leveraging modern technology, data science, predictive analytics, and big data in supply chain management will be pivotal in filling this research gap and providing insights to guide

¹¹ Although the relationship between socio-economic growth and development does not form the core of this study and will not be empirically tested in isolation, this relationship is vital to note, as it adds to the motivation of why investigating logistics performance is important for South Africa's socio-economic growth and development goals.

policies and strategies aimed at improving logistics performance, and subsequently fostering socio-economic growth and development, particularly in the context of South Africa.

Therefore, this thesis aims to bridge critical gaps in understanding the interplay between improved logistics performance and global competitiveness, offering valuable insights for policymakers, academics, and practitioners in the field of logistics and trade.

1.4 Research objective

The primary objective of this thesis is to contribute toward measuring the performance of the logistics system at a national level for all actors from the perspective of the freight forwarder, aimed at reducing the time and cost of trade internationally. In essence, how can the freight forwarder reduce the time it takes to move a container from the origin (shipped on board – SOB) to final delivery? Also, how can the freight forwarder reduce the total cost of moving goods from origin to final delivery?

The secondary objectives of this thesis are two-fold. Firstly, this thesis aims to comprehensively assess and synthesize existing scholarly works on the logistics performance of import flows. Secondly, it aims to evaluate the operational model of South African imports, employing data analytics to identify areas for potential improvement in logistics performance at an operational and detailed level and to quantify cost-saving potential. Since the freight forwarder is the main actor orchestrating the functioning of the logistics system and offers amalgamated logistics solutions, the secondary objective of this thesis is to develop an operational framework and bottom-up diagnostic tool to determine where and how the logistics performance can be improved from the perspective of the freight forwarder.

1.5 Research questions

To fill this knowledge gap outlined above and contribute to the body of literature on logistics performance, the following five questions will form the core of this investigative study into logistics performance in South Africa:

1. What is the role of ICT in logistics and supply chain management globally, and what opportunities have the advancement of ICT technologies created in improving logistics performance?
2. What is the process flow of the logistics system for South African imports from the perspective of a freight forwarder?
3. What role does data analytics play in the logistics system for South African imports?

4. What are the most important performance criteria within the logistics system for South African imports, and which of the factors within the identified performance criteria can freight forwarders control to improve logistics performance?
5. How can the identified performance criteria be used to act as trigger functions in designing an improved logistics system for South African imports?

To summarise these five main questions into a cohesive research question, this study will aim to answer the following:

How can data analytics be used to improve logistics performance for South African imports from the freight forwarder's perspective?

1.6 Research methodology

The research method includes a literature study across three chapters, data collected from a South African freight forwarder at the firm level, and several subsequent empirical studies spread across two chapters. The following three subsections explain the research methodology in more detail.

1.6.1 Literature review methodology

The methodology employed in this literature review focuses on comprehensively assessing and synthesizing existing scholarly works on the logistics performance of import flows. However, seeing that logistics performance is seated under the umbrella of international trade theories and global competitiveness, these top-contour research areas will first be investigated. After that, using a systemic top-down approach, as illustrated in Figure 1-1, the current international trade landscape, global value chains, global supply chains, and logistics will be investigated in detail.

The literature review is grounded in a systematic approach aimed at identifying, selecting, and critically evaluating relevant academic publications, research articles, global research reports (encompassing several important subjects on trade, competitiveness, and logistics performance), and studies published across various essential sources. The methodology comprises a rigorous search strategy, inclusion and exclusion criteria, data extraction techniques, and thematic analysis. By employing these robust research methodologies, this literature review seeks to provide a holistic understanding of the critical dimensions, determinants, and implications of logistics performance in the context of import-oriented supply chains and logistics networks.

1.6.2 Empirical study methodology

The following approach will be applied to extract meaningful information from the available dataset, consisting of the following sequential steps:

1. Identification of process steps and data sources.
2. Collection of data, pre-processing, cleaning, etc.
3. Defining the performance criteria (i.e., time delay or cost).
4. Creating a total economic cost (TEC) model to translate time variation into cost.
5. Identifying the input variable which will allow the measurement of performance based on the defined performance criteria.
6. Dividing the data into categories according to the values of the input variables and determining the performance criteria within each category.
7. Measuring performance against the defined criteria by processing the identified input variable.
8. Measuring performance against the defined criteria performance within each category.
9. ANOVA analysis to determine which of the categories and which process segments are statistically significantly different from the population, and therefore, which of the factors has a significant impact on time delays.
10. Comparing performance against defined benchmarks.
11. Identifying sporadic and systematic deviations from the benchmark performance.
12. Quantifying the operational and financial impact of performance deviations.
13. Determining which input variable influences the performance criteria the most.
14. Identifying causes for performance deviations.
15. Investigating possible solutions to performance deviations.
16. Calculating total costs spanning diverse buffer stock scenarios to identify optimal buffer stock periods that minimise total costs.

Finally, after determining the significant factors contributing to logistics performance as outlined above, a simulation model will be created to determine the performance, using the various input variables as alternatives. In this manner, the performance of the logistics process can be predicted and can showcase, for example, the typical elapsed time for the logistics part of an import process, which can, in turn, provide insight into the typical performance of a logistics import process. This can further aid in the critical management of supply chain questions. These important questions include (but are not limited to) said questions, such as determining when to start specific logistics processes (such as customs clearance), which criterion must be fulfilled as requirements to proceed to the subsequent logistics process steps, and the amount of buffer stock that needs to be carried by warehouses.

1.6.3 Data collection

The data represents transactional-level flows between July 2017 and August 2023 (six years) from the perspective of a South African freight forwarder¹² captured in terms of time, cost, and service reliability. Three intertwined, daily operational sources were used, including:

1. Technical service provider data showcasing the documentary process flows;
2. Container tracking data showcasing the physical process flows;
3. Financial data showcasing the monetary flows.

The combined database comprises approximately 5 374 shipments. The aim is to explore the time-sensitive data points in the logistics system of the end-to-end supply chain, of which there are currently 44 different hand-over points (or 'triggers') collected over six years. These hand-over points can be subdivided into a physical and documentary process flow. Various important role-players within the process facilitate these hand-over processes, notably import controllers, customs brokers, customs administrators, shippers, and handlers (see a comprehensive overview of the logistics role players illustrated in the logistics layer in Figure 4-11). The most crucial measurable hand-over points in a shipment transaction are identified as the following:

Table 1-2: Final logistics import process flow

No	Process step	No	Process step
1.	Purchase Order	23.	SARS Case Closed Date
2.	Order Confirmation	24.	Final Bill of Entry
3.	Shipping Booking	25.	Other Government Stop Start Time
4.	Packaging & Containerisation	26.	Other Government Stop Finish Time
5.	Origin Inbound Transportation to Port	27.	Port Health Examination Date (if required)
6.	Invoice Date (first date)	28.	Revised Estimated Time of Arrival
7.	Transport Documentation Date	29.	Cargo Dues Order
8.	Estimated Time of Vessel Departure (Origin)	30.	Actual Time of Arrival
9.	Shipped on Board	31.	Discharged Date
10.	Documents Received Date	32.	Left Port Date
11.	Date Created	33.	En Route to Depot
12.	Estimated Time of Arrival (SS)	34.	Arrived at Depot Date
13.	Date Framed	35.	Left Depot Date
14.	Assessment Date (System risk assessment)	36.	Delivery Date Expected
15.	Ready for Quality Assurance	37.	Planned Delivery Date
16.	Quality Assurance Date (Bond/Brokerage)	38.	Arrived at Warehouse Date

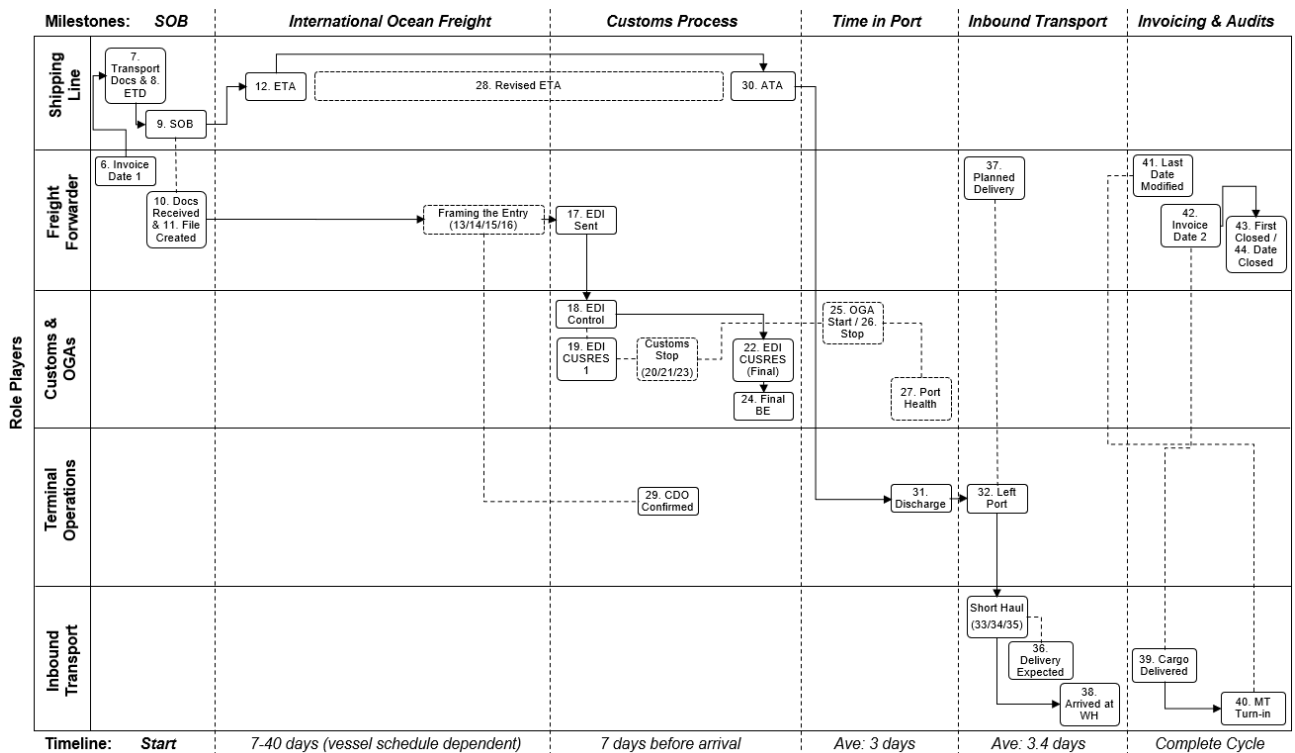
¹² Permission to use, analyse, and comment on the company data was granted by the freight forwarder.

17.	Electronic Data Interchange Sent Date	39.	Cargo Delivered Date
18.	EDI Control Date (Customs' first response, i.e., received)	40.	Empty Turn-In Date
19.	EDI Customs Response Date	41.	Last Modified Date
20.	Stopped for Inspection	42.	Invoice Date (second date)
21.	Embargo Released	43.	First Date Closed
22.	EDI Customs Final Response	44.	Date Closed

Source: Author's own compilation.

The following illustration further shows the key process milestones and average timeline, with solid lines denoting steps happening in sequence (in series), whereas dotted lines denoting steps not necessarily happening in sequence (in parallel). The illustration shows the typical process flows in a diagram and is explained in detail in Section 5.3.4.

Figure 1-3: Typical process flow per activity by the respective role players (benchmarked performance in days)



Source: Author's own compilation.

1.7 Contribution

This research study substantially advances existing knowledge in the intricate domain of logistics performance and serves as a valuable resource for diverse stakeholders engaged in LSCM, ranging from national policymakers to multilateral agencies, economic actors, and logistics service providers. The innovative investigation introduces a comprehensive approach grounded

in a bottom-up, process-oriented framework for evaluating logistics performance. Its notable contribution lies in the detailed exploration of logistics performance metrics encompassing time, cost, and service reliability, specifically from the standpoint of a freight forwarder.

1.8 Study outline

The proposed outline of this study will follow that of a thesis. The content will be presented in seven chapters and divided as follows: Chapter 1 will introduce the subject matter and the research topic that will be investigated, including an overview of the limitations of available literature, problem statement, research objectives, and questions and research methodology.

Chapter 2 will then present an investigation into the current environment of international trade, starting with an overview of trade theories and the respective evolution behind the reasons why countries engage in trade. After that, an overview of globalisation, global supply chains, as well as the impact of the recent pandemic on the current landscape of global trade will be provided. Along with recent developments in global trade literature, Chapter 2 will also discuss the role of technology and the Fourth Industrial Revolution (4IR) in facilitating trade.

Chapter 3 will then provide an overview of recent global supply chain and logistics management literature. Since very few empirical studies have been conducted on the subject area within the South African context, the focus will first be on the broad literature globally. Thereafter, the literature on logistics systems in the greater supply chains within the South African perspective will be investigated.

Among other aspects, Chapter 4 will provide a comprehensive overview of the logistics sector in South Africa, including the transportation infrastructure, transport modalities, and role players (and main activities performed) in the extended network. Furthermore, Chapter 4 will provide a detailed description of the typical processes involved within the logistics system for South African imports, and the position and performance of the logistics system in South Africa's supply chains. Since freight forwarders are the major players within the logistics system, often being the ones controlling and enabling the respective ICT in these processes, their role in the efficiency of these processes is critical and needs to be investigated in-depth.

Chapter 5 will then describe the data, including pre-processing, cleaning, and challenges found with the data. The chapter will provide various standard descriptive statistics, including measures such as average, standard deviation, range, and variance. Visualisation tools will illustrate data patterns and determine the areas where logistics performance can be improved the most.

Chapter 6 will empirically analyse, design, and propose policies and strategies that can be implemented as suggestions to improve the performance of the logistics system. Performance criteria (such as time delay and cost) will be investigated by identifying various input factors (such as country of origin, HS code, product valuation, etc.) within these processes. After identifying the most important performance indicators, the best-fit model will be extracted and used to simulate expected logistics performance as a function of input variables. A total economic cost model will also be conducted to relate the logistics performance of alternative strategies. The significance of the findings in the context of the research questions and objectives will finally be discussed.

Chapter 7 will summarise the study, provide some practical suggestions, and conclude how the implementation of data analytics can serve as a catalyst towards improved logistics performance for South African imports from the perspective of a freight forwarder.

CHAPTER 2: LITERATURE REVIEW ON THE INTERNATIONAL TRADING ENVIRONMENT

2.1 Introduction

This chapter provides a comprehensive literature review divulging the intricacies of the current sphere of the international trading environment. The chapter aims to showcase the changing nature of global trade from a historical perspective, and attempts to set the scene in satisfying the first secondary objective in assessing and synthesizing existing scholarly works on LSCM in general, and on logistics performance in particular, using a specific literature review methodology. The chapter outline includes a discussion of the applicable trade theories and the foremost international role players. The chapter will further set the scene concerning the role technology now plays in global trade, which is Chapter 3's core theme. Realising the ever-increasing importance of technology within the modern international trading environment is essential to understanding trade's modern ethos.

Although the trade theories discussed in this chapter will commence by going as far back as the eighteenth century, the narrative will rapidly be fast-tracked to the present day. Especially important in telling the story of the international trading environment is the emergence of global supply chains. The world of merchandise goods – particularly in the production ecosystem – is no longer limited to fixed final goods originating from one country. In modern times, merchandise trade has become so integrated that the buying and selling of goods along various stages of the processing timeline – from sourcing of raw materials to finalisation of finished goods – almost dominate global trade. This can be illustrated by the sourcing of components and origins required to produce a modern-day cell phone. Apple, the tech giant from California, sources components from 43 different countries on six different continents (Petrova, 2018). Goods at the far end of the processing scale, such as cell phones, laptops, drones, and the like, are no longer "made in China", for example, but rather "assembled in China".

Using China as an example is appropriate. Since opening its borders, its subsequent accession to the WTO, and the ultimate dominant role in global trade, China has been at the forefront of trade liberalisation (Ianchovichina & Martin, 2001; 2004). Although the country has subsequently not traded without objections, as there have been 265 WTO disputes involving China at the time of writing (WTO, 2023a), the country has been a pioneer in integrating value chains in the present globalised world.

Furthermore, the WTO has also been at the head of promoting a globalised approach through several initiatives, such as their "*Made in the World initiative*" (WTO, 2017b). Instead of assigning

the entire industrial supply to the final country of origin, the initiative ensures that a more transparent and accurate chain is shown across various countries of origin. Through continued transparency in trade – which is one of the WTO's principles – we are only now fully realising the extent of global value chain integration.

Through elaborate and highly integrated value chains, globalisation has emerged in the twenty-first century, becoming one of the key drivers economically and socially. Certainly, as far as trade is concerned, globalised work has created value chains with minimal delay between intertwined nodes in the chain. Even though the world has recently experienced a supply chain shock through the spread of the novel coronavirus pandemic, the world remains one big, connected marketplace. Despite these strong connections, the global value chains were strongly tested recently, as the shocks caused by the coronavirus and accompanying restrictions reverberated throughout the globe. According to the United Nations Conference on Trade and Development (UNCTAD), the value of global merchandise trade dropped by 5.6% in 2020 compared with 2019 (UNCTAD, 2021a). Global services trade was hit even harder by the pandemic, declining by 15.4% in 2020 – the largest drop since 1990. Therefore, the role and performance of logistics were once again highlighted as being paramount to the success of the global supply chain. However, before its importance can be discussed, the broader environment should first be addressed, which is the central theme of this chapter.

This chapter's structure is as follows: Section 2.2 sets the scene and briefly discusses the background and evolution of the most critical trade theories to date. Trade theories will assist in setting the context of international trade, which is the fundamental reason why supply chains and logistics networks developed in the first place. Section 2.3 provides an overview of the international trading environment, from its infancy to its modern-day business dominance. This section includes four sub-sections, covering globalisation, containerisation, Global Value Chains (GVCs), the rapid emergence of technology and the 4IR along with its subsequent central role in trade, and the impact of the COVID-19 pandemic and the rearrangement of the state of global trade. Then, finally, Section 2.4 concludes this chapter with a summary.

2.2 Trade theories

International trade theory took its roots in the 18th century, most notably with Scottish-born Adam Smith. Smith's ideas included the free market principle, theories of absolute advantage and the "invisible hand" (Smith, 1776). Because of his immense contribution to advancing the field of international trade and development, he was subsequently dubbed the "father of modern-day international economics". Since Smith laid the foundation concerning trade, various international trade theories have been formed to explain why countries trade. Initially, to foil the thinking behind

the sixteenth century's mercantilist traders, the following section discusses the background and evolution of the most critical trade theories to date. Since international trade theory is a standalone research subject, a comprehensive discussion and explanation thereof fall outside this study's scope. Therefore, the following section aims to provide a succinct summary of international trade theories to highlight that trade mechanisms have changed over time, especially over the past few decades.

2.2.1 Classical trade theories

Throughout Europe in the 17th and 18th centuries, the mercantilist school of thought dominated economic theory. The mercantilist theory implied several critical approaches to gaining prosperity. These approaches included the state's trade regulation for wealth promotion, employment maximisation, achieving a favourable trade balance, and protecting domestic industries (Van Marrewijk *et al.*, 2007:49). Because of mercantilism, the government intervened by hoarding international reserves with the ultimate goal of increasing export growth (Aizenman & Lee, 2007:6). In this way, countries amassed wealth by accumulating gold and silver and further protecting these commodities by restricting imports.

The belief behind mercantilism was that one country could only prosper at the expense of another country. By challenging the mercantilism theory, Adam Smith introduced his idea of absolute advantage in 1776, explaining how countries could benefit from trade through specialisation (Smith, 1776:17-19). When producing a similar product in a more cost-effective way than another country, a country has an absolute advantage regarding the product. Consequently, a country should export the products for which they enjoy an absolute advantage and import the products for which they do not enjoy an absolute advantage. Thus, nations are encouraged to focus their production on products that they can produce more efficiently and cheaply compared to other countries. Therefore, under circumstances where an absolute productivity advantage is enjoyed by two countries engaging in trade, both countries will benefit (Van Marrewijk *et al.*, 2007:50). Furthermore, consumers were encouraged to purchase goods in the markets offering the lowest prices. In contrast to mercantilism, Smith's theory of absolute advantage opposed government intervention in trade.

At the turn of the 19th century, David Ricardo challenged Adam Smith's idea of absolute advantage by introducing his comparative advantage theory. Ricardo explained that countries engaging in trade could benefit even in the absence of absolute advantage. The benefit derived from the comparative difference in opportunity costs that the countries faced. Through his historical example of England and Portugal trading wine and cloth, David Ricardo explained how (through specialisation) both countries benefitted by trading with one another, even though Portugal

enjoyed an absolute advantage in both goods (Van Marrewijk *et al.*, 2007:55). Therefore, all goods' production needs to be evaluated when trading with another country, even when producing the same goods.

2.2.2 Neo-classical trade theories

During the 1930s, Swedish economists Eli Hecksher and Bertil Ohlin brought about the foundations of the period, which is now known as the neo-classical economic school of thought. By extending Ricardo's comparative advantage theory, the Hecksher-Ohlin theory was conceived, with the authors claiming that most international trade patterns are determined by the differences in resources or the abundant production factors in certain countries (Van Marrewijk *et al.*, 2007). The Hecksher-Ohlin theory explained that countries are either capital-intensive or labour-intensive, and concluded that countries would specialise in producing those goods that they are better endowed with (Krugman & Obstfeld, 2009:54). The theory was based on the idea of two countries, two products and two factors of production, namely capital and labour, and was later dubbed the "neo-classical structure".

Testing the Hecksher-Ohlin theory on the United States (US) in 1953, Russian-born American economist Wassily Leontief found the approach contradictory. In the first and most famous empirical study undertaken in neo-classical economics, Leontief found that the US has an abundance of capital-intensive goods, yet the US's exports are predominantly labour-intensive. Leontief explained the contradiction by demonstrating that US labourers enjoy increased productivity levels compared to their foreign counterparts (Leontief, 1953:349). It was during this time in economic history when more robust empirical work became possible. The basic structure of neo-classical trade theories was not comprehensive enough to explain the changing global trade patterns.

Further critiques of the neo-classical trade theories included the endogenous growth theory, which showed that growth comes from adding more capital and labour inputs, ideas and new technology. The growth model was developed by Robert Solow, for which he won the Nobel Prize in 1987. Instead, neo-classical growth theories assume that a savings rate exogenously determines a country's long-run growth rate. A central prediction of the neo-classical model is that countries' or regions' growth rates will converge over time (Barro & Sala-i-Martin, 1992:239). However, several studies have revealed that the rate of regional convergence is much slower than the rate proposed by traditional neo-classical models (Martin & Sunley, 1998).

2.2.3 New trade theories

As globalisation gathered force and the international trading environment became more complex (globalisation is discussed further in Section 2.3), traditional trade theories became ineffective in explaining why countries presently engage in trade. Classical theories principally explained specialisation, with neo-classical theories limiting the theoretical structure to only two goods, two countries, and two production factors. In the 1980s, it became apparent that the tide was turning, since countries began importing goods similar to those produced in their domestic markets. Krugman and Obstfeld (2009) called this intra-industry trade, mentioning that most trade occurs between countries with similar resources and similar product offerings. Furthermore, new trade theories were based on the notion that international trade can still happen even in the absence of comparative advantage.

A fair amount of the new trade theory's foundation can be attributed to American economist Paul Krugman. His pivotal contribution to trade appeared in 1991 when he offered a different view on the reasons for trade and inequalities. Krugman added transportation costs and spatial factors of production, and his theoretical contribution could be summarised in the concept of "geographical economics" (Van Marrewijk *et al.*, 2007:54). Along with further iterations to the new theory of economic geography by Krugman, the concept combines international economics, industrial organisation, economic geography, spatial economics, urban economics, and endogenous growth (Fujita *et al.*, 1999). Furthermore, the theory explains geographical clustering and the influence of spatial economic activity on a given region's export activity (Krugman & Obstfeld, 2009). Krugman's new economic geography neatly fits into explaining the second phase of globalisation's unbundling (more in Section 2.3.1) and the eventual description of a "spiked" economic ecosphere.

In conclusion, international trade theories contribute to the study by outlining how global trade has evolved, especially in the containerised era, to where it is going in the future, as the next section will explain. By clarifying trade theories' theoretical context, it is simpler to explain the foundation of globalisation and global value chains and trade, which the following section will do.

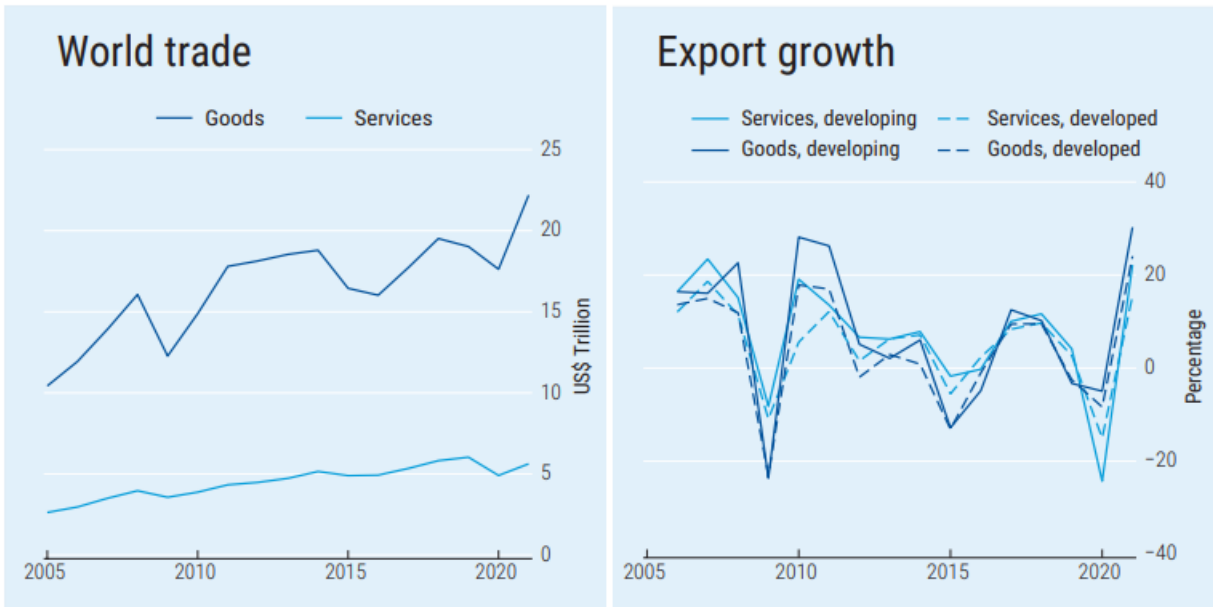
2.3 Overview of the current landscape of international trade

As alluded to in Section 1.1, international trade has grown swiftly over the past 50 years. As such, it has emerged as a focal point of global economic activity and has served as a significant driver of economic growth in both developed and developing countries. International trade can be broadly differentiated between trade in merchandise (goods) and trade in services (UNCTAD, 2020). In fact, the greater part of international trade involves trade in physical merchandise, while

trade in services accounts for approximately 21.4% of total world trade in both goods and services in 2021 (UNCTAD, 2023a).

An analysis of the global trade in merchandise over the previous decade reveals that merchandise trade has increased considerably, expanding from approximately \$10 trillion in 2005 to more than \$18.5 trillion in 2014, before reaching \$18.8 trillion in 2019, and finally, \$22 trillion in 2021 after the immediate recovery from the pandemic, as shown in Figure 2-1 (left). Trade in services, on the other hand, has also significantly improved over the same period, expanding from about \$2.5 trillion in 2005 to almost \$6 trillion in 2019, and dropping to \$5.6 trillion in 2021. It is also apparent in Figure 2-1 (left) that the value of global trade in both merchandise and services declined substantially in 2015 and 2016, but later recovered during 2017 and 2018 before dropping sharply in 2020 and subsequently rebounding (although not to pre-pandemic levels, as is the case with services).

Figure 2-1: Value and growth of global trade in goods and services, 2005-2021



Source: UNCTAD (2023b:6).

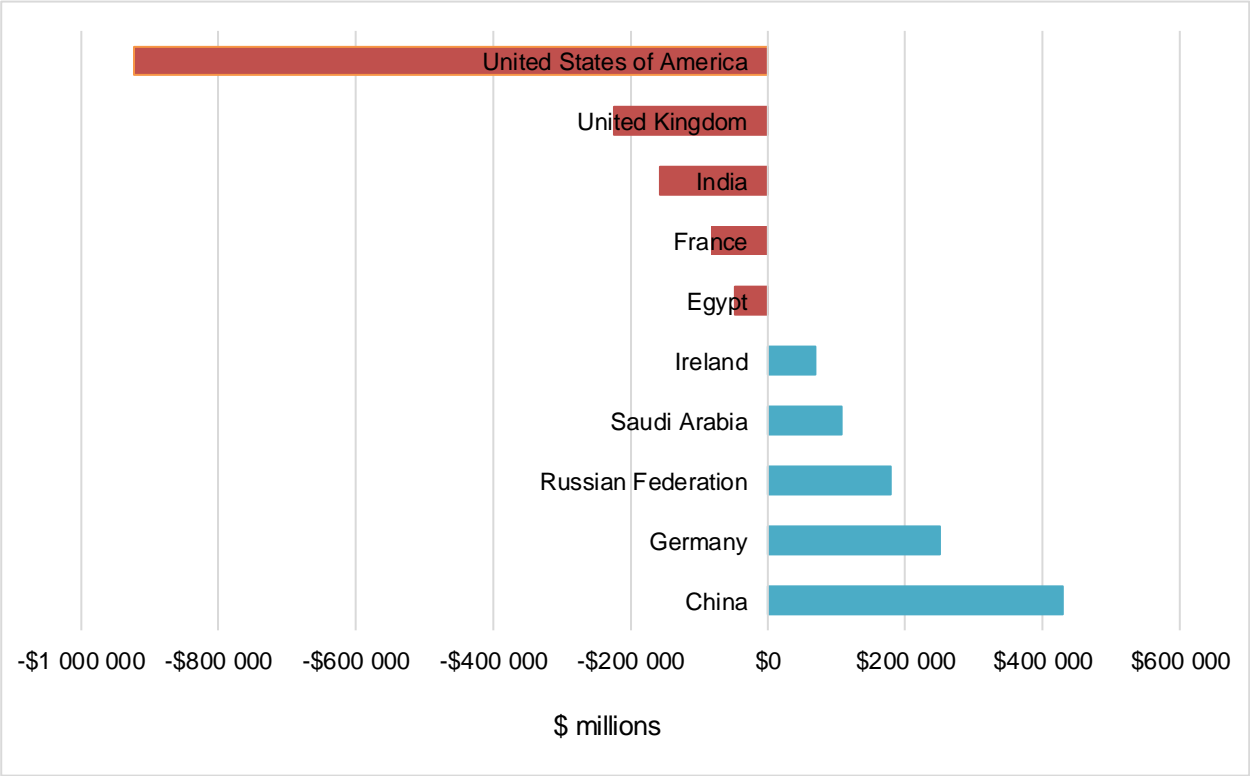
Figure 2-1 (right) shows that the deceleration in export growth rates of both goods and services exhibited similarities in developed and developing economies during the GFC of 2008/09 and the trade contraction in 2015/16. Nevertheless, notable distinctions emerged concerning the COVID-19 pandemic. While developing nations encountered a relatively milder reduction in goods export growth at an aggregate level, their services sector witnessed a substantially more pronounced decline (UNCTAD, 2023b:6).

The outbreak of the COVID-19 pandemic (further discussed in Section 2.3.5) worsened global trading conditions and resulted in a decline in both global merchandise and services trade

volumes in 2020 (WB, 2021). This was mainly due to lockdown regulations instituted by various countries in a bid to curb the spread of the virus, which negatively affected the movement of merchandise and people around the globe. However, global trade prospects have improved, with indications of a recovery in merchandise trade and industrial production clearly emerging by the end of 2020. Indeed, the WTO in 2021 expected the volume of global merchandise to increase by 8% in 2021 after having declined by 5.3% in 2020 (WTO, 2021). The latest figures from the WTO show that global trade grew by 9.4% in 2021 before slowing to 2.7% in 2022 (WTO, 2023b:3). Trade is projected to slow to 1.7% in 2023 and 3.2% in 2024. The International Monetary Fund projects 2.9% in 2023 and 3.2% in 2024 (IMF, 2023b)

Regardless of this projected robust but irregular recovery of global trade after the COVID-19 pandemic shock, global trade is still mainly unbalanced (Cuñat & Zymek, 2020). For instance, China, Germany, Russia, Saudi Arabia, and Ireland maintained the largest surplus positions in 2019 (see Figure 2-2), while the US, the United Kingdom (UK), India, France and Egypt primarily maintain enormous trade deficit positions, along with a number of other developing and developed countries.

Figure 2-2: Top 5 countries by trade surplus or deficit, 2019



Source: Author's calculations from the International Trade Centre (ITC) Trade Map, 2021a.

In addition, natural resources and agricultural products still account for a large proportion of the export baskets of several developing countries despite their apparent efforts to diversify their

exports (UNCTAD, 2020). Even though the dependency indices for various countries have declined over the past years, commodity dependence is very noticeable for agricultural exporters in Latin American countries, raw material-exporting countries in Africa, and energy exporters in the Middle East (UNCTAD, 2019).

Global trade has also been affected by rising protectionism and trade tensions in recent years, particularly between China and the US (Brown, 2020). Trade conflicts between China and the US were commonly centred on the inward-looking policies of the Trump administration (Baldwin & Evenett, 2020). While the current administration is likely to revise the trajectory and follow a broader, more multilateral trade policy, in general, a stronger position on China will likely persist. However, at the time of writing the Biden administration is expected to be more inclined to restore trade relationships with the US's traditional trading partners, as well as follow a more open policy with multilateral institutions such as the WTO (Piesse, 2021).

The international trading environment has significantly transformed from what we knew it to be. This transformation is mainly attributable to the positive and negative effects on global trade, brought about by factors such as globalisation, containerisation, GVCs, how technology and the 4IR are shaping the immediate future of global trade, and the impact of the COVID-19 pandemic. A further discussion of each of these elements follows in Sections 2.3.1 to 2.3.5.

2.3.1 Globalisation and the impact of technology on trade

The term “globalisation” is wide-ranging and encompasses many different aspects, such as culture, geography, institutions, politics, and economy (Brakman, 2006:26). For this study, the focus is on economic globalisation, as defined by Neary (2003:246):

“Economic globalisation is the increased interdependence of national economies, and the trend towards greater integration of goods and factor markets.”

The existing economic globalised world is so interconnected that the composition of several daily-used products makes (in some cases) a total of ten country stopovers before the product reaches the end consumer. An example that is often used is the Apple iPhone 6's production network. Although developed in the US, the components of an iPhone are sourced from numerous countries, including China, Japan, Korea, Taiwan, and the US, to name but a few. The product is finally assembled in China, after which it is shipped back to the US for final distribution (Barker, 2014).

Furthermore, the act of purchasing a new iPhone 6 from an online supplier takes mere seconds to complete. The product duly arrives a week or so later in a case where express delivery is chosen.

Two factors in the iPhone 6 example above showcase the state of modern-day globalisation, which is transmission and transportation. Firstly, the speed of transmission in capturing the order. And secondly, the ease of transportation for the phone to reach the consumer. Advances in these two factors have been the key drivers in globalisation (Baldwin, 2012:14). However, these two factors explain the role of globalisation in the case of the consumer placing an order for a new phone, and the role of globalisation in the entire value chain of manufacturing goods such as the Apple iPhone.

The smooth functioning of modern-day transportation has made it possible to extend the value chain across many different countries, as per the above example. Also, since the knowledge, expertise and technological know-how can now be transmitted seamlessly between subsidiaries, partners, and organisations alike, the technical impact of globalisation has influenced the dispersion of tasks within an organisation, whereby these tasks can directly be sent to the most suitable geographical location (Baldwin, 2012:13-15). The phenomenon is the result of a truly globalised world. To fully grasp these results, a brief historical perspective of globalisation is required.

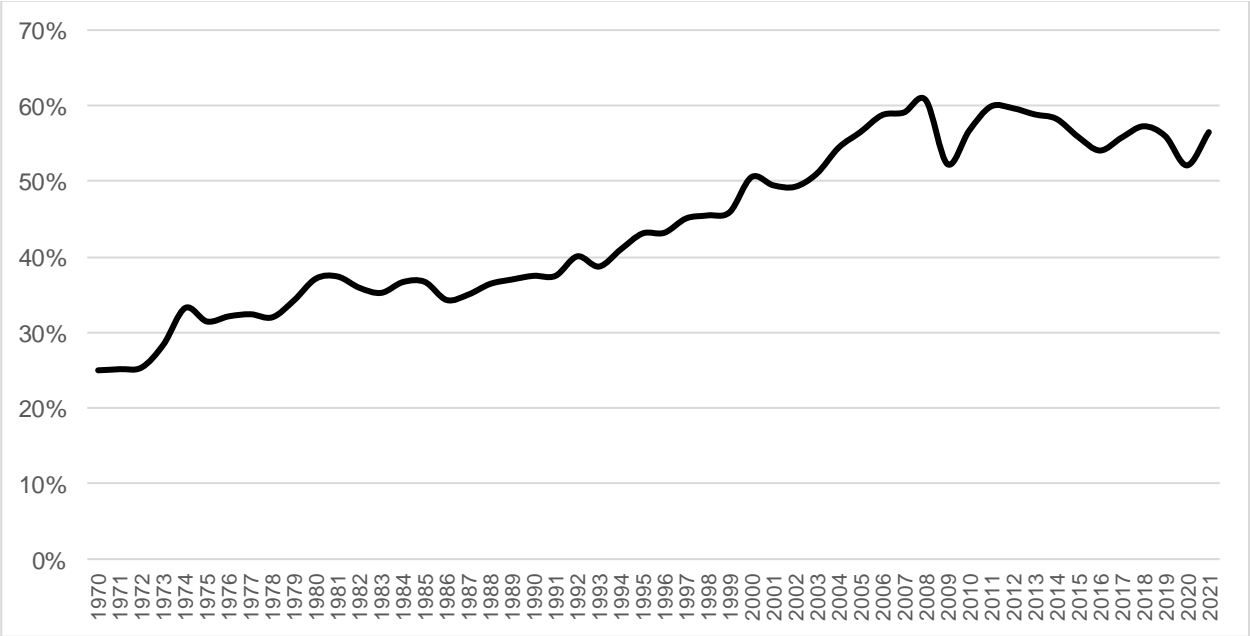
Globalisation has occurred over three centuries in two phases of “unbundling” (Baldwin, 2012:12-19). The first unbundling commenced with the steam revolution starting in the 1830s. Europe, North America, and Japan collectively industrialised, while notably, China and India stayed behind. The economic events that marked this period were rapid growth in the industrialised countries through innovation, economies of scale, and specialisation. Furthermore, a significant divergence in income was experienced between the Global North (Europe, North America, and Japan) and the Global South (especially China, India, and Korea), which has only started to reverse in recent times (Pritchett, 1997:5-6). The international movement of goods and labour that flourished from 1870 onwards was only halted by two world wars and a subsequent surge of protectionism after World War II (Jacks *et al.*, 2011). Subsequently, through the liberalisation of trade policy and the role of international trade organisations like the WTO (more in Section 2.3.3), trade continued to grow. Ultimately, the world's economic geography went from homogenous (subsistence farming) to “spiky” as production and other economic activity clustered in various locations (Florida, 2005).

The second phase of unbundling was characterised by the role of information and communication technology (ICT). For optimal production to occur in factories, a certain amount of coordination

needs to happen, as complex stages of various tasks typify most production processes. “The ICT revolution made it possible to coordinate complexity at a distance” (Baldwin, 2012:16). The previous cumbersome transfer of technology (particularly firm-specific technology) was subsequently alleviated. Along with the decreases in transportation costs and the vast wage gap between the Global North and the Global South (which originated during the first phase of unbundling), the geographical dispersion of the production process was made profitable. This second phase of unbundling is currently continuing, with some referring to modern times as the 4IR (Bloem *et al.*, 2014; Schwab, 2017).

The critical impact of the 4IR on trade cannot be overlooked. From the 1990s onwards, international trade has increased its stake in worldwide GDP and has played a pivotal role in countries' economic development. The following figure shows trade as a share of global GDP since 1970:

Figure 2-3: Trade¹³ as a share of global GDP, 1970-2021



Source: Author's calculations from the World Bank development indicators, 2023.

Seemingly, international trade has formed a focal point of global economic activity over the last 50 years, increasing from around 25% of gross domestic product (GDP) in 1970 to approximately 60% of GDP in the 2000s. Despite an evident plateau in the last few years, the more recent era of globalisation has also encouraged faster international trade growth. Furthermore, the cost, size,

¹³ Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product (WB, 2019b).

and complexity of the world's trading ecosystems are expected to grow continually (IBM, 2018). Noticeable from the figure is the significant impact of the two major crises in modern times, namely the global financial crisis and COVID-19. However, despite these shocks trade has rebounded strongly and remains a significant driver of economic growth and development (Raghutla, 2020).

Even so, regardless of the dominant role of trade in economic growth and development, trade experienced a decline in 2008, primarily due to the impact and subsequent aftermath of the global financial crisis that year (Chor & Manova, 2012). Following the crisis, trade's share in global GDP has not reached pre-2008 levels, with the increased role of recent protectionist policies employed (notably by the US) adding to the current situation in international trade (Irwin, 2017). Nonetheless, trade still represented more than half of the world's GDP in 2023, validating the description of "a truly globalised world". Along with globalisation, global value chains have hallmarked the recent sphere of international trade.

Globalisation remains as strong as ever. Some would claim that immediately post the age of the coronavirus, we see a reversal of integrated global economies and value chains. However, there remains little evidence at this juncture that this is indeed the case. As posited by several authors (Antràs, 2020; Jaklič *et al.*, 2020), some are saying that the pandemic will accelerate a reversal of globalisation and global value chains. Of course, we do have to revise our understanding of the world a little bit, because the current model does not account for the kind of external long-term shocks to the system that the coronavirus represents.

However, within the realms of external shocks, some truths remain clear. Considering the conflict between China and the United States, investment in China has been higher than before the pandemic (Higgins, 2021). The initial reason proposed is, of course, that China has recovered much faster than everybody else (UNCTAD, 2021b:9).

Adding to the current narrative, the underlying forces of globalisation are so powerful that they cannot simply be undone from one day to the next. If there is a huge difference in wages between the rich Western countries and those in Asia or Africa, the underlying forces of capitalism will always be on the side of globalisation. The only thing that could possibly undo that trend would be a global convergence of incomes, in which the advantage of cheap overseas labour disappears. However, it will be a long time before that happens since vast areas of the world remain that have not yet stopped their economic development.

2.3.2 Containerisation and the maturity of modern-day trade

The earliest shipping container was invented and patented by an American entrepreneur named Malcolm McLean in 1956 (Song, 2021). He developed the metal shipping container, which

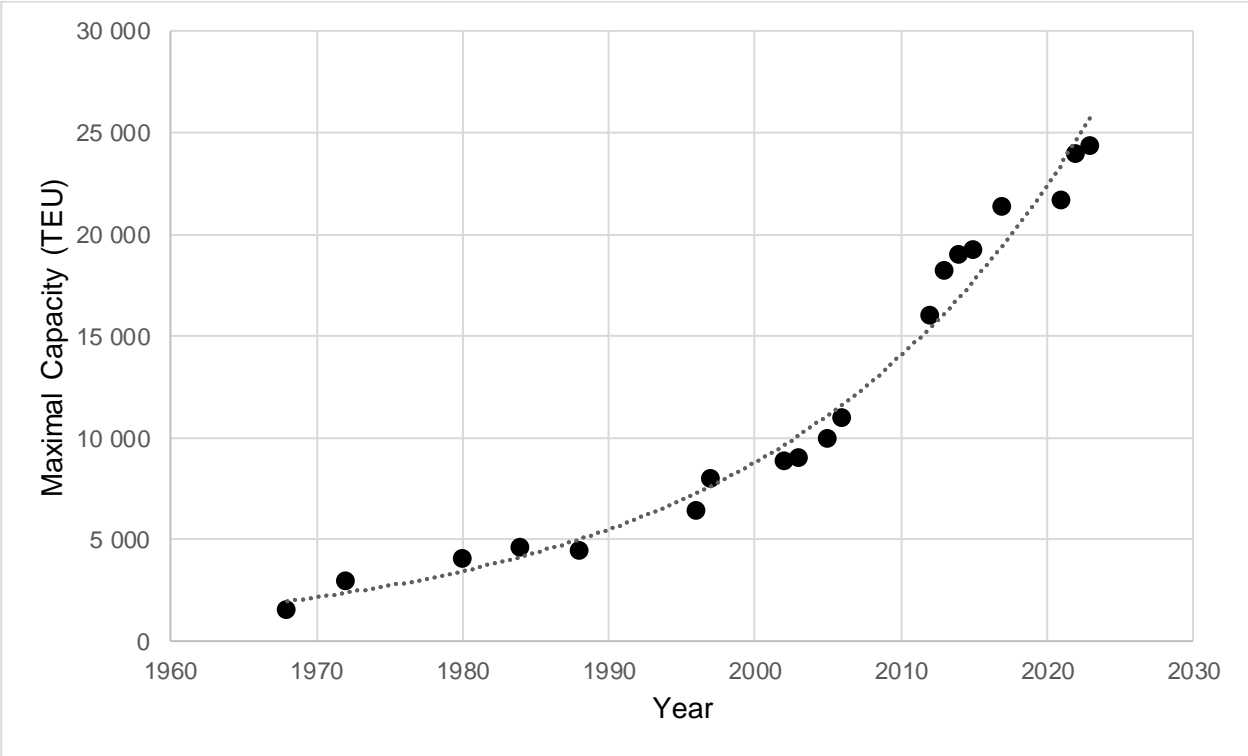
replaced the traditional break bulk method of handling dry goods and revolutionised the transport of goods and cargo worldwide. Prior to the adoption of containerisation in 1970, the design of containers was not standardised (Mrázek, 2021). This resulted in challenges involving a lack of collaboration amongst diverse earlier shipping companies. For instance, different dimensions of shipping containers meant that the container could only be transported by the shipping company that owns it (Yang *et al.*, 2021). However, the shipping container, as we know it today, is standardised according to the specifications outlined by the International Organisation for Standardisation (ISO).

Regarding standardisation, the following four crucial ISO recommendations standardised containerisation internationally (Rushton *et al.*, 2014): ISO 668 (January 1968), which outlined the dimensions, ratings, and terminology; R-790 (July 1968), which defined the container identification and markings; R-1161 (January 1970), which made recommendations about corner fittings; and R-1897 (October 1970), which defined the minimum interior dimensions of general-purpose freight containers. Hence, the modern-day intermodal shipping container is known to be durable, secure, and easy to load and offload from different modes of merchandise transportation.

Figure 2-4 shows the largest maximal capacity of a container carrier, expressed as a Twenty-foot Equivalent Unit (TEU), for the last six decades (i.e., from 1960 to 2020). Since the adoption of containerisation in 1970, the growth of world container traffic (the number of containers being carried) has been a continuous process, with an average annual compound growth of 9.5%. During the same period, container throughput (containers handled at ports, which includes the port of origin, destination, and transshipment) had an average annual compound growth of 10.5%. This underlines a divergence between container throughput and traffic as global supply chains become more complex (Rodrigue, 2020).

The main dimensions of ship sizes have also increased dramatically over the last two decades (Sardain *et al.*, 2019). A more than exponential increase is observed (see the dashed line in Figure 2-4). In fact, the largest capacity container carrier of 2013, the Maersk Triple E-class (18 270 TEU), carries more than double the quantity of the largest capacity container carrier of 2003, Orient Overseas Container Line (OOCL) Shenzhen, with a carrying capacity of 8 063 TEU (Paul, 2018). In 2021, the HMM Algeciras was the world's largest container ship, with a capacity of 23 964 TEU. The ship is also regarded as one of the most technologically advanced container ships globally (Edwards *et al.*, 2021). Currently, the MSC Irina holds that honour, with a capacity of 24 346 TEU (Ahmed, 2023). The following figure shows the increase in container ship capacity since the advent of containerisation.

Figure 2-4: Increase in container ship capacity (since 1960)



Source: Adapted and updated from Latair, 2014:4.

The surge in container throughput is linked to several factors, such as the growth of international trade in addition to the adoption of containerisation as a privileged vector for maritime shipping and inland transportation (Farhan & Ong, 2018). Until 2008, the growth of container throughput behaved according to the standard technological diffusion (or product life cycle) curve, which is S-shaped (De Monie *et al.*, 2011). However, the GFC had a significant impact on container flows, which experienced a drop of 49 million TEUs (9.3%) between 2008 and 2009. This was the first time that container volumes at the global level diminished (Rashed *et al.*, 2017). However, the growth of container throughput recovered afterwards, though at an inferior level, to reach 750 million TEUs in 2017 and about 866 million TEUs in 2022 (Statista, 2023).

With the S-shaped product life cycle curve in mind, the following developmental stages in containerisation can be suggested and insinuated (Broeze, 2002; Notteboom & Rodrigue, 2008; Guerrero & Rodrigue, 2014):

- First, the introduction stage (1958-1970). From the initial containerised commercial services in the late 1950s until the design of the first cellular containerhips in the 1960s, the shipping container was an unknown variable in global merchandise shipping

(Marcadon, 1999). Consequently, investments were sparse because of the high risk generally associated with unproven technology.

- Second, the adoption stage (1970-1990). During this period, the intermodal shipping container became acknowledged as a transport product, and investments in intermodal shipping facilities intensified (Rua, 2014). Such investments were centred around the construction and reconversion of numerous container port terminals as well as the introduction of cellular containerships (Herod, 1998). This originated from the fact that the structure of the conventional port system, port dimensions, geographical positions, and tributary areas are all legacies of the pre-container era and the outcome of various historical, domestic, and distant inspirations and circumstances (Hayut, 1981). The risk factor also became less of a concern, and investments were made in line with commercial opportunities.
- Third, the growth stage (1990-2008). Despite containerisation remaining a classic example of unsung heroes of globalisation, it began to tremendously affect international trade patterns and production strategies, particularly with the integration of China into the world economy following the country's accession to the multilateral trading organisation, the WTO, in December of 2001 (Lardy, 2004). The development of new production clusters because of economic globalisation inspired long-distance (Transatlantic and Transpacific) pendulum container services (Pitelis *et al.*, 2006). During the growth stage, a new class of Post Panamax containerships also turned out to be a dominant trajectory of maritime shipping. Additionally, containerisation started to go further inland with rail and barge services (Rodrigue & Notteboom, 2009).
- Fourth, the maturity stage (2008 to present). The maturity of container traffic will be associated with the maturity of the world economy (Cho & Yang, 2011). This can comprise numerous factors, such as restrictions to the exploitation of comparative advantages in manufacturing, along with related trade imbalances and volatile energy prices (Theofanis & Boile, 2009). Technical limits to economies of scale, both from the maritime and land sides of containerisation, are also likely to play a significant role in containerised traffic, but the maturity of containerisation is likely to be more an economic than a technical process (Cho & Yang, 2011). The GFC of 2008 to 2009 is strongly associated with a substantial decline in containerised traffic. Nevertheless, volumes improved subsequently, and it is still indeterminate as to what throughput levels of 'peak containerisation' would comprise (Rashed *et al.*, 2017).

As an innovation, containerisation was introduced into logistics mainly to enhance the turn-around time of trucks and ships in ports, as well as to diminish the rising costs of loading and off-loading shipments (Rodrigue & Notteboom, 2009). However, the effects of this innovative approach to cargo handling are extremely remarkable, ushering in significant modifications in the structure and operations of merchandise logistics, transforming some port functions, and changing the scope and lines of movement in port vicinities. In fact, containerisation encompasses a novel system of intermodal conveyance, which has had tremendous effects on the geography of production and distribution (Rodrigue & Notteboom, 2013). Consequently, production became globalised through better utilisation of comparative advantages, while logistic systems were able to interact more efficiently, supporting and influencing the coherence of the GVCs (Memedovic *et al.*, 2008).

2.3.3 Global value – and supply chains, logistics networks, and the shrinking of the international business landscape

The term “value chain” was first coined in the early 1980s to accentuate the need to integrate key business processes and ensure continuity (Rushton *et al.*, 2010:9). Through business continuity, along with a streamlined business approach, value chains can manage operational risks and provide cost-saving approaches to the business, as well as strengthen customer-supplier relations (Kildow, 2011:60).

Widely quoted, Kaplinsky and Morris (2001:4) provide a benchmark definition of a “value chain”:

“The value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use.”

To be sure, global value chains are the backbone of international trade and include the various sub-systems therein, which can be referred to as global supply chains.

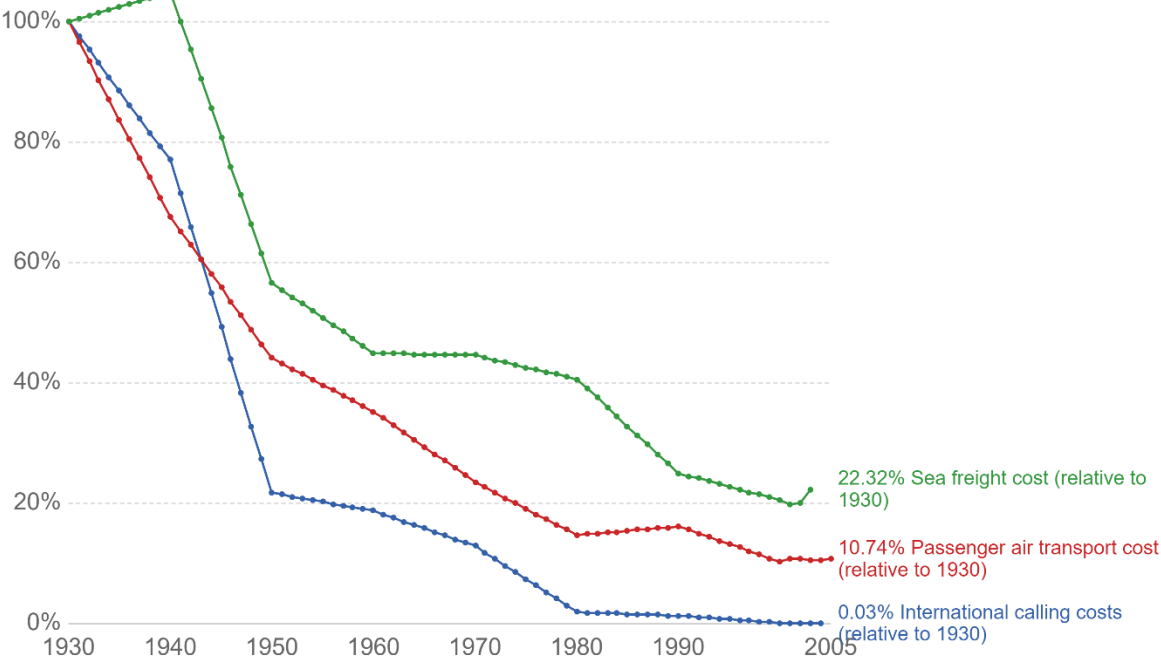
Supply chains have been instrumental in integrating key business processes and ensuring continuity. As the key vehicle driving international trade, the performance and efficiency of global supply chains have been among the factors distinguishing some countries from others in terms of trade growth (Mazzawi & Alawamleh, 2013:122).

Within this research, global supply chains can be defined as *“the distribution of goods and services throughout a trans-national companies' global network to maximise profit and minimise waste”* (Bhatnagar, 2012:146). Global supply chains include the supplier and the end-user in the

process or the upstream (supply-side) and downstream (demand-side) partners in the supply chain (Rushton *et al.*, 2010:27). However, supply chains are one dimension removed from the global value chain, in that supply chains do not require a product from conception. Global supply chains can be divided into six main areas of concentration: logistics management, competitor orientation, customer orientation, supply-chain coordination, supply management, and operations management (Hult, 2004:3-5). These six areas of concentration, therefore, form the holistic system of global supply chain management.

One of the significant drivers in modern supply chains globally have been the decreasing costs to facilitate goods and services flowing across international borders. The following figure illustrates this by using international sea freight rates, air passenger transport, and international port calls from New York to London as proxies for decreasing costs.

Figure 2-5: The decline of transport and communication costs¹⁴ relative to 1930



Source: Huwart and Verdier (2013).

From this figure, sea freight cost has decreased nearly fivefold, passenger air transport nearly tenfold, and international calling costs more than 3000-fold (Huwart & Verdier, 2013). Collectively, transport and communication cost has dramatically declined since 1930. Furthermore, as the cost of transport and communications dropped, trade increased even more. However, there is not

¹⁴ Sea freight corresponds to average international freight charges per tonne. Passenger air transport corresponds to average airline revenue per passenger mile until 2000 spliced to US import air passenger fares afterwards. International calls correspond to cost of a three-minute call from New York to London.

always a linear relationship between trade cost and trade growth. For instance, during the COVID-19 pandemic, international freight rates rose to record-breaking levels (UNCTAD, 2021d:59), which necessitates the need to optimise logistics networks to reduce costs. Indeed, the core of this study is to investigate how ICT and data analytics can help to reduce trade costs in the new global landscape, as this research focused on the penultimate phrase, the “delivery to the final consumer”. However, before one can explain delivering the final goods to final consumers in modern times, a brief historical perspective needs to be explained. With the liberalisation of trade policies, goods and labour became more mobile during this time. In trade, the focus also shifted from a country-level to a firm-level perspective (Bernard *et al.*, 2007).

Michael Porter (1985) introduced the world to the competitiveness theory, explaining that firms spend too many resources on the performing stages and support activities where they do not enjoy a competitive advantage. He proposed that firms should rather focus on the tasks within the value chain in which they enjoy a competitive advantage and outsource all the other tasks. Subsequently, he popularised the value chain concept (Baldwin, 2012:27). Porter explained the value chain as a single stage of operations, optimally taking out pre-fabrication, as well as post-fabrication stages and other support activities (Porter, 1985). The focal point of his argument was to apply the Ricardian principle (as mentioned in Section 2.2.1) of comparative advantage to firms’ value chains to achieve competitiveness.

The competitiveness theory came about in a time following the phenomenon of intra-industry trade. Intra-industry trade was realised in the formation of the European Common Market (Van Marrewijk *et al.*, 2007:202). With trade policies more liberalised, countries within the market imported and exported similar goods. Intra-industry trade can be explained by the fact that consumers demand different varieties of similar goods. It is at this juncture that it is also worth noting the impact of the Dixit-Stiglitz model of monopolistic competition, where firms should offer market solutions (or product diversity) at the appropriate profit margins while considering the consumer’s surplus (Dixit & Stiglitz, 1977:308).

Being competitive while still providing consumers with a variety of choices was key to Multinational Corporations (MNCs) continuing their existence in a time when the ICT era came about, shaping the future environment of global value chains. This necessity can be highlighted by the fact that a mere 60 US-based MNCs that were listed in the Fortune 500 in 1955 were listed in 2016 (Perry, 2016). Furthermore, in this fast-paced consumer world we live in, change is inevitable. As the world changed due to globalisation, firms and their relevant value chains changed as well. Therefore, Baldwin encouraged firms to move away from Porter's framework in modern times (2012:27).

Moving towards a modern framework, Baldwin (2012:27) unbundled the value chain into four levels of aggregation: products, stages, occupations, and tasks. Each of these four “operations” is geographically dispersed to the optimal location within the value chain. These four levels are coordinated through two ICT channels, namely communication and organisational technologies. Each level of aggregation also demands operations of various skills or technology levels. In the case of a low-skill or low-technology operation, geographical dispersion will result in the operation being sent to a low-wage location. Conversely, a high-skill or high-technology operation will be dispersed to a high-wage location. In essence, the value chain is unbundled in a functional way, resulting in operations that have more homogenous skills or technology demands.

GVCs have greatly contributed to the international fragmentation of merchandise trade, especially in the manufacturing sector (WTO, 2017c:43). Ultimately, the geographical unbundling of the value chain has created hub-and-spoke networks (as seen in the Apple iPhone example). The hub-and-spoke can also be applied to South Africa’s position in Southern Africa, as the country serves as the gateway to numerous Southern African value chains (Games, 2012).

As with all value chains, the external trading environment needs to be conducive to the optimal functioning thereof. Over the course of the last 80 years, international trade organisations (such as the WTO and UNCTAD) and the proliferation of international trade agreements have pushed for (and created) a trading environment which is freer and more open. Multilateral trade and the evolution of doing business across borders will continue to shape our global economy, as will the evolution of technology and 4IR, which is the focus of the following section.

2.3.4 Technology and the Fourth Industrial Revolution

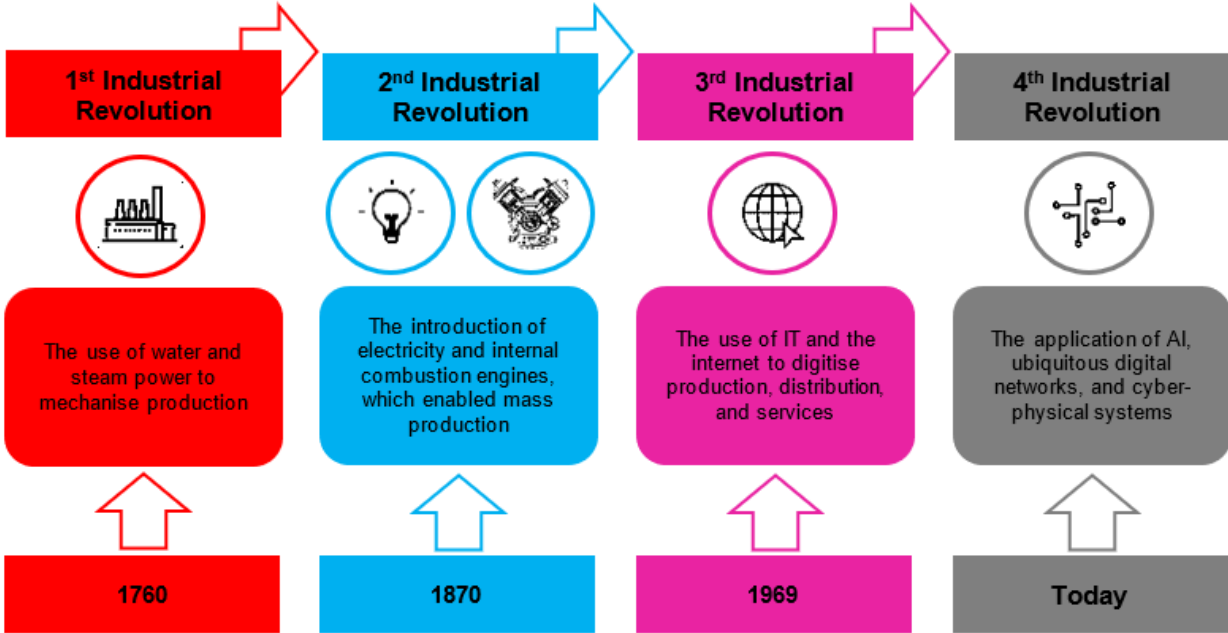
The Industrial Revolution was defined as a major technological, socio-economic, and cultural transformation in the late 18th and early 19th century because of the replacement of a physical labour-based economy to an economy governed by industry and machine manufacturing (De Vries, 1994). Prior to its spread to America, other parts of Europe, and the rest of the globe, by the 1830s and 1840s, the historical origins of the Industrial Revolution can be traced back to Great Britain (Mokyr, 2018). To distinguish the first phase of industrialisation from the other three subsequent phases of industrialisation, this period is often referred to as the first industrial revolution (see Figure 2-6).

The first industrial revolution followed the proto-industrialisation era and commenced during the late 18th century up to the early 19th century. This phase of industrialisation gave birth to industrial and technological innovations such as the utilisation of water and steam power to mechanise production (Pozdnyakova *et al.*, 2019). The second industrial revolution transpired in the late 19th

century up to the early 20th century. The main technological innovations in this phase of industrialisation were the discovery of electricity and the invention of internal combustion engines, which permitted mass production (Zhang & Yang, 2020). The third industrial revolution emerged during the second half of the 20th century and ushered in the application of information technology and the internet to digitise manufacturing, supply, and services (Dosi & Galambos, 2013).

The 4IR is building on the third industrial revolution (i.e., the digital revolution) and is typified by a synthesis of technological innovations that are blurring the lines between the physical, digital, and biological domains (Lee *et al.*, 2018). This current phase of industrialisation is an outcome of technological advancements such as the Internet of Things (IoT) and robotics. Completely automated production is the nature of the technological approach that will be established during this revolution (Schwab, 2016). As in the case of the previous three industrial revolutions, the 4IR is also expected to positively affect global production and trade in an incredibly significant manner.

Figure 2-6: Phases of Industrialisation



Source: Adapted from Quest (2020).

The technological innovations within the current wave of industrialisation will affect trade through the following (Washington International Trade Association [WITA], 2018): first, improvements in trade logistics and lower trade transaction costs. Logistical vicissitudes include robotics, which allows transporting hefty loads over long distances; second, a transformation of the real content of what firms trade (i.e., advancing from trade in merchandise to trade in services and data); and third, alteration of production processes and the geographical location of production, which in turn diminishes the threshold for enterprises – particularly Small to Medium Enterprises (SMEs) – to

enter the global supply chain and participate in the production as well as global trade. Resulting modifications in products include new production inputs for which fabrication was previously unfeasible (e.g., optical fibre and nanomaterials).

As a result of the 4IR, novel global supply chains are being generated in the services domain, unlocking new entry points for services exports originating from poorer countries (Schwab, 2016). For instance, digitally facilitated services are stabilising global production networks, facilitating the rejuvenation of traditional exports across agriculture, fisheries, handicrafts, and tourism, and continuing through to improved matching of buyers and sellers, as well as finance access provision (Drake-Brockman *et al.*, 2020). In fact, new global trade prospects are emerging for both developing and developed countries.

In the future, technological innovation will also lead to a supply-side miracle through long-term advancements in productivity and efficiency (Popkova *et al.*, 2019). As already mentioned, transportation and communication costs will diminish, logistics and global supply chains will become more effective, and trade costs will shrink, all of which will expose new markets and inspire economic growth and development (WITA, 2018; Schwab, 2016).

While all industrial revolutions possess common facets that endorse classifying them as revolutions, the 4IR is anticipated to emerge as an unparalleled phenomenon in the development of the real economic sector and, eventually, global trade. Although technology and the 4IR will have a significant and lasting effect on international trade, exogenous shocks – whether or not global trade cohorts can see them coming or not – will also impact the course of future trade. As such, the following section briefly discusses the latest major exogenous shock, namely the impact of the pandemic on international trade and the subsequent rearrangement of the state of global trade.

2.3.5 Impact of the pandemic and a rearrangement of the state of global trade

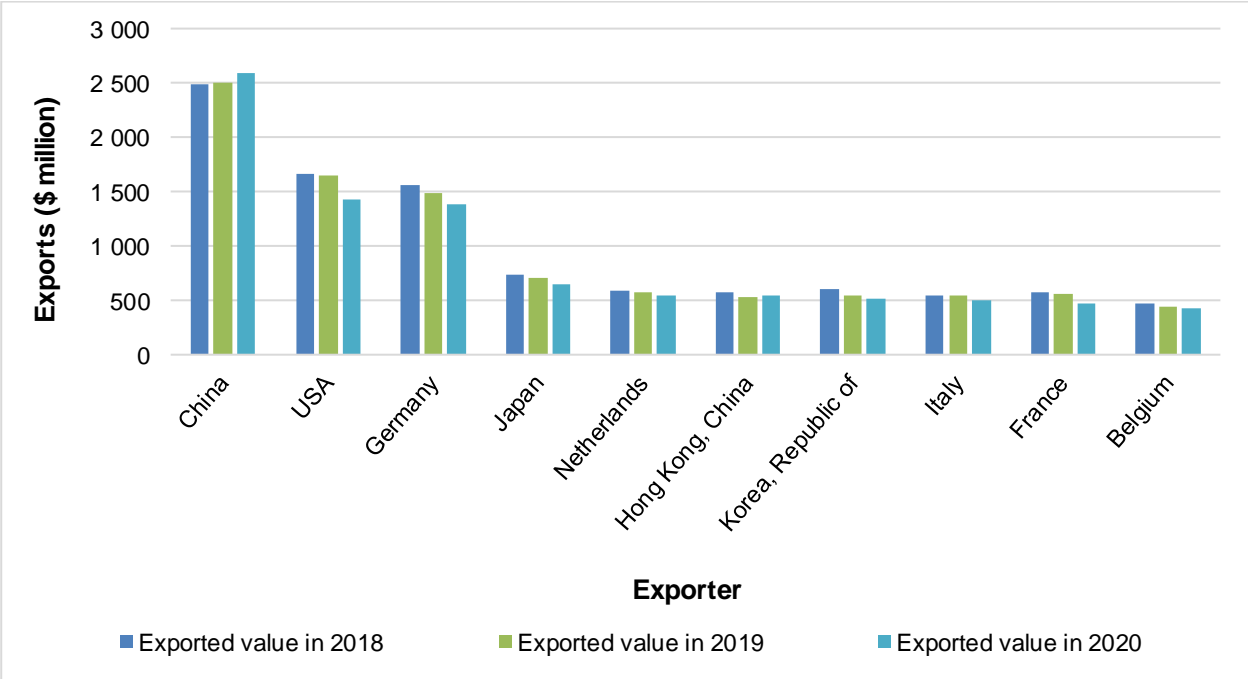
The COVID-19 pandemic will undoubtedly be remembered as the main driving force in the economic and trade discourse of 2020 and, indeed, spilling over into 2021 (Miroudot, 2020). As such, the pandemic has generated remarkable economic adjustments with severe penalties affecting diverse communities and people around the globe (Brunnermeier *et al.*, 2020). Spreading swiftly across territorial boundaries, along the fundamental arteries of the global economy, the dispersion of the COVID-19 virus has immensely benefited from the structural inter-linkages and weaknesses of globalisation. Consequently, this has propelled a global health crisis into a global economic shock that has significantly affected the welfare of the most vulnerable

populations (UNCTAD, 2020). Since the virus initially commenced to disseminate in late 2019, the prospective ramifications for trade and economic development became ostensible.

Despite the expectation that international trade is essential to save lives and livelihoods in an unprecedented global health crisis, the COVID-19 pandemic has negatively impacted global trade in both merchandise and services (Organisation for Economic Co-operation and Development [OECD], 2020). This mainly emanated from the disruptions in global supply chains due to restrictions in the movement of container ships, increases in the prices of air cargo freight, and lockdown restrictions that interrupted the mobility of both freight and people (Shih, 2020).

Figure 2-7 and Figure 2-8 show the exports and imports of the top 10 global exporters and importers from 2018 to 2020¹⁵.

Figure 2-7: Top ten global exports, 2018-2020



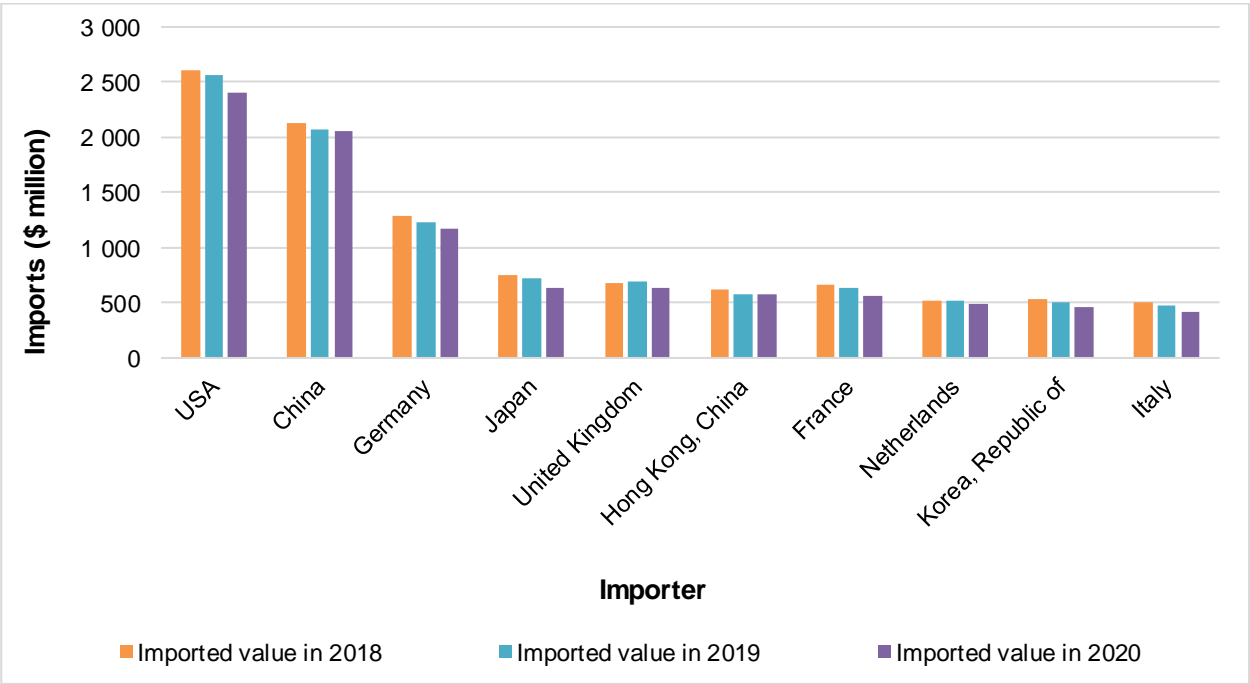
Source: Author's calculations from the International Trade Centre (ITC) Trade Map, 2021b.

¹⁵ The aim with these two figures is not to show the latest data, but rather the significant drop in exports and imports which nearly all countries (bar China and Hong Kong) experienced during the pandemic year of 2020 in comparison with the two relatively “normal” years preceding 2020. As was the case with most countries, restrictive policies for both the movement of people and goods were implemented, which meant that overall business activity – and trade in particular – greatly suffered under these conditions, as illustrated by Figure 2-7 and Figure 2-8. Although many countries re-opened borders and relaxed many restrictions on the aforementioned policies for people and goods, the years following 2020 could not be described as “normal” years, hence these have not been added to the figures, as recovery was also uneven across economies (for a comprehensive overview, see WTO, 2021). Nevertheless, the overall global economic and trade recovery has been mentioned in the text.

As revealed in Figure 2-7 above, the pandemic has negatively affected global merchandise exports and the exports of many other countries around the globe. In total, global merchandise exports declined by \$1.4 billion (i.e., 8%) during the period between 2019 and 2020. While China is the only country amongst the top 10 global exporters that registered a 4% growth in exports, the respective exports of all the other countries in this category declined during this period. France (14%), the US (13%), and Japan (9%) were the most affected countries. Depending on the magnitude of the decline in imports, the decline in exports entails the deterioration of the affected countries' trade balance.

Figure 2-8 below also reveals that the COVID-19 pandemic negatively affected global merchandise imports as well as the imports of various countries around the globe.

Figure 2-8: Top ten global importers, 2018-2020



Source: Author's calculations from the International Trade Centre (ITC) Trade Map, 2021c.

While the trend seemed to be declining from 2018, it can be seen in Figure 2-8 that global merchandise imports declined by \$1.6 billion (i.e., 8%) between 2019 and 2020. A similar trend is observed in all the global top 10 importers from 2018 to 2020. While a decline in imports is welcomed in terms of enhancing the trade balance, the most affected countries were Japan (whose imports declined by 12% between 2019 and 2020), France (11%) and Italy (11%). China and Hong Kong were the least affected, with a 1% decline in their imports over the same period.

Throughout much of 2020, the global maritime eco-system was also marred by container imbalances, port congestion, and low productivity. Given the interconnectedness of the global

supply chains, the effects were felt worldwide. In a supply chain round table discussion, Gardner (2021:23-27) outlined the US's experience, which largely mirrored the experience of South Africa and many other countries. In summary, the following main points capture the global effect:

- Initially, the impact on global supply chains (i.e., USA and EU) and logistics infrastructures from the Coronavirus came in the form of a "supply shock";
- China's shutdown and the slow return to full production capacity caused the USA and EU importers to panic and "front-load" their purchases on Chinese vendors (buy early/often buy mentality);
- When surges answer a supply shock in goods movement, a ripple effect of bottlenecks occurs across both international and domestic supply chains;
- In terms of the effect on a maritime eco-system, some of those bottlenecks show up at crucial points:
 - Port terminals
 - Freight corridors
 - Warehousing and distribution facilities;
- In the case of the USA, there were fewer ships at ports from which empty containers could be returned to China, creating bottlenecks and congestion at terminals;
- Intermodal export shipments originating in the US's interior have been slowed down due to a lack of empty containers to load.

In essence, the same type of issue has typified the global maritime industry's operational headaches for the majority of 2020/2021. The constraints of container imbalances, coupled with a spike in demand, meant that global freight rates surged through the roof. During various periods throughout the first quarter of 2021, the "*World Container Index*" (WCI), compiled by the UK-based maritime research and consulting firm Drewry, nearly hit \$5 250 per forty-foot container (Drewry, 2021). At the time, the composite index was up by 213.9% compared with the same period in 2020, as the average composite index of the WCI for year-to-date was \$5 246, which was \$3 586 higher than the five-year average of \$1 660 (Drewry, 2021). The rate has subsequently subsided from these stratospheric levels, although in summary, for much of 2022, it has been recalculated at a much higher equilibrium than before the pandemic. At the end of October 2023, the rate has subsided to below pre-pandemic levels and is trending around the \$1 400 mark (Drewry, 2023).

Nevertheless, amid major uncertainties posed by the COVID-19 pandemic, there is an obvious need to sustain trade flows to ensure the supply of essential merchandise and to convey a gesture of confidence in the global economy (OECD, 2020). However, the need to sustain trade flows is

a considerable challenge, given the trade tensions that have been witnessed in recent years, which have exposed the international trading system to an augmented amount of novel trade restrictions and alterations (Baldwin & Evenett, 2020). Such trade restrictions and alterations traverse from increases in tariffs amongst major trading partners (e.g., the US and China), to ample government subsidies in strategic production sectors (Brown, 2020).

Logistics networks – which function within extended supply chains – must operate within the confines of predictability, sustainability, reliability, and agility. The pandemic-induced crisis tested these attributes and the overall adaptability of logistics networks – highlighting the dire need for their smooth functioning in testing times. Moreover, as Notteboom *et al.* (2021:180) state, “*each crisis reveals the weaknesses of a system and tests its resilience*”. Consequently, the authors investigated the temporal and spatial sequences of the supply and demand shocks of COVID-19 and compared these events with the 2008/2009 financial crisis. Their findings indicated that shipping lines, terminal operators, and ports had all demonstrated an increased resilience, partly supported by the rediscovery of risks in the aftermath of the 2008/2009 crisis and partly by the organisational changes in each of these industries. Also, especially for shipping lines, COVID-19 reconfirmed the market position and bargaining power, with an upsurge in freight rates and a positive impact on financial results (Notteboom *et al.*, 2021:207). Nevertheless, the authors warned about the long-term impacts amid “*highly uncertain conditions generated by a new wave of COVID-19 cases and restrictions in countries around the world*” (Notteboom *et al.*, 2021:186). These warnings were echoed by others, as the pandemic-induced crisis has not yet passed and continues to create significant levels of global uncertainty (Ciravegna & Michailova, 2022:173), which is also true for South Africa (see Grater & Chasomeris, 2022 for an in-depth examination of the effects of COVID-19-related trade disruptions on port tariffs and container freight rates in South Africa.).

Despite these substantial uncertainties originating from the COVID-19 pandemic, there are five critical things that can be done to sustain global trade flows (OECD, 2020): (i) inspiring confidence in trade and international markets by enhancing openness regarding trade-related policy positions and objectives; (ii) keeping supply chains operational, particularly for essential merchandise such as food and health provisions; (iii) avoiding escalating the consequences of the pandemic through avoidable export barriers and other trade-related restrictions; (iv) promoting the COVID-19 inoculation drive and vaccine manufacturing by temporarily waiving certain intellectual property rights provisions covering the production of COVID-19 vaccines; and (v) even though confronted with the global health crisis, thinking beyond the prevailing economic growth and development circumstances.

As mentioned in Section 2.3, even though the pandemic has adversely affected global trade, prospects have improved, with indications of a recovery in merchandise trade and industrial production noticeably emerging in the 4th quarter of 2020. It is sensible to expect the recovery in global trade to draw significantly from the merits of the 4IR, which has the capacity to generate a supply-side miracle that will culminate in diminishing trade costs.

2.4 Conclusion

The focal point of this chapter was two-fold: firstly, to provide a brief discussion of the background and evolution of the most critical trade theories to date, and secondly, to provide an overview of the international trading environment and the immediate outlook for the future. Hence, to understand this study's positioning – with logistics performance as its fulcrum – the theoretical framework of trade and accompanying trade theories first needed to be investigated. It is acknowledged that the groundwork of classical trade theories was laid down by Adam Smith and David Ricardo in the 18th and 19th centuries, which provided us with absolute and comparative advantages. By extending the comparative advantage theory, Heckscher-Ohlin, in the 1930s, demonstrated that countries are either capital-intensive or labour-intensive, and that countries should specialise in the production of those goods in which they are better endowed. However, the Leontief paradox duly contradicted the Heckscher-Ohlin theory in the case of the US.

As with the accelerated nature of global trade, globalisation, and the evolution of global value chains in the 1990s, Krugman's new economic geography theory indicated that trade is fast becoming regional, with economic clusters forming geographically as transport costs are continually decreasing. Moreover, the focus of production shifted from being country-specific to being firm-specific. The new economic geography partially explains the formation of new value chains in a globalised world.

Seeing that the modern world has become so interconnected, it is paramount for firms to join a value chain to assist their economic growth in trade. Baldwin (2012) explained the evolution of globalisation and value chains through the two stages of unbundling. The first stage is defined by the industrialisation of the Global North and the de-industrialisation of the Global South. However, hallmarked by the ICT revolution from the 1970s onwards, the Global South (especially China, Korea, and India) caught up in the second stage of unbundling. The question of when Africa will catch up also arises in this regard. Globalisation and global value chains furthermore explain the continued role of trade in worldwide production, which is illustrated by the continual growth of trade's share in global GDP.

The introduction and adoption of containerisation between 1958 and 1990 significantly improved logistics and reduced trade costs. As an innovation, containerisation encompasses a novel system of intermodal conveyance, which has had tremendous effects on the geography of production and distribution. As a result, production became globalised through better utilisation of comparative advantages, while logistics systems were able to interact more efficiently, supporting and influencing the coherence of the GVCs.

As the worldwide trading landscape has become a lot more liberalised with the WTO and the recent ratification of the AfCFTA on the African continent, it is essential to trade more efficiently across borders and accelerate the flow of goods. In essence, the liberalisation of these trade agreements will duly assist in creating a more simplified, harmonised, and modernised approach to cross-border requirements, which is a crucial consideration for increased cargo flows and the need for improved logistics performance facilitating global trade.

Moreover, since logistics is described as the system carrying the flow of merchandise goods across borders, realising their role is essential when considering that trade constitutes almost 60% of the global GDP. As such, the importance of increasing logistics performances is further highlighted within the broader value chain system, which is perhaps not as well discussed in the existing global trade literature. However, before one can realise the impact of improved logistics performances within the extended supply chain, it is first necessary to investigate the literature on supply chains as a whole and, more specifically, logistics networks. Therefore, the following chapter aims to provide a literature review of supply chain and logistics management from a global perspective.

As with the previous industrial revolutions, the 4IR is expected to have an extremely positive impact on global trade. For instance, the technological innovations within this current wave of industrialisation will affect trade improvements in trade logistics and lower trade transaction costs. Novel global supply chains are also being created in the services domain, inspiring services exports originating from poorer countries. Technological innovations brought about by the 4IR will lead to a supply-side miracle through advancements in productivity and efficiency in the long term.

While globalisation and its effects (including that of technology and the 4IR) on global trade remain as strong as ever, some would claim that in the age of the COVID-19 pandemic, we see a reversal of integrated global economies and value chains. However, there remains little evidence at this juncture that this is indeed the case. As posited by several authors, some are saying that the pandemic will mean a complete reversal of global value chains. Of course, we do have to revise our understanding of the world a little bit, because the current model does not account for the kind of external shocks to the system that the coronavirus represents.

CHAPTER 3: LITERATURE REVIEW OF SUPPLY CHAIN AND LOGISTICS MANAGEMENT

3.1 Introduction

This chapter provides a comprehensive literature review of the logistics and supply chain management principles in today's business environment. There are many factors driving and revolutionising the present-day global business environment. Major driving factors are climate change, convergence, demographics and human migration, energy, food, oceans, poverty, waste, and water (Arup, 2019). Other practical factors to consider in our current economic climate are a turn against liberalisation, the geopolitical situation, renewable energy, and globalisation 4.0, which was the focus of the WEF for 2019 (WEF, 2019). All these factors listed above impact business differently. Furthermore, these factors significantly add to the uncertainty surrounding doing business in modern times, especially in the global world of logistics and supply chains.

Nonetheless, as global merchandise trade continues to expand in volume and complexity, ensuring the smooth functioning of logistics systems that carry international goods becomes paramount. Therefore, it is important to ascertain the current design of the logistics systems for global merchandise trade, especially from the perspective of a logistics service provider, which plays a pivotal role in conveying goods from origin to destination. As this chapter will show, ICT is greatly assisting with almost all steps of the logistics processes. Moreover, technology is playing an ever-increasing role in global trade on all accounts. This chapter builds on the literature presented in Chapter 2 and aims to add to the first secondary objective of assessing and synthesizing existing scholarly works on LSCM using a specific literature review methodology.

Against this background, this chapter's structure is as follows: Section 3.2 will provide a literature overview on supply chain management and design. Then, Section 3.3 will investigate the role of the logistics provider – operating as the primary actor – in supply chains. Thereafter, Section 3.4 will provide a literature overview of the role of ICT in supply chains – firstly examining the role of ICT in the broader sense of the supply chain and then secondly examining the role of ICT in the logistics industry specifically. In conclusion, Section 3.5 will investigate the use of data analytics in supply chain modelling.

3.2 A literature overview of supply chain management and design

A fundamental feature of modern-day business is the notion that it is supply chains that compete, not enterprises (Christopher, 1992). Consequently, the efficacy or failure of supply chains is ultimately revealed in the market by the final consumer. Hence, supply chain management is

essential in getting the right product to the consumer at the right price and at the right time. In fact, supply chain management not only forms the lynchpin to the likely effectiveness of an enterprise, but is also the key to the survival of the enterprise (Christopher & Towill, 2001). Emanating from this, interest in supply chain management had gradually strengthened since the last two decades of the 20th century, when enterprises realised the gains of mutual affiliations within their own organisations and elsewhere (Lummus & Vokurka, 1999). Furthermore, the surge in globalisation and the accompanying challenges it ushered in inspired both practitioner and academic interest in global supply chain management. Despite this proliferating interest, there seems to be an apparent lack of shared meaning amongst scholars of what supply chain management pertains to.

The definitions of supply chain management as a concept that have been proposed by diverse scholars in supply and logistics literature can be classified into the following three groupings (Mentzer *et al.*, 2001): a management philosophy, implementation of a management philosophy, and a set of management processes. As a philosophy, supply chain management takes a systems approach to view the supply chain as a solitary entity rather than as a set of disintegrated parts, each executing its own function in isolation (Tyndall *et al.*, 1998). Thus, supply chain management is considered a set of beliefs that each respective enterprise in the supply chain explicitly and implicitly influences the functioning of all supply chain members, as well as the functioning of the overall supply chain (Cooper *et al.*, 1997).

As a set of activities aimed at implementing a management philosophy, supply chain management calls for enterprises to institute management systems that warrant them to act or behave consistently with the philosophy. It is in this regard that a number of authors have focused on the following activities that constitute supply chain management: advancement of cohesive actions aimed at incorporating customers and suppliers (Bowersox & Closs, 1996); reciprocal distribution of information amongst supply chain members (Tyndall *et al.*, 1998); jointly sharing threats and opportunities that generate competitive advantages (Cooper & Ellram, 1993); collaboration among the supply chain members (Ellram & Cooper, 1990); similar aim and focus amongst supply chain members on serving customers (Lassar & Zinn, 1995); an amalgamation of practices across the entire supply chain (Tyndall *et al.*, 1998); and building and maintaining long-standing associations among supply chain partners (Cooper *et al.*, 1997). As a set of management processes, supply chain management is regarded by some authors (e.g., Cooper *et al.*, 1997; Ellram & Cooper, 1990; Tyndall *et al.*, 1998) as a detailed ordering of work activities across time and place, with a beginning, an end, clearly identified inputs and outputs, and a structure for action.

Given these distinct classifications of supply chain management definitions, this study follows Lummus and Vokurka (1999) in defining supply chain management as all the undertakings involved in delivering a product, from raw materials through to the customer, including the procurement of raw materials and parts, production and assembly, warehousing and the tracking of inventory, order entry and order management, distribution across all channels, delivery to the customer, as well as the information systems required to monitor all of these undertakings.

As stated by Stevens (1989:3), the primary objective of managing the supply chain is to synchronise the customer's requirements with the flow of materials from suppliers. In this manner, the balance between conflicting goals such as high-quality customer service, good inventory management, and low unit cost could then be achieved. Monczka, Trent and Handfield (1998) also explain that supply chain management is a concept "whose primary objective is to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers".

Since a supply chain is a coalition of autonomous business processes (e.g., supplier, production, and distribution processes) that execute the essential functions in the order fulfilment process, effective supply chain design is vital in the production and delivery of diverse products at lower costs, high quality, and shorter lead times (Talluri & Baker, 2002; Goldman, 1994). In fact, efficient supply chain management calls for robust supply chain design. Supply chain design is defined as the process of determining the supply chain infrastructure, such as the plants, distribution centres, transportation modes and lanes, and manufacturing procedures that will be utilised to fulfil customer demands. It is a significant facet of supply chain management that traverses beyond issues of make/buy, buyer-supplier relations, or vertical integration (Fine, 1998).

The importance of supply chain design is emphasised in the supply and logistics literature, and the discipline has been singled out as an essential part of the logistics decision-making process in many enterprises. The significance of supply chain design has also been amplified, because enterprises progressively recognise the prospects of gaining additional value for their customers through restructuring their supply chain. In fact, the growing awareness of the crucial impact of supply chain management and design on an enterprise's effectiveness, together with its accompanying strategic benefits, has made the supply chain an exceptionally tactical issue.

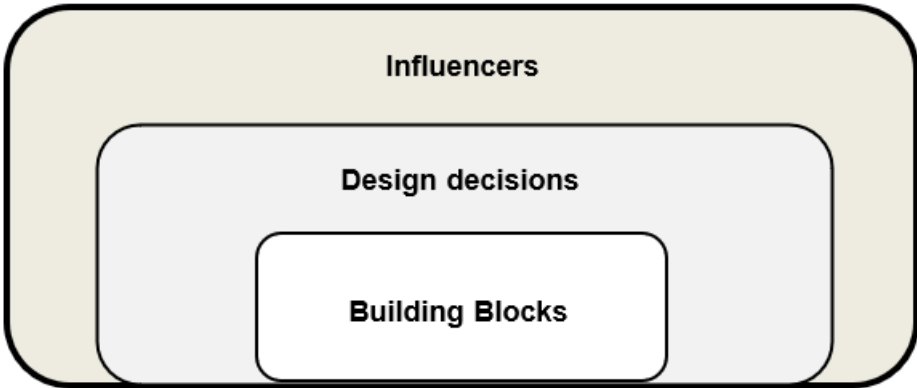
Supply chain design defines the nature of the supply chain, and generally consists of those decisions that influence the investment patterns made by the enterprise across its diverse supply chains (Melnyk, Narasimhan & DeCampos, 2014). These decisions eventually affect the competencies of the supply chain. In other words, the decisions affect the problem that the supply chain is capable and incapable of addressing (Wu, Melnyk & Flynn 2010). These decisions also

influence the form of affiliation which develops among supply chain partners, the functional measurement systems applicable to the supply chain at hand, the level of supply chain visibility accomplished, and the overall susceptibility of the supply chain.

According to Chopra and Meindl (2004), supply chain design problems comprise the decisions pertaining to the amount and location of production facilities, the extent of capacity at each facility, the assignment of each market region to one or more locations, and supplier selection for sub-assemblies, components, and materials. Decisions of this nature are often made in a setting typified with uncertainty, full of multi-conflicting objectives, and imperfect information. Such environments usually encompass the following aspects: redesigning of the supply chain, novel processes, factors that impact multiple groups, organisational incentives that may counteract transformation, coordination across functional boundaries, and data needs, all of which are difficult to satisfy. Supply chain design also addresses a wide range of an enterprise's strategic infrastructure issues, which includes the manufacturing strategy (in terms of plant requirements and the respective geographical locations, for instance), supply base design, outsourcing, and new product and process design.

Melnyk *et al.* (2014) view the supply chain design, together with the ensuing supply chains, as an outcome of a process that is shaped by the following three outstanding dimensions that possess a tiered relationship: influencers, design decisions, and building blocks. The element of influencers (see Figure 3-1), which is the domain where supply chain architecture is most evident, consists of broad-based environmental factors that constrain and significantly influence the overall nature of the resulting supply chain. These include life cycle considerations, desired supply chain outcomes, business models/critical customers, and the overall operating environment.

Figure 3-1: Three levels of dimensions shaping supply chain design



Source: Adapted from Melnyk et al. (2014).

Design decisions are the specific decisions that must be made regarding the overall structure and design of the supply chain. These decisions are constricted by the influencers (see the preceding

discussion) and include decisions concerning the physical supply network design, procurement strategies, social network design, relationship control mechanisms, and behavioural management approaches. Building blocks are the explicit investments required to execute the design decisions and are the necessary inputs into building the desired supply chain. They include investments such as physical structures, modes of transportation, procurement decision mechanisms and techniques, contracts, inter-firm process development, and social capital investments.

A plethora of scholarly studies in the realm of supply chain management investigated the efficiency of supply chain models at the firm level. Within this framework, a supply chain model refers to a system linking multiple firms, both upstream (i.e., supply) and downstream (i.e., distribution), and the ultimate consumer (Rushton *et al.*, 2010:27). The research's focus also migrated towards designing supply chain models which could potentially perform more efficiently.

Christopher and Towill (2001:235), for instance, theoretically investigated an integrated model of supply chain design where 'lean' and 'agile' are not mutually exclusive paradigms that can be incorporated in many ways. Within this framework, 'lean' supply chains refer to streamlined processes, eliminating waste and non-value-added activities. On the other hand, 'agile' supply chains refer to the flexibility and responsiveness of how well an entity can adapt to changing daily operational demands. The authors proposed a model that explored how hybrid strategies can be developed to create cost-effective supply chains, and proposed an integrated manufacturing/logistics model for enabling the essential infrastructure. The subsequent model represents the fundamental principles that underpin the supply chain: rapid replenishment and postponed fulfilment. They concluded by suggesting that competitive advantage derives from the combined capabilities of the network of linked firms, and not from the competitive advantages of organisations on their own (Christopher & Towill, 2001:245).

In their 2005 literature review study, Meixell and Gargeya also investigated supply chain design models. Studying international models between 1990 and 2005, the authors found that models developed prior to 1990 regarded corporate taxes, tariffs and duties as prominent issues (see Hodder & Dincer, 1986; Breitman & Lucas, 1987; Cohen & Lee, 1989). Furthermore, the technology supported by these early studies was the production-distribution model. However, in the period between 1991 and 1995, variability and uncertainty in exchange rates became primary concerns. As noted in Meixell and Gargeya (2005), scholars developed stochastic programming and option valuation models to assist in addressing these concerns. From 1996 to 2000, there was sustained interest in uncertainty in the parameters of the problem, as well as attention to the transfer price and supplier selection decisions. In the period after 2000, scholars again expanded technologies utilised to address these problems, developing network equilibrium models and multi-phase approaches that deploy multiple technologies.

Meixell and Gargeya (2005) additionally found that, although most supply chain design models solve multifaceted features associated with globalisation (dispersed production and distribution sites), few models address the practical global supply chain design problem in its entirety (2005:531). Since manufacturers rarely owned all the production sites globally, the authors insisted that future work on global supply chains should address the composite supply chain design problem by extending models to include internal manufacturing and external supplier locations (2005:547).

To distinguish between the various supply chain design models that the literature on the subject suggested, Klibi *et al.* (2009) presented a critical review of the optimisation models proposed in the literature. Within their review context, optimisation models can be explained as a mathematical model that attempts to optimise (maximise or minimise) an objective function without violating resource constraints. Through an analysis of supply chains, uncertainty sources and risk exposures, the study reviewed key random environmental factors and discussed the nature of major disruptive events threatening supply chain networks. The authors concluded by stating that most design models make significant assumptions and simplifications, falling short of current business needs.

To combat these assumptions and simplifications and ultimately develop a comprehensive methodology for supply chain network design under uncertainty, Klibi *et al.* (2009:292) proposed that various factors should be considered when designing a supply chain model. These factors include risk analysis, hazard modelling, scenario development and sampling, value-based design, modelling for robustness, resilience, and responsiveness, and finding solution methods. The authors concluded that, although all these elements mentioned above make the elaboration of design models quite complex, the challenge remains achievable. The objective is realised by striking a balance between realism and tractability (or solvability), using data available in typical practical contexts (2009:292).

Garcia and You (2015) conclude that globalisation and technological advancement have connected industries, firms, and countries like never before, providing ample opportunity to improve or refine supply chain design. The authors noted that some of the key opportunities for the advancement of supply chain design stem from Enterprise-Wide Optimisation (EWO) techniques as well as society's increasing interest in energy/sustainability topics. The authors further assert that EWO can provide opportunities for modelling and optimising supply chain designs. Moreover, these opportunities are shared with other academic communities, including operations research and industrial ecology, allowing for possible collaborations.

Garcia and You (2015) also point out that while much progress has been made in the large-scale modelling of complex supply chain design, there still exists a great need for efficient approaches to deal with the multi-scale, multi-objective, and multi-player challenges of modern supply chains. In this regard, multi-objective supply chain design will require the development of better measures and models for a variety of economic, environmental, and social objectives.

Since Klibi *et al.* (2009) published their research, the amount of available data in typical practical supply chain contexts has increased exponentially. To derive knowledgeable supply chain design solutions using data available in typical practical contexts (as proposed by Klibi *et al.*, 2009), ICT can be used as a key strategy for efficient supply chain management, as presented by Colin *et al.* (2015). Therefore, Section 3.4 provides an overview of the role of ICT in the global supply chain.

3.3 The role of logistics service providers in supply chains

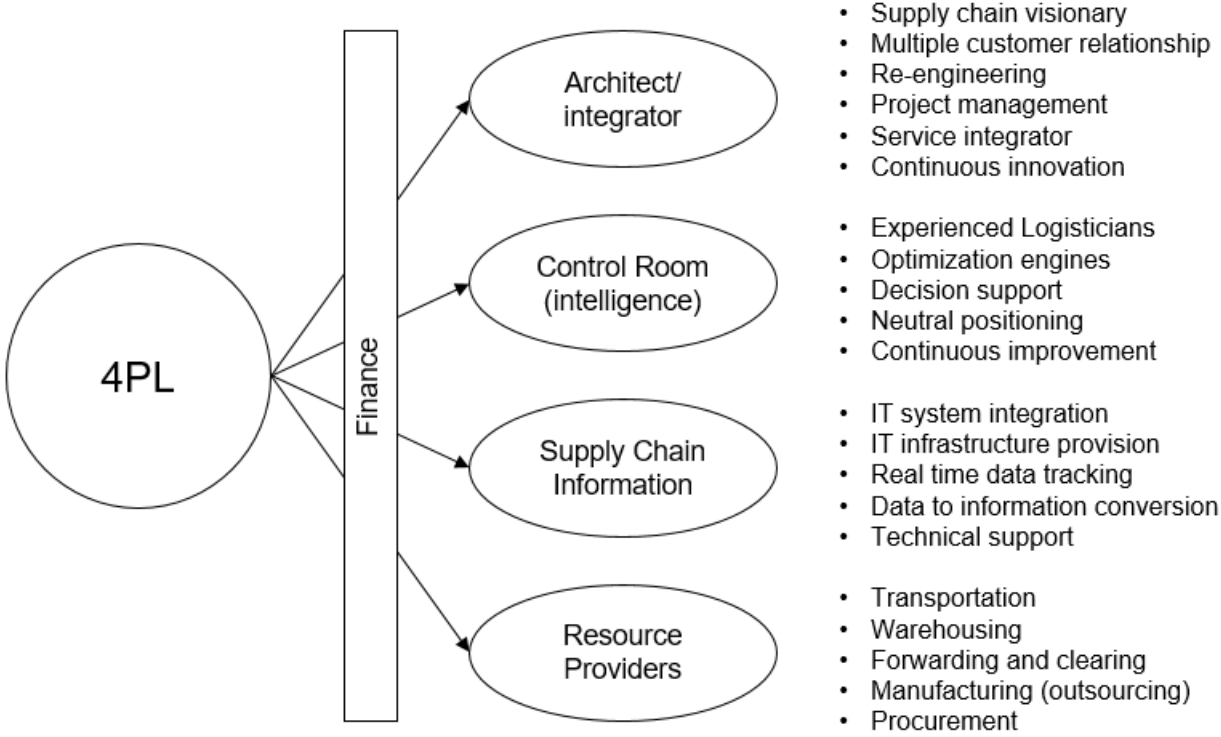
Due to the complex nature of international trade processes, many enterprises that had previously operated internal logistics departments are now, to an increasing degree, choosing to outsource logistics functions such as transport and warehousing to specialised logistics service providers (Abidi, De Leeuw & Klumpp, 2015). Logistics service providers, commonly known as Third-Party Logistics (3PLs), are enterprises that offer amalgamated logistics solutions which incorporate various modes of transportation (Baharmanda, Comesa & Lauras, 2017). They also act as an intermediary between parties, often providing a host of services such as, *inter alia*, freight forwarding, packaging, labelling, recording of inventory, distribution, brokerage, customs clearance, warehousing, and handling customer returns (Rushton *et al.*, 2010:59). The services of the 3PLs within the greater supply chain, can be scaled and customised to the needs of customers.

Enterprises have progressively considered the role of 3PLs as “strategically complementary” to their pursuit of international competitiveness, and are profoundly looking for their services (Coyle, Bardi & Langley, 1996). In fact, an extremely imperative common ground between internal logistics departments of mostly manufacturing enterprises and 3PLs has always existed. This common ground is particularly noticeable in supply chain functions like transportation, warehousing, fleet management and tracking of shipments (Zacharia, Sanders & Nix, 2011). Because of the shifting attention in the global logistics industry to customer service, 3PLs have made considerable investments in technology relating to areas such as, among others, warehouse automation, information technology for automated reporting, bar-code scanning, and online tracking of items (Baharmanda *et al.*, 2017). 3PLs have, therefore, built unique proficiencies in the numerous aspects of the supply chain logistics function.

Over the last two decades, services from these 3PLs have developed further to include value-added services related to the production or procurement of goods, such as services that integrate parts of the supply chain. Consequently, 3PLs have evolved into 4PL service providers (Bumstead & Cannons, 2002:18) by way of further enhancing the extent to which the logistics services are outsourced in the supply chain. Being independent from production, a 4PL services provider is “where an external organisation can provide a user with an overall supply-chain-wide solution by incorporating the resources and expertise of any number of third parties to best effect” (Rushton *et al.*, 2010:70). The primary difference between a 3PL and a 4PL lies in the management of various third-party functions outsourced to the logistics service provider. Furthermore, a 4PL oversees the entire supply chain. They’re known as lead logistics providers. A 4PL company typically has partnerships with several established 3PL companies, which it manages alone without client input.

With these collaborative ventures, there is a need for an organisation “that can use its knowledge of supply chains and specialist third-party service providers to manage and integrate the complete end-to-end supply chain” (Christopher, 2011:223). Figure 3-2 summarises the evolution of these joint ventures.

Figure 3-2: Fourth-party logistics and their areas of service that could be provided



Source: Adapted from Bumstead & Cannons, 2002.

As Figure 3-2 illustrates, the 4PL concept will, therefore, bring together a combination of the most specialised service providers and – using its information systems capability – ensure an efficient, cost-effective, and sustainable supply chain solution (Christopher, 2011:223). Ultimately, the logistics service provider's role in supply chains can be summarised as the intermediary facilitating the process of distributing the goods between the suppliers at the origin and the final customers at the destination.

Some previous studies have explored the reasons why enterprises typically outsource supply chain logistics activities to 3PLs. For instance, a study by Zacharia *et al.* (2011) upheld that outsourcing logistics functions to 3PLs may perhaps be the best alternative, especially for non-dominant enterprises, to leverage the supply chain best practices. Lambert *et al.* (1999) also put forward that, to generate competencies in providing value to customers, enterprises should concentrate on the fundamental business elements and outsource the non-fundamental elements to third parties who can accomplish them more effectively. In this regard, conventional logistics functions such as transportation and warehouse management are generally regarded as non-fundamental functions by most business entities (Zacharia *et al.*, 2011).

In the relief efforts context, Baharmanda *et al.* (2017) employed both qualitative and quantitative approaches to investigate the way some humanitarian organisations in Nepal's response made use of logistics service providers in handling moderate- to high-level freight transportation risks. Their qualitative analysis reveals that some of the most significant domestic transportation risks were in the form of delivery interruptions, market instabilities, inadequate capacity, cargo theft, cargo deterioration, untrustworthy information, and ethical concerns. Their quantitative analysis, on the other hand, established that whereas the research participants classified the first three risks (i.e., delivery interruptions, market instabilities, and inadequate capacity) as high-level, the rest of the risks were rated as moderate-level.

Further investigation by the authors indicated that utilising logistics service providers significantly assisted humanitarians in administering, in advance, domestic freight transportation risks during the Nepal response. The use of logistics service providers also enriched the overall humanitarian supply chain performance regarding flexibility, effectiveness, and responsiveness. Baharmanda *et al.* (2017) stated that while their finding empirically confirms the “tools” role of 3PLs for managing internal transportation risks in humanitarian response efforts, it infers another role for 3PLs, namely “contributors” to performance enhancements.

This research will focus on the logistics system in a South African supply chain from the logistics service provider's perspective. The following section will investigate the current processes and available ICT for logistics systems in South Africa. ICT in the logistics and supply chain is

significant, since it speeds up the flow of information and funds between the upstream and downstream of the whole supply chain, leading to better services, diminished logistics costs, and rapid communication between suppliers and their clientele (Pienaar, 2009).

3.4 A literature overview of the role of ICT in supply chains

This section will provide a literature overview of the role of ICT in supply chains. Since the extended supply chain is a much broader concept compared to logistics, as mentioned in Section 1.1.3, the section will first examine the role of ICT in the extended supply chain. After that, the section will examine the role of ICT in the logistics industry specifically. Logistics is, of course, a key element in supply chain management, allowing the smooth functioning of the extended supply chain system. As this section will further demonstrate, logistics systems operate at different, intersecting and/or aggregative organisational and geographical levels, encompassing critical actors. Moreover, the use of ICT can potentially significantly improve the various activities involved in moving goods across borders, allowing trade to occur faster and more cost-effectively.

3.4.1 The role of ICT in the broad supply chain

The increased use of information and communications technology (ICT)¹⁶, especially after 1990, has been an important driver of the decreasing transport and communication costs in international trade (Behar & Venables, 2011:107). This period is referred to as globalisation's second unbundling, which has significantly lowered the cost of moving ideas, and has made it possible to coordinate complex ideas at a distance (Hummels, 2007:131; Baldwin, 2016:5). This lowering cost has removed certain trade barriers, especially in terms of the time and cost to do business internationally. International business processes during this time were developed to encompass not only the key functions within an organisation's own boundaries, but also those external functions that contribute to the provision of a product to a final customer (Rushton *et al.*, 2010:8), which largely explains the term "supply chain management" as it is currently used.

Another factor that can be attributed to the ICT 'revolution' is the way data has expanded and been managed. Since the amount of data has increased rapidly, ICT has created the prospect of measuring and managing numerous actions and handover points within the supply chain. Due to this emergence, Waller and Fawcett (2013) have indicated that many opportunities exist to use data science, predictive analytics, and big data in supply chain management (Waller & Fawcett,

¹⁶ The term 'information and communications technology' refers to the integration of information technology and telecommunications that enable users to access, store, transmit, and manipulate information (Murray, 2011). Throughout this research, ICT will be used as a collective term in describing any technology capable of accessing, storing, transmitting, and manipulating information.

2013:77). Various researchers (Hazen *et al.*, 2014; Schoenherr, 2015; Gunasekaran *et al.*, 2017) have echoed Waller and Fawcett's sentiment.

However, many researchers (e.g., Apiyo & Kiarie, 2018) uphold that efficient management of the supply chain, to a large extent, can help enterprises achieve their full potential. In fact, it is generally agreed among the scholarly community that supply chain management emphasises the overall and long-term benefits of all parties involved across the supply chain through cooperation and information sharing (Gunasekaran & Ngai, 2004). It is in this regard that ICT can be viewed as a significant catalyst in integrating the supply chain by ensuring real-time information flow across the chain, thereby reducing uncertainty and enhancing the performance of the whole supply chain system (Pereira, 2009).

Understanding the significance of unconventional and real-time information and knowledge in effective supply and logistics decision-making for the commercial production community, governments all over the globe are making concerted efforts to explore innovative information delivery mechanisms. Indeed, the ICT that enables better visibility and tracking can allow for real-time monitoring of the entire supply chain, including shipping and invoicing (Robinson, 2019). Hence, the dynamism in technology products, including smartphones, GPS devices, and tablets, has seen a steady rise in mobile supply chain ICT, which is invaluable in monitoring the supply chain using wireless technology (Shin *et al.*, 2011:706).

ICT has also been singled out as one of the major factors contributing to the 4IR, which has driven a 'new' era of globalisation. In the last decade, ICT has played a critical role in shaping the business world. Therefore, its role, especially in the modern supply chain, cannot be over-emphasised. Patterson *et al.* (2003:98) foresaw this role and listed various factors such as organisational performance, supply chain strategy integration, environmental uncertainty, and decentralised organisational structure as the forerunner for supply chain ICT adoption.

The increasing role of ICT in supply chain management and related functions has received considerable attention in the literature. In this regard, three strands of literature can be isolated. The first strand of literature has seen some scholars questioning the influence of ICT on supply chain management and its effectiveness, as well as the role of ICT as a medium of dissemination of information and knowledge in diverse supply chains. For instance, Zhang *et al.* (2011) were among the first authors to investigate whether ICT can influence supply chain management and how it impacts its performance. The authors reviewed survey-based literature and found that measurements and concepts in ICT, supply chain management, and overall supply chain performance are diverse and often incomparable, and contextual factors are not systematically considered. Despite these differences, the research reviewed shows that, generally, there is a

positive direct or indirect effect of ICT on performance and supply chain management (Zhang *et al.*, 2011:1215).

Ali and Kumar (2011:154) empirically analysed the role of information delivery through ICT in enhancing the supply chain decision-making competencies of Indian farmers. The authors stressed that the openness of information and knowledge induces a significant effect on the quality of decision-making for varied activities across the agricultural supply chain, especially when the educational level of the user farmers is moderate. Their results reveal that there are some undertakings across the agricultural supply chain, the decision-making of which gets significantly enhanced with the availability of information across most socio-demographic profiles. Such undertakings comprise the adoption of crop rotation practices, the use of certified seeds, sorting and grading, and market analysis. Ali and Kumar (2011:154) suggested that the identified four undertakings must be the fundamental focus of information distribution of ICT-enabled initiatives in agricultural supply chains.

Kumar, Singh and Modgil (2019) investigated the role of ICT in the agri-food supply chain by reviewing the literature pertaining to ICT, supply chain management practices, and its impact on organisational performance. Their results indicate that ICT and supply chain management practices (i.e., logistics integration and supplier relationships) have a significant relationship. Furthermore, supply chain management practices (i.e., information sharing, supplier relationship and logistics integration) have a significant as well as positive impact on the performance of the organisation.

The second strand of literature has focused on the impact of "big data" on supply chain management and its performance. In fact, since the emergence of the term (i.e., big data), various authors have investigated the opportunity of applying the science to supply chain management and its related functions. Essentially, big data is an extension of ICT from traditional LAN (local area network) and WAN (wide area network) to Internet and cloud storage (Misra *et al.*, 2016:41).

In order to alleviate ambiguity that hampers discourse relating to big data research, Ward and Baker (2013:2) surveyed big data definitions to come up with a coherent definition: "Big data is a term describing the storage and analysis of large and or complex data sets using a series of techniques including, but not limited to, NoSQL, MapReduce and machine learning" (Ward & Baker, 2013:2). Therefore, the essence of the term 'big data' is associated with the three concepts of volume, variety, and velocity (Laney, 2001). Current big data practices include the use of predictive and behaviour analytics, along with other advanced data analytics methods that extract value from large datasets.

Within this context, Waller and Fawcett (2013) were among the first to investigate the use of big data in supply chains. They posited that data science, predictive analytics, and big data (collectively dubbed DPB using the first letters of "data", "predictive" and "big") would revolutionise supply chain management. The authors examined the possible applications of DPB in practice and provided examples of research questions from these applications, as well as examples of research questions employing DPB that stem from management theories. The authors then called upon researchers within the field of supply chain management to investigate these possible applications.

Rozados and Tjahjono (2014) further investigated the emergence of big data and the potentially crucial role that big data analytics can play in supply chain management. The authors argued that big data should no longer be considered an information asset, but rather a strategic asset that can be successfully applied in supply chain management. By doing so, organisations in supply chain management could realise the economic value inherent in the data and the potential to capitalise on it when combined with big data analytics through revenue-generating activities. In both studies (Misra *et al.*, 2016 and Rozados and Tjahjono, 2014), the evidence presented was mostly conceptual in nature, and therefore lacked empirical evidence to showcase the role of ICT, moreover big data, in supply chain management.

The third strand of literature focused on the role of ICT in logistics and freight transportation. One of the essential studies in this category is that of Perego *et al.* (2011), who investigated ICT in the context of logistics and freight transportation. They found that, while there are many contributions from the perspective of the "public transporter" (i.e., the viewpoint of public stakeholders), studies focussing on the perspective of the "private transporter" (i.e., the viewpoint of the private companies offering logistics and transportation services) are fewer and relatively more recent.

Perego *et al.* (2011:457) further found that, as far as the methodology is concerned, many of the studies examined in their review are either conceptual or empirical studies (i.e., primarily based on surveys, case studies or interviews). Simultaneously, simulation and modelling (whereby a supply chain process is created and analysed by means of a digital prototype to predict its performance in the real world) are rarely present. Since there have been very few studies that have modelled a supply chain's performance based on various input factors such as ICT, there is a clear gap to address these issues. The research of Perego *et al.* (2011) serves as a significant motivation for investigating ICT implementation in South Africa's supply chains.

Gunasekaran, Subramanian and Papadopoulos (2016) reviewed the literature on the role of ICT in achieving efficiency in logistics and supply chains, based on the linkages between the triple-A's (i.e., adaptation, alignment, and agility) of Lee (2004). In their review, the authors maintained

that while ICT has revolutionised traditional logistics and supply chains to achieve numerous benefits, such as increased efficiency and responsiveness, it is not still clear to what extent ICT has contributed to a competitive advantage within logistics and supply chains. Based on their review, Gunasekaran *et al.* (2016) further argue that the achievement of competitive advantage in logistics and supply chains through ICT is based on the ability of organisations to utilize ICT strategically and synergistically to achieve alignment, adaptability, and agility. However, even those organisations that fail to build the appropriate capabilities through IT to achieve the synergy of these attributes may still be able to achieve a competitive advantage, but it is short-lived.

Gunasekaran *et al.* (2016) also noted that the literature on triple-A's underlines mostly the importance of ICT for value creation and business performance, as well as the role of resource commitment and ICT resources on performance, and suggests that ICT can be explored and exploited for logistics and supply chain innovation and also to obtain a distinctive logistics and supply chain advantage. The authors further observe that commercial enterprises would need to invest in ICT with the intention of obtaining significant organisational capabilities and strategic processes that permit them to adapt and respond swiftly to market changes and build competencies on both the supply and demand side.

While the specific instances where supply chain problems were addressed utilising ICT are sparse in literature, Fahimnia *et al.* (2017) presented a stochastic bi-objective supply chain design model for the timely and effective supply of blood in humanitarian disasters. They find that the association between cost and delivery time is a function of supply chain magnitude as well as time tolerance. Their results also indicate that adjustments in referral rate (i.e., the rate at which blood transfusion services are directed to regional blood centres) and the capacity of blood transfusion facilities can be used to enhance the supply chain cost and delivery time performance. The model proposed by Fahimnia *et al.* (2017) can be employed for cost/benefit analysis in order to pinpoint the areas and operations along the supply chain where investments can be made to enrich supply chain efficacy.

Ali and Haseeb (2019) also examined the effects of Radio Frequency Identification (RFID) on the supply chain activities of the Malaysian textile and apparel industry. The results of their study revealed a significantly positive relationship between ICT and supply chain operations. Therefore, it can be concluded that ICT enhances supply chain operations in the Malaysian textiles and apparel sector. The improved supply chain operation leads to better performance of the entire textile and apparel industry. In other words, it is apparent that ICT and efficient delivery time enhance supply chain operations, which in turn enrich the performance of the textiles and apparel industry in Malaysia.

Another study by Ul-Hameed *et al.* (2019) investigated the influence of IT capability and ICT on the logistics and supply chain performance of e-logistic firms in Pakistan. Their results indicated that ICT has a significant and positive relationship with the logistic and supply chain performance of e-logistic firms. Moreover, both the e-logistic firms' IT capability and ICT as moderators improved the positive effect of staff service quality, website design, and e-traceability.

In concluding this section, the present study acknowledges that ICT plays an increasingly important role within the supply chain, highlighting the necessity to manage it optimally. In fact, ICT offers immense opportunities for the dissemination of appropriate information and provision of services in supply chains, which leads to reductions in production and transaction costs, a rise in production efficiencies, access to better markets, and ultimately an increase in income (Lio & Liu, 2008). Realizing the role ICTs can play in supply chain management, several supply chain initiatives are at present making extensive use of modern ICT. This has facilitated decision-making relating to the day-to-day supply and logistics activities of individual enterprises, thereby improving the functional performance of the entire supply chain.

Unfortunately, supply chains are data-rich but information-poor. Due to the highly complex and fragmented nature of global supply chains and the role that logistics play in the movement of goods, getting goods from A to Z is more complicated than ever. To overcome these challenges, research has started to focus on finding new and innovative ways to bridge the information divide and move goods faster, cheaper, and more reliably.

Since logistics service providers oversee the process of managing cargo movement from the point of origin to the point of destination, many aspects of ICT within the supply chain are enabled by them. The following section provides an overview of the role of ICT in the logistics industry.

3.4.2 The role of ICT in the logistics industry

The utilisation and optimisation of ICT have greatly decreased trade costs, as outlined above in Section 2.3.4. Implementing more advanced ICT processes and applications in supply chain management seems to be an important consideration for the future of international trade and global supply chains – specifically concerning the movement of goods through the logistics network. The background above indicates that more efficient ICT processes and the implementation thereof can have significant benefits for global supply chains. Furthermore, improving on the determinants of logistics performance can have significant benefits for reducing the time and cost of procurement, movement, and storage of materials throughout the logistics network. Therefore, the link between ICT and the supply chain needs further exploration, as does

the link between the determinants of logistics performance and the corresponding efficiency thereof.

One such key determinant is the role of data analytics in the context of the logistics industry. Data significantly drives the logistics business and provides new service opportunities due to the emergence of technological platforms (Heinbach *et al.*, 2022:809). With the rapid increase of data produced and communicated over the internet, Wang *et al.* (2016) investigated big data analytics applications in logistics and supply chain management. Big data analytics in LSCM has received increasing attention because of its complexity and the prominent role of LSCM in improving overall business performance (Wang *et al.*, 2016:1). The authors highlighted the need for managers to understand big data business analytics and supply chain analytics as strategic assets that should be integrated across business activities to enable integrated enterprise business analytics. Moreover, with the integration of E-commerce and new sources of data such as smartphones, sensors, GPS, and other devices, Ayed *et al.* (2015:315) urged logistics and transportation companies to shift to big data analytics to improve their performance.

Previous studies advocated for the significance of ICT in the management of logistics functions and its influence on organisational performance (Evangelista & Sweeney, 2006; Varma & Khan, 2014; Wen, Choi & Chung, 2018). In fact, ICT has been recognised as an essential facet in the integration of diverse processes across operational divisions, including upstream and downstream partners, toward the enhancement of logistics practices (Kumar *et al.*, 2019). Moreover, in the present era of digitalisation, the role of ICT in logistics is not only limited to that of an auxiliary function, but also includes an active role that leads to sustained logistics competitive advantage for a supply chain (Han, Wang & Naim, 2017). ICT is known to assist in restraining the bullwhip effect, and thus facilitates logistics and supply chain performance enhancement (Vanpoucke *et al.*, 2014). It also assists in logistics integration and effective communication with suppliers, along with the provision of quality information (Pham *et al.*, 2019).

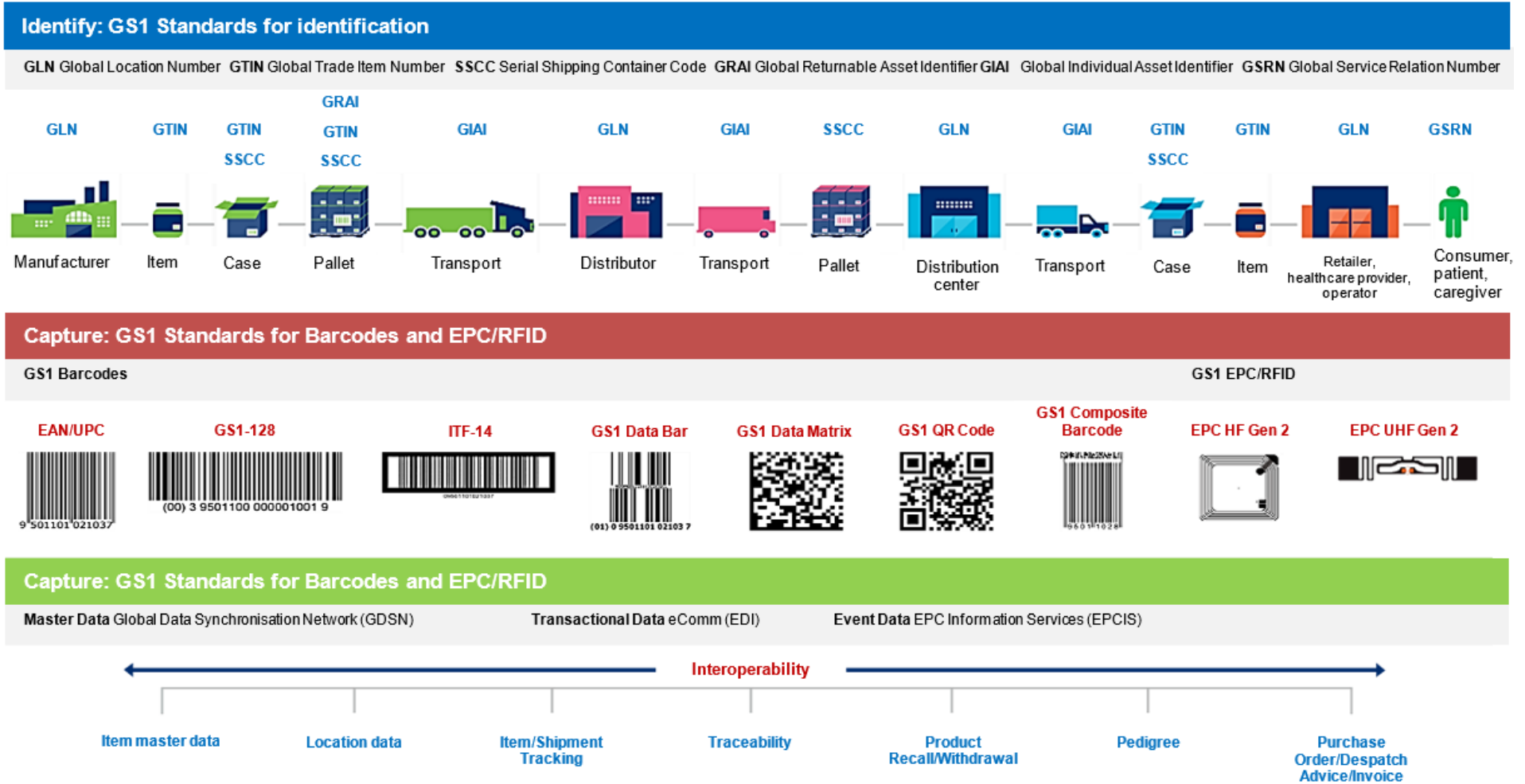
Based on the literature, specific ICT facilities are most widely used or applied in logistics with the intention of improving the quality of services. Such ICT facilities include (Omotayo & Melan, 2017): (i) Enterprise Resource Planning (ERP) software, which presents enterprises with the opportunity to strategise and regulate all the necessary resources for ordering, processing, forwarding and assigning clients' orders; (ii) software for planning material resources, which is used for the optimisation of material requirements and planning; (iii) software for interchanging of electronic data, which transmits telemetry information in a standardised manner from enterprises to another system, and which eliminates manual interference that can arise through a network managed by third-party operators; and (iv) software for transport optimising technology, which is in the form of

ordinary gadgets such as the Global Positioning System (GPS), utilised for planning and tracking of routine movements.

Literature also suggests that supply chain management practices (e.g., logistics integration) supported by ICT usher in general effectiveness and competence in supply chains. Kumar *et al.* (2019), for instance, empirically investigated the role of ICT in the agri-food supply chain, and determined the impact of supply chain management practices on firm performance. Their results indicated that ICT (i.e., information sharing, supplier relationship and logistics integration) and supply chain management practices (i.e., logistics integration and supplier relationships) have a significant and positive impact on organisational performance. The authors further assert that their findings can assist in facilitating the decision-making process in the field of agri-food supply chains, as well as inspire better comprehension of the significance of the relationship between ICT and supply chain management practices such as logistics integration.

Through the application of ICT systems, logistics enterprises and other organisations are functioning together with the intention of efficiently serving the final consumer. In fact, the level of sophistication of end-users has amplified because of better access and utilisation of mobile digital technology (Pokharel, 2005). Hence, conventional logistics and supply chains are becoming networks with consumers at the core. Such networks require open, multi-industry standards – such as the GS1 system of standards depicted in Figure 3-3 – to operate efficiently.

Figure 3-3: GS1 standards for identification and barcodes



Source: GS1 (2021).

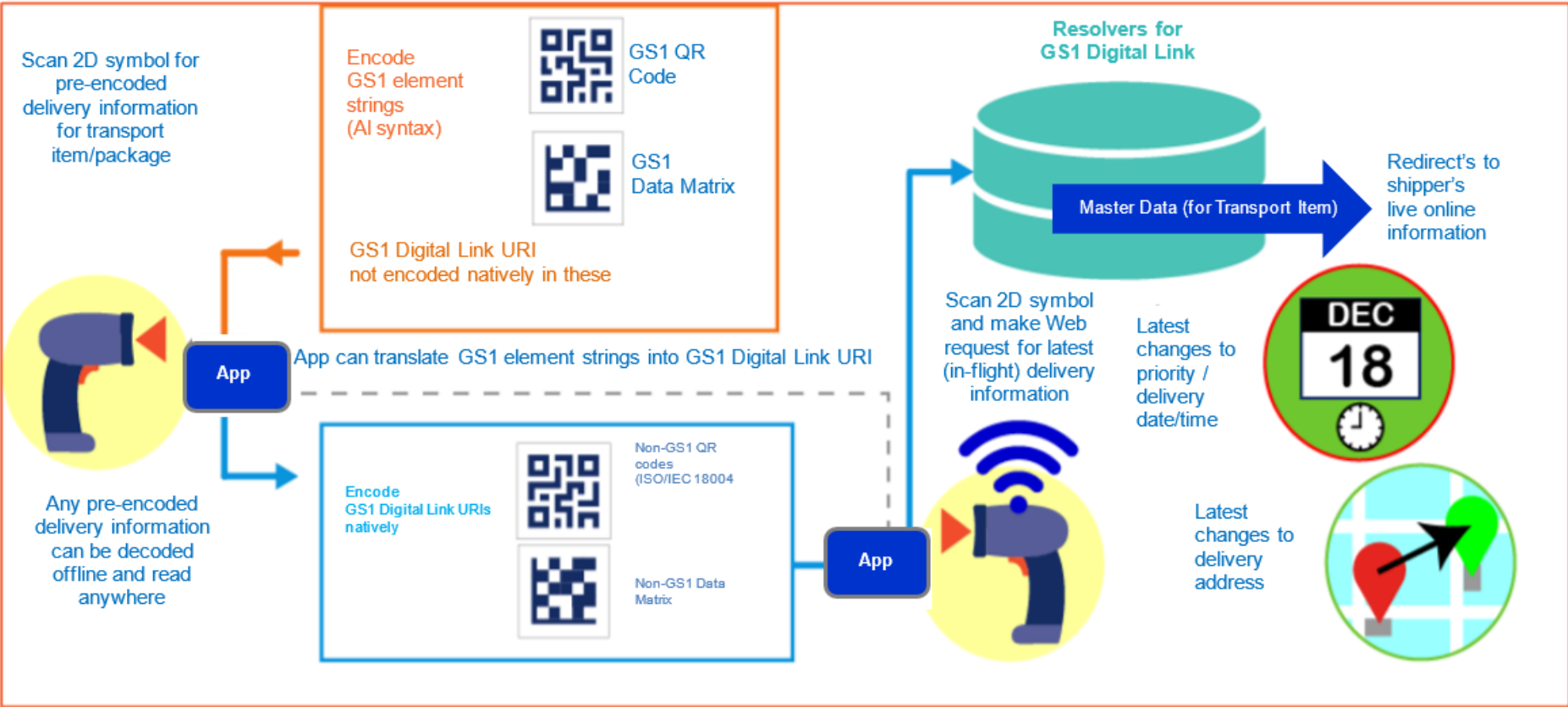
The GS1 system of standards refers to global standards for commercial communication, which facilitates the identification of commercial items and the transmission of data about these items in ways that can be utilised in any industry, country, and with any trading partner (GS1, 2021). From a logistics and supply chain perspective, the GS1 system of standards is intended to improve the efficacy of the logistics and supply chain processes, and to deliver cost savings through automation grounded on globally exclusive identification and digital information.

As shown in Figure 3-3, which portrays business processes that support the retail sale of consumer goods, GS1 standards may be categorised into three clusters, namely (GS1, 2020): identify (GS1 standards for identification); capture (GS1 standards for barcodes and EPC/RFID), and share (GS1 standards for data exchange). In terms of the GS1 standards for identification, every merchandise item is allocated a GS1 Global Trade Item Number (GTIN). By adhering to GS1 identification standards, every retailer is assured of having a unique way to refer to a given trade item in its information systems, and each product brand owner is required to merely allot a single identification to each trade item.

Under GS1 standards for barcodes and EPC/RFID, each trade item carries its GTIN directly on the product package using a barcode that conforms to the GS1 standards for barcodes, or alternatively using GS1-compliant RFID tags. Data capture systems compatible with GS1 standards are utilised to record trade items automatically and consistently as they progress through the logistics and supply chain, from shipping to receipt or point-of-sale (GS1, 2021). In terms of the GS1 standards for data exchange, the retailer obtains product master data, compliant with GS1 master data standards, from the brand owners. Data of that nature is used by the retailer in various ways, such as displaying a short description of the product when it is scanned at the point-of-sale terminal.

While GS1 standards may be utilised in any combination in a specified commercial application, the “identify, capture, share” model is universal in circumstances where GS1 standards are applicable. Employing the GS1 technical standards from the three clusters can provide solutions for commercial applications such as logistics and supply chain visibility and traceability (GS1, 2020). Traceability is a broad concept that refers to the ability to identify, track and trace elements of a product as it moves along the supply chain, from raw materials to finished products and anywhere in its life cycle (Schuitemaker & Xu, 2020). Traceability is not a new phenomenon. In fact, paper-based traceability has been in existence for many centuries, although it only began to be digitised in the 1950s (Cheng & Simmons, 1994). Because of technological advancements originating from the previous and current industrial revolution (i.e., industry 3.0 and 4.0), digital traceability is becoming more desirable for enterprises in all industries (Schuitemaker & Xu, 2020).

Figure 3-4: GS1: Global system of standards that supports traceability



Source: GS1 (2021).

Various information technologies and tools are also available on the ICT market to support traceability implementations (see Figure 3-4). Generally, multiple system components must work together to deliver an overall system. Parties in a supply chain may also comprise diverse levels of technical maturity. For instance, they may have chosen different technologies, or they may have applied the same technology in divergent ways (e.g., using different software or platforms). However, standards-based ICT systems and components are, to a certain degree, naturally interoperable with other ICT systems and components that conform to the same standards (GS1, 2020). Hence, logistics and supply chains encompass numerous operators that are symbiotic (in terms of traceability). In other words, whether the enterprise is an upstream materials provider or a downstream retailer, all parties trading and/or handling traceable units have a shared responsibility when it comes to achieving full-chain traceability (Schuitemaker & Xu, 2020).

In the domain of traceability, various studies reveal that commercial enterprises have adopted and implemented Radio Frequency Identification (RFID) technology in supply chain management (Angeles, 2005; Michael & McCathie, 2005; Lin, 2009; Jedermann *et al.*, 2009; Zacharewicz *et al.*, 2011; Hoffman *et al.*, 2013). In addition to RFID innovations in supply chain management, transport management systems, which deal with the planning, execution, and optimisation of goods' physical movements (Egawa, 1997), have also been implemented in transport management systems (Oswal, 2018).

Another logistics area in which ICT is perceived to have a significant impact is route-based logistics performance benchmarking. Benchmarking is defined as a management instrument that ascended in association with the surging economic globalisation (Moriarty & Smallman, 2009). As a result, executives of multinational enterprises considered the comparison of their operational undertakings necessary with those of the best competitive enterprises globally. In fact, to become or remain viable, enterprises had to strive for greater productivity, efficiency, and quality (OECD, 2000). It is in this regard that benchmarking made it possible to set targets and comprehend the way best operational practices are executed.

The liberalisation of trade in goods and services (i.e., trade globalisation), together with the expansion in E-commerce, underscores the need for commercial enterprises and the whole economy, in general, to embrace ICT to organise logistics as efficiently as possible. Hence, scholars in the transportation research discipline (see Saxena, 2017; Melo *et al.*, 2018; Koch & Klein, 2020; Serra & Fancello, 2020; Larrain *et al.*, 2021) have proposed several approaches to effectively monitor and manage logistics and transport systems.

Larrain *et al.* (2021), for instance, introduced a new route-based equilibrium assignment formulation and algorithm for congested transit networks. Melo *et al.* (2018) applied the data

envelopment analysis to measure and compare the effectiveness of Brazilian and American soybean transport corridors from farmers to export ports. Their findings reveal that efficient routes and corridors are inclined to consist of short-distance truck trips and long-distance train or barge trips. Furthermore, the effectiveness of inland waterway trips is contingent on the number of barges utilised in an identical expedition. The results of Melo *et al.* (2018) further reveal that routes with four or more transport modes are susceptible to inefficiency, which suggests the presence of a multimodality constraint.

Since this research is also concerned with data analytics in supply chain management, the following section provides a brief overview of data analytics and supply chain modelling.

3.5 Data analytics and supply chain modelling

The final sub-category of possible ICT implementation in the supply chain serves as the most important one within this research scope. Aptly labelled the age of information, the 21st century has been characterised by the immense flow of readily available data (Davenport & Patil, 2012:71). Every new system, application, and operation is generating enormous volumes of data driving intelligence, that supply chain management can use effectively (Hazen *et al.*, 2014:73). In a sense adjoining the previous two sections, the supply chain's modern design needs to incorporate all ICT facets in one, and analyse the various performances and models through multiple metrics. These models include all data sources from RFID, EDI, shipping lines, customer surveys, monetary transactions, and delivery notices.

Due to the emergence of data in supply chain management, Waller and Fawcett (2013) have indicated that many opportunities exist to use data science, predictive analytics, and big data in supply chain management (Waller & Fawcett, 2013:77). The authors proposed specific steps that researchers can take to combine supply chain management and data analytics. There is a "myriad of opportunities for research where supply chain management intersects with data science, predictive analytics, and big data" (2013:77).

In addition to this debate, Wang *et al.* (2016) investigated big data analytics applications in logistics and supply chain management. Reaffirming the fact that data is ever-increasing in the logistics industry, the authors argued that data analytics, especially on big datasets, can provide unique insights into market trends, customer buying patterns, and maintenance cycles. Further insights also include ways of lowering costs and enabling more targeted business decisions (2016:98). Showcasing various applications of supply chain analytics and big data business analytics, the authors stress the need for managers to use data analytics as strategic assets that should be integrated across business activities, especially at an operational level (2016:106).

Furthermore, the authors proposed that "researchers develop a model that considers the role of linking supply chain analytics and big data business analytics to the organisational and supply chain performance... [which] could be validated empirically by collecting data from supply chain partners" (2016:101).

The authors further indicated that although several studies have attempted to merge data analytics into supply chain management, most studies have only been predictive and not descriptive by using actual operational-level data. In conclusion, the authors highlight that "equal importance should be paid to both strategy and operations of LSCM [logistics supply chain management]" (2016:108).

Kache and Seuring (2017) investigated the opportunities and challenges associated with the application of big data analytics in supply chain management. Their Delphi study results reveal the following opportunities at the logistics and supply chain level: increased information availability emanating from the optimisation potential of inter-firm logistics; supply chain visibility and transparency in the form of availability of end-to-end real-time information access and control; greater availability of information on operations efficiency and maintenance capabilities; intensified integration and collaboration efforts along the supply chain leading to higher levels of information-sharing across parties; the enhancement of innovation and product design capabilities across the supply chain; and efficient inventory management practices, ultimately resulting in optimised inventory stocks.

Roßmann *et al.* (2018) also employed a Delphi research technique to analyse the impact of big data analytics on the future development of supply chain management and the organisational role of supply chain managers along with the involved dynamics. The results of the Delphi study reveal that applications of big data analytics facilitate the decline of the uncertainty of supply chain operations, by diminishing information processing requirements through improving the precision of forecasts and predictions, and expanding information processing capacity through the strengthening of supply chain transparency, which facilitates swift decision-making and reactions to supply chain interruptions. Specifically, demand forecasting approaches are anticipated to become considerably more accurate, inventories may be significantly reduced to lower levels as a result, and the administration of suppliers will be enhanced by surging volumes of data that are accessible for analytical purposes (Roßmann *et al.*, 2018).

The literature overview has provided some insight into the use of ICT, specifically data analytics in supply chain management in general and in supply chain performance in particular. Firstly, most of the research has been conducted within an international context. No empirical research on data analytics in the logistics industry has been conducted within a South African context.

Furthermore, the focus of most of the research listed has been investigated from a theoretical point of view in that certain supply chain models have been proposed. Only a small number of studies have made use of empirical data.

The factors mentioned in this section serve as a reminder of the myriad of obstacles in designing an end-to-end supply chain that can optimally perform in the changing landscape of the South African and, indeed, global economy. By incorporating various data points throughout the import process within the end-to-end supply chain, this study will use data analytics to act as 'trigger functions' to design and manage a more effective logistics system from a logistics service provider's perspective.

3.6 Conclusion

The literature presented in this chapter underscores that the interest in studying the supply chain has grown over the last couple of decades. Within the current changing landscape that businesses must deal with, this is especially true given the increased opportunities and subsequent threats of ICT use. The greatest motivation for adopting ICT within the end-to-end supply chain's logistics systems is to simplify the process. By requiring a seamless process, modern ICT will help with the efficiency and performance of the logistics system. It will also reduce costs and minimise the risks imminent in the system. Adopting these changes is an innovative way to stay ahead of the competition by enhancing customer satisfaction and improving efficiency. In fact, commercial enterprises across the globe are now fully aware of the importance of contemporary and real-time information and knowledge in effective logistics and supply chain decision-making.

The complexity of the global trading procedures has necessitated the outsourcing of logistics functions to 3PLs. To generate competencies, enterprises ought to focus on the core business elements while outsourcing the non-core elements to capable third parties. By developing further to encompass value-added services relating to the production or procurement of goods, 3PLs have evolved into 4PLs over the previous two decades. Eventually, the role of logistics service providers can be synopsised as the mediators speeding up distributing the goods between the suppliers at the origin and the final customers at the destination.

The importance of ICT in the management of logistics functions and its influence on organisational performance has also been highlighted in the literature. Within the current digitalisation era, ushered in by the third and fourth industrial revolutions, ICT has assumed an active role in logistics and supply chains. As a result, manifold ICT facilities have been extensively applied in logistics and supply chain activities, with the aim of enhancing the quality of service. The literature also

submits that supply chain management practices sustained by ICT usher in efficiency and competence in the overall logistics and supply chains.

Implementation of ICT systems has transformed traditional logistics and supply chains into networks with clientele at the core. Linkages of this nature call for open, multi-industry standards such as the GS1 system of standards. GS1 standards, in particular, may be employed in any combination in a specified commercial application. In circumstances where GS1 standards are applicable, the “identify, capture, share” model is global. Employing the GS1 technical standards from these three clusters can provide solutions for commercial applications such as logistics and supply chain visibility and traceability.

While the literature presented in this chapter provides valuable insights into the integration of ICT and supply chain management, it lacks empirical evidence or quantitative analysis demonstrating the actual impact of ICT adoption on logistics performance on a systems level. Furthermore, there is a gap in the literature regarding specific strategies or frameworks for effectively implementing data analytics to optimise logistics performance for import industries – South African or otherwise. This absence of empirical operational-level research limits a comprehensive understanding of the practical implications of ICT adoption and data analytics implementation on logistics performance, thus representing a notable gap in the existing literature.

The logistics system of the future, while more complex, will undoubtedly be less expensive and a lot more efficient. How money is spent across some of the supply chain's key variables, such as transportation, labour, inventory carry, and other factors, will undergo notable changes. For any country, industry, or business entity to compete, designing an efficient supply chain will be paramount to reap the rewards in today's globalised world. For this reason, it is imperative to implement data analytics in designing an efficient logistics system for South African import industries.

CHAPTER 4: TRADE AND LOGISTICS IN SOUTH AFRICA AND ITS RELATIVE COMPETITIVE POSITION IN THE GLOBAL ECONOMY

4.1 Introduction

This chapter provides a comprehensive overview of the trade and logistics industry in South Africa. Furthermore, this chapter elaborates on South Africa's relative position in global trade routes and networks and comments on South Africa's trade and logistics performance relative to its peer countries and position in a global perspective. When considering trade and logistics in South Africa, it is worth reiterating that, as illustrated in Figure 2-3, international trade has formed a focal point of global economic activity over the last 50 years, increasing from around 27% of GDP in 1971 to almost 60% of GDP in 2021 (WB, 2019b). For international trade and global supply chains to continue to flourish, they need the support of a properly functioning transport and logistics industry. Although trade in services and the growth of virtual trade is ever-increasing, the very fact that merchandise trade remains the bulk of global trade accentuates the need for transport and logistics to continue to play a burgeoning role in the economy.

Furthermore, the transport and logistics industry is rooted in many other sectors, serving as a 'feeder network' to many industries, especially retail, agriculture, and manufacturing, among others. Likewise, without transport and logistics, the basis of economic principles of supply and demand cannot be met since producers and consumers are far removed in the interconnected world of the 21st century.

International trade transactions exhibit a complex system involving a plethora of inputs, of which logistics is an underlying input. The need for efficient and unwavering physical distribution of goods from sourcing to production to the supplier to the final customer has enhanced the importance of logistics, especially as trade has grown through the modern ages. Consequently, logistics is a critical component of relevance across many important sectors in South Africa, none more so than manufacturing, mining, and agriculture. Therefore, the South African logistics network's smooth functioning must be optimally managed in terms of production and distribution operations.

Progress in logistical performance for the world's least developed economies has slowed for the first time since 2007, while developing countries that implement comprehensive initiatives continue to improve their performance, according to a recent World Bank Group report (Arvis *et al.*, 2018).

Furthermore, logistics cost accounts for a significant component of the input cost in all sectors (see seminal work done by Ghodsypour & O'Brien, 2001 and Zeng & Rossetti, 2003). Additionally, the time-lapse in production and distribution operations is a critical component in a country's competitiveness (see, for example, Shailendrakumar, 2007). Consequently, countries have been forced to develop and integrate logistics strategies into policies and the way cross-border trade is orchestrated. It is understood and exhibited more clearly by those countries capable of taking the lead over competitors, with adjustments to be made on logistics activities and comprehensive logistics strategies. Consequently, this chapter will investigate the concepts of trade, transport, and logistics in South Africa.

This chapter will attempt to add to – and link – the literature overview presented in Chapters 2 and 3 before setting the scene for the empirical work to follow in Chapters 5 and 6. As such, this chapter speaks to both the primary and secondary objectives in that the chapter will first provide further background to the latter by presenting a complete overview of the South African logistics landscape and practical, operational functioning of imports, after which the chapter will add to the former by contributing towards the framework of South African logistics (particularly imports) by outlining all the activities, role players, and requirements of South African imports from the perspective of freight forwarders. As is the case throughout this research, assessing the logistics performance will be done in terms of reducing the time and cost of trade – and ultimately improving the service reliability of logistics service providers in general and South African freight forwarders in particular.

This chapter's structure is as follows: Section 4.2 builds on the brief overview provided in Chapter 1 (Sections 1.1.1 and 1.1.2) and provides an overview of South Africa's current trading landscape by investigating the macro environment, top export and import products, and trading partners and determining the current trends and challenges which the country faces. Section 4.3 provides an overview of the logistics sector in South Africa. This section includes four sub-sections covering logistics infrastructure, transport modalities, role-players within the logistics sector, and the main activities performed. Section 4.4 then inspects the role of ICT in the logistics industry from a South African perspective. These measurements include a view of South African performance, as well as international indices. With a view to the empirical chapter, which is to follow, Section 4.5 and 4.6 then examines the various logistics performance measures conducted to date. Then, finally, Section 4.7 concludes the chapter.

4.2 Overview of the South African trade environment

Until recently, South Africa has been known as the most diversified and industrious economy in Africa (Songwe, 2021). Although the country has lost its crown as the largest economy on the

continent, having been overtaken by both Nigeria and Egypt in the last decade, South Africa remains an African leader on many fronts, including international trade. The following section will highlight South Africa's current trading landscape by investigating the macro environment, top export and import products, and trading partners, as well as determine the current trends and challenges which the country stands facing.

4.2.1 Macroeconomic landscape

South Africa is classified as a middle-high-income country according to the United Nations Population Fund (UNFPA, 2019:1). According to the Economic Complexity Index¹⁷ (ECI), which is a holistic measure of an economy's productive knowledge, South Africa ranked as the 63rd most complex economy in 2018 (Harvard Growth Lab, 2021). In 2022, South Africa generated a GDP¹⁸ of \$380.91 billion (IMF, 2023a) and is currently regarded as a relatively open economy. As such, trade¹⁹ remains an important factor for the economy, constituting approximately 61% of GDP in the last decade (WB, 2023). Consequently, there is a significant reliance on doing business across borders. However, the current level of openness was not always the case, especially in the country's recent history. In 1962, the United Nations General Assembly passed a resolution calling on all member states to impose a trade boycott against South Africa (UN, 1962:9).

Fortunately, global relations have been subsequently turned around, as South Africa's political transition is known as one of the most significant political accomplishments of the past century. The political feats culminated in 1993, when the Nobel Peace Prize was awarded jointly to Nelson Mandela and Frederik Willem de Klerk "*for their work for the peaceful termination of the apartheid regime, and for laying the foundations for a new democratic South Africa*" (The Nobel Peace Prize, 1993). The presiding African National Congress (ANC) had driven the policy agenda from 1994 until mid-2016, when the country held the most competitive local government election since 1994. During the elections, the ANC lost the majority support in half of the eight metropolitan municipalities. Consequently, several political parties (notably the Democratic Alliance and the Economic Freedom Fighters) negotiated coalition deals that have left the ANC unseated in Pretoria and Nelson Mandela Bay.

The following table, calculated from the Penn World Table 10.1 (Feenstra *et al.*, 2015), summarises the main macroeconomic variables for South Africa over the course of the last five

¹⁷ Harvard Growth Lab's Country Rankings assess the current state of a country's productive knowledge, through the Economic Complexity Index (ECI).

¹⁸ Current \$ prices.

¹⁹ According to the WB, "trade" is the sum of exports and imports of goods and services.

years (2015-2019). To provide a more succinct view and accommodate gaps in the data, the average value has been returned.

Table 4-1: South Africa's macroeconomic landscape

Variable definition	Average value (2015-2019)
<i>Real GDP, employment, and population levels</i>	
Expenditure-side real GDP at chained PPPs ²⁰ (in mil. 2017\$)	734 069.90
Output-side real GDP at chained PPPs (in mil. 2017\$)	724 461.69
Population (in millions)	56.99
Number of persons engaged in employment (in millions)	18.28
Average annual hours worked by persons engaged	2 199.55
HCI ²¹	2.81
<i>Current price GDP, capital and TFP²²</i>	
Real consumption, at current PPPs (in mil. 2017\$)	601 437.73
Real domestic absorption ²³ , at current PPPs (in mil. 2017\$)	728 542.30
Expenditure-side real GDP at current PPPs (in mil. 2017\$)	732 304.34
Output-side real GDP at current PPPs (in mil. 2017\$)	723 211.86
Capital stock at current PPPs (in mil. 2017\$)	2 812 466.50
Capital services levels at current PPPs (USA=1)	0.03
TFP level at current PPPs (USA=1)	0.56
Welfare-relevant TFP levels at current PPPs (USA=1)	0.55
<i>National accounts-based variables</i>	
Share of labour compensation in GDP at current national prices	0.57
Real internal rate of return	0.10
Average depreciation rate of the capital stock	0.05
<i>Exchange rates and GDP price levels</i>	
Exchange rate, national currency/\$ (market + estimated)	13.70
Price level of CCON (PPP/XR), price level of USA GDP 2017=1	0.45
<i>Shares in CGDP</i>	
Share of household consumption at current PPPs	0.61
Share of gross capital formation at current PPPs	0.18

²⁰ PPPs = Purchasing Power Parities.

²¹ HCI = Human Capital Index, based on years of schooling and returns to education.

²² TFP = Total Factor of Productivity.

²³ Absorption = Real consumption plus investment.

Share of government consumption at current PPPs	0.22
Share of merchandise exports at current PPPs	0.18
Share of merchandise imports at current PPPs	-0.19
Price levels, expenditure categories and capital (USA GDP 2017=1)	
Price level of household consumption	0.45
Price level of capital formation	0.50
Price level of government consumption	0.45
Price level of exports	0.64
Price level of imports	0.60
Price level of the capital stock	0.31
Price level of the capital services	0.53

Source: Author's calculations based on data from Feenstra et al. (2015²⁴).

In summary, the macroeconomic landscape has been somewhat stagnant of late, with average GDP growth of approximately 1.7% over the last decade to 2019, according to Table 4-1. Indeed, South Africa entered the pandemic after several years of low growth. In 2019, the economy grew by a paltry 0.2% (in 2018, it was 0.8%), partially caused by the resurgence of load shedding associated with operational and financial difficulties at the energy utility Eskom (see Winckler et al., 2023). In addition, as economic activity restarted post-pandemic, pre-existing structural constraints, such as electricity shortages, are becoming binding again (Powanga & Kwakwa, 2023). Global conditions were supportive, but domestic constraints caused a slowdown in GDP growth in 2022 to 1.9% from 4.7% in 2021 (WB, 2023a). The poor growth was driven by a decline in mining production, stagnation in manufacturing, and challenges such as load-shedding and transport bottlenecks. Services sectors, including finance, transport, and domestic trade, were the main growth drivers. The labour market remained weak, with the employment ratio increasing only slightly. The COVID-19 *Social Relief of Distress Grant* was extended until March 2024 to address socio-economic challenges exacerbated by rising fuel and food prices. Inflation averaged 6.9% in 2022, disproportionately affecting the poor. Commodity prices remain important for South Africa, a major net exporter of minerals and a net importer of oil. Strengthening investment, including foreign direct investment, will be critical to propel growth and create jobs (WB, 2023a).

4.2.2 South Africa's top ten products exported and imported

Concerning product groups internationally traded, precious metals, base metals, and agricultural goods have long been leading exports for South Africa, with the country being a world leader in

²⁴ Although the citation notes 2015, the latest available 2019 data has been used. The authors requested to attribute the citation to the original article.

some groups. On the opposite side, chemicals, chemical products, motor vehicles and electronic goods are the main product groups being imported. The following table summarises South Africa’s main products traded, as calculated with the latest 2022 data:

Table 4-2: South Africa’s top 10 products²⁵ exported and imported (\$ billions, 2022)

South African products exported				Products imported by South Africa			
Product	Value	Share ²⁶	Growth ²⁷	Product	Value	Share	Growth
Platinum	16.75	23%	29%	Refined oils	18.69	1.7%	41%
Coal	13.04	5.3%	18%	Cars (passenger)	4.58	0.6%	1%
Iron ore	6.70	4.3%	16%	Crude oils	4.41	0.3%	-21%
Cars (passenger)	5.80	0.7%	-4%	Telephones (Smartphones)	3.54	0.5%	1%
Gold	5.28	1.1%	4%	Computers	2.07	0.4%	4%
Ferroalloys	4.30	8.1%	5%	Cash movement	1.89	40.2%	13%
Delivery vehicles	4.04	2.6%	4%	Vehicle parts	1.80	0.4%	3%
Manganese	2.91	49.3%	-6%	Packaged medicaments	1.80	0.4%	0%
Refined petroleum	2.83	0.3%	-4%	Delivery vehicles	1.02	0.6%	4%
Diamonds	2.66	2%	8%	Batteries	1.00	0.8%	32%

Source: Author’s calculations from the International Trade Centre (ITC) Trade Map, 2023.

From the table, several observations can be made, most notably the mineral-rich nature of South Africa’s resources as showcased in the country’s exported products. The fact that in 2022, South Africa was the world’s largest exporter of platinum (\$16.75bn), manganese ore (\$2.91bn), and chromium ore (\$2.50bn – not listed) illustrates the reliance of trade on natural resources aptly (ITC, 2023b). Other mineral export sectors are also very important, including coal (\$13.04bn), gold (\$5.28bn), and ferroalloys coal (\$4.30bn).

Despite several failings of South Africa’s manufacturing industry, as mentioned in Section 1.1.1, the automotive industry stands out as an important exporting sector, with both passenger vehicles (\$5.80bn) and delivery vehicles (\$4.04bn) featuring in the top ten basket of South African exports.

²⁵ Products at HS level 4.
²⁶ Share in world trade.
²⁷ Annual growth in value between 2018-2022 (% , p.a.).

The products showing the fastest annual growth across the last five years include platinum (29%), coal (18%), and iron ore (16%).

For products imported by South Africa, the reliance on fossil fuels is evident, with refined oils (\$18.69bn) and crude petroleum (\$4.41bn) being two of the top three imported products (ITC, 2023c). Furthermore, the significant share of cars (\$4.58bn), delivery vehicles (trucks) (\$1.02bn), and vehicle parts (\$1.80bn) are also noteworthy. The importation of cash movement (movement of cash via bank notes, postage stamps and revenue stamps) makes an intriguing appearance on the list, as South Africa is incidentally the top importer thereof, at \$1.89bn imported in 2022. The products showing the fastest annual growth across the last five years include refined oils (41%), batteries (32% - these two product groups owing much to the increases in commodity prices, the struggles of South Africa's power utility Eskom, and the closure of two crude oil refineries), and cash movement (13%).

4.2.3 South Africa's main international trading partners

South Africa depends on foreign trade, and its economy is sensitive to global economic conditions. The following table summarises South Africa's main trading partners, as calculated with the latest 2022 data:

Table 4-3: South Africa's top 10 trading partners (\$ billions, 2022)

South African imports				South African exports			
Partner	Value	Share ²⁸	Growth ²⁹	Partner	Value	Share	Growth
China	22.52	20.1%	7%	China	11.94	9.7%	10%
India	8.36	7.5%	19%	USA	10.96	8.9%	20%
Germany	8.27	7.4%	-4%	Germany	10.00	8.1%	10%
USA	8.23	7.4%	10%	Japan	8.60	7%	21%
Saudi Arabia	4.39	3.9%	-3%	UK	6.32	5.1%	11%
UAE	4.14	3.7%	22%	Netherlands	6.00	4.9%	18%
Thailand	3.08	2.8%	2%	Mozambique	5.77	4.7%	14%
Japan	2.84	2.5%	-1%	India	5.14	4.2%	3%
Oman	2.65	2.4%	27%	Botswana	4.71	3.8%	3%
Italy	2.47	2.2%	1%	Belgium	3.98	3.2%	13%

Source: Author's calculations from the International Trade Centre (ITC) Trade Map, 2023.

²⁸ Share in South Africa's trade.

²⁹ Annual growth in value between 2018-2022 (% , p.a.).

China, India, Germany, the United States, and Saudi Arabia are South Africa’s top five biggest importing partners (ITC, 2023d). South African imports have grown the most rapidly from Oman (27%), the UAE (22%), and India (19%) in the last five years. For exports, the same countries feature once more, with China, the USA, Germany, Japan, and the UK being South Africa’s top five biggest exporting partners (ITC, 2023a). South African exports have grown the most rapidly to Japan (21%), the USA (20%), and the Netherlands (18%) in the last five years.

Regional trade in Southern Africa is becoming increasingly important, especially through the Southern African Development Community and, most recently, through the implementation of the African Continental Free Trade Area Agreement (AfCFTA), which establishes a single market for goods across 54 countries, making it the world’s largest free trade area by the number of countries. According to the latest information available from the World Trade Organisation (WTO, 2023c), in 2022 South Africa exported \$122.9 billion worth of products (ranking 39 globally) and imported \$136.2 billion worth of products (ranking 36 globally).

Specific to African trade, almost 90% of South Africa’s exports to the rest of Africa go to SADC member countries, while intra-Africa exports account for only 15% of South Africa’s total exports (calculated from ITC, 2023a). South Africa has numerous agreements with trade partners across the globe, some of which are listed below, but the new AfCFTA agreement will be an enormous opportunity for South Africa to expand its export and import markets.

Table 4-4: List of South African trade agreements and trading areas/blocs

Trade Agreement	Type of agreement	Countries involved
Southern African Customs Union (SACU)	Customs Union	Botswana, Eswatini, Lesotho, Namibia and South Africa
Southern African Development Community (SADC): Protocol on Trade in Goods	Free Trade Agreement: Protocol on Trade in Goods	Among 13 of the 16 SADC Member States
Southern African Development Community (SADC): Protocol on Trade in Services	Services trade liberalisation: Protocol on trade in services	Among 15 of the 16 SADC Member States
Trade, Development and Cooperation Agreement (TDCA)	Free Trade Agreement	South Africa and the European Union (EU)
EFTA-SACU Free Trade Agreement (FTA)	Free Trade Agreement	SACU and the European Free Trade Association (EFTA) – Iceland, Liechtenstein, Norway and Switzerland

SADC EPA States	Economic Partnership Agreement	South Africa, Botswana, Eswatini, Namibia, Lesotho and Mozambique (referred to as the SADC EPA Group), and the European Union (EU)
SACU-Southern Common Market (Mercosur) PTA	Preferential Trade Agreement	SACU and Argentina, Brazil, Paraguay and Uruguay
Zimbabwe/South Africa Bilateral Trade Agreement	Bilateral Preferential Trade Agreement	South Africa and Zimbabwe
Generalised System of Preferences (GSP)	Unilateral preferences granted under the enabling clause of the WTO	Offered to South Africa as a developing country by the EU, Norway, Switzerland, Russia, Turkey, The US, Canada, and Japan.
Africa Growth and Opportunity Act (AGOA)	Unilateral assistance measure similar to the GSP.	Granted by the US to 39 sub-Saharan African countries
Trade agreement under negotiation		
SACU-India PTA	Preferential Trade Agreement	SACU and India
SADC-EAC-COMESA Tripartite FTA	Free Trade Agreement	26 countries with a combined GDP of \$860 billion and a combined population of approximately 590 million people
The African Continental Free Trade Area (AfCFTA)	Free Trade Agreement	The AfCFTA builds on the Tripartite Free Trade Area (TFTA), with the Common Market for East and Southern Africa (COMESA), the East African Community (EAC), and the Southern Africa Development Community (SADC).

Source: Summarised from DTIC (2023).

The composition and reciprocation of the table's trade agreements have undergone a significant change of late, particularly concerning the recent entering into force of the AfCFTA on 30 May 2019 (AU, 2019), and the UK was officially leaving the EU trading bloc on 31 January 2020 (EC, 2020). Nevertheless, since South Africa trades large quantities of goods with most developed countries (note Table 4-4 above), its reliance on the efficacy of these markets and trade agreements is undeniable.

This reliance is noted concerning trade with the UK. When the UK officially left the EU trading bloc, the UK government made it clear that no already established trading agreements were to be affected by this movement. In their attempt to emphasise this promise, the UK government developed a new bilateral agreement to replicate the country's existing trade agreements. As a

result, the SACUM-UK Economic Partnership Agreement, which is a trade agreement between the UK and the Southern African Customs Union Member States and Mozambique, plays a significant role in South Africa's international and regional trade environment. Accounting for 91% of UK trade with SACUM, South Africa ranks as the UK's 27th largest trading partner and produces 0.7% of total UK trade at the time of leaving the EU trading bloc (UK DIT, 2019:8).

On the African continent, South Africa's strongly integrated regional economic infrastructure is represented by its membership towards trade relations such as SADC (Southern African Development Community) and SACU (Southern African Customs Union agreement – a trade agreement with Botswana, Eswatini, Lesotho and Namibia). Another newly introduced trade agreement is the AfCFTA, which commenced in January 2021, bringing enormous hope for an improved regional trading environment for South Africa. The purpose of this agreement, of which 31 of 55 African Union members have signed and ratified (AfCFTA, 2021), is to improve and facilitate intra-Africa trade by cutting tariffs on 90% of goods traded within the continent (ITC, 2018:3).

In summary, South Africa has, over the years, benefitted immensely by moving towards an open economy for trade. Controversially, the country has become severely reliant on the export of primary and intermediate commodities. Although some parts of the country offer well-developed and diversified industries, the country is still earmarked as a developing country due to its large agrarian sector – with a huge part of the population troubled by severe poverty and a lack of access to basic needs, proper healthcare, and education. From an investment point of view the country suffers, as difficulties posed by public enterprises, such as the state-owned power company Eskom, are frequently flagged within the media, not to mention the political unrest and corruption.

4.2.4 Trends and challenges

South Africa has made considerable strides to improve the well-being of its citizens since its transition to democracy in the mid-1990s (see a comprehensive overview by Gumede, 2014:278-299), but progress has stagnated in the last decade. The percentage of the population below the upper-middle-income-country poverty line fell from 68% to 56% between 2005 and 2010, but has since trended slightly upward to 57% in 2015 and is projected to reach 60% in 2020 (WB, 2023a).

Structural challenges and weak growth have undermined progress in reducing poverty, which has been heightened by the COVID-19 pandemic. The achievement of progress in household welfare is severely constrained by rising unemployment, which reached an unprecedented 32.5% in the

fourth quarter of 2020. The unemployment rate is highest among youths aged between 15 and 24, at around 61% (WB, 2023a), which tells a dire tale about the progress.

South Africa remains a dual economy with one of the highest persistent inequality rates in the world, with a consumption expenditure Gini coefficient of 0.67 in 2018 (WB). High inequality is perpetuated by a legacy of exclusion and the nature of economic growth, which is not pro-poor and does not generate sufficient jobs. Inequality in wealth is even higher, and intergenerational mobility is low, meaning inequalities are passed down from generation to generation with little change over time (WB, 2023a).

COVID-19 has had a major impact on South Africa's economy. The World Bank estimated that the economy contracted by 7% in 2020, as the pandemic weighed heavily on both external demand and domestic activity as the government implemented containment measures (WB, 2021b). This severe contraction is estimated to increase poverty by 2 million people (living below the poverty line for upper-middle-income countries, \$5.5 per day in 2011 Purchasing Power Parity exchange rates, PPP) (WB, 2021b). Similar to most countries, an economic rebound occurred in 2021, as the global environment remained supportive, but increasingly severe domestic constraints led to GDP growth slowing to 1.9% in 2022 from 4.7% in 2021 (WB, 2023a). These constraints – although not necessarily directly (as they would need to be tested, which is outside the scope of this research), put further emphasis and potential strain on the logistics network of South Africa. Consequently, the following section will provide an overview of the logistics sector in South Africa.

4.3 Overview of the logistics sector in South Africa

South Africa's logistics costs totalled R429 billion in 2014, and equated to 11.2% of GDP or 51.5% of transportable GDP (Havenga *et al.*, 2016:5). Between 2013 and 2014, logistics costs increased by 9.2% after showing modest growth of 3.5% in the previous period. At 11.2% of GDP, South Africa's logistics cost is significantly less than emerging markets such as Russia, China, and Brazil (20%; 18% and 15% of GDP, respectively), but also considerably more than developed countries such as Denmark, Sweden, and the United States (6.1%; 7.3% and 7.9% of GDP, respectively), (Havenga *et al.*, 2016:6). More recent (albeit less comprehensive) data suggests that South Africa's logistics cost amounted to \$32.9 billion in 2020 (Statista, 2023a), which correlates to an improved 9.7% of GDP according to IMF figures of 2020 (IMF, 2023). Nevertheless, since South Africa is an open economy, thriving on international trade (both imports and exports), logistics cost is especially important.

Logistics cost is not the only consideration for the industry, as significant focus has turned to the productivity and efficiency of the extended logistics network, especially the productivity and efficiency of the state-owned logistics and transport conglomerate Transnet. In fact, the overall performance and related business activities have been so poor that the President created a National Logistics Crisis Committee (NLCC) on 6 June 2023, jointly led by the National Treasury and organised business (SA Government, 2023). The NLCC structure adds to the structure created for the National Energy Crisis Committee (NECOM) and the Joint Initiative to Fight Crime and Corruption (JICC), which will be overseen by a Joint Strategic Operations Committee. The committee is tasked to actively work towards removing obstacles to inclusive economic growth and job creation.

The creation of the NLCC confirms posits that South Africa's logistics industry is, in fact, in a crisis. For the port's economy, not only is the country shipping the same containerised volumes as in 2009, but TPT is doing it 25% less productively than in 2009 (BUSA, 2023:12). Transnet's operational shortcomings have been well-documented, as the extended logistics network has not come anywhere close to its demonstrated capacity (BUSA, 2023:3). Furthermore, Transnet's financial crisis has also been well-documented in the public space, with the Public Investment Corporation (PIC) announcing it has rolled over R4,4 billion of its exposure to the Transnet (TN23) bond that matured on 6 November 2023 into a new short-term commercial paper, maturing in March 2024, and received the balance of more than R250 million (Paton, 2023). Consequently, the creation of an NLCC and the degradation of logistics performance of South Africa's logistics performance (as per TPT's performance, at least) further confirms instances of stagnation and decline, as warned in Section 1.1.2. Therefore, this section will attempt to provide further clarity as to why the South African logistics industry finds itself in a crisis position.

Collectively, this section will provide an overview of the transportation and logistics infrastructure, transport modalities, role-players within the logistics sector, and the main activities performed. Worth reiterating is the overview of logistics systems, as illustrated in Figure 1-2, which shows the various actors involved and the respective levels at which logistics take place. As a reminder, national logistics systems are the providers of infrastructures and spatial connectivity, whereas business logistics systems are the users. This distinction is key, especially when considering which actor is responsible for which activity within the system. This section will elaborate on these considerations.

4.3.1 Transportation and logistics infrastructure

South Africa, akin to numerous analogous emerging economies, presents a unique scenario concerning some of its economic indicators, and this peculiarity extends to its transportation

infrastructure. In specific metrics, such as the aggregate extent of its road and railway networks, the nation attains a prominent position in global rankings. However, within the same top contour indicators, the picture becomes less clear (and certainly more complex) when one considers the level of development within the indicators. As such, the following table, taken from the CIA World Factbook, provides an overview of South Africa's transport infrastructure.

Table 4-5: Transportation infrastructure in South Africa

National air transport system	
Number of registered air carriers	17 (2020)
Inventory of registered aircraft operated by air carriers	243
Annual passenger traffic on registered air carriers	23,921,748 (2018)
Annual freight traffic on registered air carriers	716.25 million metric km ³ (2018)
Airports	407 (2020) – 20 th globally
Airports with paved runways	130 (2020)
Airports with paved runways – over 3,047m	11 (8% of total)
Pipelines	94 km condensate, 1 293 km gas, 992 km oil, and 1 460 km refined products (2013)
Railways	
Total	20,986 km – 13 th globally
Standard gauge	80 km 1.435-m gauge (80 km electrified) (2014)
Narrow gauge	19 756 km 1.065-m gauge (8,271 km electrified) (2014)
Other	1 150 km (passenger rail, gauge unspecified, 1 115.5 km electrified) (2014)
Roadways	
Total	750 000 km (2016) – 10 th globally
Paved	158 124 km (2016)
Unpaved	591 876 km (2016)
Merchant marine	
Total	103 – 86 th globally
By type	Bulk carrier 3, general cargo 1, oil tanker 6, other 93 (2020)

Major seaports(s)	Cape Town, Durban, Port Elizabeth, Richards Bay, Saldanha Bay
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Source: CIA (2021).

As Table 4-5 indicates, South Africa is undeniably endowed with an abundance of transportation infrastructure. Nevertheless, the state of development, as well as the maintenance, often falls short of the desired global standards. To illustrate this point, one can refer to the subsequent table showcasing the insufficient maintenance of the nation's road infrastructure per province:

Table 4-6: Provincial paved and gravel road conditions

Authority	Very poor		Poor		Fair		Good		Very good	
	Paved	Gravel	Paved	Gravel	Paved	Gravel	Paved	Gravel	Paved	Gravel
Eastern Cape	6.0%	30.0%	35.7%	35.0%	36.3%	25.0%	21.8%	8.0%	0.2%	2.0%
Free State	33.0%	11.0%	33.0%	23.0%	27.0%	24.0%	6.0%	23.0%	1.0%	19.0%
Gauteng	0.8%	0.0%	9.3%	33.0%	33.5%	65.8%	26.3%	1.2%	30.1%	0.0%
KwaZulu-Natal	7.0%	3.7%	29.0%	53.2%	34.0%	40.1%	16.0%	2.7%	14.0%	0.2%
Limpopo	2.5%	35.0%	10.6%	50.0%	18.0%	15.0%	26.8%	0.0%	42.1%	0.0%
Mpumalanga	6.0%	0.0%	28.0%	61.0%	35.0%	32.0%	21.0%	7.0%	10.0%	0.0%
North West	39.6%	93.0%	11.5%	7.0%	15.6%	0.0%	21.2%	0.0%	12.0%	0.0%
Northern Cape	1.0%	2.0%	13.0%	33.0%	32.0%	51.0%	32.0%	11.0%	22.0%	3.0%
Western Cape	2.0%	4.6%	11.0%	38.8%	29.0%	45.5%	36.0%	9.3%	22.0%	1.8%
Total	11.5%	21.1%	20.7%	34.5%	28.6%	29.3%	22.3%	9.9%	16.9%	5.2%

Source: Ross & Townshend (2019:4).

The table, which was calculated by Ross and Townshend (2019:4) based on 2017 provincial Road Asset Management Plans (RAMP) data, shows that a mere 39.2% of paved and 15.1% of gravel roads are in good or very good condition. Furthermore, according to the road condition data presented in Table 4-6, which was taken from the provincial RAMPs, 15 728 km of provincial paved roads were in poor and very poor condition in 2017. This maintenance backlog is 10 834 km above the acceptable benchmark of 10.0%.

The South African Institution of Civil Engineering (SAICE) scored provincial paved roads a "D" (at risk of failure) in the 2017 Infrastructure Report Card (IRC). The current IRC, following the initial 2006 and the follow-up 2011 IRCs, extended the sectors assessed to ten, comprising 29 sub-sectors. These include water supply and distribution, electricity, roads and rail, schools and universities, sanitation and wastewater, solid waste management, etc. The overall grade awarded for the state of South Africa's infrastructure in 2017 is D+.

A short explanation of the symbols is as follows: A = World-class; B = Fit for the Future; C = Satisfactory for Now; D = At Risk of Failure; and E = Unfit for Purpose.

Provincial gravel roads were in a relatively worse condition and hence scored an “E” (unfit for purpose) by SAICE (2017) in the 2017 Infrastructure Report Card. Table 4-6 indicates that 55.6% of the provincial gravel road network was in poor and very poor condition in 2017. This equates to a 96 703 km maintenance backlog on provincial gravel roads, which exceeds the acceptable limit of 10.0% by 79 330 km.

As far as rail is concerned, heavy-haul freight was given a B+ with a D+ for passenger lines. Unfortunately, the importance of rail has diminished and has seen its market share being taken by road transport. According to the Road Freight Association (RFA), its volumes have grown more than 20% from 2005 to 2015. Moreover, approximately 88% of all cargo is transported by road. RFA said this was a significant increase from 76% of freight transported by trucks 20 years ago. However, the country's rail freight network owner and operator, Transnet, said in its annual report that it had at least 24% of the market share in 2012-13 and planned to increase this to 35% by 2018-19 (Maqutu, 2015).

Certainly, there is substantial heterogeneity in the development, extent, and, debatably, the significance of various modes of transport, as evidenced by the diminishing market share of rail transport. However, owing to South Africa's geographical positioning, encompassing domestic, regional, and global dimensions, all modes of transport assume a pivotal role in the intricate nature of the operation of South Africa's broader transportation and logistics framework. Therefore, the subsequent section offers a comprehensive survey of the different transport modalities in the country.

4.3.2 Transport modalities

The following section outlines the most common transport modalities used worldwide, as is indeed the case in South Africa. Since maritime transport accounts for over 80% of the world trade volume and is the backbone of the global economy (Kosowska-Stamirowska, 2020:12719), the section will start with the most important transport modality. Thereafter, the other important transport modalities – air, road, and rail³⁰ – in South Africa will also be investigated.

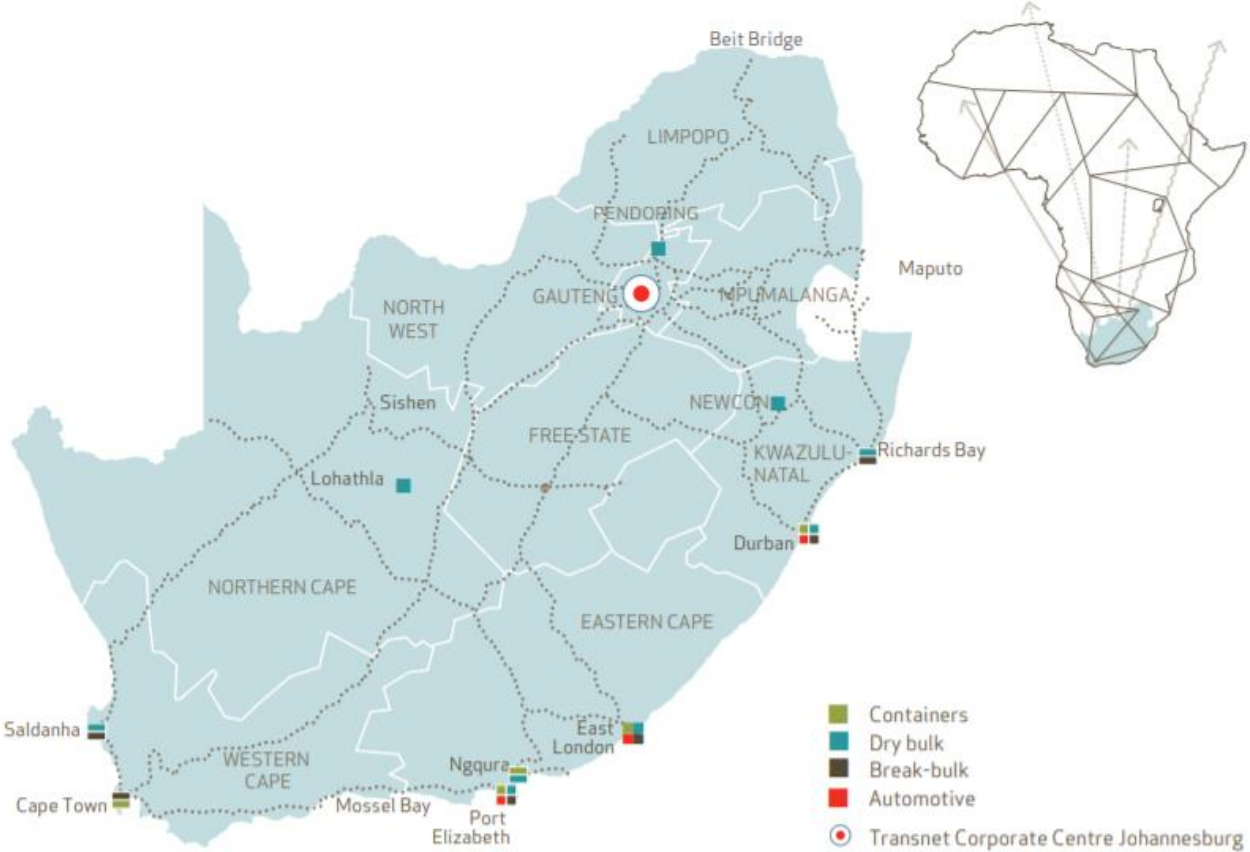
4.3.2.1 Ocean

The ports under the control of the TNPA span the South African coastline, which measures approximately 2 800 km (TNPA, 2020:2). South Africa has eight commercial ports, with a total of

³⁰ Inland waterborne shipping and pipeline transport have been excluded from this analysis, as the former is not a prevalent mode of transport within South Africa, while the latter is infrequently orchestrated by freight forwarders; instead, the majority of pipeline transportation in South Africa is overseen by Transnet Pipelines (Transnet Pipelines, 2023).

five container terminals (Cape Town, Durban, East London, Ngqura, and Port Elizabeth – although some containerised operations take place at Richards Bay) operated by Transnet Port Terminals (TPT). TPT was established in 2000, when Transnet’s then single port division, South African Port Operations (SAPO), was divided into operations and landlord businesses, namely, TPT and the National Port Authority (TNPA). The following figure provides a general overview of the geographic location of the national ports system, as well as notes the main types of cargo being handled at these commercial ports.

Figure 4-1: South Africa’s commercial ports



Source: TNPA (2020).

As depicted in Figure 4-1, the South African port systems consist of seven commercial ports spanning across the entire coastline, from Richards Bay in the northeast to Saldanha in the southwest. The figure also depicts the core rail network linking the respective ports with the rest of the country, and, indeed, the economic hub of Gauteng (more on rail cargo in Section 4.3.2.4.). In the top right of Figure 4-1, South Africa’s position within the greater African continent is also illustrated, which has long been seen as the “gateway into Africa”, or at least, southern Africa. Although South Africa is arguably losing its label as the “gateway into Africa” (Barron, 2021; Venter, 2021), the country nevertheless enjoys an important position within global maritime trade lanes.

The important position is illustrated by Figure 4-2, which illustrates the prominent international maritime trade routes. The merchant fleet is divided into five categories and accompanying colours, namely container (yellow), dry bulk (blue), tanker (red), gas bulk (green), and vehicle (Ro-Ro) transporters (purple). Despite the map's origin in 2012, the key focal areas it portrays have persisted to this day.

Figure 4-2: Global shipping routes in 2012



Source: Clark & Houston, 2012.

As illustrated above, most of the maritime traffic occurs in the northern hemisphere, especially concerning containerised cargo. A significant volume of dry bulk is shipped in the southern hemisphere around South Africa; however, what is key to notice is that a fair amount of traffic does flow around the Cape of Good Hope.

The following table outlines the respective services and South African port calls of international container carriers. Many services are in competition and call at several South African ports; however, with several services, the choice of port is limited to one or sometimes two of our major commercial ports.

Table 4-7: Services and port South African port calls (container liners)

Carrier	Service	Frequency	First port	Second port
CMA CGM	Shaka 2	Weekly	Durban	-
Hamburg Sud	ASAF 1	Weekly	Durban	Port Elizabeth
Hamburg Sud	ASAF 2	Weekly	Cape Town	-

Maersk	Safari (West)	Weekly	Durban	-
Maersk	FEW 6 – (West)	Weekly	Cape Town	-
CMA CGM	Asia – West Africa	Weekly	Cape Town	-
COSCO	ZAX1	Weekly	Durban	Port Elizabeth
Maersk	FEW6	Weekly	Cape Town	-
Nile Dutch	FEWA	Weekly	Cape Town	-
OOCL	WAF4	Weekly	Cape Town	-
PIL	ASA	Weekly	Durban	Cape Town
Evergreen/PIL	FAX	Weekly	Durban	-
COSCO	ZAX2	Weekly	Durban	Cape Town
Evergreen	ASA	Weekly	Durban	Cape Town
ZIM/GSL/Hapag Lloyd	SA1	Weekly	Durban	-
ZIM/GSL/Hapag Lloyd	SA2	Weekly	Durban	Cape Town
ONE	SAS	Weekly	Durban	Cape Town
OOCL	SAF2	Weekly	Durban	Cape Town
COSCO	ZAX3	Weekly	Durban	-
ONE	SAC	Weekly	Durban	-
MSC	INGWE	Weekly	Durban	Ngqura ³¹

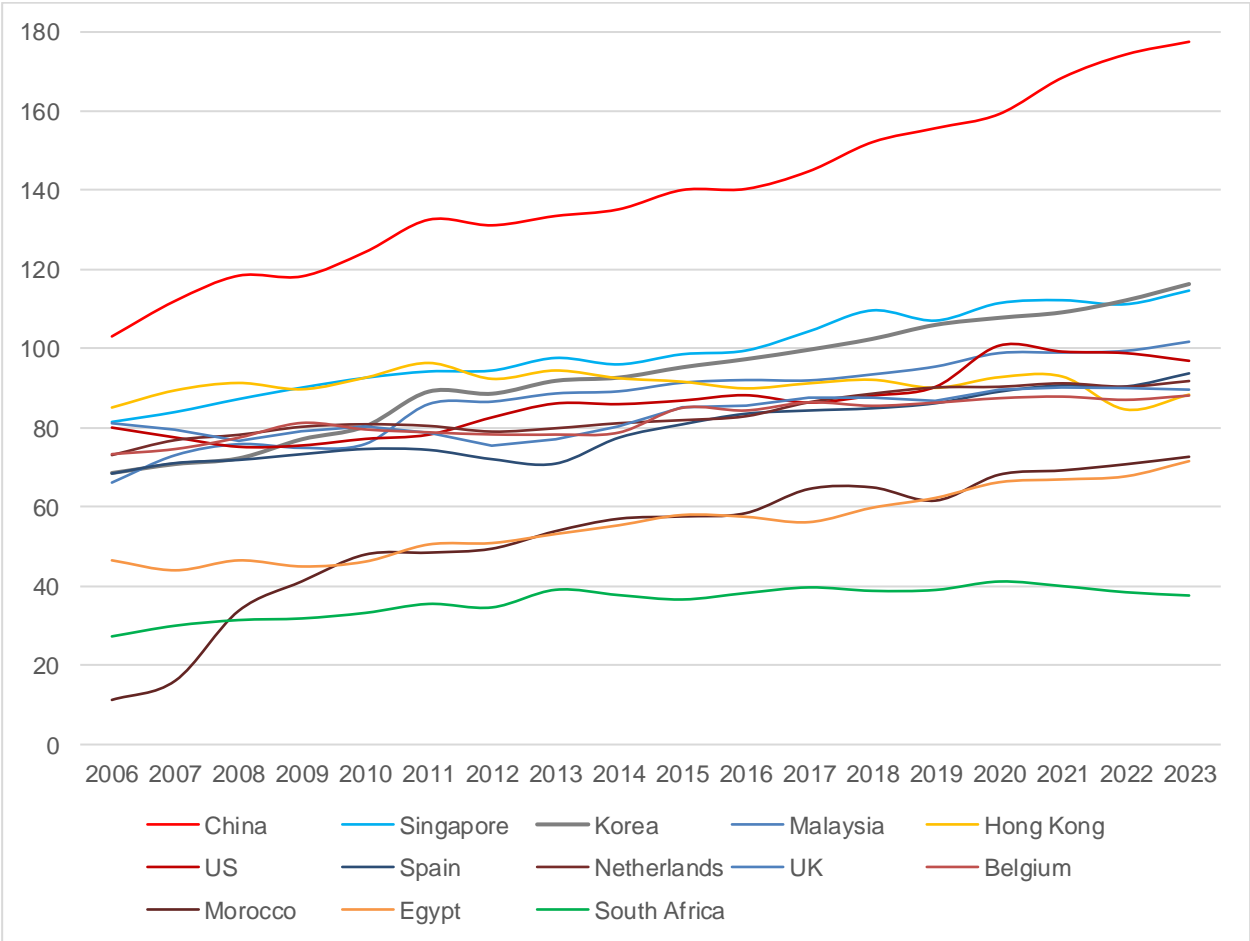
Source: Author's own compilation based on respective carriers' services³².

By consulting the Liner Shipping Connectivity Index (LSCI) developed by UNCTAD, further insight into the subject can be provided. The LSCI indicates a country's integration level into global liner shipping networks. The LSCI is an index set at 100 for the maximum value of country connectivity in the first quarter (Q1) of 2006, which was China (UNCTAD, 2021). Included in the comparison is South Africa, along with several top-performing African countries. UNCTAD calculates the LSCI quarterly. However, for ease of reference, the yearly average (i.e., averaged across four quarters) is shown.

³¹ The INGWE service also calls at a third South African port, namely Cape Town.

³² The information is correct for July 2021 to August 2023, and falls within the investigated period for this thesis.

Figure 4-3: LSCI, top ten and selected African countries (2006-2023)



Source: Author’s calculations based on data from UNCTAD, extracted via the WB development indicators, 2023.

Several matters stand out from Figure 4-3, namely that most countries have experienced a significant increase in LSCI. Moreover, each country’s connectivity has consistently grown over the last 17 years. Over the period in question and concerning the top ten countries and the top three African countries, the average annual increase in connectivity is 2.4%. Most countries hover in the 1%-3% range, with the standout being Morocco, growing at an annualised return of 11%. For South Africa, the growth rate, incidentally, is 1.8%. However, clearly illustrated above is the apparent plateau experienced from 2013 onwards. Nevertheless, in an overall sense, South Africa comes in at 39th position globally concerning liner shipping connectivity. Given South Africa’s geographical location, 2 800 km of coastline, as well as its important economic position as the gateway to (at least) southern Africa, one would expect that South Africa should be reasonably well-connected with its international trading partners. However, as Figure 4-3 illustrates, shipping connectivity has seemingly plateaued in the last decade.

The following table shows the volume of cargo handled by South Africa's respective commercial ports in the last four years (2019 to 2022), which also provides a distinct view of the impact of the pandemic on South African maritime trade.

Table 4-8: TNPA – volume and growth: January-December 2019 to 2022

Cargo type	Jan-Dec 2019	Jan-Dec 2020	Jan-Dec 2021	Jan-Dec 2022	Growth '19-20	Growth '20-21	Growth '21-22
Containers (TEU)	4 528 467	4 075 618	4 415 401	4 250 464	-10%	8%	-4%
Landed	2 319 625	2 017 264	2 227 031	2 178 876	-13%	10%	-2%
Shipped	2 208 842	2 058 354	2 188 370	2 071 588	-7%	6%	-5%
Dry bulk (MT)	185 680 653	177 699 490	172 451 138	167 909 017	-4%	-3%	-3%
Liquid bulk (MT)	41 666 684	38 255 183	40 418 515	36 632 947	-8%	6%	-9%
Breakbulk (MT)	5 314 201	3 601 646	5 116 841	5 711 796	-32%	42%	12%
Vehicles (Units)	774 028	496 768	648 044	830 701	-36%	30%	28%
Total Cargo³³	232 661 538	219 556 319	217 986 494	210 253 760	-6%	-1%	-4%

Source: Author's calculations based on data from TNPA, 2023.

The impact of the pandemic on ocean freight is clear (see Grater & Chasomeris, 2022), as the overall growth across the board in 2020 was -6%, which excludes motor vehicle trade. However, during the year, the volume of vehicles moving through South Africa's port systems was the hardest hit of all commodities, falling some 36%. For 2021, most sectors returned positive growth compared to 2020 but failed to register pre-pandemic levels of 2019. Container throughput in 2021 grew by 8%, but still fell short of 2019 numbers. Subsequently, container throughput has subsided further and is roughly similar to levels seen in 2009 (which was around 4.33 million TEU, according to TNPA data (TNPA, 2023)). As for total cargo handled, 2021 saw another year of contraction, with a 1% reduction in activity. Vehicles trade grew by 30% in 2021 but was still -16% down on 2019 levels. For 2022, total cargo decreased further, by -4%, as dry bulk and liquid bulk were mostly down. The overall picture does not bode well for trade and further confirms the stagnation and decline of the sector, as mentioned in Section 1.1.2.

4.3.2.2 Air

In South Africa, Airports Company South Africa (ACSA) owns and manages a network of nine commercial airports in South Africa, including the three main international gateways of O.R. Tambo International, Cape Town International and King Shaka International Airports. In the financial year 2019/20, the nine airports facilitated nearly 42 million passengers (ACSA, 2021). As with the rest of the aviation industry, the industry was severely hit by the global pandemic in

³³ Measured in metric tonnes, excluding containers and vehicles.

2020 and 2021 as passenger numbers dwindled. For the financial year 2022/2023, approximately 35 million passengers (ACSA, 2023) passed through, recovering to 84% of pre-COVID traffic. The following images show the locations of South Africa’s commercial airports:

Figure 4-4: South Africa’s commercial airports



Source: ACSA, 2022.

Besides the passengers making use of these airports, all nine commercial airports have domestic cargo handling facilities, with the main international gateways also handling international cargo. The following shows a breakdown of the passenger numbers and cargo volumes handled per airport. Due to the devastating effect of the pandemic, the passenger numbers shown are from the 2022/2023 financial year and depict international, regional, domestic, and unscheduled passengers. The cargo numbers shown are the latest figures from 2023, as provided by the Air Cargo Operators Committee (ACOC).

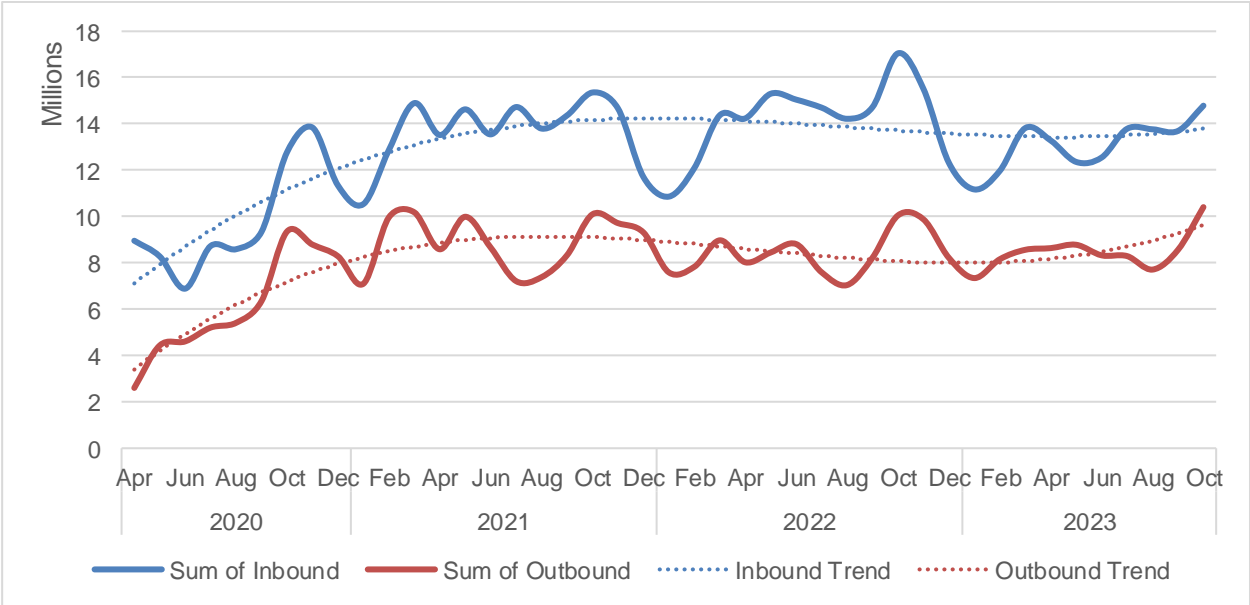
Table 4-9: South Africa’s commercial airports – passengers and cargo (2023)

Airport Name	City	Passengers share	Domestic cargo share	International cargo share
OR Tambo International Airport	Johannesburg	45%	30%	80%
Cape Town International Airport	Cape Town	24%	43%	18%
King Shaka International Airport	Durban	12%	5%	2%
Lanseria International Airport	Johannesburg	7%	0%	-
Port Elizabeth Airport	Port Elizabeth	3%	12%	-
Ben Schoeman Airport	East London	2%	5%	-
George Airport	George	2%	4%	-
Bram Fischer International Airport	Bloemfontein	1%	1%	-
Eastgate Airport	Hoedspruit	1%	-	-
Kruger Mpumalanga International Airport	Nelspruit	1%	-	-
Others	-	2%	-	-

Source: Author’s calculations based on data from ACSA and ACOC, 2023.

OR Tambo International Airport accounts for almost half of the passenger numbers, approximately 30% of the domestic numbers, and approximately 80% of the international air cargo handled. However, these numbers have all declined in recent years, as Cape Town International Airport is playing a more prominent role for both passengers and cargo handled. The following graphs show the movement since the pandemic’s onset for OR Tambo International Airport, with export cargo seeing a very welcome uptick to its highest levels since the pandemic:

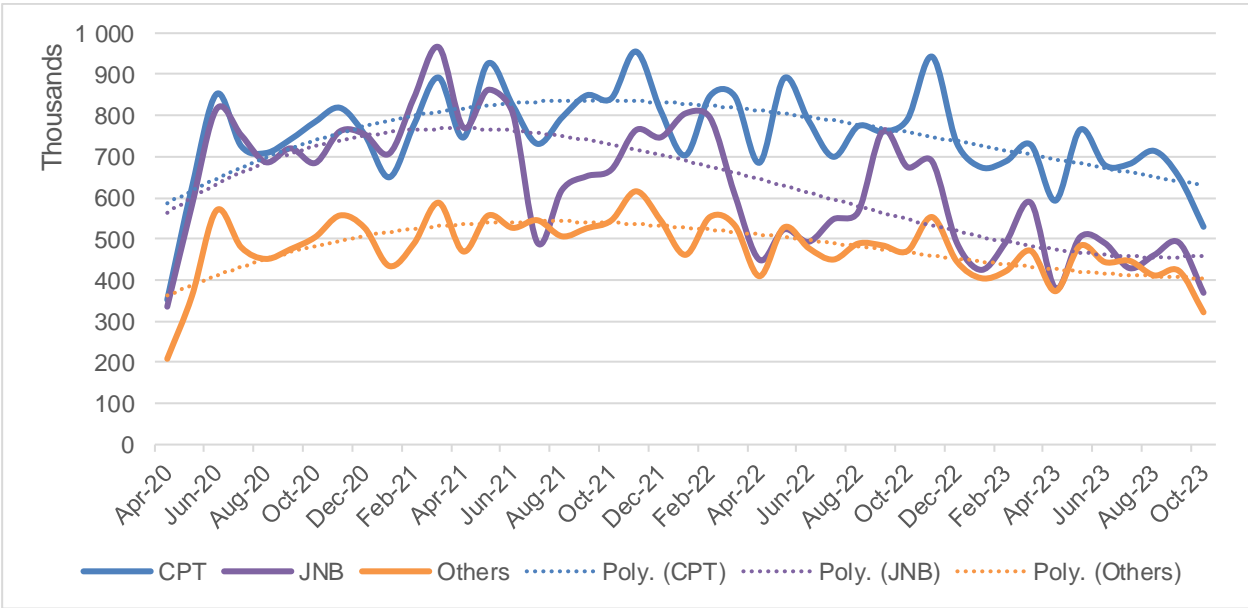
Figure 4-5: International cargo from OR Tambo – volumes per month (kg millions)



Source: Author’s calculations based on data from ACOC, 2023.

The following table shows the domestic cargo handled at OR Tambo, Cape Town, and King Shaka International Airports since the start of the pandemic:

Figure 4-6: Domestic inbound and outbound cargo (kg, thousands)



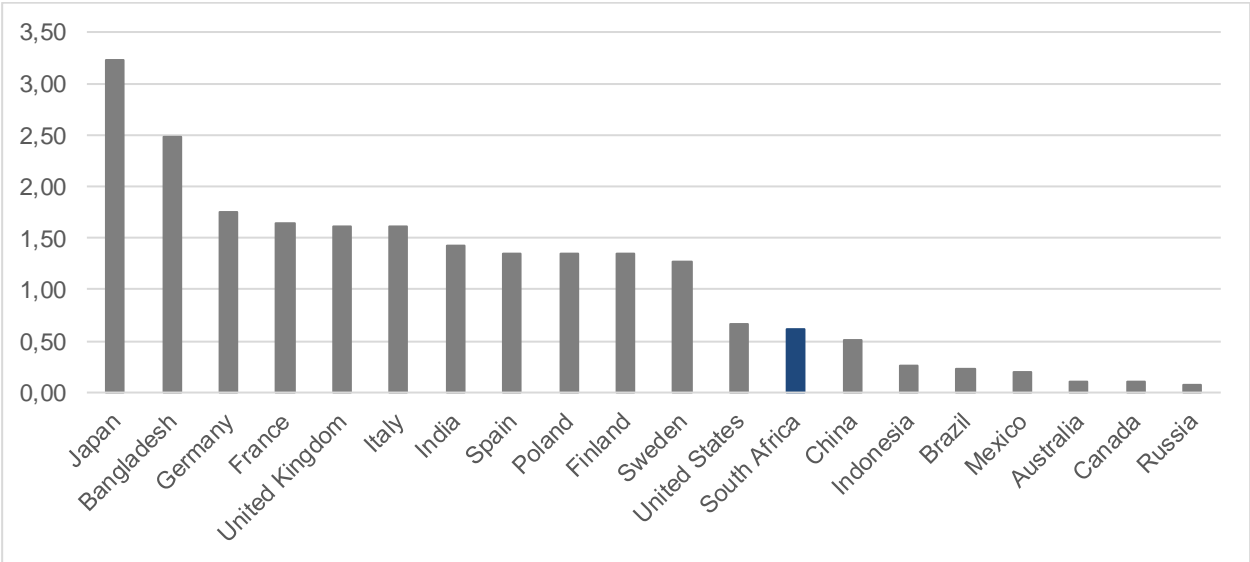
Source: Author’s calculations based on data from ACOC, 2023.

As Figure 4-6 illustrates, there has been an evident decline in domestic air cargo handled in the last two years. The decline has been apparent across all airports but more pronounced at Johannesburg’s OR Tambo. Cape Town has dropped off significantly, but has maintained some level of air cargo throughput during this time.

4.3.2.3 Road

South Africa has one of the world’s largest road networks. The whole South African road network is approximately 750 000 km. The 163 472 km of paved roads within this entire network places South Africa 18th in terms of the volume of surfaced roads (SANRAL, 2016). Concerning road density, the country compares even better, globally ranking 13th. Figure 4-7 analyses and compares the extent of the South African road network concerning the surface area. With 0.62 km of road per km² of surface area, the South African road network density is comparable with developed countries and their BRICS partners. This relatively high level of service demonstrates that South Africa has a mature road network that resembles developed rather than developing countries.

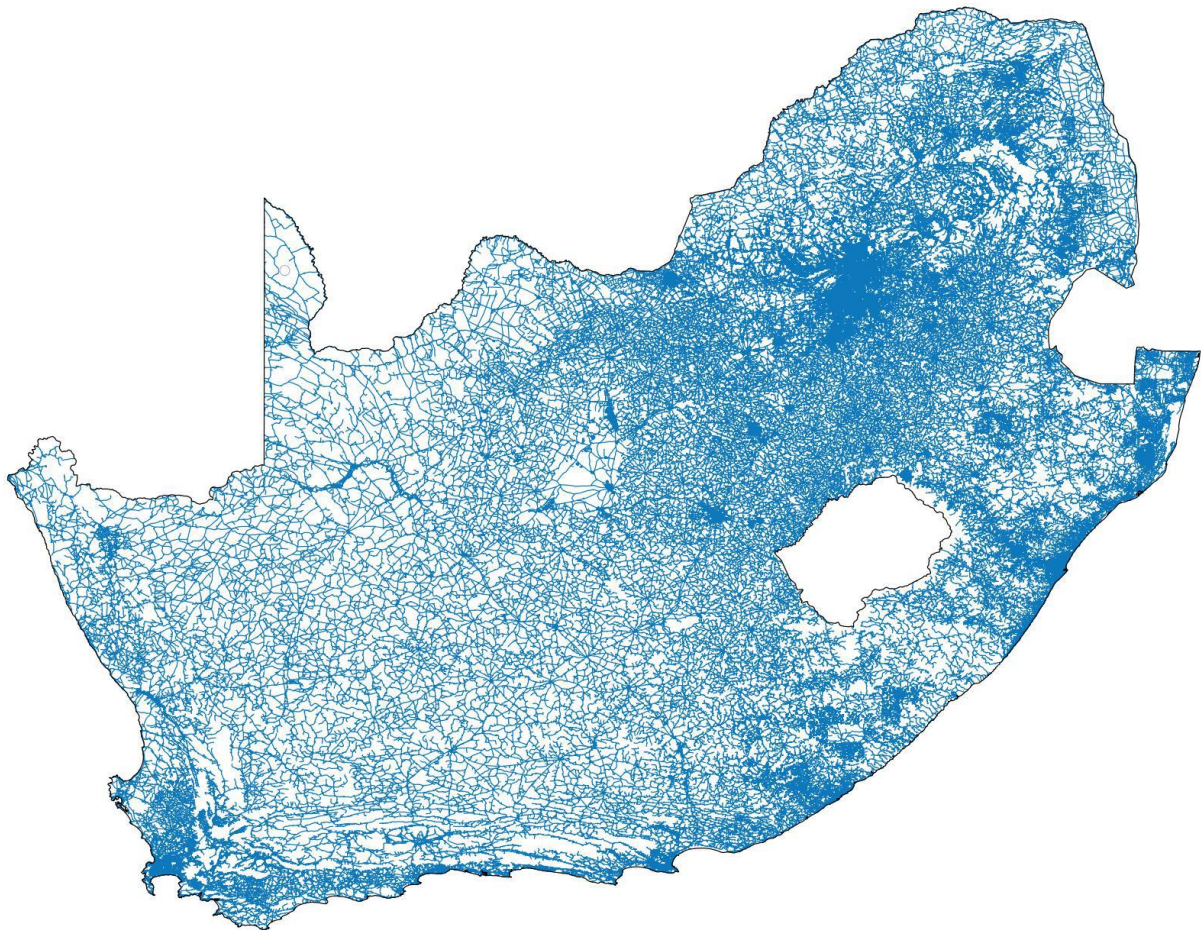
Figure 4-7: Kilometres of road per area (km²), top 20 based on the total road network



Source: Author’s calculations based on CIA (2021).

To visualise the system, Figure 4-8 maps the recorded South African road network. The figure shows a vast extension of the national road network across the entire country. The high number of connections suggests a high degree of first and last-mile access, along with many cross-country mobility routes. The road density is visibly higher in certain areas, which tend to mirror the urban boundaries and regions with more economic activity (Townshend, 2020:16). These regions are evident in the Gauteng province, as well as along the coast – with significant concentrations around Cape Town, Gqeberha (Port Elizabeth), and Durban.

Figure 4-8: The South African road network



Source: CSIR, 2011.

Along with the extensive length and good connectivity of the South African road network, there has been a slight upward trend in the overall quality of the road infrastructure. SANRAL reports an overall condition index average of 74 in 2018, which is also above the international norm of 70 (Nkabine, 2019:22). The index has been trending upward from around 68 in 2013. The overall picture is similar when compared to international measures. Moreover, within the WEF’s GCI report sub-index of “quality of roads”, South Africa was ranked between 29th and 58th over the period 2007 to 2019, with an overall increase in score. The significance of this road quality indicator is heightened by the relative transport intensity of the South African economy and the heavy reliance on road transport (Townshend, 2020:28). Certainly, the continued reliance on road freight sounds alarms for accompanying road infrastructure and, alternatively, the failings of rail freight. Industry role players are well aware of the state of road infrastructure – especially linking the rural economy with the major transport networks in the country – even though the latest (although slightly dated) “SA Infrastructure Report Card” (SAICE, 2017:9) lists our national roads at “B” grade. Delving deeper, our paved provincial roads score a “D”, and our paved metropolitan

roads a “C-minus”. South Africa’s freight demand is high, and road freight cannot maintain the burden. We need a multi-modal approach and a working rail sector to play its part.

4.3.2.4 Rail

Railway transport in South Africa has a history of more than 150 years. Rail transport in South Africa is an important element of the country's transport infrastructure. Despite the development of other modern and sophisticated transportation modes, rail transport still ranks as the most efficient means of transport for the conveyance of bulk freight over medium and long distances and for mass commuter traffic. Freight rail maintains a complex rail network of approximately 31 000 track km (20 911 route km) over which commodities are railed. The diverse rail network comprises ~1 500 km heavy haul lines. The network also includes 3 928 km of branch lines that serve as feeders to main lines (TNPA, 2020:4). It is an incredible national asset and makes up more than 85% of the total installed rail track base on the continent of Africa. It should be the source of a great national competitive advantage.

Figure 4-9: The South African rail network

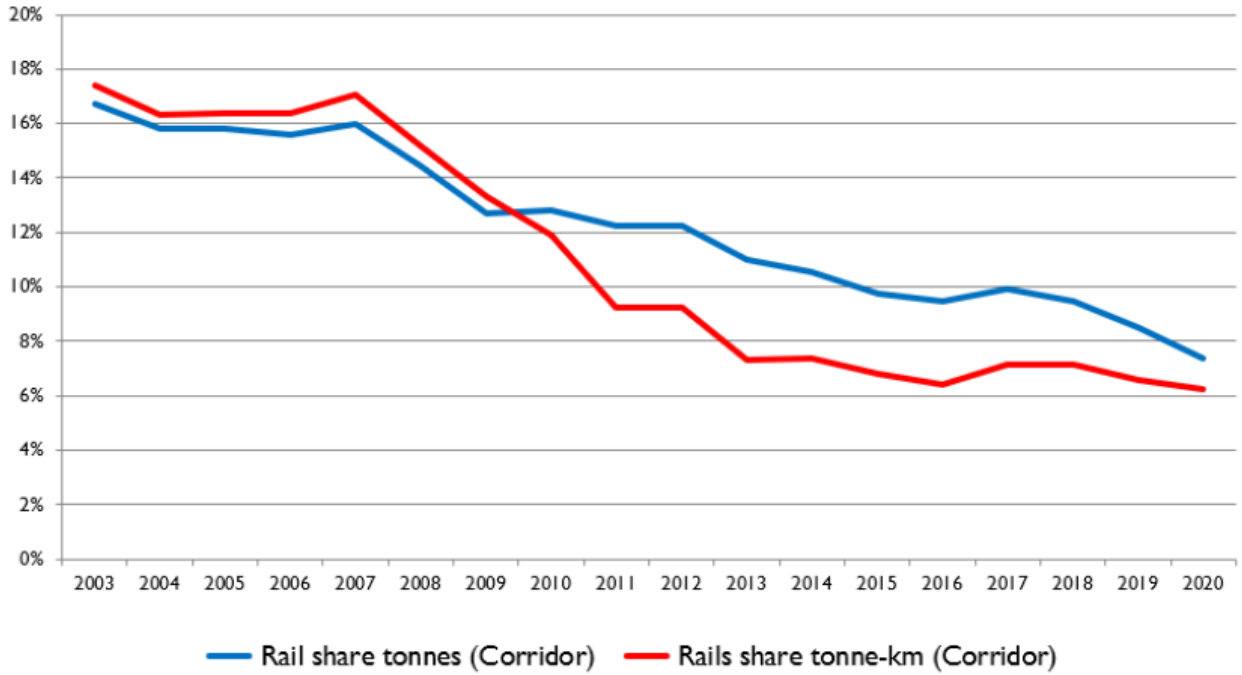


Source: TNPA, 2020.

Unfortunately for rail transport in South Africa, the sector lost significant market share to road transports from 1975 onwards – culminating in the late 1980s – when the land freight transport sector was deregulated. These policy developments ultimately affected rail’s capacity to compete with road, and significantly reduced its capacity through rationalisation over approximately 20-25

years. Furthermore, a huge backlog in the maintenance of infrastructure and rolling stock had accrued (CSIR, 2013:43). Nevertheless, since 2005, there has been a concerted drive by TFR to restore rail competitiveness. Moreover, with the establishment of the African Rail Industry Association (ARIA), TFR’s strategic plan has been assisted by the private sector’s drive to get historic rail cargo back on the rail. ARIA estimated that some 58 million tons of cargo would immediately move to rail when third-party access is permitted (ARIA, 2021). These potential structural shifts are key, as the rail sector has performed very poorly in recent years, as depicted in this figure:

Figure 4-10: Trends in South African rail corridor market share (tonnes and tonne-km)



Source: Havenga et al., 2020.

The railway sector saw a slight increase in its market share for tonne-kilometres, rising from 35% to 37% during the period (Havenga et al., 2021:11-12). This was primarily due to significant growth in the transportation of export manganese, coal, and iron ore via dedicated ore lines. However, when mining commodities for export are excluded, rail's tonne-kilometres market share decreased from 11% to 10%. When considering market share as a percentage of outsourced freight (freight transported for compensation, accounting for approximately 50% of all freight), rail's share declined from 31% to 27%. In terms of general freight corridor tonnage, rail's market share decreased from 19% to 11%. Even when focusing solely on palletised long-distance freight, which aligns with rail's strengths but is scarcely present in South Africa, there has been minimal market penetration. The declining trends in rail corridor market share over the past two decades represent a significant policy failure, as reestablishing density in corridors was a key objective outlined in early rail policy and strategy documents in South Africa (Havenga et al., 2021:11-12).

4.3.3 Role players within the logistics sector in South Africa

Linking all the different cargo owners and role players in the extended supply chain is crucial for the success of any complex system, such as the logistics network in South Africa. The following table provides a non-exhaustive list of the role-players within the logistics industry, including the associated industry body.

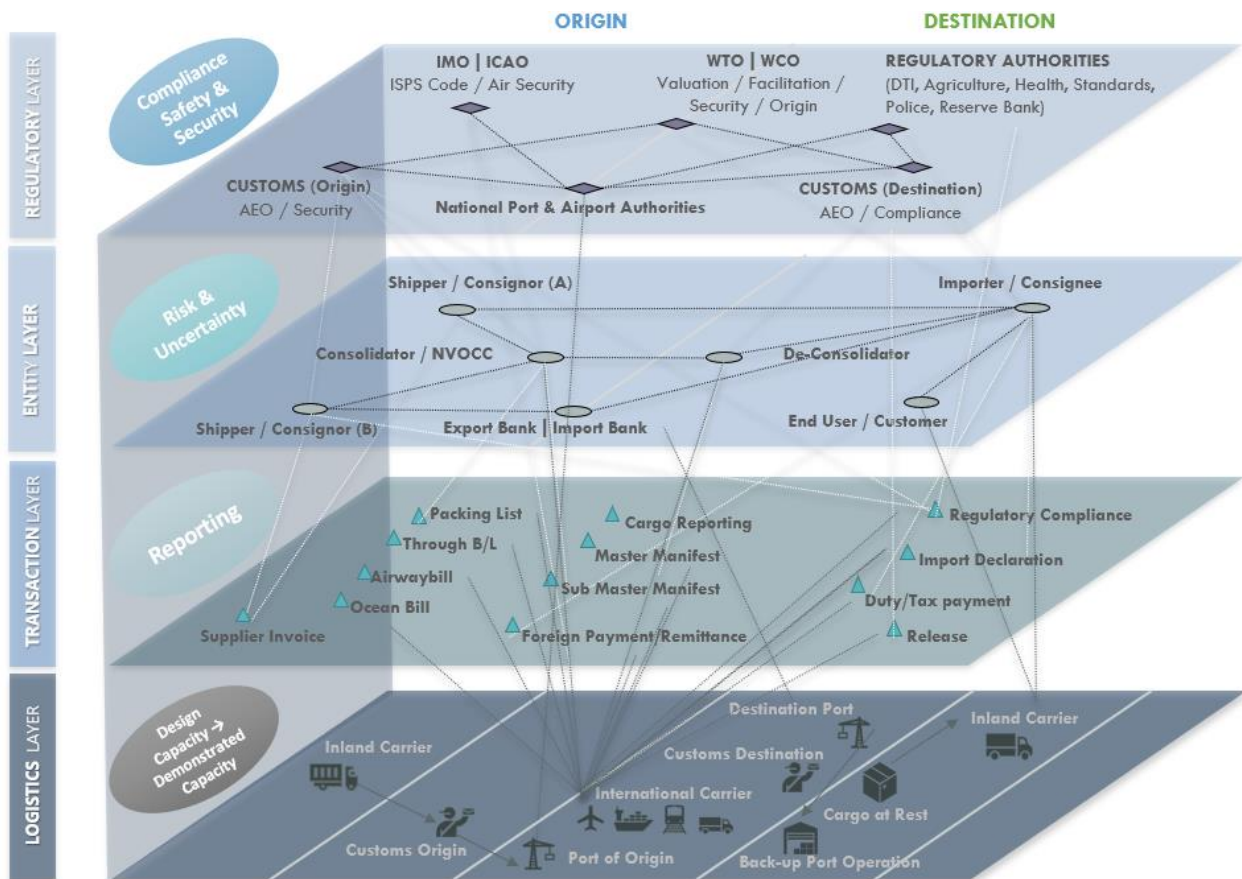
Table 4-10: Logistics industry role players active in the extended supply chain

Role player	Industry body
Banks and financial service providers	The Banking Association South Africa (BASA)
Banks and financial Cargo owners	Business Unity South Africa (BUSA)
Customs authority	South African Revenue Service (SARS)
Other government authorities	Border Management Authority (BMA), The Cross-Border Road Transport Agency (C-BRTA), The Department of Transport (DOT)
Shipping lines	South African Association of Ship Operators and Agents (SAASOA)
Terminals	Transnet Port Terminals (TPT), private operators
Depots	The South African Association of Freight Forwarders (SAAFF), SAASOA, and other privately owned facilities
Warehouses (storage facilities)	Intermediates, cargo owners, government
Air cargo	Airlines, de-grouping facilities, Air Cargo Operators' Committee (ACOC)
Courier companies	South African Express Parcel Association (SAEPA)
Freight forwarders and Customs Brokers	Customs brokers, SAAFF
Transporters/long distance	Road Freight Association (RFA), Federation of Southern African Road Transport Associations (FESARTA), harbour carriers
Technical service providers	Technical Service Providers Association of South Africa (TSPA)

Source: Author's own compilation, 2022.

The following figure provides a general overview of the role players mentioned in the table above, showcasing the South African supply chain's intertwined nature.

Figure 4-11: Understanding the players in the South African supply chain



Source: Adapted from Poverello, 2019.

The South African supply chain can be roughly divided into four distinct layers: (1) a regulatory layer, (2) an entity layer, (3) a transaction layer, and (4) a logistics layer. The regulatory layer enforces rules of behaviour and is captured by legislation, external policy guides, and international trade regulations. In South Africa, SARS Customs and Excise plays an integral role in facilitating the movement of goods entering or exiting the borders of the country, as well as facilitating the levying of duties on certain locally manufactured goods and their imported equivalents (SARS, 2021).

The entity layer interconnects various actors in the supply chain according to their role and function in the supply chain, and facilitates all key steps of the system as a whole. The transactional layer comprises the role players driving international trade, including manufacturers and traders (or cargo owners), facilitating entities such as banks, insurers, and guarantors, and logistics services providers, such as transporters, carriers, and agents. The transactional system produces and distributes goods that are driven primarily by the exchange of information. Lastly, the logistics layer involves the physical flow of cargo, i.e., the transnational transportation of goods.

4.3.4 Main activities performed in a logistics system

The following image depicts a generic, over-simplified, ten-step supply chain starting from a manufacturing plant. The use of this image explains the processes of the following sub-sections in greater detail. Figure 4-12 illustrates a typical import process, although the fundamental steps for an export process are similar, albeit in reverse order.

Figure 4-12: A generic supply chain



Source: Author's own compilation, 2021.

4.3.4.1 The customs clearance process

Since a significant amount of data gets captured in and around the customs clearance process, the main reason behind the richness of data is the fact that many aspects of the customs clearance process are mandatory, and are therefore required for official purposes, such as the clearance of goods (country of origin, product classification, valuation, and the like), taxation (duties, rebates, and more), and trade statistics (balance of payments). Consequently, an understanding of the process is crucial. Subsequently, a brief explanation of the customs clearance and port clearance process follows:

- Commercial cargo is precleared in all instances – no conveyance carrying commercial cargo can enter a border post without pre-clearing the goods.
- Goods are divided into two types of cargo: cargo in free circulation and bonded cargo. Bonded cargo is cargo moving in transit through South Africa or goods placed in a licenced Customs warehouse facility, on which duty and VAT have not been paid and removed for export, or goods arriving at an entry point and cleared for warehousing, or removal in bond to an inland office.
- A declaration is lodged mainly via electronic data interchange (EDI) to Customs – manual declarations are permissible but limited in terms of legislation. Henceforth, most declarations are lodged by clearing agents on behalf of importers and exporters and are, therefore, electronically lodged.

- Reference to online preclearance as a caution and specifically if an SWS³⁴ is envisaged. It must be noted that for a goods declaration, specific data fields need to be declared, which are contained in the WCO Data Model. Certain data communicated to SARS also contains confidential information relating to payments, etc., which needs to be treated in confidentiality.
- The declaration is lodged prior to the arrival of goods at the border post. Customs validate and assess the risk of the declaration upon electronic receipt and, based on their findings, would communicate a response message to the client. These messages may be:
 - To reject the declaration – this will happen when the declaration lodged is not correct and compliant in all aspects. The benefit of this is that the declarant could correct the declaration before the goods reach the border post.
 - If the declaration meets all expectations but risks are identified, supporting documents can be requested. This message is conveyed electronically to the declarant, which in turn uploads the supporting documents electronically.
 - For the export of free circulation goods and imports, Customs will issue a proceed to the port response message if all validation rules are met.
 - In the case of export clearances of bonded goods (goods in a licensed Customs warehouse), cargo may only proceed to the border once released.
 - All carriers of goods must register with Customs and submit an electronic goods manifest (eRFM) of cargo carried, which is cross-referenced against goods declaration details.
- Since all goods must be precleared and reflected on the eRFM, all declarations are verified against the manifest at the arrival gate, and access is allowed for all declared goods and either released or placed on proceed to border status (important to note that no undeclared goods are entering a POE for clearance once inside – obviously, this excludes cases where goods are smuggled).
- Once marked for arrival, the status of the “proceed to border” goods will become known on the system. Goods stopped for physical inspection will be routed to the inspection area.
- Goods with a status Customs released but detained for Another Government Agency (OGA) will have to report to that OGA and only be permitted to continue their journey once released by that OGA.

³⁴ A Single Window System (SWS) is a facility that allows parties involved in trade and transport to lodge standardized information and documents with a single-entry point to fulfil all import, export, and transit-related regulatory requirements (UNECE, 2004:3).

- At the exit gate of the border post, a systematic process is in place to scan the exit, which links directly to the manifest and declaration details of the cargo as marked for arrival.
- The other aspect that requires separate completion is the passport control function – which at Beitbridge contributed to delays when DHA officers leave their posts.
- SARS would be in a better position to provide a time study as well as the evidence of the time it takes on average for a commercial vehicle to pass through the border post – during the 2011/2012 phased roll-out period of the Modernisation project, the average period was well below 10 minutes (closer to 4 minutes).

Because this process is nearly 100% automated, it contributes to the quick processing time through the border post. It is acknowledged that the system is currently only requesting documents on a risk-based approach as determined by SARS and not for all OGAs stationed at the POE, but it demonstrates the capability which may be enhanced into a fully-fledged SWS with abilities to share the information with the neighbouring State. The success of the clearance mechanism is only as strong as the cooperation of all role players, which will be reliant on all government departments of both States (export and import).

For road hauliers specifically, it is required that hauliers refrain from approaching border posts with cargo without having precleared and received either “proceed to border” or “release” for bonded goods, as it contributes to congestion.

4.3.4.2 Import leg

As mentioned before, the basis of analysis concerns the import process and the role of logistics therein. Indeed, the logistics system links a vast network of nodes, all of which are some form of processing point or dispensing point of service. These nodes where all the activities take place usually tie into an information network of different interlinkages ranging from:

1. Pick at point of origin (origin hubs)
2. Customs clearance at the origin
3. Booking of cargo
4. Packing of cargo
5. Transport of cargo (air, sea, road, or rail)
6. Arrival in South Africa
7. Customs clearance at destination (in the cloud, as this is all electronic via the SARS-EDI gateway)
8. Release from the releasing authority, payment of all charges

9. De-consolidation of cargo
10. Movement to the licensed depot, storage facilities or intended destination
 - a. Rail, long-haul by road
11. De-stuff cargo method (de-consolidate)
12. Place in storage
13. Send empty packing unit back to licensed facilities (FCL, air pallet)

4.3.4.3 Export leg

By taking the import process as a base, the export process can be investigated in reverse order by means of the following:

1. Fetch cargo or deliver cargo to consolidated hubs
2. Prepare for exports (labelling, consolidation, and other physical requirements)
3. Customs clearance at origin (digital)
4. Pack and seal cargo
5. Transport to exit point
6. Load cargo (per modality: air, sea, road, or rail)
7. Official departure

4.3.4.4 Activities for both imports and exports

By taking the import process as a base, the export process can be investigated in reverse order by means of the following:

1. Planning
2. Customs Clearance
3. Inspections, when dictated by the authorities
4. Packing, sealing of cargo
5. Conveyance to exit or entry point
6. Loading per modality
7. Off-loading, de-stuffing
8. Storage
9. Final delivery

4.3.4.5 Summary

The importance of this section, namely that of the main activities performed in a logistics system, is intended to provide a holistic overview of the logistics system concerning its various nodes. As mentioned before, the increased role which technology plays within logistics (and indeed supply

chain) investigations is the fact that a great richness of data now gets generated by all these functions within all the steps. The advantage of this data generation lies in the opportunity to now analyse these datasets to provide some insight into logistics performance. Therefore, the following section will investigate the role of ICT in the logistics industry.

4.4 The role of ICT in the logistics industry from a South African perspective

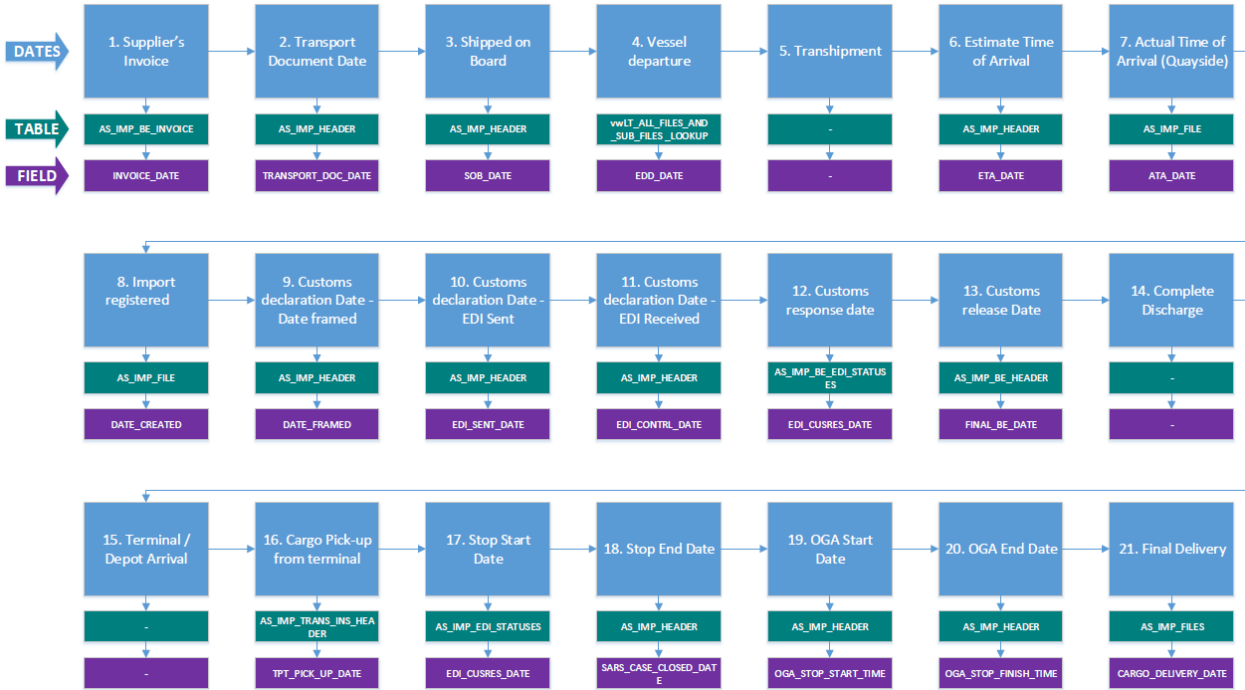
If the South African economy wants to experience significant growth, it needs to obtain comparative advantages in its supply chain processes. However, within the myriad of performance indices, the trend that undoubtedly sticks out is South Africa's dwindling global performance. In terms of the DHL Global Connectedness Index, South Africa's ranking has decreased from a high of 42nd in 2006 to a current position of 54th in 2022 (Altman *et al.*, 2023:60). Furthermore, in terms of the World Bank's Logistics Performance Index, South Africa's ranking has decreased from 20th in 2016 to 33rd in 2018 (Arvis *et al.*, 2018:10), although there has been a welcome and unexpected improvement to 25th out of 139 countries in 2023 (Arvis *et al.*, 2023).

South Africa cannot do anything about its geographic location (or its proximity to markets). Still, the South African trading community can undoubtedly influence the chains, links, and integration of routes within their logistics system. Although the country has experienced a decline in the indices mentioned, instead of comparing to yesteryear and comparing to others, what can the South African logistics industry do about it now?

An area that offers room for improved performance and that the local logistics industry has not optimally exploited is ICT usage. As was stated in a recent online article, "the shipping and logistics industry, though usually a bit slower to pick up on digitisation, is now realising the importance which data and ICT have on making it relevant, competitive and susceptible to change" (Freight & Trading Weekly, 2018), highlighting the need to implement ICT in the logistics systems of the country.

The following figure provides an overview of a typical South African import process from a logistics service provider's perspective.

Figure 4-13: South African sea freight import process and data collection from the perspective of a logistics service provider



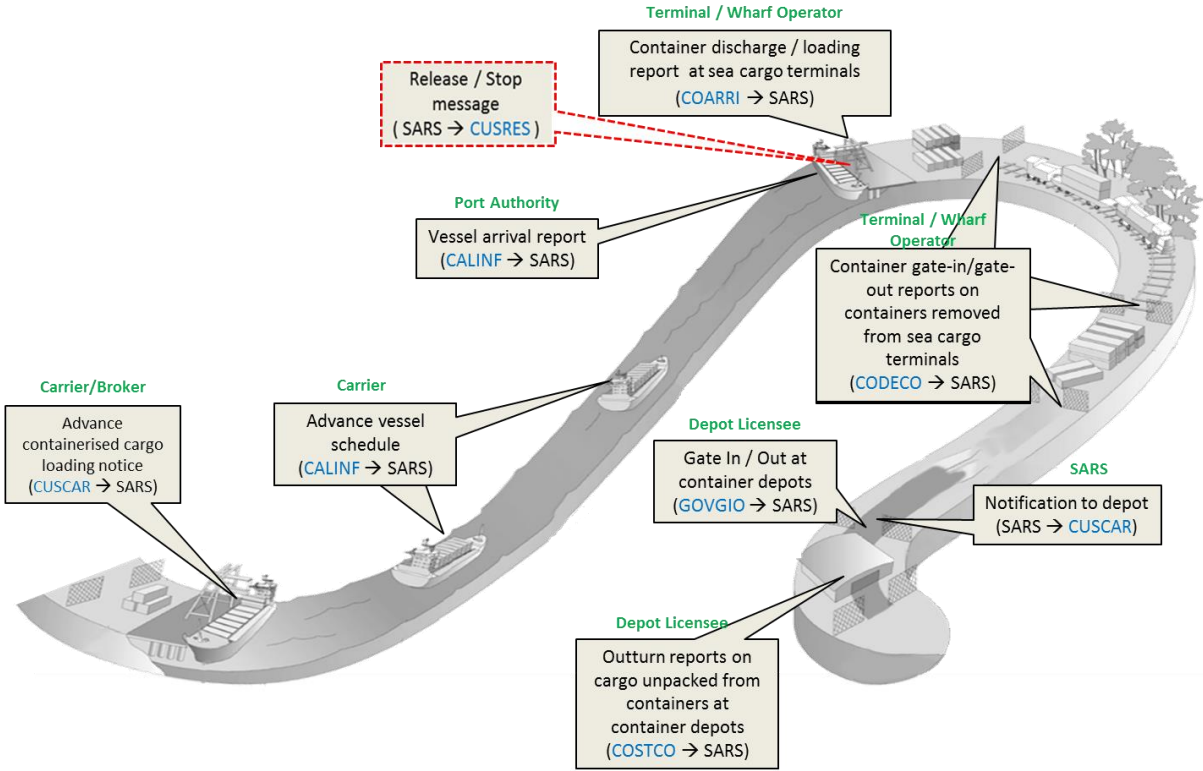
Source: Author's own compilation.

Figure 4-13, illustrated above, shows the various steps involved in the logistics process when importing a foreign consignment into South Africa via sea freight. Furthermore, the process offers examples of the internal data tables and fields that are used by these logistics service providers to monitor and track the process, from the supplier's initial invoice all the way to the final delivery of the consignment. Worth noting is that the figure illustrates the typical information that a South African logistics provider will capture from the import process's destination side. Between the initial charging of the supplier's invoice (as illustrated by the first step), various steps occurred on the import process's origin side. These steps include an initial inquiry from a South African buyer, the placement of an order, packing and marking of goods, outbound transportation, and origin customs clearance.

Although this process includes a mere 21 high-level actions to simplify this complex flow of information and goods, the number of sub-steps, systems, role players, e-mails, laws, data points and overall flow serves as a reminder of the utter complexity of just a single importation into South Africa.

Adding to the complexity of the process, the following figure illustrates the process involved with clearing the consignment into South Africa through customs. The figure provides an example of steps 10 to 15 in Figure 4-13 in practice.

Figure 4-14: South African import process and data collection from the perspective of SARS³⁵ Customs



Source: Theron, 2018.

The process illustrated above shows the various steps involved in the communication between a logistics service provider and South African customs when importing a foreign consignment into South Africa. Communication occurs in the form of electronic data interchange (EDI) messages, and has a total of nine points of interest, such as loading information, clearance messages and discharge reports, as shown in the figure. When viewed in conjunction with Figure 4-13, the complexity becomes even more apparent. An analysis based on data collected from a 3PL in South Africa that implements these kinds of processes indicated any disruption within the South African side of the supply chain could cause a delay of as much as 15 days. Furthermore, more than 90% of the delayed cargo was delayed unnecessarily by South African customs, indicating inefficient risk identification in the South African customs process (Hoffman *et al.*, 2018:63).

³⁵ The South African Revenue Authority (SARS) is the controlling customs and excise administration in South Africa. The abbreviations illustrated in the figure relates to EDI communication between SARS and customs brokers. The abbreviations are as follows: CUSCAR – Cargo Report (Manifest); CALINF – Schedule/Arrival Information; CUSRES – Customs Response Message; COARRI – Container Discharge/Loading Report; CODECO – Container Gate-In/Gate-Out Report on terminals; GOVGIO – Container Gate-In/Gate-Out Report on depots; COSTCO – Outturn Report (SARS, 2019b).

However, on the positive side, these two figures indicate the immense opportunity that the implementation of ICT can have on streamlining this process.

So far, very little academic research has been conducted on the performance and efficiency of logistics systems within any of South Africa's import industries. Van Dyk and Maspero (2004:55) provided some background to the South African fresh fruit industry and its export supply chain, but research on the import process is lacking.

One of the critical takeaway factors from the latest ICT developments that have been researched internationally is the possible flexibility it could offer logistical providers in tracking and monitoring the entire chain. Supply chain managers can now adjust almost immediately, which averts disruptions in the supply chain. These near-instant changes happen in supply chain management systems through information technology, according to Gunasekaran and Ngai (2004:290). An ICT-based supply chain management system can be described as a set of software solutions that manages and oversees supply chain management. Since no research has been done on the role of data analytics in South Africa's logistics system, an opportunity arises to determine how the use of data analytics can assist in designing an improved ICT-based supply chain management system for a South African 3PL. Therefore, the following two sections will investigate logistics performance measurements used to analyse logistics performance on both a micro and a macro level.

While Section 1.2 acknowledges the existing literature's limitation in diagnosing system failures and proposing performance improvement strategies, various macro-level performance measurement indices have been developed. However, these indices, while valuable for analysing logistics at a national level, do not align with the specific objectives of this study. The study seeks a bottom-up, process-oriented framework for assessing logistics performance from the freight forwarder's perspective, a requirement not adequately addressed by the existing tools. Additionally, the data provided by macro-level logistics performance measurements is insufficient for a comprehensive investigation into the logistics process in South Africa.

4.5 Micro-level logistics performance measurements

The following section describes the various micro-level metrics used to ascertain logistics performance, as introduced in Section 1.2. Most of the metrics pertain to sub-sets or sub-categories of logistics services, as mentioned in Section 1.1.3, and include logistics cost, customs operations, transport flow modelling, cross-border freight management, and infrastructure. The output measurements include time, cost, and service reliability.

4.5.1 Measuring logistics time

The reduction of time in transport is one of the important objectives of transport policy (Rezaei *et al.*, 2018:160), as policies will often be evaluated in cost-benefit analysis using the effect on this performance measure. In fact, reducing time is the most important factor to consider concerning logistics performance management (see Djankov *et al.*, 2010). A plethora of studies exist measuring the timeliness of the logistics process; indeed, almost all studies on logistics performance mention time as a key element (for example, see Ramaa *et al.*, 2009 and Gani, 2017). Furthermore, Hummels (2001) concluded that a 1% reduction in the processing time of a container at the exporter can lead to 0.4% more bilateral trade, while 1% less variability in shipping times can lead to up to 0.2% increase in bilateral trade, meaning that better timeliness and prediction of when shipments will arrive increases trade. Djankov *et al.* (2010) obtained similar results, which showed that a reduction in international shipping times by one day was associated with an increase in trade by 0.8%. More than 100 practitioners, academics, and consultants identified as logistics experts agree with the preceding assessments, as shown by Keebler and Plank (2010). The study focused on benchmarking logistics performance in the supply chain and identified time as a critical factor in measuring the success of logistics operations at the firm level.

4.5.2 Measuring logistics cost

The logistics cost model is a bottom-up aggregation of logistics-related costs, comprising transport (and transport packaging) costs, warehousing (and other handling and storage) costs, management and administration costs, inventory carrying costs, and indirect logistics costs (see the comprehensive overview conducted by Engblom *et al.*, 2012, Pettersson & Segerstedt, 2013, and Muha, 2019, as well as the South African overview by Havenga, 2010). These cost components are invariably orchestrated by the freight forwarder in a combination of interrelated approaches, with various levels of integration between in-house and outsourced activities, which is a fundamental consideration in this thesis.

The core logistics cost components can be divided into the following:

1. Transport (of freight) costs, which include expenses related to moving goods from one location to another and encompasses sub-components such as:
 - a. shipping costs associated with ocean, air, or rail transportation;
 - b. terminal handling costs by port facilities (in South Africa's case, these costs have been argued as being high – see Grater & Chasomeris, 2022, where the authors demonstrated the possibility of significantly reducing the tariffs established by TNPA by between 5.7% and 20%, depending on scenarios);

- c. trucking costs related to road transportation, including fuel, maintenance, and driver wages;
 - d. intermodal costs involved in using multiple modes of transportation, such as combining truck and rail transport;
 - e. distribution costs, which include last-mile delivery costs and cross-docking costs; and
 - f. transport packaging costs concerning the unpacking and repacking of goods at any of these process steps in the logistics chain.
2. Warehousing (and other handling and storage), which relates to expenses for renting or maintaining storage facilities, including rent, utilities, and security. As per Havenga *et al.* (2022:111), “*Warehousing costs include all costs associated with keeping a commodity in storage, including rent, equipment costs, direct labour costs and insurance.*” Therefore, the related sub-components to warehousing include:
- a. handling costs associated with loading and unloading goods, including labour and equipment; and
 - b. inventory management costs related to tracking and tracing, managing, and organising inventory within warehouses with related warehouse management systems (WMS).
3. Management and administration costs, which typically include:
- a. labour costs, such as salaries and wages of personnel involved in logistics management and administration;
 - b. technology costs related to software, hardware, and IT infrastructure used for logistics management; and
 - c. overhead costs related to general administrative expenses not directly tied to specific logistics activities.
4. Inventory carrying costs, also known as holding costs, refer to the expenses associated with holding and storing inventory. This sub-component is often grouped with storage; however, there is a significant financial opportunity cost related to this category. As such, inventory carrying cost typically includes:
- a. carrying cost of capital, which relates to financing the inventory, including interest or the opportunity cost of capital tied up in inventory;
 - b. storage costs akin to warehousing costs; but also
 - c. insurance costs against theft, damage, or loss; and
 - d. obsolescence and depreciation costs, depending on the commodity and its life cycle, when inventory becomes obsolete or loses value over time.
5. Indirect logistics costs are typically not captured on the expense sheet of service providers, notably the following:

- a. Impact of varying time delays, including when stock is in transit;
- b. interest paid on investments in stock in transit from origin to points of manufacturing or consumption;
- c. shrinkage of stock in transit; and
- d. losses in sales or production should out-of-stock situations occur.

Ultimately, these cost components, when aggregated, provide a comprehensive view of the total logistics-related costs within a supply chain. Accurately measuring and managing these costs is crucial for optimising supply chain efficiency and profitability (see Gunasekaran *et al.*, 2004). Indeed, each day in transit is equivalent to an ad-valorem tariff of 0.6% to 2.3%, and the most time-sensitive trade flows are those involving parts and components trade (Hummels & Schaur, 2013:2935). Businesses often use various tools and strategies to control and reduce these costs while ensuring goods are delivered timeously and efficiently to customers. However, as Muha (2019) has demonstrated, reducing the costs of one logistic component may cause an increase in the costs of another logistic component, which may result in higher total logistics costs (2019:102). Consequently, and as guided by the available literature, this thesis will also produce a Total Economic Cost or TEC (ahead in Section 6.5) attempting to capture all of the above-outlined logistics cost components.

4.5.3 Measuring logistics service reliability

Logistics service reliability is an essential aspect of logistics service quality (LSQ). There are several principles to measure logistics service reliability, including the following (see, for example, Beniušienė & Petukienė, 2012; and Arabelen & Kaya, 2021):

1. On-time delivery rate, which is the percentage of shipments that arrive at their destination on time. For a freight forwarder in particular, the underlying driver of logistics performance based on service reliability is the difference between the expected performance as per the service-level agreements, and the actual, measured performance. This metric will be the core determinant in measuring logistics service reliability.
2. Order fill rate, which is the percentage of orders that are filled correctly and delivered on time. For a freight forwarder, in particular, the order fill rate will depend on the level of upstream and downstream service offering integration. Often, one 3PL handles the forwarding, another 3PL handles the customs clearance, and another 3PL handles the storage and warehousing. The success of the order fill rate – especially when spread between service providers – depends on the transparency and seamless handover between functions.

3. Order cycle time, which is the time it takes to process an order from the time it is received to the time it is delivered. For a freight forwarder in particular, the order cycle time will significantly depend on the relationship between other role players in the extended logistics network (i.e., shipping lines, transporters, etc.), as well as their respective schedules.
4. Damage rate, which is the percentage of shipments that are damaged during transit. For a freight forwarder in particular, the damage rate would primarily be determined by the cargo carrier, such as vessels for ocean freight, trucks for road transport, etc.

Ultimately, logistics service reliability is one of the five dimensions of service quality, which also includes tangibility, responsiveness, assurance, and empathy. The SERVQUAL (service quality) metric is a widely used tool to measure service quality based on these five dimensions (see, for example, Awasthi *et al.*, 2018:196-197). To measure logistics service reliability, it is essential to track and analyse key performance indicators (KPIs) such as on-time delivery rate, order fill rate, order cycle time, and damage rate. By measuring these KPIs, logistics companies can identify areas for improvement and optimise their processes to provide better services to their customers (Beniušienė & Petukienė, 2012:67).

Service reliability is a difficult performance measurement to determine in the public domain environment, since the metric will invariably enter the private and confidential landscape. Nevertheless, for some parts of the logistics network, this metric is tracked, notable for liner shipping schedules. *Sea Intelligence* – a provider of research, analysis, and related services within the global supply chain industry – uses a methodology based on vessel arrival time information to calculate schedule reliability (Murphy, 2019:9). The researchers collect data on vessel arrivals and departures and use this information to determine the percentage of vessels that arrive on time. Sea Intelligence has developed this methodology to track global schedule reliability monthly, and used this methodology to guide shippers and carriers in selecting services based on schedule reliability. Incidentally, liner shipping schedule reliability between 2018 and mid-2020 hovered around the 70-80% mark, but was significantly impacted by the global pandemic (as discussed in Section 2.3.5), after which reliability dropped to as low as 30% (Murphy, 2023). Fortunately, liner shipping schedule reliability returned to around 60% for much of 2023.

4.5.4 Summary of micro-level logistics performance measurements

This section provided a short overview of the most important logistics performance measurements on a micro-level, namely the LPI indicators of time, cost, and service reliability. Within these logistics performance measurements, reducing time was seen as arguably the most important

factor to consider concerning logistics performance management, as mentioned by domain experts and shown in the data. Reducing cost was also shown to be key, particularly as the various logistics elements (such as transport costs, warehousing, inventory costs, and the like) could be and have been studied in isolation. Lastly, service reliability is also considered a key performance measurement, especially being part of the logistics service quality aspect. Moreover, the quality and service offering are important for several role players in the end-to-end logistics offering, including transporters, freight forwarders, shipping lines, and others.

4.6 Macro-level logistics performance measurements

The following section describes the various macro-level – both national and international – literature used to ascertain logistics performance, as introduced in Section 1.2. Some of the performance measurements concern logistics as a whole, while other measurements concern a part or parts of the greater supply chain, as defined in Section 1.1.3. As with the previous section, the output measurements include time, cost, and trade volumes. Most literature in this section is presented at a macro-level and based on survey data, serving as an international benchmarking tool useful for countries to identify areas for improvement in their performance, and to compare it with other countries.

Despite being useful to policymakers, multilateral agencies, economic actors, investors, and logistics service providers, these reports often fail to capture the essence of detailed, operational-level performance within the national setting. The section will outline the various available international trade and logistics metrics, commencing with arguably the best-known benchmarking tool created by the WB on trade logistics, namely the LPI, and ending with a national logistics performance measurement created specifically for South Africa.

4.6.1 World Bank Logistics Performance Index

Developed by the WB, the Logistics Performance Index (LPI) is an interactive benchmarking tool created to help countries identify the challenges and opportunities they face in their performance on trade logistics, along with what they can do to improve their performance (WB, 2020). The LPI is based on a worldwide survey of global freight forwarders and express carriers, providing feedback on the ease of logistics operations of the countries in which they operate. The feedback includes informed qualitative assessments of countries where they trade and experience the logistics environment. In addition, feedback from operators is supplemented with quantitative data on the performance of critical components of the logistics chain in the country of work.

Each reporter rates eight specifically selected countries (depending on their main trading partners, proximity to a coastline, among other metrics) on six points as listed below. Once 200

surveys have been completed, a system generates random countries on which the subsequent respondents will base their answers, which exist to represent underrepresented countries. The LPI is an aggregate of the six components that the index measures. If respondents do not report a specific indicator, the indicator's value is interpolated to fill in the missing values.

The six components of the LPI are:

1. The efficiency of customs and border clearance.
2. The quality of trade and transport infrastructure.
3. The ease of arranging competitively priced shipments.
4. The competence and quality of logistics.
5. The ability to track and trace consignments.
6. The frequency with which shipments reach consignees within scheduled or expected delivery times.

Although the LPI provides the most comprehensive international comparison tool to measure countries' trade and transport facilitation friendliness (Ojala & Celebi, 2015:5), the index is not without criticism. Notably, the experience of eight international companies may not represent a broader logistical situation. Furthermore, the LPI may reflect problems in freight transit for landlocked countries and small island states (Arvis *et al.*, 2018). Beysenbaev and Dus (2020) have put forth proposals for improving the logistics performance index. The authors propose a modified index that qualitatively and quantitatively represents an objective view of 159 countries' logistics systems and subsystems based on international statistical data, which can be used as a benchmarking tool for governments. As a recurring theme in analysing the current scope of logistics (and other related) performance metrics, a need arises to follow a more rigorous scientific approach when compiling these indices (more on these gaps in Section 4.6.3).

4.6.2 World Bank Doing Business – Trading across borders

The WB's 'Doing Business' report formed part of its annual portfolio of flagship reports before it was discontinued, covering 11 areas of business regulations by collecting data from local experts across 190 economies. 'Trading Across Borders' (TAB) is one of these areas, focusing specifically on the logistical processes of exporting and importing. Indeed, the TAB pillar measures the time and cost (excluding tariffs) associated with three sets of procedures – documentary compliance, border compliance, and domestic transport – within the overall exporting or importing of a shipment of goods. The data on trading across borders are gathered through a questionnaire administered to local freight forwarders, customs brokers, port authorities and traders. Domestic information is not included in the ease of trading across borders indices. For 2019, South Africa

ranked 143 out of 190 countries in the WB's EODB TAB metric (WB, 2019a), which is considerably worse than the overall ranking and the comparative LPI ranking during the time (33 out of 160)³⁶.

4.6.2.1 Documentary compliance

Documentary compliance captures the time and cost associated with all government agencies' documentary requirements of the origin economy, the destination economy, and any transit economies.

The aim is to measure the total burden of preparing documents that will enable the completion of the international trade process for the product and partner pair assumed in the case study. The documentation includes the process of obtaining, preparing, processing, presenting, and submitting documents. In addition, documents completed to obtain preferential treatment are also included (including certificates of origin, for example).

4.6.2.2 Border compliance

Border compliance captures the time and cost associated with enforcing compliance with the economy's customs regulations, with regulations relating to other mandatory inspections for the shipment to cross the economy's border, and the time and cost for handling that takes place at its port or border – for example, the time and cost for conducting a phytosanitary inspection.

If all customs clearance and other inspections take place at the port or border simultaneously, the time estimate for border compliance takes this simultaneity into account. However, suppose this is not the case, and inspection and other procedures are completed at a different location. In that case, these durations are added together, which influences the total time and cost recorded.

4.6.2.3 The difference between LPI and TAB

The LPI is a qualitative measure of supply chain performance and provides a global benchmark of logistics efficiency and service quality not explicitly treated in the 'Doing Business' survey. It

³⁶ The substantial incongruity observed in the LPI and TAB rankings for South Africa can be attributed primarily to the underlying assumptions inherent in the TAB component of the Doing Business report. It is noteworthy that the methodology employed in the TAB indicator introduces an unintended bias against South Africa, thereby influencing the resultant rankings. The indicator adheres to a set of case study assumptions to facilitate cross-country comparability within the report. This targeted emphasis on a specific sector and trade route introduces a skew in the evaluation, arguably neglecting a broader spectrum of trade activities and thereby contributing to the observed discrepancy in rankings. Moreover, a noteworthy limitation in the EODB survey lies in the non-comprehensive representation of logistics service providers active in the South African industry. The roster of participants enlisted in the survey fails to encompass the entirety of entities operating within the logistics landscape, thus potentially overlooking critical perspectives and nuances inherent in the intricacies of the country's trade-related operations. This inadequacy in participant inclusivity may further contribute to the pronounced incongruity between the LPI and EODB rankings for South Africa.

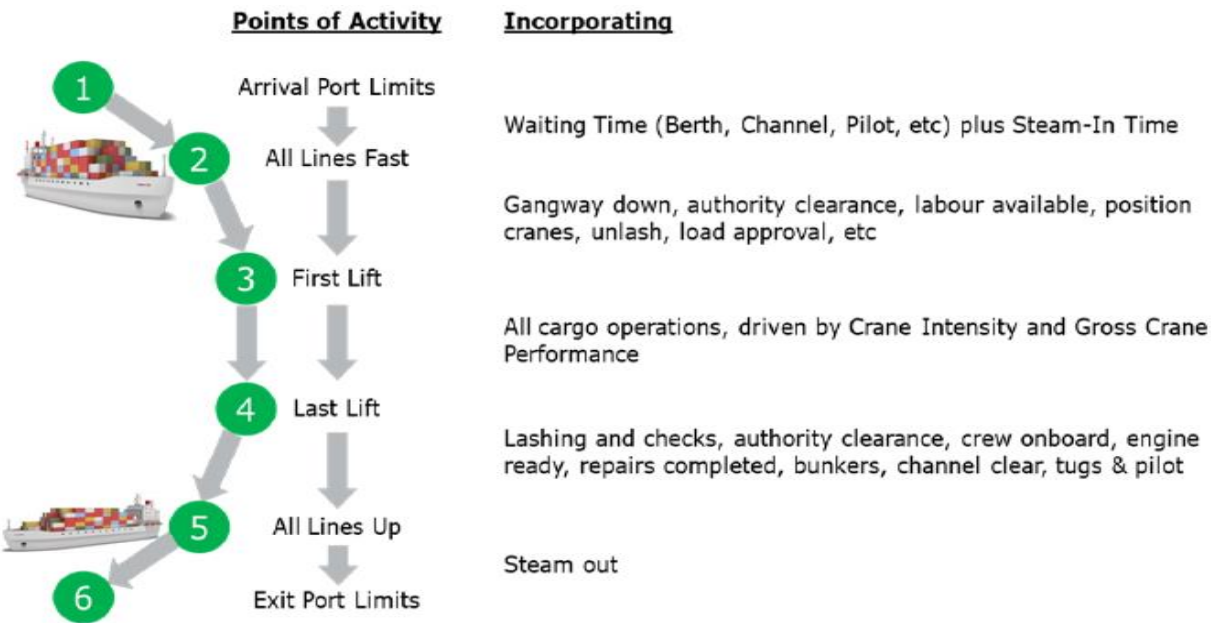
provides an assessment of trade logistics by collecting data on Customs, infrastructure, international shipments, logistics competence, tracking and tracing, domestic logistics costs, and timeliness by examining trade procedures, infrastructure, services, and reliability. Furthermore, the LPI is constructed from a worldwide survey of multinational freight forwarders and express carriers.

The TAB, forming part of the 'Doing Business' survey, follows very specific case study assumptions to allow for comparability across all countries included in the report (Saltane & Georgieva, 2016). The LPI – although constructed from survey data – does not follow specific case study assumptions. The respective difference also relates to the way the rankings are compiled. The TAB is based on the 'distance to frontier score' for eight indicators, whereas the LPI is based on six indicators using principal component analysis. Nonetheless, analysis shows that countries that perform well on TAB tend to perform well on LPI, although not as a rule. The correlation between the TAB rank and the LPI rank is 0.59. Moreover, the relationship is significant at the 1% level after controlling for income per capita (Saltane & Georgieva, 2016).

4.6.3 World Bank Container Port Performance Index

In May of 2021, the WB released its inaugural 'Container Port Performance Index (CPPI)', a measurement focusing on a specific logistics element, namely container port performance – an essential consideration in the logistics system (WB, 2021a). In collaboration with external contributions from IHS Markit, the CPPI is based on two different methodological approaches, or what has been termed the administrative approach: a pragmatic methodology reflecting expert knowledge and judgment, and the statistical approach, using factor analysis (WB, 2021c:12). The critical indicator is total port time spent by a container vessel, i.e., the total elapsed time between when a ship reaches a port (either port limits, pilot station, or anchorage zone) to when it departs from the berth after completing its cargo exchange (WB, 2021c:45). These functions are split into six different stages, which is illustrated by Figure 4-15.

Figure 4-15: The anatomy of a port call



Source: WB, 2021c:45.

Despite segmenting the total elapsed time into six distinct stages, the WB notes that the time expended from berth departure (all lines upstage five) to the departure from the port limits (stage six) is deliberately excluded. The justification for the exclusion is any performance loss that pertains to departure delays, such as (i) pilot or tug availability, (ii) readiness of the mooring gang, (iii) channel access and water depths, and (iv) ship readiness will be incurred while the ship is still alongside (WB, 2021c:45).

Despite the rigorous analytical approach followed by the inaugural CPPI, the reaction did not come without criticism. The reproach included ranking (South Africa’s ports were ranked as four of the bottom five ports), methodology (the inclusion of two approaches), and timing of the report (the data used spanned across an unprecedented time in history with lockdowns, stringent regulations, and an environment far from normal because of COVID-19). Nevertheless, implementing new technologies and increased data analytics is welcomed, and undoubtedly the preferred way forward. Indeed, the WB notes that the introduction of new technologies, increased digitisation, and the willingness on the part of industry interests to work collectively toward systemwide improvements now provides the capacity and the opportunity to measure and compare container port performance robustly and reliably for the first time (WB, 2021c:9).

4.6.4 World Customs Organisation Time Release Study

The WCO Time Release Study (TRS) is a strategic and internationally recognised tool to measure the actual time required for the release and clearance of goods, from the time of arrival until the

physical release of cargo, to find bottlenecks in the trade flow process and take necessary measures to improve the effectiveness and efficiency of border procedures (WCO, 2018:9).

The updated version of the WCO TRS Guide, known as the “*Guide to Measure the Time Required for the Release of Goods (Version 3)*”, incorporates several vital features/elements. It brings forward new dynamics and opportunities for Customs Administrations to work collaboratively with other relevant government agencies and trade stakeholders in the arena of performance measurement.

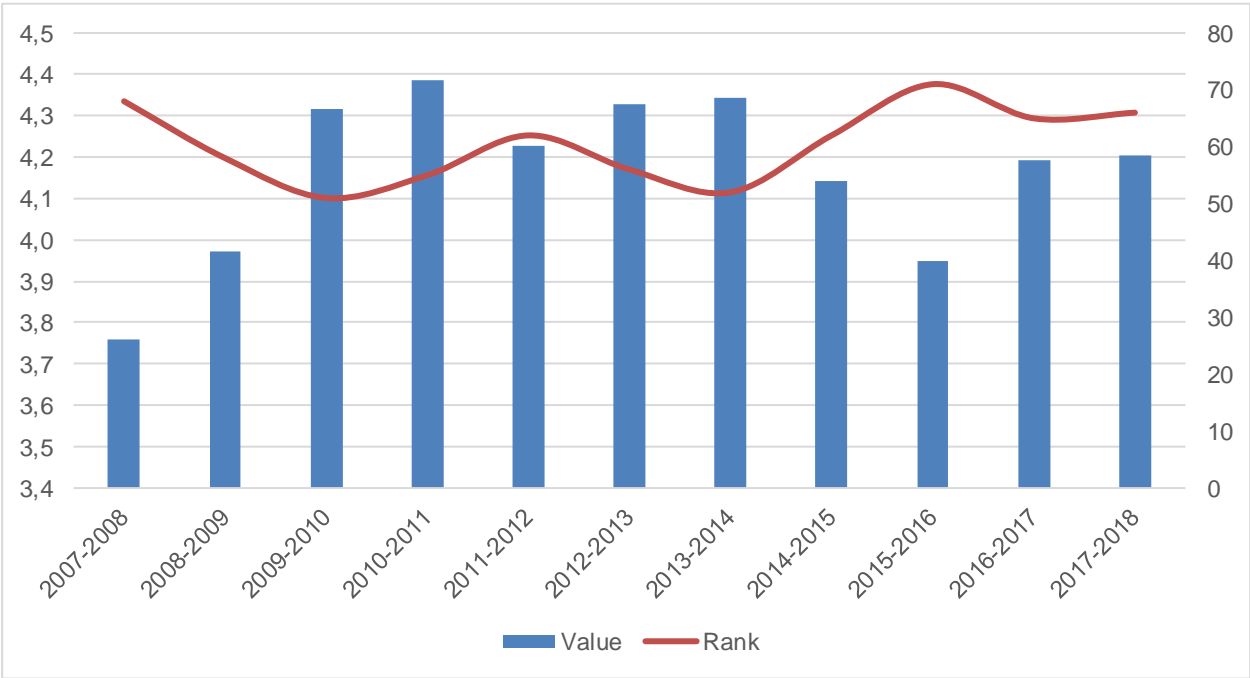
The WCO TRS is referenced explicitly in Article 7.6 of the WTO Trade Facilitation Agreement (TFA) as a tool for Members to measure and publish the average release time of goods. In addition, members increasingly use the TRS concerning strategic planning and the proper sequencing of TFA measures following their National Committees on Trade Facilitation (NCTF). In recent years, the tool has been capturing much attention worldwide; the international donor community and the WCO development partners recommend it as a critical performance measure to assess, evaluate, and enhance the WTO TFA implementation.

4.6.5 World Economic Forum – Burden of Customs Procedures

Until the 2017/2018 edition of the Global Competitiveness Index report, the WEF measured each country’s burden of customs procedures. Grouped under the 6th pillar – Goods market efficiency – the burden of customs procedure investigated the performance of customs. More specifically, the WEF survey asked the question, “*In your country, how efficient are customs procedures (related to the entry and exit of merchandise)?*”, with 1 being an extremely inefficient score and 7 being an extremely efficient score (WEF, 2017:347). In a similar vein to the CPPI mentioned above, the burden of customs procedures only measures one node in the logistics network, albeit an important one, since all goods traded must be declared to customs authorities.

Despite the WEF excluding the measurement from the 2018/2019 edition onwards, the metrics provided insight into comparative customs performance globally. Figure 4-16 illustrates the eleven historical data points captured by the report for South Africa.

Figure 4-16: Burden of customs procedures (score out of 7, rank out of 139³⁷)



Source: WEF datasets, 2021.

In summary, South Africa’s performance improved slightly in the initial years of the measurement, but stagnated somewhat as the years went by. Although the WEF has abandoned the metric in introducing the *Global Competitiveness Index 4.0* from the 2018/2019 edition onwards (WEF, 2018:1), the role of customs authorities remains very important in facilitating trade and changes as trade also evolves. Certainly, the changing role of customs administrations can be explained by the need to facilitate trade through integrated supply chain activities on the one hand, while protecting the treasury and the safety and security of their citizens on the other (Creskoff, 2016:193). Moreover, as Chapter 5 will showcase, the role of customs is crucial in maintaining an efficient logistics network, as customs can have a wide-ranging impact to either ensure a smooth flow of goods or lead to a significant delay in the processing thereof.

4.6.6 DHL Global Connectedness Index

The DHL Global Connectedness Index tracks the depth and breadth of international trade, capital, information, and people flows. The biennial index draws upon more than 3.5 million data points across the 13 measures of country-to-country flows to examine globalisation worldwide, by region,

³⁷ The number of countries surveyed in the annual WEF GCI ranged from a minimum of 133 in the 2009/2010 edition, to a maximum of 148 in the 2013/2014 edition, with the average around 139 across the year-span.

and across 169 countries (Altman & Bastian, 2020:15). The key objective of the DHL Global Connectedness Index is to ascertain how connected the world is.

The index differs from other metrics by virtue of its three key features. Firstly, it measures actual flows between countries. Secondly, the index seeks to go beyond trade flows by also investigating the flows of capital, information, and people. Thirdly, the index looks at the depth and breadth of each flow. For example, depth refers to the size of a country's international flows as compared to a relevant measure of the size of its domestic economy. Whereas breadth measures how closely a country's distribution of international flows across its partner countries matches the global distribution of the same flows in the opposite direction (Altman & Bastian, 2020:76-79)³⁸. For 2022, the DHL Global Connectedness Index ranked South Africa 54th out of 171 nations (Altman & Bastian, 2023:60).

4.6.7 Agility Emerging Market Logistics Index

The Agility Emerging Markets Logistics Index (AEMLI) presents a data-driven analysis of 50 of the world's most promising emerging logistics markets, reflecting the complexity, connectedness, and opportunities each market provides (AEMLI, 2021:11). The AEMLI, which was developed by the international research firm, Transport Intelligence (Ti), was established 12 years ago and estimated the potential attractiveness of the domestic logistics markets for foreign investments.

The AEMLI has three main components made up of (1) the index country rankings, (2) a survey of trade and logistics industry professionals (1 206 were surveyed for the 2021 version), and (3) an examination by volume and mode of transport, of the largest and fastest-growing major trade lanes linking emerging and developed markets (AEMLI, 2021:68).

To assess and understand these trends and their effects on 50 of the world's most promising emerging logistics markets, the AEMLI 2021 examines three key areas for logistics market development to make up the index country rankings:

- Domestic Logistics Opportunities
- International Logistics Opportunities
- Business Fundamentals

³⁸ The "breadth" measure in the index refers to the geographic distribution of these international flows (with "these" referring to internationally traded goods versus domestically traded goods). It evaluates to what extent flows are distributed broadly around the globe rather than concentrated between specific origins and destinations. In a truly globalised world, one would expect countries to trade not just with a few neighbours but with a wide variety of nations.

These three factors are all equally weighted and are underpinned by data from international sources, such as the IMF, WB, and WEF, amongst others. In addition, Ti's own proprietary market size and forecast data are used. Then, finally, trade lane data is derived from the United States Census Bureau and Eurostat data. For 2021, the AEMLI ranked South Africa 24th out of the 50 emerging countries, noting a drop in two of the three metrics, as well as a position on the overall list. Although the AEMPLI attempts to assess logistics performance in a more modern way, the measurement has been criticised because of several index factors (e.g., “market accessibility” and “domestic stability”) being more directed at socioeconomic rather than logistical aspects (Beysenbaev & Dus, 2020:35).

4.6.8 Stellenbosch logistics barometer

Developed by the Department of Logistics at Stellenbosch University, the Logistics Barometer “*provides a numerical analysis of logistics costs trends in South Africa supported by insights from logistics industry specialists and academia*” (Havenga *et al.*, 2016:3). In short, the Logistics Barometer relies on established research to quantify logistics costs and volumes transported. The barometer comprises the Freight Demand Model (FDM) and the National Freight Flow Model (NFFM). Combining these two models allows for bi-directional flow analyses. The FDM considers both the supply and demand of commodities in geographical areas using a gravity model. The gravity model considers 83 commodities in 372 geographical areas for 30 years. The FDM uses two sets of data. One set is collected through surveying freight forwarders and other involved parties; the other is a traffic count, which SANRAL does. The NFFM focuses on defining surface freight transport (i.e., road and rail) based on the two definitive measures of flows, namely tons and ton-kilometres.

The logistics cost model used is a bottom-up aggregation of logistics-related costs, including transport, storage and port handling costs, management and administration costs, and inventory carrying costs. The model has recently been updated to include more detailed externalities per mode, including accidents, congestion, emissions, noise, policing, and land-use value.

4.6.9 Summary of macro-level logistics performance measurements

As presented throughout this section on macro-level logistics performance measurements, most of the international benchmark research is focused on a country's (in this case and throughout this thesis, South Africa) relative international competitiveness with respect to the logistics measurement in question. Moreover, the majority of these annual reports present the performance based on survey data. In addition, none of these measurements capture the overall performance of a country's logistics network at a detailed level.

For example, although the Doing Business report and LPI measure two different logistics aspects, both use surveys to collect their data, while the Logistics Barometer uses data collected by SANRAL and previous research rather than using surveys. Perhaps the best measurement of South Africa’s logistics performance is captured by the Logistics Barometer; however, the metric does not show South Africa’s performance relative to other countries. In contrast, the Doing Business report and LPI collect data for nearly 200 countries. The following table summarises these respective studies on macro-level logistics performance measurements:

Table 4-11: Macro-level logistics performance measurements

Measurement	LSPs	Measurement	Method	SA Rank	Year
WB LPI	Global freight forwarders and express carriers	Logistics performance	Survey	25/139	2023
WB EODB TAB	Time and cost to export the product of comparative advantage and to import auto parts	Export/import performance	Survey	143/190	2019
WB CPPI	Container terminal operators	Container port performance	Empirical	~329/348 ³⁹	2022
WCO TRS	Customs Authority	The time required for the release of goods	Empirical	N/A	N/A
WEF Burden of customs procedures	Customs Authority	Customs performance	Survey	66/139	2018
DHL Global Connectedness Index	National logistics system	Performance of logistics systems at the national level	Empirical	54/171	2022
AEMLI	National logistics system	Complexity, connectedness, and opportunities of logistics	Empirical & Survey	24/50 ⁴⁰	2021

³⁹ The average ranking of South Africa’s four major commercial container ports was 328.5 out of 348 ports for 2022.

⁴⁰ The AEMLI ranks 50 of the world’s most promising emerging logistics markets.

Logistics Barometer	National logistics system	Quantification of logistics costs and volumes transported	Empirical	N/A	2014
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Source: Author's own compilation.

As derived from the table above, within these macro-level logistics measurements presented in this section, no logistics metric exists that follows a rigorous empirical and data-driven procedure which measures logistics performance for all actors from the perspective of freight forwarders, using actual timestamp and invoiced cost data. The newly introduced CPPI attempts to measure the efficiency of container port performance through timestamp data in its statistical approach; however, the focus is limited to the confines of the port. Herein lies the opportunity to include additional nodes in the network of a logistics system, not only port performance but also the accompanying functions. Ultimately, as is evident from all the macro-level measurements presented in this section, the national and international literature on logistics performance can significantly benefit from creating an operational framework and bottom-up diagnostic tool to determine where and how the logistics performance can be improved, which will be where this thesis turns to in the subsequent chapters.

4.7 Conclusion

This chapter contained an overview of the trade and logistics environment in South Africa. Since South Africa is regarded as an open economy, trade plays a crucial role in the economic functioning of the country. Moreover, the leading role of trade can be showcased by the fact that South Africa trades a diverse number of products with all the foremost developed countries in the world. Despite the dwindling volumes in recent years, coupled with a distinct push for export promotion and industrialisation on the part of South Africa's government (which is seen in not only policy but also the reversal of South Africa's trade balances), trade remains as strong as ever.

Consequently, for goods (and services) to move seamlessly across international borders, one needs a robust and streamlined logistics network. Indeed, this chapter has shown an in-depth view of the current design of the greater logistics network in South Africa, especially regarding the four main transport modalities, namely ocean, air, road, and rail. Indeed, ascertaining the current design of the logistics system for South African imports from the perspective of a logistics service provider was one of the primary objectives of this research. This design is key, as it sets the scene for the next chapter to come, whereby the performance of the system will be measured.

The existing literature, while providing a comprehensive overview of the logistics system's design, notably lacks empirical evidence at the firm level. This gap limits our understanding and hampers the development of targeted interventions for improvement. The reliance on assumptions in

existing research methodologies further undermines the statistical rigour of logistics performance measurement studies.

Consequently, these two main issues highlighted – that of country-level and survey approach – illustrate the significant drawback of several of these metrics. Therefore, there is a pressing need for empirical research utilising data analytics to fill this identified gap and provide a more robust understanding of logistics performance for South African imports at the firm level. This absence of empirical evidence and statistical rigour represents a notable gap in the existing literature, which Chapter 5 aims to address through an empirical analysis applying data analytics techniques towards improved logistics performance for South African imports.

CHAPTER 5: RESEARCH METHODOLOGY, DATA EXTRACTION AND DESCRIPTIVE AND EXPLORATORY DATA ANALYSIS

5.1 Introduction

This chapter aims to provide an overview of the research methodology employed for this thesis. Furthermore, the chapter outlines the description of the data used, including pre-processing and cleaning of the data, as well as challenges found with the data. To provide a further understanding of what the essence of this thesis is, the chapter will provide some common descriptive statistics, including measures such as mean, standard deviation, and ranges. Visualisation tools will be used to illustrate data patterns, which will then be empirically analysed and tested in greater detail in the following chapter. Worth reiterating is the study-derived definition of logistics performance as mentioned in Section 1.1.3, which is the *overall aggregate performance of the interconnected elements [processes] and sub-systems connected with each other in specific relations, as measured in terms of time, cost, and service reliability*.

Therefore, the primary aim of this chapter is to provide extensive information on the various interconnected elements of the logistics process and their relation to each other. As such, this chapter aims to satisfy the primary objective of contributing to measuring the performance of the logistics system at a national level for all actors from the perspective of the South African freight forwarder. Furthermore, the chapter adds to the secondary objective in that it evaluates the operational model of South African imports, employing data analytics to illustrate areas for potential improvement in logistics performance at an operational and detailed level. The core performance criteria of this chapter will be on measuring logistics performance based on reducing the time taken to trade (and, by implication, improving the service reliability by achieving delivery targets set out). Some of the analysis will also include a discussion on the logistics cost of importing goods to South Africa. However, the discussion on logistics cost and the time delay variability resulting in indirect cost will form the basis of the discussion in Chapter 6.

As mentioned in Section 1.2, no empirical literature could be found that underscores a systemic, quantitative, bottom-up, operational approach to logistics as a microeconomic factor to enable a data-driven system's development, measurement, and improvement which can spill over into integrated management with other supply chain performance factors. Furthermore, very limited empirical literature could be found that followed a rigorous, data-driven method to investigate the performance of a logistics system as a whole. Rather, the limited literature which incorporated data analytics to measure (and improve) logistics performance was limited towards investigating

specific processes of the country's logistics system, and not the performance of the system as a whole.

Because of these limitations in the previous literature presented throughout this thesis, no existing method for investigating the use of data analytics towards improved logistics performance for South African imports will be followed. In fact, only Section 6.5.4 in the subsequent chapter will build on any existing method (Chapter 6 will further elaborate on this method). Rather, this study will develop a new operational framework which serves as a bottom-up diagnostic tool to determine where and how the logistics performance can be improved.

As mentioned throughout this thesis, the key logistics performance output measures are time, cost, and service reliability. Hence, the data required to measure these performance outputs must be translatable into these output measures. Furthermore, the key source of the actual economic data must be from the primary actor orchestrating the functioning of the logistics system, which is the freight forwarder. As such, the data used throughout this thesis – presented in detail in this and the next chapter – originates from a South African freight forwarder. Moreover, the process flow – although concentrated on the import flow of a specific product-vertical – facilitates a realistic reflection of a typical import process flow and could be successfully used as a proxy for moving any final merchandise product into South Africa.

The key logistics performance output measures (time, cost, and service reliability) can be further elaborated on. Firstly, the underlying driver of logistics performance based on time is the disaggregation of the various process steps involved in the end-to-end logistics process flows. For import flows, these involve (on a top contour level) origin inbound transportation, ocean freight, the customs clearance process, destination inbound transportation, and storage and warehousing. Then, the underlying driver of logistics performance based on cost is the disaggregation of the various service offerings made by the 3PL. These include customs clearance, freight and landsides, transportation, storage, and the like. Lastly, the underlying driver of logistics performance based on service reliability is the difference between the proposed performance as per the service-level agreements and the actual, measured performance, which includes both the cost and the time measurement components.

This chapter's structure is as follows: Section 5.2 provides an overview of the respective datasets and the methodology applied, including the iterative process steps to derive information from the data. Section 5.3 provides an overview of the respective datasets obtained from a South African Freight Forwarder. The data comprises more than 42 900 product imports in the tyre industry. Section 5.4 then presents some descriptive statistics, as well as the results and findings of the

exploratory data analysis. Then, finally, Section 5.5 concludes the chapter on descriptive and exploratory data analysis.

5.2 Data overview and methodology for extracting information from the data

Data was obtained from a South African freight forwarder on transaction-level flows between July 2017 and August 2023 (six years). Three separate sources were used, including:

1. Technical service provider data showcasing the documentary process flows:
 - a. The dataset comprises date/time stamped process flow data from the ShipShape⁴¹ portal of all import transactions per documentary requirement.
 - b. The data is stored on a digital platform and is used as an electronic data interchange tool to communicate and interface closely with other key role players in the extended South African logistics network, including SARS and TNPA.
 - c. The platform offers a wide-range of solutions – ranging from a purchase order management system to final delivery and invoicing, with the dataset capturing a total of 139 different data fields for each product line imported into South Africa during the period in question.
2. Container tracking data showcasing the physical process flows:
 - a. The dataset comprises time/date stamp process flow data from several sources.
 - b. The data is stored on a bespoke digital platform and is used as a communications tool to keep clients informed of the movement of cargo (per container) per each key process segment of imported cargo to South Africa.
 - c. The dataset captures a total of 44 different data fields, of which 19 data fields are fully captured and complete.
3. Financial data showcasing the monetary flows:
 - a. The dataset comprises invoice data (in ZAR) of all monetary transactions on all freight forwarder files (forwarding, clearing, warehousing, bond).
 - b. The data is stored on a secure, encrypted digital platform and is used as a record-keeping tool to aid financial accounting requirements of all transactions between the relevant role players involved in importing goods to South Africa.
 - c. The dataset has 24 different data fields, of which all data fields are fully captured and complete.

Collectively, the datasets captured all documentary, physical, and financial flow of information between the freight forwarder orchestrating the movement of goods and the respective role

⁴¹ ShipShape Software is a privately owned company providing tailored software solutions to the customs clearing and forwarding industry.

players involved in the extended South African logistics network for imported cargo. After collecting all the data, the data was rigorously scrutinised in order to meaningfully combine the datasets into one usable set for further in-depth analysis. A significant number of data fields within the datasets (particularly the documentary data flows) were bespoke, non-mandatory fields, which often contained no data at all. Consequently, the data was cleaned (removing missing values, duplicates, outliers, etc.) and sorted into a useable, logical, step-by-step sequence. As is the case with any similar type of information flows between cargo owners, freight forwarders, and any other role players in the extended South African (and indeed, any) logistics network, the information flows are confidential⁴² and not open to the public.

The approach described below was applied to extract meaningful information from the available dataset, consisting of the following sequential steps:

1. Data collection, cleaning, sorting, and categorising:
 - a. First, all process flow data – albeit being captured from the same underlying movement of goods – was collected, cleaned for errors, and sorted into a logical, process-based, sequential flow per consignment.
 - i. Further sorting was done based on the chronological flow of goods as each consignment was captured on the respective systems.
 - b. The data was then combined into one database using several unique consignment reference (UCR) numbers such as “File Reference” and “Container Number”.
 - c. The documentary process flow database was used as the basis for combining the datasets, since the documentary process flow gets initiated for each transaction when the freight forwarder receives the transportation documents from the origin (usually once the ocean transport is confirmed or goods have been physically shipped on board).
 - i. Therefore, the combined data now contained the documentary, physical, and financial information of all the transactions mentioned above.
 - ii. The dependent output variables for each process flow were time and cost, while the independent input variables were obtained from supplementary process information. These variables served as key differentiators to define input factor categories (such as country of origin, country of export, shipping line, etc.).

⁴² As mentioned in Section 1.6.3, permission to use, analyse, and comment on the company data was granted by the freight forwarder.

- d. Data was investigated for relevance (see a detailed outline of the relevance of each data field per respective database in the three tables of Table 5-2, Table 5-3, and Table 5-4).
 - i. Relevance was determined by the respective coverage requirement (such as being a mandatory or non-mandatory field) and accuracy of capturing.
 - e. Each process step was then analysed and, based on logical and procedural flow, sorted into chronological order to establish the final process flow from the perspective of the freight forwarder.
 - i. Ultimately, 39 of the typical 44 process steps were included for analysis.
 - ii. The other five steps concern the purchase management order, which, as with all transactions in this study, was controlled by the cargo owner's international procurement business unit (see the practical suggestion on this matter made in Section 7.3).
2. Establishment of the process flow of the logistics system for South African imports from the perspective of a freight forwarder:
- a. The detailed method described above in point 1 determined the final process flow, which is illustrated below in Figure 5-1.
 - b. The 39 steps identified – which are measured through their timestamp data (some captured by date only and some captured by date and time) – were then divided into various key segments, notably ocean freight (port to port activities), customs, customs/OGA stops, port/terminal activities, inbound transportation, and invoicing and auditing.
 - c. By implementing the two steps mentioned above, the second key research question of this thesis could be answered, namely, “*What is the process flow of the logistics system for South African imports from the perspective of a freight forwarder?*”
3. Descriptive statistical analysis:
- a. Each process step and input factor were considered to understand its distribution, central tendencies, spread, and other characteristics.
 - b. Each process step was investigated, analysed, and descriptively presented to determine the mean, median, mode, standard deviation, range, and percentiles of each process step.
 - i. The respective distributions were investigated to gather insights, including the identification of significant outliers and data errors – such as incorrect data stamps resulting in an impractical and illogical process flow).

- c. Each process step was further categorised by input factor (such as country of origin, country of export, shipping line, etc.) to determine whether different input factors resulted in different performances.
 - i. Several of these categories are illustratively shown throughout this chapter, especially concerning the categorisation of cost per key cost category, notably presented in Figure 5-4 and Figure 5-5.
- 4. Process analysis, by taking two process steps at a time to understand their correlation and causation.
 - a. As with the previous step which investigated the distribution of each process step in isolation, the sequential process steps were now investigated based on the distribution of time that elapsed from one process flow step to the next.
 - i. Not only were sequential process steps analysed, but also key milestones (as shown in Figure 5-1) were investigated to determine where the process typically deviates from the norm, and thus identify where the flows could be influenced to improve logistics performance.
 - ii. The respective distributions of several key sequential time delays are illustrated in Figure 5-3 and Figure 5-7.
- 5. For all steps, several data visualisation techniques were used to show the respective graphical representations of information and data.

Since exploratory data analysis is an iterative process, several steps outlined above can be repeated multiple times until the desired insights are obtained. Ultimately, the objective of this chapter is to gain a deeper understanding of the data and identify patterns or trends that can better inform the empirical analysis in Chapter 6.

5.3 Description of the data

As mentioned above, data was obtained from a South African freight forwarder. It included transaction-level flows between July 2017 and August 2023 (six years) from three separate sources, including (1) documentary process flow data, (2) physical process flow data, and (3) financial process flow data. Besides the transactional flow of data between cargo owners and freight forwarders as per the respective process flows, all transactions included supplementary information exchanged between the South African Customs Administration (SARS), OGAs (in the case of an OGA intervention), various other 4PLs, transporters, and other relevant stakeholders mentioned in Table 4-10. In total, the dataset includes 42 900 import transactions of 24 different tariff headings. The process flow is homogeneous, as all transactions are import flows via ocean freight through the Port of Durban, and inbound transport via road freight to several warehouses in the Gauteng area. The following table summarises the dataset.

Table 5-1: Datasets

Dataset	Description	Nested	No. of Files	No. of Containers
Documentary	Time/date stamp process flow data from the ShipShape Portal	Yes	5 374	9 433
Physical	Time/date stamp process flow data from the Customer Portal	No	6 731	13 910
Financial	Invoice data (in ZAR) on all files (forwarding, clearing, warehousing, bond) from the Financial Portal	Yes	6 602	13 910

Source: Author’s own compilation.

From Table 5-1, several important matters must be noted, especially concerning the difference in the number of files and number of containers. Although the three datasets in question are essentially the same data, often the freight forwarder will only orchestrate the forwarding and not the clearing, or vice versa, hence the disparity between the number of files in the documentary and physical datasets. Furthermore, there is a slight disparity between the number of files in the physical and financial datasets. In these instances, the same container could be first a warehouse entry and then an entry for free circulation (although, as the difference in the number of files suggests, these instances occurred only a few times). As such, the same container can be both a warehouse entry and, later, a free-circulation entry⁴³. The following sub-sections will outline the respective datasets in greater detail.

5.3.1 Documentary flow dataset

The first dataset in question revolves around technical service provider⁴⁴ data, showcasing the documentary process flows. This dataset captures a wide range of critical data fields – both mandatory (for example, required by law) and non-mandatory in nature – to efficiently monitor the movement of goods through the logistics network. The dataset in question comprises more than 5 374 shipments, capturing the movement of more than 42 000 product lines in 9 433 containers. In total, the dataset has 139 different data fields, of which 50 data fields are fully captured and

⁴³ The quantification of "the number of files" was predicated on unique file reference numbers. Diverse shipment types, encompassing import/export, ocean/air, warehouse/free circulation, among others, were identified. In the context of this investigation, which predominantly concentrates on imports, exclusive consideration was accorded to ocean import files. However, it is imperative to acknowledge that a single file, from a documentary perspective, may serve the dual purposes of an import file and a bond (SARS warehouse procedure) file. Consequently, the financial records will record the same file twice: once for the warehouse entry and once for the import entry post goods clearance. Consequently, the enumeration of files reflected in the financial data surpasses the count of documentary files within this sample. Gratifyingly, a congruence is observed between the numerical representation in the physical data, particularly the number of containers, and the financial data.

⁴⁴ In the context of international merchandise trade, a technical service provider refers to an organisation that delivers software and services to other entities engaged in international trade, freight forwarding, customs brokerage, and the international supply chain and logistics sectors.

complete⁴⁵. The following table outlines the data fields, descriptions (or full name), coverage (to what extent these fields are captured), their type, and their relevance to the study.

Table 5-2: Documentary flow dataset summary

FIELD	DESCRIPTION/FULL NAME	COVERAGE	DATA INDICATOR/TYPE	RELEVANCE
FILE REF	File Reference	100%	6-digit unique number (1/2 letter, 4/5 numbers)	High
COMPUTER REF	Computer Reference	100%	6-digit unique number	Low
PURPOSE CODE	Purpose Code	100%	2-letter code	Low
COO CODE	Country of Origin	100%	ISO 3166-1 alpha-2 letter country code	Medium
COE CODE	Country of Export	100%	ISO 3166-1 alpha-2 letter country code	Medium
TRANSPORT CODE	Transport Code (Modality)	100%	1-number transport code	Low
REMOVAL TRANSPORT CODE	Removal Transport Code (Modality)	100%	1-number transport code	Low
TRANSPORT DOC DATE	Transport Documentation Date	100%	Date	High
MCCC	Master Carrier	100%	3/4 letter carrier code	Medium
CC	Carrier Code	100%	3/4 letter carrier code	Medium
SOB DATE	Shipped on Board	100%	Date	High
ETA DATE	Estimated Time of Arrival	100%	Date	High
DEPOT CODE1	Depot Code	100%	1/2 number depot code	Low
PLACE OF ENTRY CODE	Place Of Entry Code	100%	3-letter SA place of entry code	Low
DATE FRAMED	Date Framed	100%	Time/Date	High
FINAL BE NO	Final Bill of Entry Number	100%	7-digit unique code	Low
FINAL BE DATE	Final Bill of Entry Date	100%	Date	High
IS VOC	Voucher of Correction	12%	Yes/No (Y/N)	Medium
EDI CONTRL DATE	EDI Control Date	88%	Time/Date	High
EDI CUSRES DATE	EDI Customs Response Date	100%	Time/Date	High
EDI CUSRES ERROR DESC	EDI CUSRES Error Description	1%	Text	Low
CLIENT NAME	Client Name	100%	Text	Low
CPC CODE	Customs Procedure Code	100%	1-letter code	Low
RCP CODE	Requested Procedure Code	100%	2-number code	Low
PCP CODE	Previous Customs Procedure	100%	1-letter code	Low
SARS CASE NUMBER	SARS Case Number (If Customs Stopped)	7%	9-digit unique code	Low
SARS CASE CLOSED DATE	SARS Case Closed Date (If Customs Stopped)	7%	Time/Date	High
OGA STOP ENTITY CODE	OGA Stop Entity Code (If OGA Stopped)	0%	2-number code	Medium
OGA STOP START TIME	OGA Stop Start Time (If OGA Stopped)	0%	Date	High
OGA STOP FINISH TIME	Oga Stop Finish Time (If OGA Stopped)	0%	Date	High
INVOICE NO	Invoice Number	100%	Unique code/File Ref	Medium
INVOICE DATE	Invoice Date	100%	Date	High
SUPPLIER CODE	Supplier Code	100%	Alpha-numeric	Low
PORT OF LOADING CODE	Port Of Loading Code	100%	5-letter ISO code	Medium

⁴⁵ Data availability and overall quality remains an important consideration in this thesis. As is often the case in practices, technological uptake is slow, especially in the logistics industry where the underlying reality remains simple – moving goods from one place to another. Consequently, the mandatory data fields are typically much more comprehensive versus the non-mandatory fields (even though some of these fields can significantly add to the overall visibility of the cargo movement – further creating the ability to use data analytics to improve performance, as done in this thesis).

DATE CREATED	Date Created (File created)	100%	Time/Date	High
CARGO DELIVERED DATE	Cargo Delivered Date	100%	Date	High
INCO TERM CODE	INCOTERM	100%	3-letter International Payment Terms	Medium
CONTAINER NO	Container Number	100%	alpha-numeric, 4-letters 7-numbers	Medium
EDI CUSRES DATE1	EDI Customs Response Date (IF=EDI Customs Response NOT CODE 1)	100%	Time/Date	High
EDI CUSRES STATUS CODE	EDI Customs Response Status Code	100%	1/2-digit code	Medium
EDI_SENT_DATE	EDI Sent Date	100%	Time/Date	High
TOTAL_CUSTOMS_VALUE	Total Customs Value	100%	Currency (ZAR)	Medium
REASON_FOR_VOC	Reason For Voucher of Correction	12%	Text	Low
USER_TOTAL_CUSTOMS_VALUE_BEFORE	User Total Customs Value Before (VOC)	12%	Currency (ZAR)	Medium
USER_TOTAL_CUSTOMS_VALUE_AFTER	User Total Customs Value After (VOC)	12%	Currency (ZAR)	Medium
CONTAINER_SERVICE_TYPE	Container Service Type	100%	1-digit code	Low
WH_CODE	Warehouse Code	100%	alpha-numeric, 5-letters 5-numbers	Low
INVOICEDATE2	Invoice Date (second date)	99%	Date	Medium
TRANSPORT_DOC_DATE	Transport Documentation Date (copy)	100%	Date	Low
HOUSE_BILL_DATE	House Bill of Entry Date	0%	Date	Low
DATE_FRAMED	Date Framed (copy)	100%	Time/Date	Low
ORIGINAL_FINAL_BE_DATE	Original Final Be of Entry Date (If VOC)	12%	Date	Low
ASSESSMENT_DATE	Assessment Date (QA Assessment)	100%	Date	High
EDI_REG_DATE	EDI Registration Date	0%	Date	Low
BE_SIGHT_DATE	Bill of Entry Sight Date	0%	Date	Low
FLIGHT_DATE	Flight Date	0%	Date	Low
LOCK_DATE	File Lock Date	0%	Date	Low
ACQUITTAL_DATE	Acquittal Date	0%	Date	Low
PREVIOUS_MRN_LINE_DATE	Previous MRN Line of Entry Date	0%	Date	Low
SARS_CASE_CLOSED_DATE	SARS Case Closed Date (Copy)	7%	Time/Date	Low
QA_DATE	Quality Assurance Date (Bond/Brokerage)	100%	Time/Date	High
MPR_ARRIVAL_DATE	Manifest Processing Arrival Date	0%	Date	Low
MPR_EXIT_DATE	Manifest Processing Exit Date	0%	Date	Low
READY_FOR_QA_DATE	Ready For Quality Assurance	100%	Time/Date	High
LAST_MODIFIED_DATE	Last Modified Date (File)	100%	Time/Date	Medium
QAC_DATE	Quality Assurance Correction	3%	Date	Low
ORIG_BE_DATE	Original Bill of Entry Date	0%	Date	Low
WH_BE_DATE	Warehouse Bill of Entry Date	0%	Date	Low
LINE_CREATED_DATE	Line Created Date	100%	Time/Date	Low
DLV_DATE	Delivered Date	0%	Date	Low
EUR_CERTIFICATE_DATE	EUR 1 Certificate Date	9%	Date	Low
ITEM_MANF_DATE	Item Manufactured Date	0%	Date	Low
INVOICE_DATE	Invoice Date (copy)	100%	Date	Low
CARGO_DRAWN_DATE	Cargo drawn date	0%	Date	Low
TERMINAL_ARRIVAL_DATE	Terminal Arrival Date	0%	Date	Low
LAST_SYNCH_DATE	Last Synchronised Date	0%	Date	Low
ATA_DATE	Actual Time of Arrival Date	49%	Date	High

CARGO_REQUIRED_DATE	Cargo Required Date	0%	Date	Low
PORT_HEALTH_EXAM_DATE	Port Health Examination Date (If Required)	5%	Date	High
CUSTOMS_EXAM_DATE	Customs Examination Date (If Customs Stopped)	0%	Date	Low
CTO_DATE	Container Terminal Order Date	0%	Date	Low
CARGO_PICKUP_DATE	Cargo Pickup Date	0%	Date	Low
ANF_PRINT_DATE	Arrival Notification Print Date	0%	Date	Low
DRO_PRINT_DATE	DRO Print Date	0%	Date	Low
CDO_CONFIRMED_DATE	Cargo Dues Order	90%	Time/Date	High
BE_RELEASE_DATE	Bill of Entry (Conditional) Release Date	100%	Date	Low
ORDER_DATE	Order Date	10%	Date	Low
MAWB_EXECUTION_DATE	Master Waybill Execution Date	0%	Date	Low
MT_TURN_IN_DATE	Empty Turn-In Date	20%	Date	High
DOCS_RCVD_DATE	Documents Received Date	54%	Date	High
COPY_DOCS_RECVD_DATE	Copy of Documents Received Date	20%	Date	Low
DISCHARGE_DATE	Container Discharged	24%	Date	Low
UNPACK_DATE	Unpack Date	0%	Date	Low
POD_SENT_DATE	Proof of Delivery Date	0%	Date	Low
COSTING_DATE	Costing Date	0%	Date	Low
SHIPPING_LINE_RELEASE_DATE	Shipping Line Block release	0%	Date	Low
POD_RECEIVED_DATE	Proof of Delivery Received Date	0%	Date	Low
CARGO_AVAILABILITY_DATE	Cargo Availability Date	3%	Date	Low
TRANSSHIP_ETA_DATE	Transshipment ETA Date	1%	Date	Low
TRANSSHIP_ETD_DATE	Transshipment ETD Date	0%	Date	Low
ANF_SENT_DATE	ANF Sent Date	0%	Date	Low
TRANSPORT_INSTR_SENT_DATE	Transport Instruction Sent Date	0%	Date	Low
PRODUCT_READY_DATE	Product Ready Date	0%	Date	Low
HANDOVER_DATE	Handover Date	0%	Date	Low
SARS_MPR_PORT_ARRIVAL_DATE	SARS Manifest Processing Port Arrival Date	0%	Date	Low
SARS_MPR_PORT_EXIT_DATE	SARS Manifest Processing Port Exit Date	0%	Date	Low
ON_DELIVERY_DATE	On Delivery Date	0%	Date	Low
FLIGHT_BOOKING_DATE	Flight Booking Date	0%	Date	Low
FILE_PUSHED_TO_INVOICING_DATE	File Pushed to Invoicing Date	0%	Date	Low
NAVIS_COMPLETED_DATE	Navis Completed Date	0%	Date	Low
PFQ_DATE	Projected Free on Quay	10%	Time/Date	Low
REVISED_ETA_DATE	Revised Estimated Time of Arrival Date	54%	Time/Date	Low
PLANNED_DELIVERY_DATE	Planned Delivery Date	25%	Time/Date	Low
FILE_COVER_DATE	File Cover Date	4%	Time/Date	Low
GIM_SENT_DATE		0%	Date	Low
DEACTIVATED_DATE	Deactivated Date	0%	Date	Low
REACTIVATED_DATE	Reactivated Date	0%	Date	Low
DRO_FIRST_PRINT_DATE	Container Terminal Order Date	0%	Date	Low
CONTAINER_STUFFING_DATE	For an export file	0%	Date	Low

FIRST_DATE_CLOSED	First Date Closed	100%	Time/Date	High
ETD_DATE	Estimated Time of Vessel Departure	43%	Date	High
CUSTOMS_EXAM_BOOK ED_DATE	Customs Examination Date	0%	Date	Low
INSPECTION_DATE	Inspection Date	0%	Date	Low
EDD_DATE	Estimated Date of Departure	0%	Date	Low
FINALIZED_WAYBIL_RE CVD_DATE	Finalised Waybill Received Date	0%	Date	Low
DATE_CLOSED	Date Closed	100%	Time/Date	High
DEPOT_ETA_DATE	Depot ETA Date	0%	Date	Low
DEPOT_UNPACK_DATE	Depot Unpack Date	0%	Date	Low
DATE_DUE_STATES_WH SE	Date Containers are due in Stack – From the Shipping Lines	0%	Date	Low
FIRST_DEPOT_UNPACK _DATE	Depot Unpack Date	0%	Date	Low
CTO_COLLECTION_DAT E	CTO Collection Date	0%	Date	Low
CTO_BE_DATE	CTO Bill of Entry Date	0%	Date	Low
DLV_DATE_EXPECTED	Delivery Date Expected	92%	Time/Date	High
DLV_DATE_ACTUAL	Delivery Date Actual	91%	Time/Date	High
Inv_Head_Date	Invoice Head (Office) Date	99%	Date	Low
TARRIF_HEADING ⁴⁶	Tariff Heading	100%	HS Code (6/8 digit level)	Medium
GROSS_MASS	Gross Mass	100%	Mass in Kg	Medium
VOLUME	Volume	66%	CBM	Medium
NO_OF_PACKAGES	Number of Packages	100%	Number	Medium

Source: Author's own compilation from the ShipShape Portal.

Concerning the relevance of each data field, the following factors were key when considering their use in this thesis:

- High relevance relates to key steps in the end-to-end logistics import process, particularly relating to time taken. Many of the steps are sequential and must fulfil certain requirements before being satisfied and allowing the process to continue to the next step. On a top contour, these include shipped on board, bill of entry released, discharged date, and others.
- Medium relevance relates to input variables which will have an impact on the performance criteria (i.e., country of origin, HS code, product valuation, etc.).
- Low relevance relates to any data field not directly and significantly influencing the performance of South African imports as per the datasets. Examples include transport codes (the entire sample constitutes ocean freight imports and road freight inbound transport), last sync date, and other non-mandatory data fields not captured in full.

⁴⁶ Note, "tarrif" is misspelled in the database, and should read "tariff".

5.3.2 Physical flow dataset

The second dataset in question revolves around bespoke customer portal data showcasing the physical process flows. This dataset captures several important physical flow data fields – tracking the various sequential steps as the container flows through the logistics process. The dataset in question comprises more than 6 731 shipments, capturing the movement of 13 910 containers. In total, the dataset has 44 different data fields, of which 19 data fields are fully captured and complete. The following table outlines the data fields, descriptions (or full name), coverage (to what extent these fields are captured), their type, and their relevance to the study.

Table 5-3: Physical flow dataset summary

FIELD	DESCRIPTION/FULL NAME	COVERAGE	DATA INDICATOR/TYPE	RELEVANCE
Container Number	Container Number	100%	4-letter, 5-number UCR	High
Container Status	Container Status	55%	Text (9 different statuses)	Low
Status Date	Last Status Date	55%	Time/Date	Low
Client Ref	Client Reference	100%	Alpha-numeric	Low
Company Ref	Company Reference	100%	6-digit unique number (1/2 letter, 4/5 numbers)	High
Planned Delivery Date	Planned Delivery Date	73%	Date	High
Free Storages Days Left	Free Storages Days Left	13%	Number	Low
Free Demurrage Days Left	Free Demurrage Days Left	5%	Number	Low
SOB Date	Shipped On Board	100%	Date	High
ETA	Estimated Time of Arrival	100%	Time/Date	High
Revised ETA	Revised Estimated Time of Arrival	58%	Time/Date	High
ATA	Actual Time of Arrival	48%	Time/Date	High
Discharged Date	Discharged Date	42%	Time/Date	High
Left Port Date	Left Port Date	36%	Date	High
Arrived at Depot Date	Arrived at Depot Date	16%	Time/Date	High
Left Depot Date	Left Depot Date	31%	Date	High
Arrived At Warehouse Date	Arrived At Warehouse Date	36%	Date	High
Supplier	Supplier Name	100%	Text	Low
Description of Goods	Description of Goods	96%	Text	Low
Container Type	Container Type	100%	Text (40ft/20ft)	Medium
Seal Number	Seal Number	98%	Alpha-numeric	Low
Number of Units	Number of Units	100%	Number	Low
Country of Origin	Country of Origin	100%	Text (Country)	Medium
Country of Destination	Country of Destination	100%	Text (Country)	High
Port of Loading	Port of Loading	100%	Text (Port)	High
Port of Discharge	Port of Discharge	100%	Text (Port)	High
Destination Warehouse	Destination Warehouse	98%	Text (WH)	Low
Shipping Line	Shipping Line	100%	Text (SL)	High
Vessel	Vessel	100%	Text (Vessel Name)	Low
Voyage	Voyage	100%	Alpha-numeric	Low
Master Bill Of Lading	Master Bill Of Lading	100%	Alpha-numeric	Low
Shipped On Board	Shipped On Board	100%	Date	High
Discharged	Discharged Date (replicate)	42%	Time/Date	High
Left Port	Left Port Date (replicate)	36%	Date	High
En Route To Depot	En Route To Depot	36%	Date	High

Arrived at Depot	Arrived at Depot Date (replicate)	16%	Time/Date	High
En Route to Warehouse	En Route to Warehouse	31%	Date	High
Arrived at Warehouse	Arrived At Warehouse Date (replicate)	36%	Date	High
Stopped for Inspection	Stopped for Inspection	0%	Time/Date	High
Embargo Released	Embargo Released	0%	Time/Date	High
CLIENT CODE	Client Code	100%	Alpha-numeric (4 letters, 4 numbers)	Low
FILE CLOSED	File Closed	100%	Text (Y/N)	High
CONTAINER_ID	Container Identification Number	100%	Number	Low
DELIVERY_TO_WAREHOUSE	Delivery to Warehouse	98%	Text (WH)	Low

Source: Author's own compilation from the Customer Portal.

Concerning the relevance of each data field, a similar approach to the one concerning the documentary flow was followed.

5.3.3 Financial flow dataset

The third dataset in question revolves around the financial data capturing the monetary flows concerning all transactions. This dataset captures several important financial data fields linking all the activities together. The dataset in question comprises more than 6 731 shipments, capturing the movement of 13 910 containers. In total, the dataset has 24 different data fields, of which all data fields are fully captured and complete. The following table outlines the data fields, descriptions (or full name), coverage (to what extent these fields are captured), their type, and their relevance to the study.

Table 5-4: Financial flow dataset summary

FIELD	DESCRIPTION/FULL NAME	COVER AGE	DATA INDICATOR/TYPE	RELEVANCE
invoice_no	Invoice number	100%	8-digit unique number	High
issue_date	Invoice issue date	100%	Date	High
file_ref	File reference	100%	6-digit unique number (1-letter, 5-number)	Medium
customer	Customer name	100%	Text	Low
currency	Currency (ZAR\$/etc.; Note: All = ZAR)	100%	ISO 3-Letter Currency Code	Low
inv_amount	Total invoice amount	100%	Currency	High
inv_local_amount	Total invoice amount in local currency	100%	Currency	Low
account	Account number	100%	10-digit account number	Low
status	File status (open/closed)	100%	Text	Low
type	Type (debit/credit)	100%	DB/CR	Medium
competence_dt	Competence date (vessel arrival for imports/departure for exports)	100%	Date	Medium
due_date	Invoice due	100%	Date	High
user_id	System user identification	100%	6-digit user number	Low
user_name	System user name	100%	Name. Surname	Low
branch_id	Branch identification	100%	2-digit/2-letter	Low
descr	Billing item description	100%	Text	High

tax_amount	Tax amount	100%	Currency	High
taxed_amount	Total taxed amount	100%	Currency	High
net_amount	Net amount (total - tax)	100%	Currency	High
bu	Billing unit (office/mode/flow)	100%	Text	Low
mode	Mode of transport (ocean/air/road)	100%	Text	Low
type	Type of flow (import/export)	100%	Text	Low
descr_allocation	Billing item allocation	100%	Text	Low
bu check	Billing unit checked	100%	3-digit alpha-numerical	Low

Source: Author's own compilation from the Financial Portal.

Concerning the relevance of each data field, a similar approach to the one concerning the documentary flow as discussed in Section 5.3.1 was followed.

5.3.4 Final, combined process flow

Through the rigorous scrutinising of the respective datasets, the data were combined into one usable set for further in-depth analysis. The combined data collectively comprise approximately 5 374 shipments. Through the analysis outlined above, 39 different time-sensitive data points (or logistics process 'triggers' or handover points) can be regarded as highly relevant, as per the table above. The most important measurable hand-over points in a shipment transaction are identified as the following:

Table 5-5: Final combined process flow

No	Process step	No	Process step
1.	Purchase Order	23.	SARS Case Closed Date
2.	Order Confirmation	24.	Final Bill of Entry
3.	Shipping Booking	25.	Other Government Stop Start Time
4.	Packaging & Containerisation	26.	Other Government Stop Finish Time
5.	Origin inbound Transportation to Port	27.	Port Health Examination Date (If required)
6.	Invoice Date (first date)	28.	Revised Estimated Time of Arrival
7.	Transport Documentation Date	29.	Cargo Dues Order
8.	Estimated Time of Vessel Departure (Origin)	30.	Actual Time of Arrival
9.	Shipped on Board	31.	Discharged Date
10.	Documents Received Date	32.	Left Port Date
11.	Date Created	33.	En Route To Depot
12.	Estimated Time of Arrival (SS)	34.	Arrived at Depot Date
13.	Date Framed	35.	Left Depot Date
14.	Assessment Date (System risk assessment)	36.	Delivery Date Expected
15.	Ready for Quality Assurance	37.	Planned Delivery Date
16.	Quality Assurance Date (Bond/Brokerage)	38.	Arrived At Warehouse Date

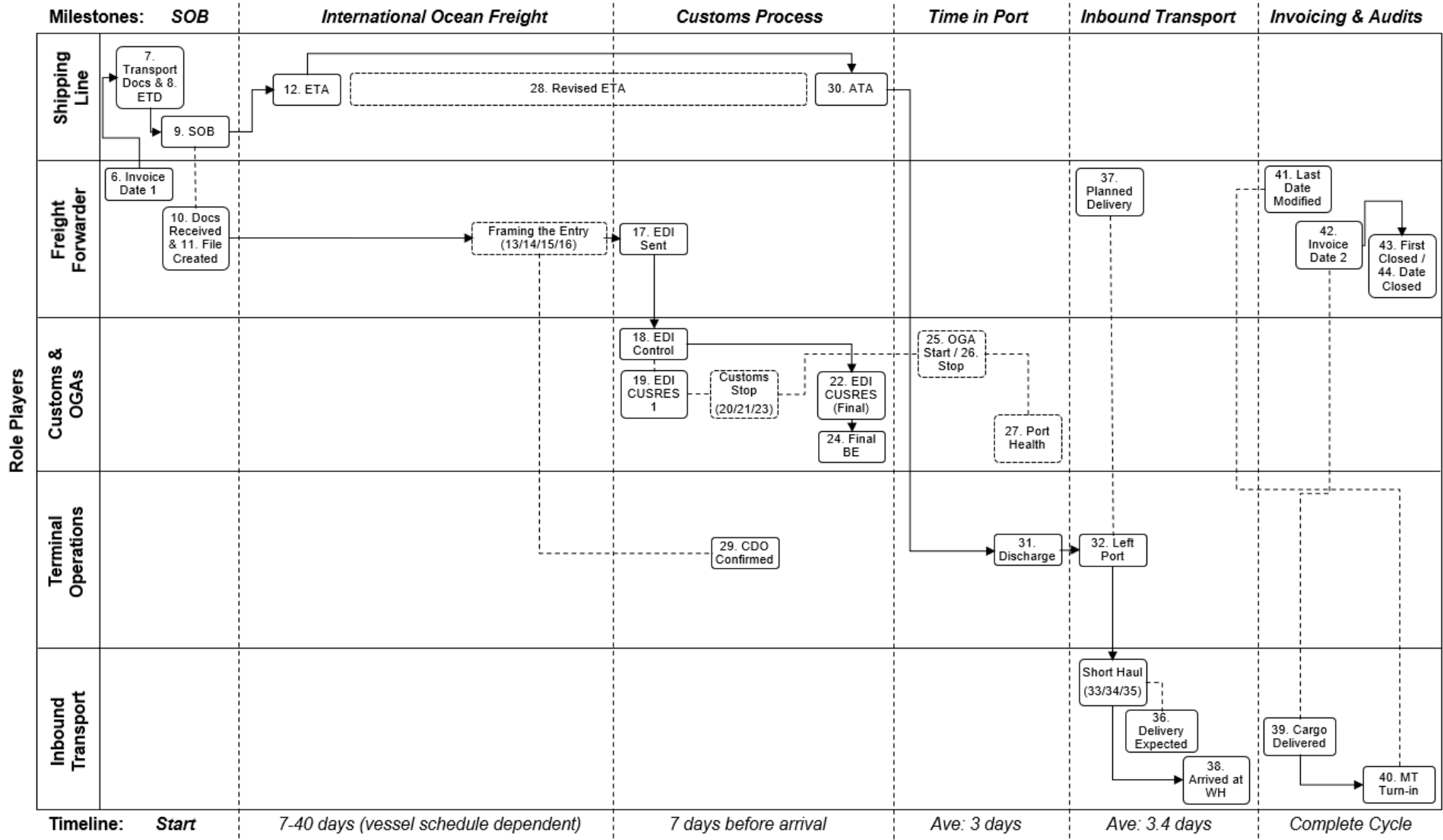
17.	Electronic Data Interchange Sent Date	39.	Cargo Delivered Date
18.	EDI Control Date (Customs' first response, i.e., received)	40.	Empty Turn-In Date
19.	EDI Customs Response Date	41.	Last Modified Date
20.	Stopped for Inspection	42.	Invoice Date (second date)
21.	Embargo Released	43.	First Date Closed
22.	EDI Customs Final Response	44.	Date Closed

Source: Author's own compilation.

These steps can be divided into event categories, notably purchase order management (and cartage from EXW to FOB – activities which the importer or freight forwarder typically does not have sight of), ocean freight (port to port activities), customs, customs/OGA stops, port/terminal activities, inbound transportation, and invoicing and auditing. The primary role players responsible for the main activity based on these process flow steps include the shipping line, the freight forwarder, the customs authority (and OGA), the terminal operator, and the inbound transporter.

As mentioned earlier, the freight forwarder is the primary actor orchestrating the functioning of the logistics system. The following schematic illustrates the sequential process flow per activity by the respective role players (note, the purchase order management functions are omitted since these take place at origin and are often – and in all cases that the dataset is based on – not visible to the freight forwarder). The illustration further shows the key process milestones and average timeline, with solid lines denoting steps happening in sequence (in series), whereas dotted lines denote steps not necessarily happening in sequence (in parallel).

Figure 5-1: Final, typical process flow per activity by the respective role players (benchmarked performance in days)



Source: Author's own compilation.

From Figure 5-1, several observations can be made about the typical import process flow. When dividing the flow into key segments, the international ocean freight segment typically takes the longest due to South Africa’s geographical location being far away from its trading partners. Therefore, a smooth, functioning international ocean freight process – even without delays – can take up to 40 days. Furthermore, there is little potential room for freight forwarder influence to improve this performance once the goods are shipped on board; however, significant room exists when choosing the combination of supplier (based on country of origin), port of loading, and shipping line. Besides the fact that international trade is based on schedules, there is significant variation based on the number of port calls per schedule – and, of course, the potential variation in performance.

Fortunately, once the goods are shipped on board, several activities can happen in parallel, notably the customs clearance process. In South Africa, the customs clearance process typically starts seven days before the vessel arrives; however, SARS legislation allows another seven days to clear the goods once the vessel has landed (SARS, 2021). As will be further elaborated on in Table 5-22, the freight forwarder can significantly influence the entire documentary process – including the customs process – as they are actively involved before, during, and after the customs process. Once the customs process has been completed and the container discharged, the goods will once again physically move as follows: from the vessel to the quay side, from the quay side to the land transport exiting the terminal, and from leaving the port to the depot or warehouse or final delivery, depending on the choice and combination of short-haul, long haul, and last-mile transport, as illustrated above. Then, after the final delivery, the invoicing, payment, and auditing process is completed. In its entirety, although the physical goods might only move for a minimum of 16 days, the entire documentary and financial process might take as long as six months to conclude.

The following three tables are complementary to Figure 5-1, and provide a description of each main segment of the respective process flows (documentary, physical, and financial) with the accompanying requirements, risks and reasons for variation related to each segment⁴⁷. The first table shows the documentary requirements orchestrated by the freight forwarder:

⁴⁷ The initiation of the documentary process is contingent upon disparate commencement times. However, the crucial imperative is to allocate a sufficient timeframe for the seamless conclusion of the process antecedent to the stipulated requirements, encompassing mandates such as the imperative clearance of goods within a seven-day timeframe and the requisite settlement of Customs Duty and Outlays (CDO) within 28 days. It is noteworthy that, even in instances where errors may arise during the documentary process, measures are implemented to facilitate the timely culmination of the process, thereby averting any associated physical delays.

Table 5-6: Documentary flow: sequence of main segments

Segment	Date milestone	Description	Requirements	Risks and potential to vary
Ocean leg transportation	Transport Docs (7)	The act of shipping containers via ocean freight from an origin port to a destination port.	A full set of international shipping documents (commercial and physical documents, notably an onboard manifest and bill of lading.	Voyage disruptions, weather and related delays, piracy, and shipping incidents resulting in damage. The risk and responsibility of the respective parties will depend on the incoterm.
File created	Date created (11)	A file of the transactions is created on the customs clearing and forwarding platform – in this case, on the SS platform.	The specific requirements may vary depending on the country, origin, destination, commodity, and value of the shipment, and may include the following: commercial invoice, packing list, bill of lading, certificate of origin, and others.	Product misclassification, incorrect country of origin, incorrect valuation.
Entry framed	Date framed (13)	Provide an official statement of specific information regarding your imported merchandise to the customs authority.	Country of origin, description of the goods as per HS classification, cost, insurance, and freight (CIF) value, and the approximate amount of duties.	Incorrect or misleading information on any of the listed requirements (which could also lead to flawed conclusions in assessing a country's international transport costs, especially with inserting incorrect CIF values – see Chasomeris, 2009).
Customs clearance	EDI CUSRES Final (22)	The clearance process includes accepting and checking the goods declaration against the documents produced, examination of the goods if necessary, and the assessment and collection of duty and VAT.	A full set of documents, as mentioned above (invoice, bill of lading, certificate of origin, permits, and others). Furthermore, the legislation gives an importer seven days (or 28 days in the case of goods in a container depot) to clear goods from the time they have landed in the Republic (SARS, 2021).	Incorrect or misleading information on any of the listed requirements. Goods can be inspected or detained, depending on the severity of the infraction. Moreover, financial penalties can be issued.
Entry accepted	Final BE (24)	The customs entry is accepted, and a final bill of entry is issued.	Adherence to all customs requirements as per the customs	Non-compliance to any of the requirements.

			external policy clearance declaration.	
Inbound transportation	Delivery expected (36)	Arrangement of the inbound transportation from the container terminal to the unpacking depot (short haul) and warehouse (long haul).	Completion of the customs clearance process and cargo dues paid for the handling of the container.	Several risks, which are not limited to accidents and collisions, infrastructure wear and tear, environmental hazards, load losses, robbery, and others.
Transaction file finalised and closed	First date closed (43)	The closure of the file once the transaction has been finalised.	Successful completion of the entire process.	Several risks, including systematic risk, process risk, and the loss of documents, information, and data.

Source: Author's own compilation.

The following table shows the physical movement of the cargo:

Table 5-7: Physical flow: sequence of main segments

Segment	Data milestone	Description	Requirements	Risks
Loaded onto the vessel at the origin	Shipped on board (9)	The specific containerised goods have been received and loaded onto the nominated vessel on the stated date.	This notation appears on all bills of lading, and is a confirmation from the shipping company to the shipper or the party dispatching the goods that the goods have been loaded onto their vessel.	Gantry operations, weather, port congestion and related risks of container handling. Furthermore, late changes in shipping schedules could potentially delay the movement of goods.
Vessel arrival at destination	Actual time of arrival (30)	The international shipping leg from the origin port to arrival at the destination port.	Several requirements by TNPA must be met, including compliance with the National Ports Act, payment of marine services charges, licensing, and compliance with regulations ⁴⁸ , among others.	Lack of adequate marine resources, availability of berthing slots, port congestion, weather, and other port-related risks.
Container discharged from the vessel	Discharged (31)	Container discharged via gantry (or ship to shore) cranes from	Several requirements by TPT must be met, including the cargo release order, customs	Gantry operations, weather, port congestion and

⁴⁸ It is noteworthy that the unloading of cargo from the vessel, denoted as the waterside operation, does not automatically signify the release of cargo for retrieval at the terminal, designated as the landside. Consequently, cargo may undergo the discharge process without undergoing the release procedure, potentially leading to the accrual of charges such as storage fees, demurrage charges, and other associated overstay fees.

		the vessel on the waterside to the container stack on the landside.	clearance, and payment of terminal handling fees.	related risks of container handling.
Short haul road transport leg to unpack depot	Left port (32)	Arrangement of the inbound transportation from the container terminal to the unpacking depot (short haul).	All terminal requirements must be completed.	Slow truck turnaround times, terminal congestion, weather delays.
Arrival at depot	Arrived at depot (34)	Arrival of containerised goods to a facility where those goods will be unpacked or deconsolidated.	Several documents related to the goods, including the bill of lading, commercial invoice, packing list, and the like.	Several risks, including (but not limited to) accidents and collisions, infrastructure wear and tear, environmental hazards, load losses, robbery, and others.
Long haul road transport leg	Arrived at warehouse (38)	Arrival of containerised goods to a facility where those goods will be stored until the final last-mile delivery to the customer.	Several documents related to the goods, including the bill of lading, commercial invoice, packing list, and the like.	
Last mile delivery	Cargo delivered (39)	The arrival of goods (typically de-consolidated from the container) via final last-mile delivery to the customer.	Proof of delivery.	
Empty container returned at shipping line depot	Empty turn-in (40)	Transportation of the empty container to the shipping line depot.	Completion of the inbound transport leg.	

Source: Author's own compilation.

The following table shows the financial flows of each transaction:

Table 5-8: Financial flow: sequence of main segments

Segment	Data milestone	Description	Requirements	Risks
Invoice received for ocean transport leg	Invoice date 1 (6)	The cost incurred for the international shipping leg.	Typically, the bill of lading; however, the cost for international shipping can be incurred (even before cargo is loaded onboard the vessel at origin). These conditions will depend on the Incoterms, as well as the contract between the parties.	Non-payment and failure to deliver service.

Cargo dues paid to the port	CDO confirmed (29)	Cargo dues (also known as wharfage in some countries) are fees levied by TNPA for the use of port facilities and services.	Cargo dues orders for containerised cargo must be submitted within three (3) days after vessel departure (TNPA, 2023). Cargo dues must be paid within 25 days after receipt of the TNPA and be accompanied by several documents (including the cargo dues order, vessel manifest, and empty container list). However, cargo dues can only be processed once the container manifests are loaded by TPT's system, when the shipping line has communicated the Bill of Lading documentation to TNPA, and TNPA has invoiced the cargo dues and related charges applicable to the shipping line.	Failure to pay the cargo dues within the specified timeframe may result in penalties or additional charges, and could potentially incur delays.
Invoice issued for forwarding and clearing charges	Invoice date 2 (42)	The cost incurred for all forwarding and clearing costs (these include landside charges, customs, 3PL charges, storage, transport, and cargo dues).	For duty and VAT paid to SARS, the agent is liable for the duty and VAT as soon as the customs entry is released by SARS. This cost is automatically added to a deferment account unless it is a cash payment entry (which is not the case with this dataset in this study). The transport costs are received by the freight forwarder when the container is delivered, who then pays the transporter. Collectively, invoice date 2 is the balancing of all services rendered and services received by the respective parties (as orchestrated by the freight forwarder).	Non-payment and failure to deliver service.
Transaction file finalised and closed	Date closed (44)	The closure of the file once the transaction has been finalised.	Successful completion of the entire process.	Several risks, including systematic risk, process risk, and the loss of documents, information, and data.

Source: Author's own compilation.

The datasets utilised in this study are further characterised by their complexity, featuring three distinct levels of data. These tiers provide a comprehensive and multi-dimensional perspective,

enabling a thorough exploration and analysis of the research topic. However, seeing that these process steps – captured by the respective data fields – are combined from both the physical and documentary process databases, the data are represented in several important hierarchies, notably:

Table 5-9: Level of data per dataset

Data level	Corresponding data field	Example
Shipment	FILE REF	One shipment of several containers containing multiple products.
Container	CONTAINER NO	One container containing one or more products of different tariff headings.
Product	TARRIF_HEADING	One product as per a distinct tariff heading.

Source: Author’s own compilation.

Therefore, in descending order, the respective data levels are as follows:

1. Shipment (identified by the file reference number).
 - 1.1. Container (identified by the container number).
 - 1.1.1. Product (identified by the respective tariff headings per file reference number).

The following aspects are key:

- On the documentary flow, the primary identifier is the file reference number (as it identifies a unique shipment which may include several containers).
 - The vessel data will not differ per container (such as shipped on board, estimated time of arrival, etc.).
 - However, the customs data might differ per product (such as stopped, embargo release, etc.) depending on the clearing process.
- On the physical flow, the primary identifier is the container number.
 - The vessel data will not differ per container (such as shipped on board, estimated time of arrival, etc.).
 - However, the customs data might differ per container (such as stopped, embargo release, etc.), depending on the clearing process.
 - Furthermore, the inbound transport data might differ per container (such as discharged – all the way along the sequence to arrival at the warehouse), depending on when containers were released or when transport was arranged.
 - Also, as is the case with many containers in this dataset, the importer and their freight agent might follow a short haul-long haul inbound transport strategy, whereby the container is shipped from the container terminal to a

nearby depot, unpacked, and then repacked and shipped via road transport for the long haul inbound transport leg.

- The prevailing reason behind this strategy is that more than a container's worth of goods can be shipped on a super-link truck, thereby saving on transportation costs. This strategy is invariably followed concerning non-time-sensitive goods.
- On the financial flow, the primary identifier is the file reference number (i.e., the shipment).

In addition to the important time-sensitive data fields, the following data fields are also included in the analysis, relating to identifiers, categorisers, types, etc. These data fields are all those with medium or high relevance to the study and supplementary to the timestamp data, as outlined in Table 5-2 to Table 5-4. Some of the data fields are replicated in more than one dataset (such as file reference, country of origin, shipped on board, etc.) and are, therefore, only shown once. Furthermore, data of low importance and low coverage will not be included in the analysis. The following fields are important to this thesis:

Table 5-10: Supplementary data fields

No	Process step	No	Process step
1.	File Reference	14.	User Total Customs Value After (VOC)
2.	Country of Origin	15.	Customs Examination Date
3.	Country of Export	16.	Delivery Date Actual
4.	Master Carrier	17.	Tariff Heading
5.	Carrier Code	18.	Gross Mass
6.	Voucher of Correction	19.	Volume
7.	OGA Stop Entity Code (If OGA Stopped)	20.	Number of Packages
8.	Invoice Number	21.	Container Type
9.	INCOTERM	22.	Country of Destination
10.	Container Number	23.	Port of Loading
11.	EDI Customs Response Status Code	24.	Port of Discharge
12.	Total Customs Value	25.	Shipping Line
13.	User Total Customs Value Before (VOC)		

Source: Author's own compilation.

5.4 Overview of descriptive statistics and exploratory analysis results

The following section provides an overview of the exploratory and descriptive statistics that were extracted from the data. As mentioned above, the objective of this chapter is to gain a deeper understanding of the data and identify patterns or trends that can better inform the empirical analysis in Chapter 6. The section is divided into three subsections, including a descriptive analysis and a logistics process analysis.

5.4.1 Descriptive analysis of logistics performance criteria and input variability

The following tables provide a descriptive overview of the combined dataset. The combined dataset represents a total of 42 910 products. Each product is described by 207 different data fields. It is, therefore, necessary to reduce the amount of raw data by extracting meaningful information from the data in order to produce information that can be used to support higher-quality logistics decisions, thus improving the logistics performance of South African imports. Consequently, as already outlined in Table 5-10, the data will be divided into categories according to the values of the input variables (i.e., country of origin/export, shipping line, customs response, etc.), to allow the extraction of performance measures within each category. This will enable a comparison between performance levels achieved within different categories, as category membership is often determined by logistics decisions (e.g., which country to ship from or which shipping line to use). A comparison of category performance levels can inform improved decision-making. Furthermore, the input variables which influence the performance outcomes the most will be identified, including the identification of sporadic and systematic deviations from the benchmark performance. As such, the descriptive analysis will focus on the following key input variables:

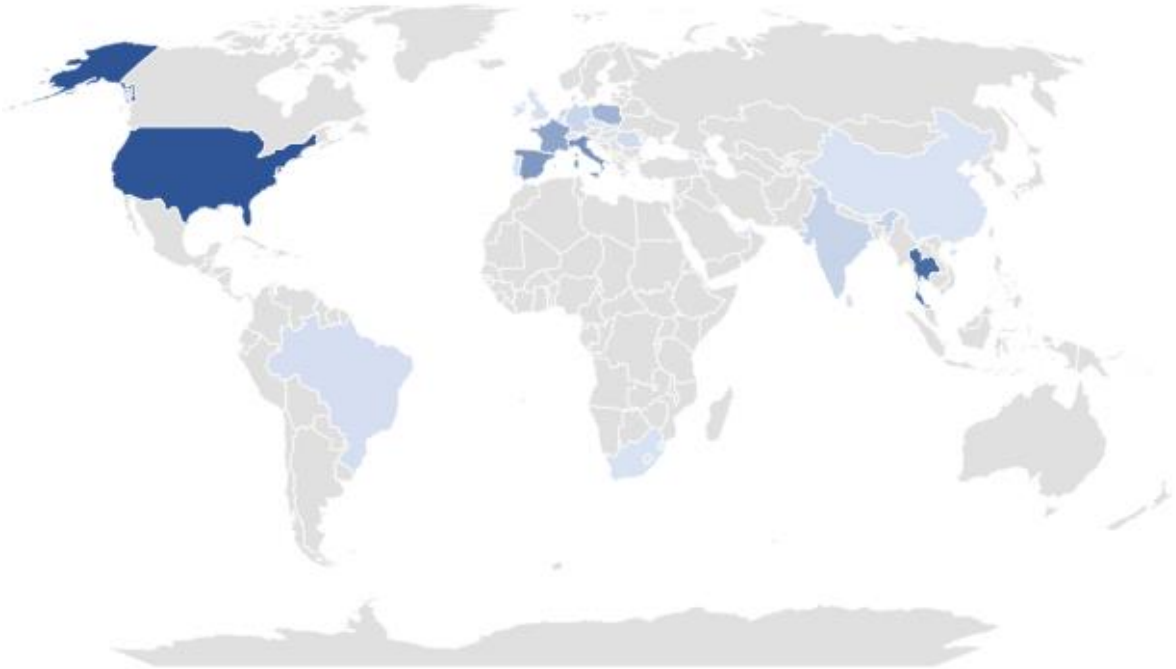
1. Country of Origin/Export⁴⁹ – Selection of supplier
2. Port of Loading – Selection of supplier/service provider combination
3. Shipping Line – Selection of service provider
4. Tariff headings – Determining whether some product lines move faster than others
5. Incoterm – Selection of incoterm (level of risk and responsibility per party)
6. VOC – Determining whether errors were made during the customs process, especially in case of duty having been calculated incorrectly
7. EDICUSRES – Determining the influence of Customs/Customs' response on performance
8. OGA – Determining the influence of OGAs on performance

In total, the data set comprises 13 910 containers, which shipped a total of more than 15 million tyres worth more than R31 billion in customs value, with 42 910 products from 23 different

⁴⁹ It is worth pointing out that country of origin and country of export is not the same thing. For example, according to the WTO rules of origin (which are the criteria needed to determine the national source of a product), a product could be manufactured in Belgium and shipped out of France. However, within the dataset, there are very few instances of country of origin and country of export being different. Therefore, the country of origin and the country of export are essentially interchangeable in this thesis. However, where the slight difference is import, for example, with customs clearance of goods, the country of origin will be used, as SARS' risk engine (and indeed many other customs authorities' risk engine) is based on country of origin and not country of export. Furthermore, as outlined above, the WTO rules of origin, as well as trade agreements, operate on the country of origin rather than the country of export.

countries shipped via 14 shipping lines. The following image illustrates the geographical sourcing based on the number of product lines:

Figure 5-2: Country of origin (per number of products imported – darker = more)



Source: Author’s own visualisation.

The origin of cargo is not too dissimilar to South Africa’s main trading partners shown in Table 4-3, with the United States, Thailand, Italy, Spain, and France being the top five countries of cargo origin. The next five include Poland, India, the Netherlands, Germany, and Belgium. The following table shows the respective customs value based on country of export:

Table 5-11: Overview of the dataset: Country of export (sum of value, ZAR)

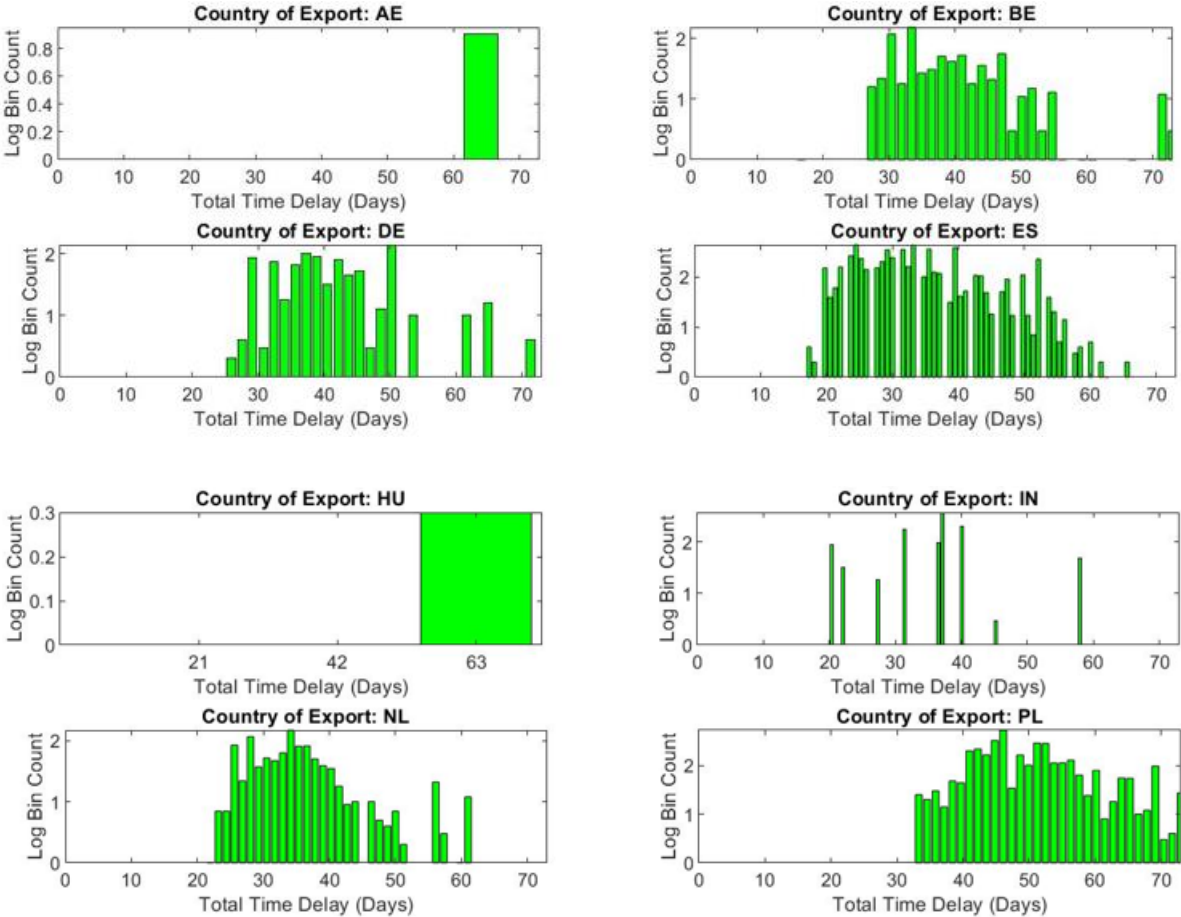
Country of export	Customs Value
United States of America	R6 793 901 671
Thailand	R5 828 943 994
Italy	R5 268 940 596
Spain	R4 272 415 535
France	R3 015 458 577
Poland	R1 976 591 234
India	R1 312 349 899
Netherlands	R804 316 629
Germany	R700 255 169
Belgium	R379 946 451
Portugal	R317 780 470
Romania	R267 648 073
Brazil	R256 533 940
Slovenia	R159 044 607

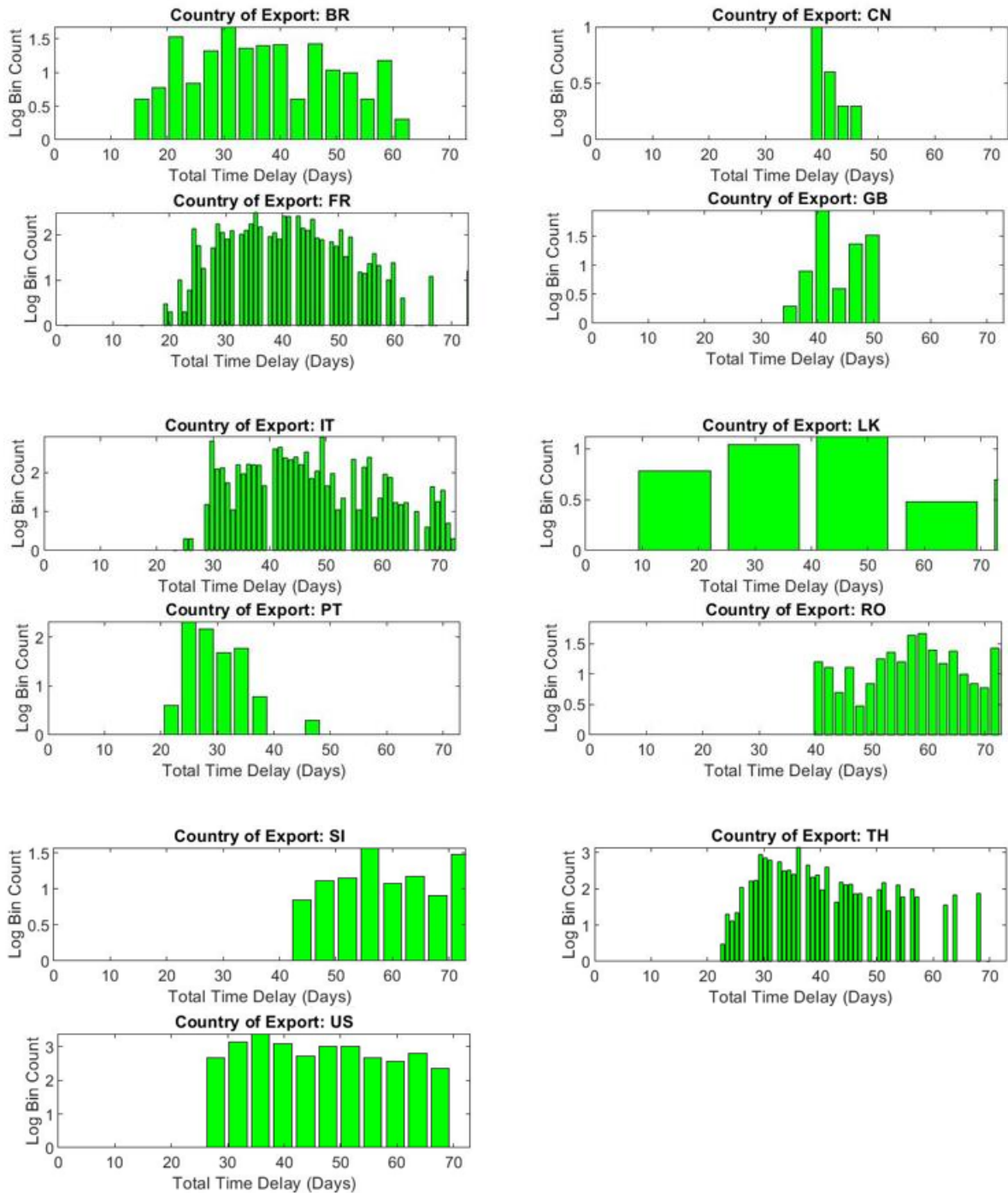
Hungary	R85 192 350
United Kingdom	R72 400 286
Czech Republic	R22 885 120
China	R13 538 759
United Arab Emirates	R12 553 838
Sri-Lanka	R6 967 043
South Africa	R4 657 323
Georgia	R853 000
Ireland	R318 708
Singapore	R194 553
Grand Total	R31 573 687 825

Source: Author's own compilation.

The following collection of histograms shows the total time delay of goods per country of export, as outlined above, with the respective distributions of the high-volume countries of particular interest.

Figure 5-3: Histograms of respective country of export: Total time delay (days)





Source: Author's own compilation.

The distribution of the top five exporting countries is curious, and showcases significantly different spreads. For example, goods originating from the USA – the top trader – take at least 24 days and average 42.79 days. Goods originating from Thailand – the top trader from Asia – take at least 22 days but average 36.39 days. Further interesting observations can be made, notably between countries of export close to one another. For example, goods from Belgium take at least 16 days and an average of 37.83 days, whereas goods from France take at least 11 days and an average of 39.28 days, and goods from the Netherlands take at least 21 days and an average of

33.78 days. The following table provides a summary of the country of export in terms of total time delays from SOB to cargo delivered:

Table 5-12: Country of export: Statistical summary maritime transport leg

Country	Size	Average ⁵⁰	Variance	Min	Max
United States of America	10 253	42.79	516.8	24	398
Thailand	8 403	36.39	65.1	22	84
Italy	5 927	43.81	98.94	23	93
Spain	5 437	32.94	81.44	17	79
France	3 879	39.28	84.05	1	84
Poland	3 510	50.76	110.71	32	128
India	1 031	35.44	60.04	20	58
Netherlands	974	33.78	50.02	21	61
Germany	879	40.95	98.18	25	81
Belgium	735	37.83	87.77	16	76
Romania	523	67.64	255.22	39	92
Portugal	479	26.42	23.2	20	78
Brazil	269	34.6	143.32	14	77
Slovenia	163	61.12	150.99	41	100
Georgia	161	41.67	26.65	33	73
Sri-Lanka	40	52.45	6 580.25	13	394
China	20	39.8	8.91	33	46
United Arab Emirates	17	87.35	560.12	63	109
Hungary	3	53	156	39	63
Singapore	2	49	0	49	49
Czech Republic	1	25	0	25	25
Ireland	1	41	0	41	41

Source: Author’s own compilation.

The distribution and summary of statistical parameters highlight the significance of choosing one supplier over another, contributing to variations in total time delays. The decision on the supplier may be influenced by multiple factors, such as the product, origin, inbound transport, port of loading (as indicated in Table 9-3 in the annexure), and shipping line. Given that these factors impacting the choice of supplier could potentially exert an influence on the time delay of goods, it is imperative to conduct a more thorough investigation into these factors.

⁵⁰ In statistics, including discussions on international shipping delays, the terms "mean" and "average" are frequently interchangeable; however, in the shipping industry, "average" typically refers to arithmetic means, emphasising their use for capturing the comprehensive delay experience, including outliers. Therefore, here and throughout the results discussed, the average includes the outliers. Note that the preceding histograms in Figure 5-3 show the entire distribution of the country of export; hence, adding additional measures of central tendency like median and mode to the summarised table is not necessary. Here, and throughout Chapters 5 and 6, the averages are measured in days.

Of course, the distribution shown in Figure 5-3 and Table 5-12 is highly dependent on South Africa’s linkage to the global shipping network, as illustrated by Figure 4-2. The following table shows the products (42 910 different lines – each representing a product imported) shipped via the respective shipping lines:

Table 5-13: Shipping lines: product lines shipped

Shipping Line	Products shipped
Ocean Network Express	11 706
Mediterranean Shipping Company	11 560
Safmarine Container Lines	4 978
CMA-CGM Group	3 393
Maersk Line	3 153
MOL	3 110
Hamburg Sud	2 438
Gold Star Line	1 367
Cosco Shipping Lines	792
Hapag-Lloyd	159
Evergreen Marine Corporation	134
Dal Deutsche Afrika-Linien	61
LMC	52
Pacific International Line	7
Grand Total	42 910

Source: Author’s own compilation.

International maritime liner schedules represent detailed timetables that specify the scheduled times of arrival and departure for vessels at various ports across the globe. They play a pivotal role in the strategic planning and synchronisation of the transportation of goods and cargo across diverse geographic regions. Shipping lines and carriers routinely make these schedules accessible via online platforms, enabling their clientele to review shipping timetables categorised by routing, port location, vessel, or carrier⁵¹. Among the most heavily traversed routes for container shipping are those connecting:

1. Asia to North America
2. Asia to Europe
3. Europe to North America

⁵¹ It is noteworthy that the initial ETA was derived from publicly available schedules, representing pro-forma schedules, and intended sailings. Consequently, an assessment of the extent to which each shipping line deviated from its established schedules can be conducted based on these records. While such analysis could offer supplementary insights into logistics performance from the shipping line's standpoint, it lies beyond the scope of this thesis, which primarily examines logistics performance from the perspective of the freight forwarder. Nonetheless, these observations could enhance the conceptual framework established in this thesis, and are recommended for exploration in future research. It is pertinent to mention that international research addressing service reliability of shipping lines on a monthly basis is discussed in Section 4.5.3.

4. Asia to South America
5. Europe to South America

South Africa holds a position of significance as a pivotal nexus for international shipping activities, hosting several vital recurring, major services from the major shipping lines calling at commercial ports in the country. Some of these crucial services with a presence in South African ports include MSC, Maersk (including the now-defunct South African-controlled Safmarine, which has been fully integrated into Maersk), CMA CGM, and Hapag-Lloyd, and encompass the services outlined in Table 4-7. Selecting one shipping line over the next would depend on a myriad of factors, including service, cost, space, contractual obligations, scheduling, and the like. However, since the purchase order management is controlled by the buyer and not the freight forwarder in this dataset, the reasons for selecting one shipping line over the next are not recorded. The following table shows the statistical summary of the goods shipped via the respective shipping lines in the dataset provided, in terms of the ocean freight transport leg from SOB to ATA:

Table 5-14: Shipping lines: Statistical summary⁵² of maritime leg time delays

Shipping line	Size	Average	Variance	Min	Max
Mediterranean Shipping Company	6 285	40.04	609.12	17.66	350.52
Ocean Network Express	4 054	31.30	819.66	4.00	339.98
Maersk Line	2 865	31.28	73.55	17.00	121.14
CMA-CGM Group	2 695	30.59	466.51	19.00	323.53
Gold Star Line	1 356	29.29	19.63	22.50	69.85
Cosco Shipping Lines	444	48.60	709.08	22.66	153.88
Evergreen Marine Corporation	134	175.96	42.87	151.65	177.71
Safmarine Container Lines	127	39.39	161.45	21.00	55.00
Orient Overseas Container Lines	126	28.45	14.37	22.66	36.00
Hapag-Lloyd	113	69.74	209.21	10.45	83.00

Source: Author's own compilation.

The following table provides an overview per product line, categorised by weight, volume, number of packages, and customs value.

Table 5-15: Product overview

Row Labels	Product description	Gross Mass (kg)	Volume (CBM)	Packages
4006.10	Strips for retreading tyres ⁵³	14 842	0	1
4011.10.01		93 150	198	3 808

⁵² The table shows only the top 10, as several lines, such as MOL and DAL from Table 5-13 do not feature. Additionally, Table 5-14 shows only the ocean leg transport (SOB to ATA), a measurement that was originally not captured in depth in the early years of the dataset in question.

⁵³ "Camel-back" strips for retreading rubber tyres.

4011.10.03	New pneumatic tyres, of rubber: Of a kind used on motor cars ⁵⁴	4 636 315	16 584	219 657
4011.10.05		9 425 789	41 983	493 753
4011.10.07		12 054 249	47 816	610 652
4011.10.09		79 533 002	426 551	4 291 558
4011.20.16	Of a kind used on buses or lorries ⁵⁵	550 806	1 595	30 056
4011.20.18		136 042 254	668 422	6 114 136
4011.20.22		7 020 462	29 509	270 306
4011.20.24		7 123 838	89 062	212 960
4011.20.26		139 589 221	431 343	2 290 248
4011.40	Of a kind used on motorcycles	49 534	55	4 080
4011.70.10	Of a kind used on agricultural or forestry vehicles and machines	22 311 649	138 136	521 794
4011.70.20		91 124	380	1 859
4011.80.10	Of a kind used on construction, mining or industrial handling vehicles	21 193 630	70 494	178 841
4011.90.10	Other	160 381	608	26
4012.90	Used pneumatic tyres	7 913 386	16 462	147 149
4013.10	Inner tubes of rubber	20 109	0	1 552
4013.90		20 663	0	1 259
4016.10.90	Other articles of vulcanised rubber ⁵⁶	1 379 873	7 516	108 332
4016.93.90		765 178	3 844	33 206
4016.99.90		184 787	498	5 657
8481.80.09	Valves of a kind commonly used with other inflatable articles	72 007	532	4 109
8526.91	Radio navigational aid apparatus	13 782	54	20
Grand Total	-	450 260 031	1 991 642	15 545 019

Source: Author's own compilation.

The following table provides a summary of the products in terms of total time delays from SOB to cargo delivered:

Table 5-16: Products overview: Statistical summary of the total process

Product line	Size	Average	Variance	Min	Max
4006.10	1	16.00	0.00	16	16

⁵⁴ The various products range in sizes from less than 13 inches to more than 17 inches.

⁵⁵ The various products range in load index.

⁵⁶ Of cellular rubber, gaskets, washers, and other seals, and other inflatable articles.

4011.10.01	10	37.10	38.77	33	48
4011.10.03	473	39.57	76.03	16	76
4011.10.05	977	37.61	92.91	20	82
4011.10.07	1 208	36.35	75.04	19	92
4011.10.09	8 995	41.29	118.18	18	101
4011.20.16	55	38.13	19.63	30	48
4011.20.18	13 862	40.78	401.72	15	398
4011.20.22	624	36.81	100.37	23	94
4011.20.24	651	38.08	93.46	22	75
4011.20.26	10 777	40.75	195.63	17	128
4011.40	5	24.40	1.80	22	25
4011.70.10	2 545	42.65	78.16	20	127
4011.70.20	12	44.75	54.20	38	58
4011.80.10	1 706	35.42	290.33	1	394
4011.90.10	13	32.31	12.56	22	35
4012.90	538	39.45	74.44	19	82
4013.10	2	42.00	0.00	42	42
4013.90	2	25.00	0.00	25	25
4016.10.90	155	32.76	79.90	21	75
4016.93.90	72	38.07	48.29	26	66
4016.99.90	16	47.75	119.53	38	84
8481.80.09	7	35.00	0.00	35	35
8526.91	1	46.00	0.00	46	46

Source: Author's own compilation.

The following table provides a breakdown of the cost categories of the dataset, as invoiced by the freight forwarder to the clients:

Table 5-17: Cost categories invoiced

Cost Category	Tax Amount ⁵⁷	Taxed Amount	Net Amount	Share of costs	Share of customs value of the goods
Cargo Dues	R7 631 201	R59 511 816	R51 880 615	2.3%	0.16%
Customs	0	R1 970 726 393	R1 970 726 393	89.7%	6.24%
Freight & Landsides	R2 067 350	R22 085 013	R20 017 663	0.9%	0.06%
3PL Charges	R1 460 790	R11 364 229	R9 903 440	0.5%	0.03%
Storage	R7 795	R8 556 607	R8 548 812	0.4%	0.03%
Transport	R20 014 301	R155 445 249	R135 430 948	6.2%	0.43%
Grand Total	R31 181 438	R2 227 689 308	R2 196 507 870	100%	6.96%

Source: Author's own compilation.

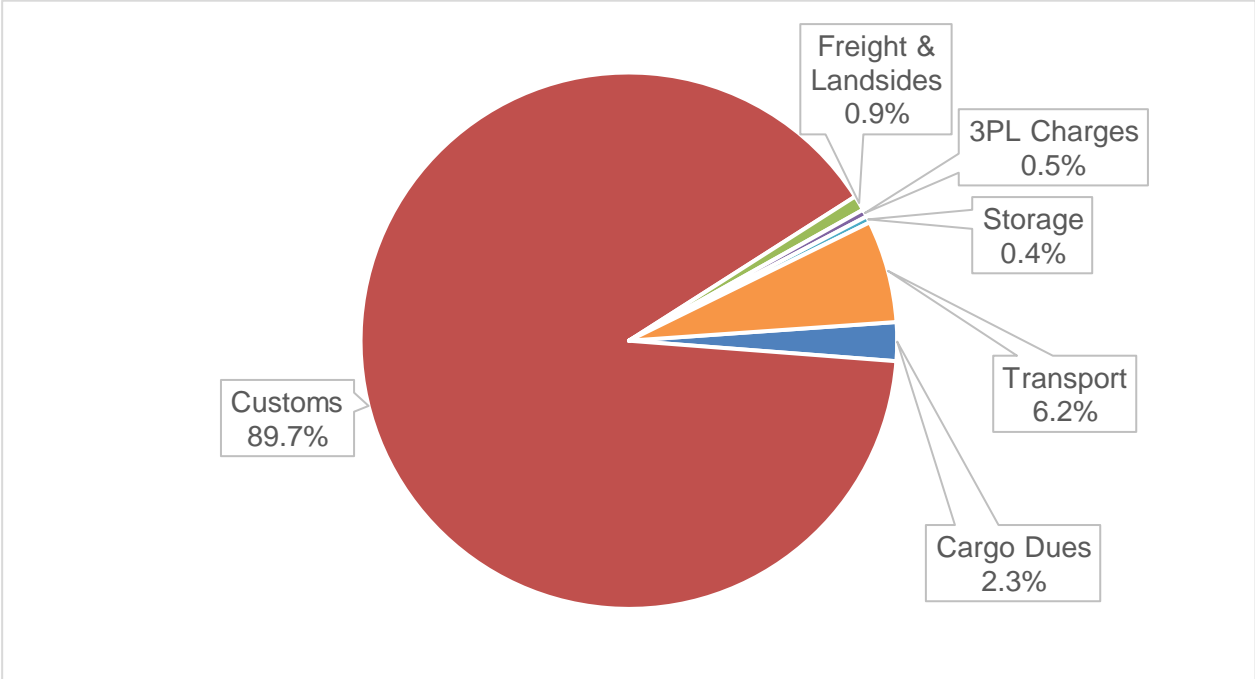
⁵⁷ The tax amount is the actual monetary value calculated based on the sales tax rate and the taxable sales amount. It is the additional cost added to the purchase price of goods or services. On the other hand, the taxed amount refers to the total amount of the sale that is subject to tax. This is the portion of the purchase price that is considered taxable and on which the sales tax is calculated.

From Table 5-17, it is clear that customs Value-Added Tax (VAT) and duties are by far the most significant 3PL service expense. Furthermore, the payment (or rather, non-payment) of VAT and duties could have a significant impact on the physical movement of the goods. As such, customs VAT and duties follow distinct payment schedules, as the time of liability for VAT and duties and their respective due dates may differ. In the case of a duty-paid entry without a deferment account with SARS Customs, payment is requisite before the client can attain a customs release for the goods entered. Therefore, without a deferment account, goods can potentially stand still for a significant period of time before being released. Conversely, if it is a duty-paid entry and the agent/importer has an account (deferment) with SARS, then it is immediately put on the deferment, resulting in an immediate customs release for the goods entered. The deferment payment then occurs at the end of the month at a predetermined time, contingent on the agreement between the agent/importer and SARS customs.

When dealing with a warehouse (WH) entry, there is no upfront payment of VAT and duties necessary. Instead, the client is only required to declare the products and indicate the customs value of the goods, since they are stored within a bonded warehouse. Upon retrieval of the goods from the warehouse, VAT and duties are declared and must be promptly paid, either immediately or through deferment. Goods may be stored in the warehouse for two years without declaring/paying the VAT and duties. After this period, they must be declared, and the corresponding taxes settled. Although the goods can still be retained in the warehouse, they must be transferred to a free store.

The following pie chart illustrates the respective share of the cost categories invoiced:

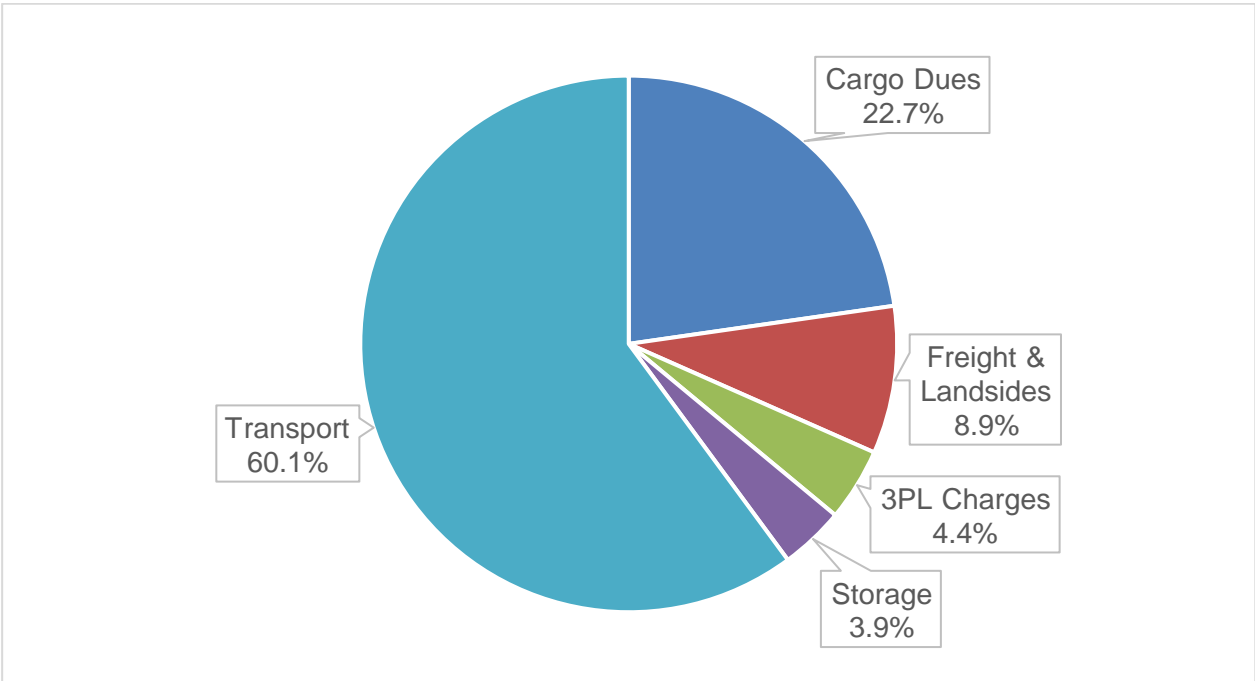
Figure 5-4: Cost categories and respective share of logistics cost invoiced



Source: Author’s own compilation.

However, when omitting the customs cost component – which is directly related to the cargo value – the following share is perceived:

Figure 5-5: Cost categories and respective share of logistics cost invoiced (excluding customs)



Source: Author’s own compilation.

As illustrated, transport cost (60%) remains the most significant cost component in the moving of imported goods. Other costs include the terminal handling charges⁵⁸ (at 23%), followed by freight and landside charges (9%), 3PL charges (4%) and storage charges (4%). Interestingly, the freight charges will vary depending on the Incoterms⁵⁹ used. The following table provides a summary of the Incoterms in terms of total time delays from SOB to cargo delivered:

Table 5-18: Incoterms: Statistical summary of the total process

Incoterm	Size	Average	Variance	Min	Max	Customs value	Share
CFR	198	41.92	118.11	20	64	R159 487 702	0%
CIF	22	30.09	228.75	13	66	R12 772 102	0%
CIP	4 879	35.02	104.95	14	394	R4 403 256 372	12%
EXW	36 307	40.85	147.03	1	128	R26 049 291 267	85%
FCA	16	39.00	0.00	39	39	R9 377 216	0%
FOB	1 285	48.24	2 994.12	16	398	R939 503 166	3%

Source: Author’s own compilation.

As per the table, the buyer (cargo owner – represented by the freight forwarder) was responsible for ~88% (EXW and FOB) of the freight charges of the shipments. The other ~12% is related to the Carriage and Insurance Paid To (CIP) Incoterm, whereby the seller is responsible for the cost of carriage as well as all-risk insurance coverage until the freight reaches the named place of destination. The choice of Incoterms is derived from factors such as cost, risk, and control over the shipment, and will be made based on the specific business needs of the parties and the existing relationship. Seeing that many of the transactions involve repeat shipments with respective suppliers, most of the responsibility landed on the buyer, which is, in this case, an international tyre procurement office.

The preceding five input variables all concerned the total time delay performance, or the ocean leg transport from SOB to ATA, as in the case of shipping lines. The following three input variables concern the time delay performance of the customs process (EDI Sent to CUSRES) and the interaction of the freight forwarder with SARS Customs and Excise, starting with determining whether errors were made during the customs process, which required a voucher of correction (VOC) to be lodged:

⁵⁸ For ease of reference, terminal handling charges include cargo loading and unloading, cargo dues and marine services and are grouped together.

⁵⁹ Incoterms® rules are a set of standards used in international and domestic contracts for the delivery of goods. They are recognised by UNCITRAL as the global standard for the interpretation of the most common terms in foreign trade, helping to avoid costly misunderstandings by clarifying the tasks, costs and risks involved in the delivery of goods from sellers to buyers (ICC, 2023).

Table 5-19: Voucher of corrections: Statistical summary of the customs clearance process⁶⁰

Is VOC?	Size	Average	Variance	Min	Max
No	37 664	0.07	0.14	-0.11	4.23
Yes	5 245	0.59	4.20	0.00	15.09

Source: Author's own compilation.

As derived from the table, there is significant variation when a VOC was required to amend an entry in case of duty having been calculated incorrectly. For observations without VOC ("No" category), the average processing time is 0.07 days, the minimum time is -0.11 days, an impractical value which indicates the potential of a systems error, and the maximum time is 4.23 days. In the "Yes" category (VOC present), with 5 245 observations, the average processing time is 0.59 days, significantly longer than the overall average, as the minimum time is 0.00 days, and the maximum time is 15.09 days, indicating substantial variation. Therefore, the results imply that VOC presence significantly affects processing time, with the "Yes" category taking considerably longer. However, the large variation suggests potential influences beyond VOC on the extended processing time in this category. For example, the physical movement of goods was impacted by not only an incorrect tariff classification or customs value declaration, but also the potential for incorrect documents or related errors when the entry was framed and lodged. Therefore, the respective customs' response should also be investigated.

The following table summarises the customs response after lodging an entry, which determines the influence of Customs' response and their administrative and risk assessment processes in assessing declarations made:

Table 5-20: EDI CUSRES codes: Statistical summary of the customs clearance process

EDI CUSRES CODE	Size	Average	Variance	Min	Max
1 – Release	35 050	0.01	0.07	-0.11	15.09
2 – Physical inspection	1	4.20	0.00	4.20	4.20
3 – Conditional release	8	15.09	0.00	15.09	15.09
6 – Reject declaration	876	0.26	2.73	0.00	15.09
9 – Already on system	2	1.27	3.03	0.04	2.50
13 – Supporting documents required	325	1.49	3.23	0.05	12.13
27 – Accept amendment	4 325	0.04	0.10	0.00	7.11
28 – Accept cancellation	14	5.89	7.95	3.84	12.13
31 – Request additional supporting documents	226	2.55	5.26	0.08	12.13
33 – Supporting documents received	2 023	1.71	5.51	0.05	15.09

⁶⁰ EDI Sent to CUSRES

35 – Reminder for outstanding documents	13	3.46	0.73	2.00	4.23
36 – Booking confirmation	1	4.20	0.00	4.20	4.20
49 – Provisional payment liquidated	45	1.55	0.34	0.14	3.04

Source: Author's own compilation.

A total of 82% of all entries were released (code "1") immediately after being submitted, with the average time taken between submission and confirmation around 19 minutes. Furthermore, there is very little variance between entries; however, these results indicate how important it is to ensure that all customs requirements (documentation and others as outlined in Table 5-6) are met before lodging an entry into the SARS online EDI platform, especially when looking at the negative relationship between categories and time delays.

For all the other SARS Customs' responses, only code "27" (when the amendment is accepted) positively impacts performance, with an average of only slightly more than when the goods are released upon entry. For the rest, the most significant negative impact on the customs process occurs when supporting documents are requested and then received (code "33"). Next in line is code "49" (provisional payment liquidated), with 45 observations with an average time of 1.55 days and a variance of 0.34 days. The minimum time taken is 0.14 days, and the maximum time taken is 3.04 days. Then, for Row 31, there are 226 observations with an average time of 2.55 days and a variance of 5.26 days. The minimum time taken is 0.08 days, and the maximum time taken is 12.13 days. Ultimately, whenever a customs infraction occurs, there is a high probability that the customs process could be significantly prolonged, which emphasises the importance of correctly lodging entries.

The same can be said of OGAs stopping cargo. The following table provides a summary of the cargo being stopped by OGAs in terms of total time delays from SOB to cargo delivered:

Table 5-21: OGA stops: Statistical summary of the total process

OGA stop	Description	Size	Average	Variance	Min	Max
1	SAPS	77	41.39	247.37	29	75
2	NRCS	111	51.04	71.20	33	56
NULL		42 519	40.38	233.16	1	398

Source: Author's own compilation.

For OGA code "1" stops (South African Police Service Stops), there are 77 observations with an average time of 41.39 days and a variance of 247.37 days. The minimum time taken is 29 days, and the maximum time taken is 75 days. However, for OGA code "2" stops (National Regulator for Compulsory Specifications), there are 111 observations with an average time of 51.04 days and a variance of 71.20 days. The minimum time taken is 33 days, and the maximum time taken is 56 days. For the "NULL" category (in other words, when goods were not stopped by any OGA),

the results indicate that the difference between the average time for this category and the overall average time is not statistically significant – largely because of the fact that this category contains 99.6% of the entries. Nevertheless, the results indicate that an OGA stop significantly increases the total process time.

These results of Customs and OGA stops are similar to earlier empirical findings on the subject, as previous work on South Africa’s Customs Administration’s (SARS) customs risk management system showed that a customs delay in the vertical tyre market in South Africa results in an average direct cost increase of 3.8% of customs value for the imports, and adds an additional 4.8 days to the end-to-end supply chain (Maree, 2020:172). According to the findings in this thesis, a customs stop adds, on average, 1.67 days to the supply chain. However, an OGA stop adds, on average, between one and 10.66 days to the supply chain, and a stop by Port Health adds, on average, 51.91 days and as much as 84 days to the supply chain (not presented in the above tables, as there were very few instances [38] of cargo being stopped by Port Health).

5.4.2 Logistics process analysis

The following table shows the primary results obtained by measuring the time taken between each sequential import process step. The table shows the data level, count, average, standard deviation, the potential level of influence that a freight forwarder can exert on each step, and lastly, the potential for invalid data and other related errors⁶¹. The object of this test was two-fold:

1. Firstly, to determine which process steps are key and have the most significant time variation; and
2. Secondly, to determine which process steps can potentially impact performance the most, and which steps the freight forwarder can influence the most.

Table 5-22: Process analysis⁶² (measured in days)

Segment	From	To	Count (n)	Average	Std Dev	Level of FF Influence
Documentary flow						
Date created	6. Invoice Date 1	11. Date Created	42 910	16.038	13.034	High
Entry framed	11. Date Created	13. Date Framed	42 910	21.657	49.456	High
Customs clearance	13. Date Framed	22. EDI CUSRES	42 910	2.345	9.273	High

⁶¹ As is typically the case, there are some mandatory (often by law) data fields which are system-generated. These tend to not have any errors and are always captured (all those process steps which has a count of 41 910). However, there are many non-mandatory, human captured data fields, which are prone to errors. As far as possible, it is recommended that freight forwarders design rules-based, system generated process flows to minimise errors in capturing data.

⁶² The table only shows the core segments. A full, comprehensive table, which shows the bivariate analysis of all potential segment steps, is shown in the Annexure in Table 9-2.

Entry accepted	17. EDI Sent	22. EDI CUSRES	42 909	0.133	0.818	High
SARS infraction	17. EDI Sent	23. SARS Case Closed	3 026	1.673	5.390	High
Arrange inbound	24. Final B/E	36. Delivery expected	39 580	12.169	51.783	High
Date closed	36. Delivery expected	43. Date closed	39 403	6.542	31.125	High
Physical flow						
Ocean Freight	9. SOB	30. ATA	18 460	35.973	25.917	Low
Waterside	30. ATA	31. Discharge	15 543	2.445	2.410	Medium
Terminal evacuation	31. Discharge	32. Left Port	8 392	2.775	2.558	Medium
Time in Port	30. ATA	32. Left Port	7 862	4.533	2.964	Medium
Short Haul	32. Left Port	34. Arrive at Depot	69	0.820	0.512	Medium
Time in Depot	34. Arrive at Depot	35. Left Depot	9 587	3.363	3.308	Medium
Long Haul	35. Left Depot	38. Arrive at Warehouse	12 703	1.139	2.844	Medium
Last Mile	38. Arrive at Warehouse	39. Cargo Delivered	18 119	5.839	39.849	Medium
Port to delivery	32. Left Port	39. Cargo Delivered	18 083	4.140	5.620	Medium
Empty Container Turn-In	39. Cargo Delivered	40. MT Turn-In	8 377	5.802	21.396	Medium
Total physical process	9. SOB	39. Cargo Delivered	42 707	40.409	15.266	Medium
Financial flow						
Invoice	6. Invoice	29. CDO	38 502	31.302	12.070	High
CDO paid	29. CDO	42. Invoice Date 2	38 391	11.347	20.319	High
Invoices 1 to 2	6. Invoice	42. Invoice Date 2	42 640	43.738	24.144	High
Closed	42. Invoice Date 2	44. Date Closed	42 604	92.721	189.110	High

Source: Author's own compilation.

The findings present intriguing insights, revealing notable disparities from benchmark performances, particularly in a less favourable direction. In the domain of waterside operations, the observed performance surpasses the benchmark (2.45 days compared to the designated 1.5 days), implying inefficiencies in the ship-to-shore processes. Similarly, the terminal evacuation phase (2.76 days versus the benchmark of 1.5 days) indicates suboptimal efficiency in TPT's operations, and the overall time spent in the port (4.53 days versus the 3-day benchmark, commonly known as container dwell time) falls short of the specified benchmarks. It is noteworthy that the short-haul and long-haul segments demonstrate performances approximately aligned with the targets, registering 0.82 days and 1.14 days, respectively. The duration from port to delivery slightly exceeds the benchmark performance (4.14 days versus 3.4 days), signalling potential areas for optimisation. Importantly, it is acknowledged that the COVID-19 pandemic disrupted operations, especially during 2020, influencing the outcomes.

Moreover, elements pertaining to documentary performance, both by the freight forwarder and SARS, manifest commendable efficiency. Entry acceptance operates well below the benchmark, with an average of around 3.19 hours from EDI sent to EDI CUSRES. The SARS infraction category, denoting instances where the CUSRES response deviated from "released," identifies a potential area for improvement, with the actual average performance at 1.67 days against the benchmark's 1-day turnaround time. The increased time registered suggests a subtle need for compliance improvement, contingent upon the specific case and shared responsibilities between the freight forwarder and SARS Customs.

Overall, the performance assessment illuminates strengths in certain facets, while underscoring areas primed for improvement. A more detailed exploration of these aspects is conducted in Figure 5-6. Indeed, the following figures show the relative performance per input variable of the key segments (which are most specific to the respective variables), as outlined in Table 5-6, Table 5-7, and Table 5-8.

Figure 5-6: Selective input variable performance

Country of Export	Count (n)	Date created	Entry framed	Customs clearance	Entry accepted	SARS infraction	Ocean Freight	Waterside	Terminal evacuation	Time in Port	Total physical
UAE	17	12.65	49.58	1.03	0.00	N/A	104.00	N/A	6.00	N/A	87.35
Belgium	745	17.56	11.38	2.04	0.00	N/A	32.82	1.97	3.72	4.40	37.83
Brazil	270	18.28	13.93	1.63	0.00	N/A	47.53	1.69	2.21	2.88	34.60
China	20	15.31	10.18	1.67	0.00	N/A	35.65	6.80	N/A	N/A	39.80
Czechia	1	23.30	10.10	1.01	0.00	N/A	N/A	N/A	N/A	N/A	25.00
Germany	880	22.35	13.76	1.91	0.00	N/A	47.16	2.71	2.98	3.98	40.95
Spain	5 485	19.14	9.22	1.53	0.14	0.46	29.50	2.10	3.45	4.51	32.94
France	3 903	17.16	16.56	2.27	0.39	2.05	35.67	2.40	3.47	4.62	39.28
United Kingdom	161	23.99	16.94	2.15	0.00	N/A	31.18	3.71	N/A	N/A	41.67
Hungary	3	9.99	32.48	1.40	0.00	N/A	43.63	1.99	0.27	3.08	53.00
Ireland	1	20.63	25.00	1.99	0.00	N/A	N/A	N/A	N/A	N/A	41.00
India	1 031	6.41	10.52	1.96	0.00	N/A	27.19	2.69	2.74	3.12	35.44
Italy	5 964	16.84	19.58	1.72	0.03	1.35	37.40	3.12	2.97	6.09	43.81
Sri Lanka	41	10.87	13.91	2.55	0.00	N/A	32.73	2.11	4.67	5.45	52.45
Netherlands	974	15.48	10.85	1.86	0.03	2.94	46.40	2.33	2.47	4.04	33.78
Poland	3 513	20.20	22.90	4.27	0.52	1.61	48.98	3.51	3.18	5.83	50.76
Portugal	479	20.81	5.52	1.37	0.00	N/A	22.01	5.19	N/A	N/A	26.42
Romania	524	15.59	44.01	3.28	1.39	9.33	65.60	3.02	2.96	2.70	67.64
Singapore	2	21.63	13.72	3.13	0.00	N/A	40.95	2.05	1.00	3.05	49.00
Slovenia	163	19.43	37.43	1.75	0.00	N/A	58.94	2.01	4.26	5.17	61.12
Thailand	8 460	8.81	18.28	2.19	0.07	1.81	34.48	2.84	2.05	4.34	36.39
United States	10 273	17.98	37.00	2.81	0.00	N/A	32.42	0.90	2.85	3.93	42.79
Grand Total	42 910	16.04	21.66	2.34	0.13	1.67	35.97	2.45	2.78	4.53	40.41

VOC	Count (n)	Date created	Entry framed	Customs clearance	Entry accepted	SARS infraction	Arrange inbound	Date closed
N	37 665	15.88	12.25	2.10	0.07	1.10	11.81	6.52
Y	5 245	17.18	89.18	4.12	0.59	3.46	14.60	6.68
Grand Total	42 910	16.04	21.66	2.34	0.13	1.67	12.17	6.54

OGA Code	Count (n)	Date created	Entry framed	Customs clearance	Entry accepted	SARS infraction	Arrange inbound	Date closed	Ocean Freight	Waterside	Terminal evacuation	Time in Port	Total physical process
1	77	13.04	20.50	2.02	0.23	-11.97	15.76	3.36	45.60	2.56	5.64	6.02	41.39
2	111	16.43	24.94	1.42	0.00	N/A	9.97	4.72	N/A	N/A	N/A	N/A	51.04
NULL	42 722	16.04	21.65	2.35	0.13	1.84	12.17	6.55	35.96	2.44	2.77	4.53	40.38
Grand Total	42 910	16.04	21.66	2.34	0.13	1.67	12.17	6.54	35.97	2.45	2.78	4.53	40.41

INCOTERM	Count (n)	Date created	Entry framed	Customs clearance	Entry accepted	SARS infraction	Date closed	Ocean Freight	Waterside	Terminal evacuation	Time in Port	Time in Depot	Long Haul	Last Mile	Port to delivery	MT Turn-in	Total physical
CFR	198	21.25	15.52	3.37	0.00	N/A	3.74	34.48	1.00	4.65	4.98	4.61	1.00	0.75	4.17	0.22	41.92
CIF	22	17.74	7.42	0.97	0.00	N/A	2.83	25.62	1.30	1.33	2.52	4.08	1.00	2.82	6.00	-3.26	30.09
CIP	5 005	6.26	20.50	2.13	0.19	1.68	6.95	28.10	2.65	2.19	4.03	2.48	1.01	1.24	3.71	1.77	35.02
EXW	36 384	16.57	22.35	2.39	0.11	2.18	6.52	38.78	2.40	2.90	4.67	3.78	1.18	7.56	4.30	5.96	40.85
FCA	16	14.46	2.97	9.00	0.00	N/A	0.70	37.00	1.00	N/A	N/A	N/A	1.00	0.00	1.00	20.00	39.00
FOB	1 285	38.30	7.92	1.77	0.54	0.35	2.03	32.87	3.63	3.00	3.51	2.00	1.00	0.00	3.00	16.80	48.24
Grand Total	42 910	16.04	21.66	2.34	0.13	1.67	6.54	35.97	2.45	2.78	4.53	3.36	1.14	5.84	4.14	5.80	40.41

EDI CUSRES	Count (n)	Date created	Entry framed	Customs clearance	Entry accepted	SARS infraction	Date closed
1	35 051	15.36	12.58	2.07	0.01	1.29	6.43
2	1	20.60	1.79	7.40	4.20	4.20	N/A
3	8	3.61	87.81	15.30	15.09	15.09	22.04
6	876	20.79	69.22	13.49	0.26	8.25	13.00
9	2	1.58	27.92	2.31	1.27	N/A	1.45
13	325	23.02	17.38	4.68	1.49	1.49	7.66
27	4 325	17.39	86.23	0.97	0.04	-7.85	5.55
28	14	6.78	70.65	18.91	5.89	5.89	4.61
31	226	22.32	14.29	6.31	2.55	2.55	5.13
33	2 023	21.30	20.42	4.27	1.71	1.71	8.07
35	13	20.92	6.17	4.64	3.46	3.46	3.17
36	1	20.60	1.79	7.40	4.20	4.20	N/A
49	45	7.04	59.04	1.56	1.55	1.55	18.75
Grand Total	42 910	16.04	21.66	2.34	0.13	1.67	6.54

Tariff Heading	Count (n)	Entry framed	Customs clearance	Entry accepted	SARS infraction	Ocean Freight	Waterside	Terminal evacuation	Time in Port	Short Haul	Time in Depot	Long Haul	Last Mile	Port to delivery	MT Turn-in	Total physical
4006.10	1	0.00	1.91	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16.00
4011.10.01	10	4.40	3.53	0.00	N/A	28.57	0.09	4.00	3.65	N/A	3.00	1.00	2.57	3.14	-2.00	37.10
4011.10.03	473	46.35	3.42	0.09	1.25	39.04	1.79	2.85	3.97	0.46	3.06	0.99	1.25	4.60	9.41	39.57
4011.10.05	977	15.97	2.10	0.00	N/A	31.11	1.67	3.53	4.65	N/A	3.25	1.03	3.37	4.93	5.51	37.61
4011.10.07	1 215	18.95	1.84	0.02	0.87	30.36	2.99	2.97	4.76	N/A	2.31	1.10	15.27	3.83	1.04	36.35
4011.10.09	9 047	18.80	1.98	0.04	1.17	35.76	2.26	3.03	4.56	1.27	3.33	1.16	8.14	4.01	6.43	41.29
4011.20.16	55	12.52	1.84	0.00	N/A	43.04	4.24	N/A	N/A	2.00	1.15	3.22	6.18	16.00	38.13	
4011.20.18	13 912	31.39	2.70	0.04	1.81	34.24	2.24	2.20	4.32	0.64	2.85	1.12	7.14	4.23	4.49	40.78
4011.20.22	630	16.41	1.64	0.00	N/A	31.09	1.96	2.89	4.16	N/A	3.21	1.01	1.50	3.44	7.30	36.81
4011.20.24	659	15.87	1.61	0.07	1.10	32.91	1.43	3.68	4.51	1.31	2.93	1.96	10.19	4.46	8.87	38.08
4011.20.26	10 822	15.62	2.40	0.24	4.39	39.12	3.13	3.01	4.96	0.49	4.08	1.08	1.29	4.33	6.92	40.75
4011.40	5	1.64	1.76	0.00	N/A	17.16	2.64	1.21	3.84	N/A	N/A	1.00	3.00	4.00	-2.75	24.40
4011.70.10	2 546	11.57	2.12	0.65	0.95	49.65	3.15	2.81	4.35	0.38	2.94	1.13	5.91	2.84	8.28	42.65
4011.70.20	12	19.81	0.81	0.00	N/A	N/A	1.73	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	44.75
4011.80.10	1 733	17.98	2.17	0.23	10.35	36.20	1.86	3.36	4.38	1.00	4.86	1.04	2.21	3.31	6.22	35.42
4011.90.10	13	3.09	0.94	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32.31
4012.90	545	12.24	2.41	0.01	N/A	35.96	2.05	3.12	4.07	0.50	3.02	2.24	4.83	3.54	10.89	39.45
4013.10	2	12.46	7.06	0.00	N/A	39.00	0.00	2.00	2.00	N/A	N/A	1.00	0.00	1.00	19.00	42.00
4013.90	2	2.02	1.08	0.00	N/A	17.16	2.64	1.21	3.84	N/A	N/A	1.00	3.00	4.00	-2.75	25.00
4016.10.90	155	11.24	1.80	0.18	-12.38	41.37	2.54	2.96	3.30	N/A	2.33	1.23	2.58	5.22	7.89	32.76
4016.93.90	72	25.06	2.06	0.00	N/A	35.98	1.93	4.73	6.64	N/A	6.00	1.05	90.21	2.02	12.79	38.07
4016.99.90	16	16.07	3.88	0.00	N/A	35.10	1.69	4.63	5.83	N/A	6.00	1.00	-0.10	5.00	9.00	47.75
8481.80.09	7	0.98	0.22	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	35.00
8526.91	1	5.18	11.04	0.00	N/A	33.54	1.73	3.73	5.46	N/A	6.00	1.00	0.00	7.00	8.00	46.00
Grand Total	42 910	21.66	2.34	0.13	1.67	35.97	2.45	2.78	4.53	0.82	3.36	1.14	5.84	4.14	5.80	40.41

Country of Origin	Count (n)	Date created	Entry framed	Customs clearance	Entry accepted	SARS infraction	Ocean Freight	Waterside	Terminal evacuation	Time in Port	Total physical
BELGIUM	495	16.28	13.31	1.85	0.00	N/A	32.57	2.28	2.03	2.55	37.95
BRAZIL	269	18.29	13.92	1.63	0.00	N/A	47.53	1.69	2.21	2.88	34.58
CHINA	20	15.31	10.18	1.67	0.00	N/A	35.65	6.80	N/A	N/A	39.80
CZECH REPUBLIC	50	13.10	21.05	1.03	0.14	0.23	N/A	N/A	N/A	N/A	44.00
FRANCE	4 382	17.23	17.34	2.32	0.35	1.99	35.30	2.69	3.00	5.05	39.38
GEORGIA	1	31.33	28.04	1.95	0.00	N/A	49.62	-0.62	5.00	4.38	59.00
GERMANY	953	21.26	13.53	2.12	0.00	N/A	45.42	2.53	3.66	4.77	41.96
HUNGARY	97	15.47	7.50	1.74	0.00	N/A	23.98	1.38	5.06	5.63	32.18
INDIA	1 038	6.64	10.45	1.95	0.00	0.21	27.19	2.69	2.74	3.12	35.42
IRELAND	1	20.63	25.00	1.99	0.00	N/A	N/A	N/A	N/A	N/A	41.00
ITALY	5 830	16.77	19.59	1.69	0.04	1.35	37.66	2.88	3.22	5.89	43.51
NETHERLANDS	1 230	22.44	9.84	1.80	0.11	0.72	49.18	2.69	2.51	4.22	35.29
NULL	1	22.32	1.98	1.06	0.00	N/A	N/A	N/A	N/A	N/A	N/A
POLAND	3 332	19.38	23.13	4.39	0.51	1.92	48.22	3.57	3.23	5.96	51.01
PORTUGAL	448	20.65	5.50	1.37	0.00	N/A	21.25	5.19	N/A	N/A	26.21
ROMANIA	522	15.62	44.16	3.29	1.40	9.33	65.63	2.94	2.96	2.70	67.85
SLOVENIA	159	19.50	37.70	1.73	0.00	N/A	58.94	1.86	4.26	5.17	61.42
SOUTH AFRICA	4	8.27	9.67	1.32	0.00	N/A	31.50	N/A	N/A	N/A	32.00
SPAIN	5 336	19.11	9.20	1.48	0.15	0.46	29.60	2.11	3.43	4.48	32.97
SRI-LANKA	43	11.37	13.90	2.58	0.00	N/A	33.45	2.10	4.26	5.13	52.29
THAILAND	8 428	8.79	18.10	2.20	0.07	1.81	34.55	2.85	2.05	4.34	36.42
UAE	17	12.65	49.58	1.03	0.00	N/A	104.00	N/A	N/A	N/A	87.35
UK	141	19.14	27.86	1.61	0.00	N/A	29.80	2.79	1.17	3.92	39.15
USA	10 113	17.81	37.10	2.83	0.00	N/A	32.51	0.83	2.96	3.94	42.88
Grand Total	42 910	16.04	21.66	2.34	0.13	1.67	35.97	2.45	2.78	4.53	40.41

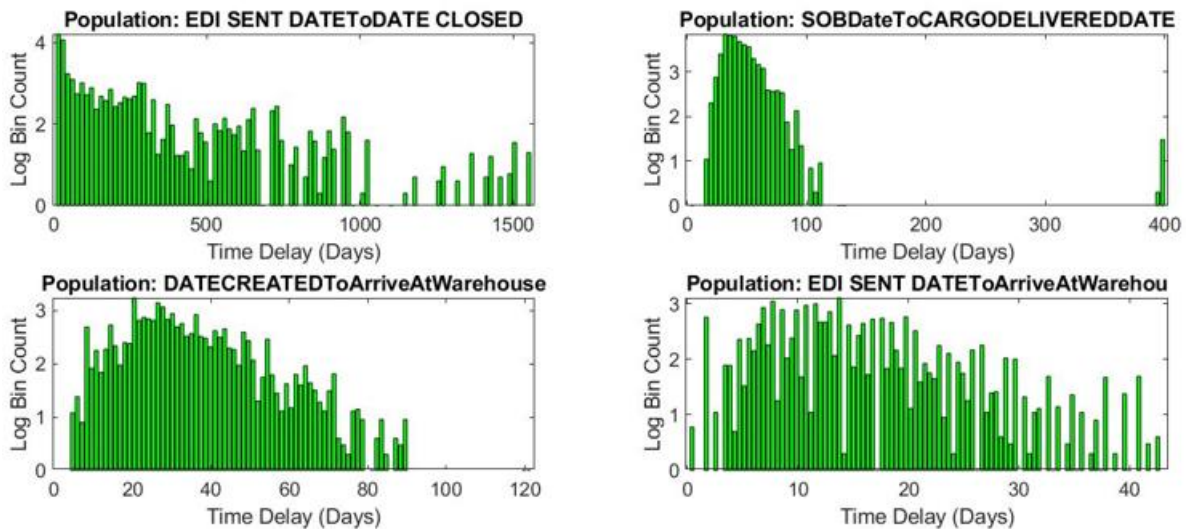
Port of Loading	Count (n)	Entry framed	Customs clearance	Entry accepted	SARS infraction	Arrange inbound	Date closed	Ocean Freight	Waterside	Terminal evacuation	Port to delivery	Total physical
ABU DHABI	8	17.68	1.19	0.00	N/A	25.00	6.47	N/A	N/A	6.00	1.00	63.00
ALGECIRAS	3 700	8.89	1.64	0.14	0.18	14.16	4.58	26.94	2.24	3.36	3.97	28.81
ANTWERP	53	3.64	1.25	0.00	N/A	14.94	3.48	23.12	0.06	5.90	1.02	30.40
ANTWERP CHURCH	4	5.25	0.98	0.00	N/A	21.00	2.33	N/A	N/A	N/A	N/A	36.00
ANTWERPEN	693	11.99	2.11	0.00	N/A	16.56	2.80	34.27	2.32	2.96	3.47	38.40
ARANDA DE DUERO	1	7.97	2.89	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25.00
BANGKOK	27	20.40	0.96	0.00	N/A	7.81	3.64	149.03	3.10	N/A	3.00	40.26
BARCELONA	88	6.90	1.98	0.00	N/A	11.61	3.90	29.37	0.84	2.95	2.93	36.09
BELFAST	2	12.50	1.47	0.00	N/A	9.00	4.33	N/A	3.82	N/A	N/A	45.50
BILBAO	1 582	9.78	1.19	0.16	0.61	16.13	5.40	73.06	2.15	4.06	4.07	41.83
BLAVOZY	7	16.04	1.74	0.00	N/A	21.33	1.06	35.80	1.20	3.00	1.00	42.67
BREMERHAVEN	846	14.12	1.92	0.00	N/A	14.77	3.72	47.26	2.72	2.98	2.91	41.22
BUDAPEST	2	32.24	0.70	0.00	N/A	18.00	1.69	25.92	2.82	0.27	10.00	48.00
CHARLES CITY	21	61.20	2.47	0.00	N/A	17.62	3.85	29.14	2.03	N/A	4.71	34.14
CHARLESTON	8 294	33.09	3.19	0.00	N/A	9.19	7.87	31.94	0.93	2.75	5.15	40.58
CHARLESTOWN	9	45.61	3.93	0.00	N/A	9.33	2.01	31.60	N/A	N/A	2.00	35.00
CHENNAI (EX MADR)	281	9.74	1.07	0.00	N/A	10.71	6.24	20.12	0.18	2.75	3.28	26.33
COLOMBO	41	13.91	2.55	0.00	N/A	11.95	2.77	32.73	2.11	4.67	4.25	52.45
COLUMBUS	1	28.04	1.95	0.00	N/A	13.00	6.73	49.62	-0.62	5.00	5.00	59.00
CONSTANTA	525	43.99	3.27	1.39	9.33	12.46	5.37	65.58	3.01	2.96	4.09	67.63
CONSTANZIA	2	55.08	5.11	0.00	N/A	10.00	1.35	75.03	N/A	N/A	1.50	78.00
DALIAN	19	10.44	1.66	0.00	N/A	13.33	1.69	36.79	6.80	N/A	5.00	39.95
DUNDEE	1	19.19	2.03	0.00	N/A	14.00	2.39	N/A	N/A	N/A	N/A	44.00
DURBAN	1	15.82	0.18	0.00	N/A	21.00	7.53	36.00	N/A	N/A	N/A	43.00
ENNORE	701	8.29	2.39	0.00	N/A	16.53	4.09	28.33	4.01	2.26	5.96	37.51
FOS SUR MER	504	9.66	1.76	1.04	2.52	13.79	8.05	27.00	4.01	N/A	N/A	37.14
GDANSK	1 345	20.94	2.15	0.47	0.84	14.98	4.27	43.71	2.10	2.31	3.85	47.95
GDYNIA	1 705	26.22	6.36	0.60	5.86	14.78	5.29	53.13	3.11	2.74	4.72	54.89
GENOA	8	10.11	3.80	0.00	N/A	14.00	2.42	28.92	0.08	2.00	2.00	33.00
GENOVA	4 507	19.34	1.81	0.05	1.35	12.83	5.38	44.44	3.83	2.46	4.14	45.86
GRANGEMOUTH	1	1.24	1.09	0.00	N/A	13.00	3.28	N/A	N/A	N/A	N/A	37.00
GRANGEMOUTH	22	43.61	1.34	0.00	N/A	17.62	1.02	34.50	4.08	N/A	N/A	43.00
GREER	11	7.18	3.53	0.00	N/A	18.29	1.36	27.33	0.96	1.00	1.86	30.43
GREER-GREENVILLE	6	14.40	4.39	0.00	N/A	16.67	2.69	28.59	0.41	1.67	1.33	32.00
HAMBURG	35	5.24	1.62	0.00	N/A	11.62	2.39	24.49	0.51	N/A	7.00	34.46
ITAGUAI	155	17.05	1.60	0.00	N/A	14.92	2.24	54.74	3.04	1.90	0.63	37.02
JACKSONVILLE	5	6.86	0.09	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37.20
JEBEL ALI	9	77.93	0.90	0.00	N/A	14.33	1.33	104.00	N/A	N/A	2.00	109.00
KATTUPALLI PORT	49	46.87	0.88	0.00	N/A	8.00	2.29	53.00	0.00	3.00	2.00	58.00
KOPER	163	37.43	1.75	0.00	N/A	13.09	2.08	58.94	2.01	4.26	3.91	61.12
LA SPEZIA	1 312	20.41	1.43	0.00	N/A	13.50	3.23	31.10	1.39	5.06	4.17	37.23
LA SPEZIA OFF-LINE	5	27.85	0.72	0.00	N/A	15.40	1.30	33.28	0.09	7.00	2.40	41.20
LAEM CHABANG	8 433	18.28	2.19	0.07	1.81	9.89	9.44	33.93	2.84	2.05	3.94	36.37
LE HAVRE	3 393	17.58	2.35	0.29	1.87	9.54	8.50	35.65	2.40	3.47	3.05	39.59
LONDON	1	18.03	3.07	0.00	N/A	16.00	11.56	35.00	N/A	N/A	N/A	46.00
LONDON GATEWAY	135	12.81	2.29	0.00	N/A	13.04	1.91	31.05	3.27	N/A	N/A	41.38
MARSEILLE	2	17.46	0.64	0.00	N/A	17.50	3.05	N/A	N/A	N/A	N/A	45.00
NULL	309	8.10	2.62	0.39	0.65	10.02	2.01	N/A	4.19	N/A	N/A	42.01
OLSZTYN	29	19.99	2.37	0.06	N/A	19.46	1.61	36.49	0.16	2.28	2.65	41.27
OLSZYNA	125	35.77	3.22	0.44	N/A	28.20	2.10	31.62	9.38	6.00	1.00	48.00
RIO DE JANEIRO	97	10.49	1.67	0.00	N/A	12.93	2.66	41.35	0.11	2.45	2.66	31.68
RIO DE JANEIRO-SA	4	0.02	0.91	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	17.00
ROTTERDAM	970	10.84	1.85	0.03	2.94	13.75	3.04	46.71	2.33	2.47	2.64	33.77
SANTOS	4	3.61	1.05	0.00	N/A	13.00	0.81	N/A	N/A	N/A	N/A	34.00
SAVANNA	9	27.07	1.87	0.00	N/A	4.00	7.55	N/A	N/A	N/A	N/A	53.00
SAVANNAH	1 904	54.29	1.18	0.00	N/A	21.11	4.22	40.06	0.02	5.09	2.73	52.62
SEPETIBA	10	8.73	2.06	0.00	N/A	11.90	1.76	28.00	N/A	N/A	3.00	32.40
SHANGHAI	1	5.34	1.84	0.00	N/A	22.00	3.29	32.21	N/A	N/A	3.00	37.00
SINES	478	5.31	1.36	0.00	N/A	10.93	1.80	20.50	5.19	N/A	N/A	26.20
SINGAPORE	2	13.72	3.13	0.00	N/A	11.00	1.59	40.95	2.05	1.00	5.00	49.00
TORINO	8	31.88	1.00	0.00	N/A	14.00	6.57	51.58	6.43	1.99	1.00	61.00
VADO LIGURE	132	18.72	1.54	0.00	N/A	5.76	12.51	32.78	1.59	2.81	3.03	38.80
VALENCIA	112	14.34	2.59	0.13	1.04	1.33	17.18	34.03	1.82	4.26	6.15	39.40
WARSZAWA	1	29.99	0.99	0.00	N/A	11.00	5.32	N/A	N/A	N/A	N/A	46.00
Grand Total	42 910	21.66	2.34	0.13	1.67	12.17	6.54	35.97	2.45	2.78	4.14	40.41

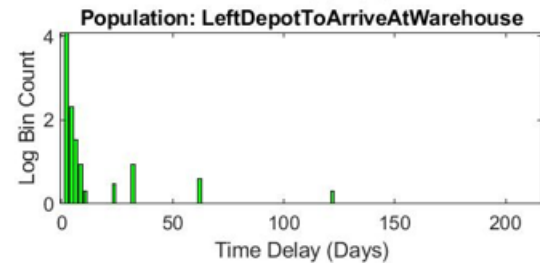
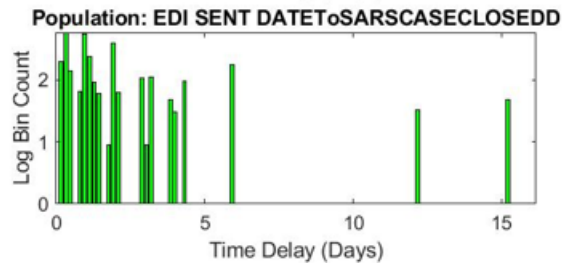
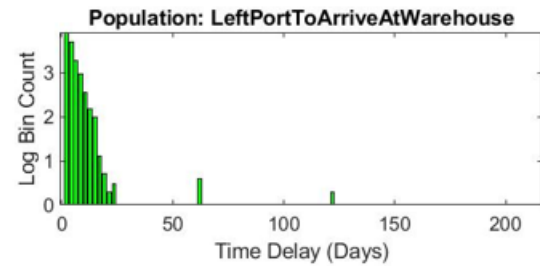
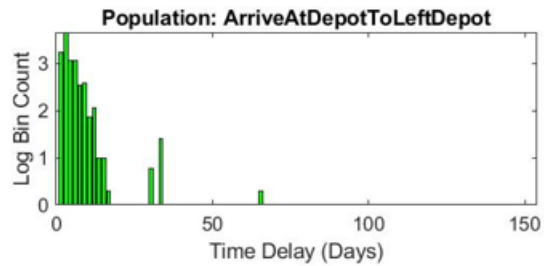
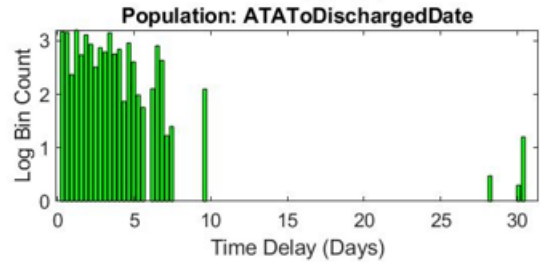
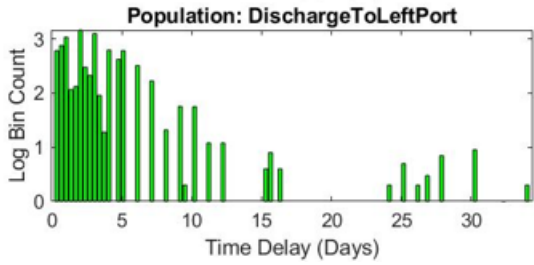
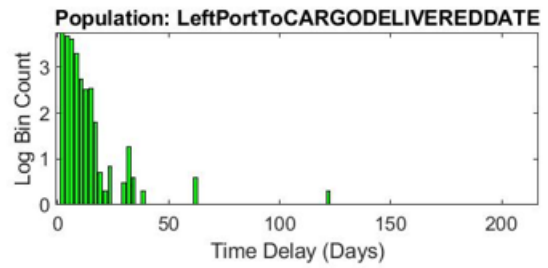
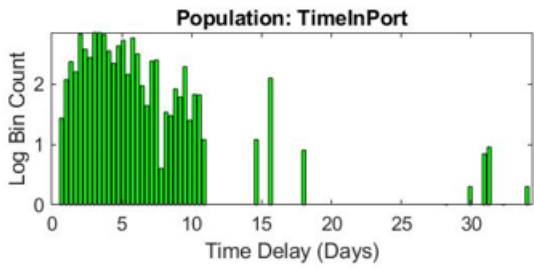
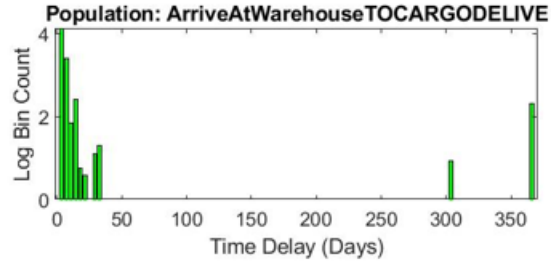
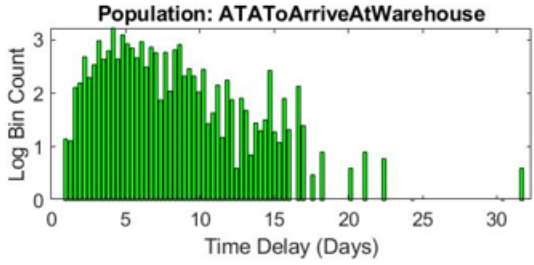
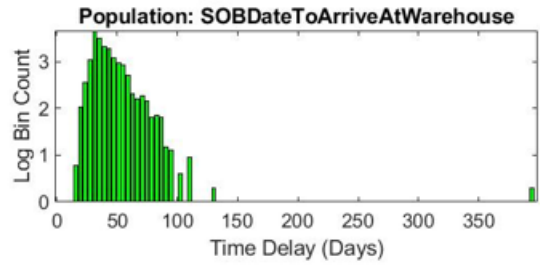
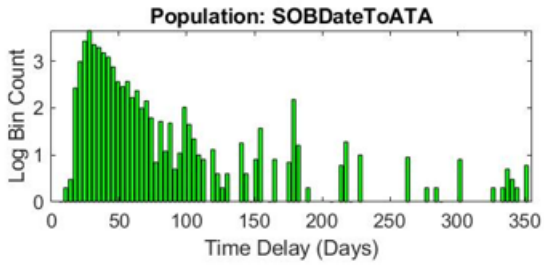
Shipping Line	Count (n)	Date created	Ocean Freight	Waterside	Terminal evacuation	Time in Port	MT Turn-in	Total physical
ARENDAL SHIPHOLDING	2	10.44	40.00	N/A	N/A	N/A	N/A	34.00
COSCO SHIPPING LINE	573	15.03	48.60	3.62	2.04	5.72	0.90	45.28
COSREN SHIPPING LINE	93	14.17	43.42	2.78	0.10	2.88	7.26	48.25
DAL DEUTSCHE AFRICA	61	12.88	37.16	3.27	N/A	N/A	4.00	42.77
DIAMOND SHIPPING LINE	11	12.16	29.10	3.11	1.00	5.00	-6.27	42.27
EVERGREEN MARINE	134	18.54	175.96	2.68	N/A	N/A	11.07	35.26
GOLD STAR LINE	1 356	5.43	29.29	2.25	1.37	3.31	-0.10	37.19
HAMBURG SÜD	2 437	22.98	29.80	N/A	3.00	N/A	16.00	54.03
HAPAG-LLOYD	159	15.39	69.83	-0.78	4.25	2.98	5.38	68.64
IGNAZIO MESSINA	52	15.68	53.29	N/A	N/A	N/A	N/A	58.85
MAERSK LINE	3 153	7.85	31.29	3.12	2.66	5.30	1.09	38.75
MSC	11 545	16.81	40.06	2.04	3.13	4.67	10.07	39.94
NULL	1	22.32	N/A	N/A	N/A	N/A	N/A	N/A
ONE LINE	11 704	15.32	31.30	2.02	3.00	4.03	3.86	37.98
ORIENT OVERSEAS	126	8.36	28.45	1.29	2.76	2.51	2.00	32.36
PACIFIC INTERNATIONAL	7	20.73	38.83	1.03	6.00	6.89	15.25	46.71
CMA CGM	3 407	10.55	30.96	3.17	2.50	5.05	3.11	37.35
SAFMARINE	4 978	23.34	39.39	3.74	N/A	N/A	N/A	45.89
MOL	3 110	18.25	N/A	3.82	N/A	N/A	N/A	35.80
Grand Total	42 910	16.04	35.97	2.45	2.78	4.53	5.80	40.41

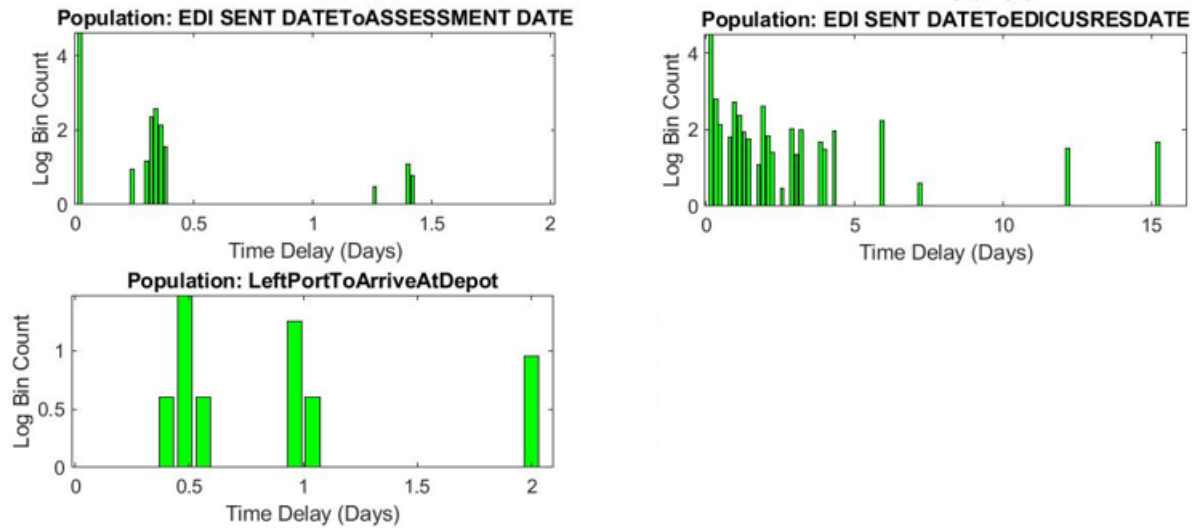
Source: Author's own compilation.

The following graphs illustrate the various distributions of key segments for all transactions:

Figure 5-7: Histogram population time delay







Source: Author's own compilation.

Figure 5-7 shows the distributions of the 19 different physical and documentary processes outlined in Table 5-22. As illustrated, many of the process steps follow a gamma distribution. The gamma distribution is a probability distribution for continuous variables that models right-skewed data. While a considerable portion of the values adheres to a normal distribution, there exists a propensity for an extended tail, indicating that, in practical terms, instances of notable time delays are infrequent among the majority of observations. Nevertheless, when time delays manifest, they tend to be protracted, extending over several days. From the figure, the processes which best display the gamma distribution include SOB to ATA (or the ocean transport leg), cargo discharged to the left port (or the time containers spent in port), and, indeed, the total process of date created to arrival at the warehouse.

Gaining a clear understanding of time delays or variations in elapsed time is imperative for the international movement of cargo, holding significance for both cargo owners and logistics service providers. In instances of delays, timely communication of achieved milestones is crucial for customer updates. This communication not only contributes to assessing service reliability, but also evaluates actual performance against predetermined benchmarks stipulated in service-level agreements. Consequently, the subsequent section provides commentary on the achieved service reliability and the ultimate on-time delivery of goods.

5.4.3 Service reliability

As outlined throughout this thesis, service reliability in logistics is crucial for maintaining customer satisfaction and ensuring smooth supply chains. From the process analysis, the results can be summarised via two aspects: the ocean freight leg and inbound road transport. In ocean freight, service reliability is essential for ensuring the timely arrival of goods and maintaining customer

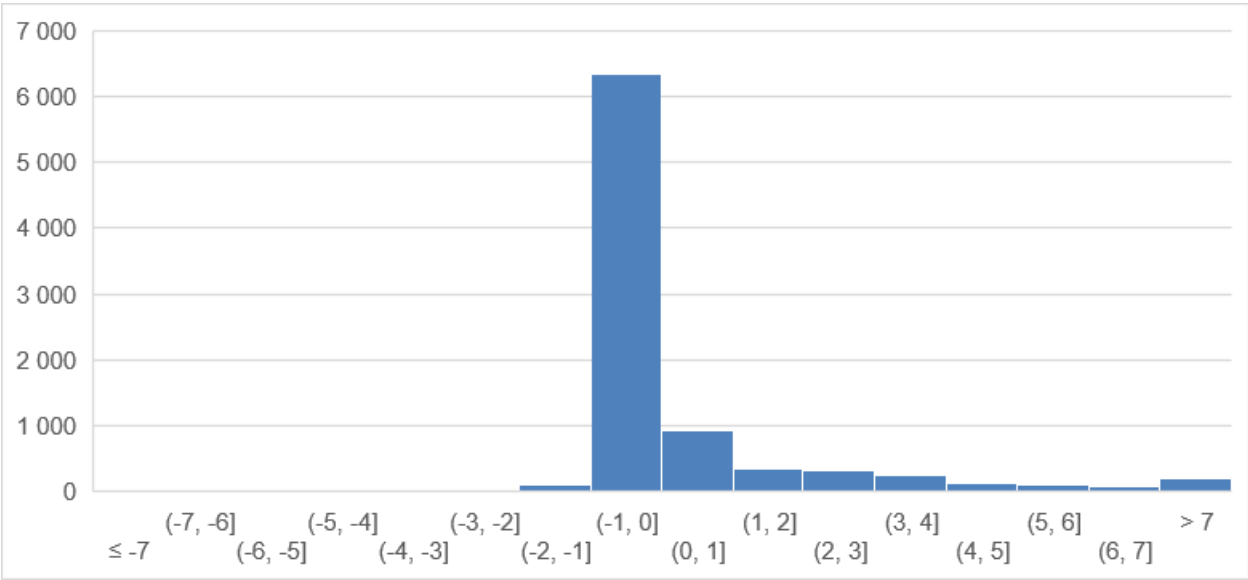
satisfaction, and it considers the two key elements, which are the estimated time of arrival (ETA) and the actual time of arrival (ATA). The ETA is the approximate time at which a vessel is expected to reach its destination port. It is calculated based on various factors, such as the vessel's speed, weather conditions, and navigation routes on behalf of the shipping line, berthing space, and available marine resources (such as tugs, helicopters, pilot bots, etc.) to berth. Providing accurate ETAs help shippers and receivers plan their operations and minimise delays.

Unfortunately, the data illuminated several constraining factors that resulted in the inability to measure service reliability from the shipping line accurately. The reliability of ETA times was questioned, as ETA was not included due to significant differences with ATA, with an average gap of several years in 2017 but nearing zero from 2022. These differences can be attributed to adjustments in data capturing principals, with the ETA constantly updated until the vessel berths. Consequently, the service reliability of shipping lines could not be accurately measured in this manner.

Fortunately, for inbound road transport, the opposite is true, as expected delivery and actual delivery were well captured. Expected delivery was not a mandatory field but was captured with the delivery of a total of 8 800 containers. Therefore, by measuring the expected delivery with the actual delivery dates, the inbound delivery could be ascertained. Typically, inbound delivery is arranged by the freight forwarder three days before vessel arrival at the quay side. The transport is then booked for a date and time; however, these arrangements could often move around, depending on when the container has been discharged.

Nevertheless, the initial arrangement, in essence, "books" the transporter, which is then updated as to the specific time and date based on the factors mentioned above. The key is to coordinate these activities between the transporter and the freight forwarder. From the results, the following distribution illustrates the inbound transport service reliability:

Figure 5-8: On-time delivery for inbound transport – expected versus cargo delivered



Source: Author’s own compilation.

From the 8 800 containers, 6 526 were delivered "on-time", with the vast majority of the on-time delivery taking place on the expected day of delivery. Therefore, a 74% on-time delivery rate was achieved. However, with some of the late deliveries, a considerable 203 (or 2.3%) were delivered later than a week. On average, the difference between expected delivery and actual delivery was 1.94 days.

5.5 Conclusion

In conclusion, this chapter has offered a comprehensive description of the data utilised in this thesis, encompassing the pre-processing and data cleaning steps, as well as addressing various data-related challenges encountered. Common descriptive statistics, such as mean, standard deviation, and ranges, have been presented to offer an initial understanding of the dataset. Moreover, the application of visualisation tools has assisted in highlighting data patterns, which will be subject to in-depth empirical analysis in the subsequent chapter.

This research seeks to bridge a critical gap in the existing literature, providing a microeconomic, operational perspective on logistics, with an emphasis on data-driven system development, measurement, and enhancement. The datasets used in this chapter were obtained from a South African freight forwarder and represented a typical import process flow, making it a valuable resource.

The primary aim of this chapter was to provide extensive information on the various interconnected elements of the logistics process and their relation to each other. As such, important segments were measured concerning the documentary, physical and financial segments of importing cargo into South Africa. The chapter also assisted in satisfying the primary objective of contributing to measuring the performance of the logistics system at a national level for all actors from the perspective of the South African freight forwarder. Indeed, the performance of various processes linking the freight forwarder with other logistics service providers was presented, particularly concerning the typical benchmarked performance and the proposed service reliability of logistics service providers.

The results highlight significant deviations from benchmark performances, particularly in waterside operations, where observed efficiency surpasses the benchmark (2.45 days compared to 1.5 days), indicating inefficiencies in ship-to-shore processes. Terminal evacuation (2.76 days versus the 1.5-day benchmark) and overall time in the port (4.53 days versus the 3-day benchmark) also demonstrate suboptimal efficiency in TPT's operations. The short-haul and long-haul segments align with targets, while the port-to-delivery duration slightly exceeds the benchmark (4.14 days versus 3.4 days), suggesting areas for optimisation. The impact of the COVID-19 pandemic on operations is acknowledged. Concerning service reliability, a 74% on-time delivery rate was achieved. However, with some of the late deliveries, a considerable 203 (or 2.3%) were delivered later than a week. On average, the difference between expected delivery and actual delivery was 1.94 days, indicating significant room for improvement.

Lastly, the chapter adds to the secondary objective in that it evaluates the operational model of South African imports, employing data analytics to illustrate areas for potential improvement in logistics performance at an operational and detailed level. The chapter has also emphasised how logistics performance is measured in terms of time, cost, and service reliability, setting the stage for further examination in subsequent sections. The subsequent chapter will delve further into the logistics performance methodology, the specific datasets derived from the South African Freight Forwarder, and the findings of the exploratory data analysis.

CHAPTER 6: EMPIRICAL ANALYSIS

6.1 Introduction

This chapter aims to empirically analyse logistics performance for South African imports through the use of data analytics. The methodology involves employing an ANOVA analysis to discern statistically significant differences in various category-process segments from the population. Subsequently, a total economic cost model is developed to explore the variability in time delays within key segments of the goods movement process into South Africa. Traditionally, the initial step involves conducting an ANOVA analysis, followed by calculating t-statistics for categorical variables exhibiting a significant relationship with the dependent variables, namely time and associated costs. This approach aims to identify categories that deviate significantly from the population average in order to enhance the understanding of logistics performance dynamics in the context of South African imports.

Ensuing from the previous chapter, this chapter aims to comprehensively satisfy the primary objective of this thesis in measuring the performance of the logistics system at a national level for all actors from the perspective of the freight forwarder, based on reducing the time and cost of trade internationally – and ultimately improve the service reliability of the offerings. Furthermore, the chapter provides additional evidence towards satisfying the secondary objective of evaluating the operational model of South African imports, by employing data analytics to illustrate areas for potential improvement in logistics performance at an operational and detailed level.

This chapter's structure is as follows: Section 6.2 outlines and discusses the methodology used in this chapter. Section 6.3 then performs an ANOVA analysis using the identified input variables as categorical variables, and time delay as the dependent variable to determine which of the categorical variables have a statistically significant influence on which of the time delays. For these categorical variables, the specific categories and process steps for which measured times are statistically significantly different from the population, are identified using t-statistics. After conducting the ANOVA analysis, Section 6.4 provides an overview of the t-statistics calculations for categorical variables which exhibit a significant relationship with the dependent variables. Section 6.5 presents a cost-benefit analysis of alternative logistics options based on the TEC model. Rounding off the chapter's findings, the results of the preceding sections are discussed. Finally, Section 6.6 concludes the chapter on descriptive and exploratory data analysis.

6.2 Methodology for extracting information from the data

The approach that will be applied to extract meaningful information from the available dataset (which is the same set as described in detail in Section 5.3) consists of the following sequential steps:

1. Conducting an ANOVA analysis to understand the possible dependencies of specific process steps on specific input variables.
 - a. The ANOVA analysis will determine which of the categorical variables (i.e., country of origin, port of loading, shipping line, and the like) have a statistically significant influence on which process steps (i.e., SOB to ATA, ATA to discharge, left port to cargo delivered, and the like).
 - b. Furthermore, the ANOVA analysis will also be used to determine the time variability of various segments to be used in the TEC model.
2. Calculating t-statistics to determine which categories (e.g., specific shipping lines or specific countries of export) cause time delays that are statistically significantly different from the population time delays. These calculations will only be performed for categorical variable and time delay combinations that have been found to be related, based on the ANOVA analysis.
3. Creation of a total economic cost (TEC) model to translate time variation into cost.
 - a. Defining all logistic costs that are sensitive to time delays, including interest paid on capital invested into stock, stock holding costs, stock shrinkage and expiry, and losses in sales in case of out-of-stock situations.
 - b. Defining the total logistics cost, including all fixed costs (e.g., the charges of shipping lines, ports and road transport operators for handling and conveying containers), as well as all time-dependent costs.
 - c. Extracting percentiles for all time delays to allow the calculation of the impact of time delay on time-sensitive logistics costs.
 - d. Accumulating total average logistic costs for all observed time delays (called the TEC) by adding the contributions of the total logistic cost for each percentile value.
 - e. Repeating these calculations for different sizes of buffer stock, identifying the buffer stock size that minimises TEC, and calculating the minimum value for TEC.
4. Application of the TEC model to selected combinations of categorical variables to identify opportunities for improved logistics decisions:
 - a. Calculating TEC for each separate category as defined by each of the categorical variables.

- b. Identification of those categorical variables that have the biggest impact on TEC – these proved to be Country of Export/Origin and Shipping Line.
- c. Identification of those cases that offer the FF the opportunity to minimise cost through improved decision-making – the case study that was used to illustrate this concept was the selection of the shipping line with the lowest TEC for each Country of Export/Origin from where goods were imported.
- d. For each Country of Origin, identification of all shipping lines servicing the routes between those countries and South African ports.
- e. Calculating time delay percentiles for each country/shipping line combination.
- f. Using these percentiles to calculate the time dependent costs for a range of buffer stock sizes.
- g. Calculating TEC for each country/shipping line combination and each buffer stock size to obtain the minimum TEC for each country/shipping line combination.
- h. Comparing the TEC linked to each shipping line for each Country of Origin, identifying the shipping lines with the lowest TEC, and determining the best buffer stock policies for each case.
- i. Calculation of the potential cost saving should the lowest TEC shipping lines always be selected.

Collectively, the key questions which this chapter aims to answer can be grouped under the following:

1. What is the average time of the total logistics process from the perspective of the South African freight forwarder – from SOB to cargo delivered to the client?
2. What is the level of uncertainty of the average time (as this should dictate the client's stock control policy – higher uncertainty will require higher stock levels and thus more costs)?
3. How do time delay and time delay uncertainty translate into the effective cost, as experienced by the cargo owner (called TEC)?
4. What are the optimal buffer stock policies to minimise TEC, and which service providers offer the lowest TEC for each origin/destination pair?
5. How much can potentially be saved on TEC through optimal choices made by the freight forwarder?

6.3 ANOVA analysis

6.3.1 Introduction of the ANOVA analysis

This section presents an ANOVA analysis of the various combinations of factors and their influence on time delays. ANOVA is a statistical method used to analyse the differences among group means in a sample. It assesses whether the means of different groups are statistically different from each other. ANOVA provides a way to test multiple factors simultaneously to understand their impact on a dependent variable. Importantly, ANOVA can help identify the impact of different logistical strategies, respective transportation trade lanes, or logistics network configurations based on cost and time efficiency.

6.3.2 ANOVA analysis overview

An analysis of variance (ANOVA) was conducted to determine which of the categories (i.e., country of origin, port of loading, shipping line, and the like) and which process segments (i.e., SOB to ATA, ATA to discharge, left port to cargo delivered, and the like) are statistically significantly different from the population, and therefore, which of the factors has a significant impact on time delays. An ANOVA analysis involves a series of steps to determine if there are statistically significant differences in the time delays concerning various categories and process segments. Therefore, multiple one-way ANOVA analyses must be conducted on one dependent variable, in this case time delay, using different categorical variables as independent variables. This process is repeated for each separate process segment.

As a null hypothesis, it is assumed that there is no significant difference in the means of time variables based on the categories and segments mentioned above, while the alternative hypothesis suggests the presence of statistically significant differences. One-way ANOVA considers one dependent variable (the time variables) and one categorical input factor at a time to test whether there are significant differences in the mean times measured within the categories, as defined by the categorical factor.

6.3.3 ANOVA analysis results and findings

The following table highlights the ANOVA results for all categories, showing the level of significance of performance variations based on their p-values and F-values (a detailed table showing all the steps is presented in Table 9-4 in the annexure):

Table 6-1: Summary of ANOVA results (p-statistic, F-values)

p ANOVA	SOBDateT	SOBDateT	SOBDateT	ATAToDisc	Discharge		LeftPortTo	ArriveAtDe	LeftDepotT	LeftPortTo
	oCARGOD	oArriveAtW	oATA	hargedDat	ToLeftPort	TimelnPort	ArriveAtDe	potToLeftD	oArriveAtW	ArriveAtWa
	ELIVERED	arehouse	oATA	e			pot	epot	arehouse	arehouse
	DATE									
ISVOC	0.00	0.79	0.00	0.11	0.29	0.93	0.00	0.00	0.34	0.27
OGASTOPENITYCODE	0.00	0.00	0.04	0.73	0.00	0.02		0.41	0.73	0.48
INCOTERMCODE	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00
EDICUSRESSTATUSCODE	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.94	0.84
TARRIF_HEADING	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CountryOfOrigin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.00
PortOfLoading	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ShippingLine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
	LeftPortTo	ArriveAtWa		DATECRE	EDI_SENT	EDI_SENT	EDI_SENT	EDI_SENT	EDI_SENT	
	CARGODE	arehouseTO	ATAToArr	ATEDToArr	_DATEToA	_DATEToD	_DATEToE	_DATEToA	_DATEToS	
	LIVEREDD	CARGODE	eAtWareho	iveAtWareh	rriveAtWar	ATE_CLO	DICUSRE	SSESSME	ARSCASE	
	ATE	ATE	use	ouse	ehouse	SED	SDATE	NT_DATE	CLOSEDD	
									ATE	
ISVOC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
OGASTOPENITYCODE	0.76	0.59	0.00	0.00	0.01	0.02	0.13	0.00	0.00	
INCOTERMCODE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
EDICUSRESSTATUSCODE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TARRIF_HEADING	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CountryOfOrigin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
PortOfLoading	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
ShippingLine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

F-Stats	SOBDateT	SOBDateT	SOBDateT	ATAToDisc	Discharge		LeftPortTo	ArriveAtDe	LeftDepotT	LeftPortTo
	oCARGOD	oArriveAtW	oATA	hargedDat	ToLeftPort	TimelnPort	ArriveAtDe	potToLeftD	oArriveAtW	ArriveAtWa
	ELIVERED	arehouse	oATA	e			pot	epot	arehouse	arehouse
	DATE									
ISVOC	264.62	0.07	80.63	2.60	1.10	0.01	21.34	142.98	0.91	1.20
OGASTOPENITYCODE	27.17	8.44	4.28	0.12	26.44	5.31		0.67	0.11	0.51
INCOTERMCODE	202.56	1.46	124.08	23.28	44.32	17.90	9.36	91.38	1.81	6.53
EDICUSRESSTATUSCODE	31.40	2.83	13.05	27.63	6.64	0.69	21.34	19.00	0.33	0.52
TARRIF_HEADING	22.61	32.21	12.89	30.93	15.92	4.88	8.05	22.52	2.53	8.67
CountryOfOrigin	371.32	49.66	67.50	133.72	27.49	42.03	7.34	36.16	0.62	16.53
PortOfLoading	200.34	26.43	54.48	118.86	26.25	94.42	7.63	19.90	5.90	15.83
ShippingLine	165.86	21.09	295.04	58.09	31.07	29.14	14.82	22.91	0.35	17.52
	LeftPortTo	ArriveAtWa		DATECRE	EDI_SENT	EDI_SENT	EDI_SENT	EDI_SENT	EDI_SENT	
	CARGODE	arehouseTO	ATAToArr	ATEDToArr	_DATEToA	_DATEToD	_DATEToE	_DATEToA	_DATEToS	
	LIVEREDD	CARGODE	eAtWareho	iveAtWareh	rriveAtWar	ATE_CLO	DICUSRE	SSESSME	ARSCASE	
	ATE	ATE	use	ouse	ehouse	SED	SDATE	NT_DATE	CLOSEDD	
									ATE	
ISVOC	29.96	21.42	218.50	162.08	1570.56	98.96	1975.94	94.11	111.35	
OGASTOPENITYCODE	0.09	0.28	13.52	64.87	6.42	4.04	2.04	35.25	252.90	
INCOTERMCODE	9.03	18.29	54.98	16.88	23.12	384.09	74.86	96.80	29.78	
EDICUSRESSTATUSCODE	10.96	5.08	27.76	25.07	524.68	10.85	1915.65	7.71	26.37	
TARRIF_HEADING	4.08	19.79	13.46	79.40	22.94	41.77	71.76	31.68	76.13	
CountryOfOrigin	11.51	8.80	19.60	464.32	63.97	185.14	128.14	72.35	27.42	
PortOfLoading	9.16	4.35	82.02	292.77	56.82	80.83	57.61	50.92	33.44	
ShippingLine	9.87	10.91	23.13	112.47	99.33	73.99	48.59	55.30	12.75	

Source: Author's own compilation.

From the table shown above, the following factors (with time combinations) must be included in the TEC model, based on the statistical conditions ((1) P < 0.05; (2) F significantly greater than 1; and (3) t-stat > 2 or < -2) include the following:

- **VOC** – Customs and delivery segments
 - SOB Date To CARGO DELIVERED DATE
 - SOB Date To ATA
 - EDI SENT DATE To EDI CUSRES DATE
 - EDI SENT DATE To ASSESSMENT DATE
 - EDI SENT DATE To SARS CASE CLOSED DATE
 - It has the biggest F-value for EDI SENT to EDI CUSRES DATE, which is as expected, because this is the process step mostly influenced by the accuracy of the customs declaration.
- **OGA** – Delivery segments
 - SOB Date To CARGO DELIVERED DATE
 - Discharge To Left Port
 - Time In Port
 - ATA To Arrive At Warehouse
 - DATE CREATED To Arrive At Warehouse
 - EDI SENT DATE To Arrive At Warehouse
 - EDI SENT DATE To ASSESSMENT DATE
 - EDI SENT DATE To SARS CASE CLOSED DATE
 - It has the biggest F-value for EDI SENT DATE To SARS CASE CLOSED DATE, which is as expected because the impact of an OGA intrusion on the process will occur between these process steps.
- **EDICUSRES** – Determining the influence of Customs/Customs' response on performance
 - This factor appears to be significantly influencing everything except for:
 - Time In Port
 - Left Depot To Arrive At Warehouse
 - Left Port To Arrive At Warehouse
 - It has the biggest F-value for EDI SENT to EDI CUSRES DATE, which is as expected because this is the process step mostly influenced by a customs' decision not to immediately release the shipment.
- **Tariff** – Determining whether some product lines move faster than others
 - This factor appears to be significantly influencing everything except for:
 - Discharge To Left Port
 - Left Depot To Arrive At Warehouse
- **Incoterm** – Selection of incoterm (level of risk and responsibility per party)
 - This factor appears to be significantly influencing everything except for:
 - Left Depot To Arrive At Warehouse

- SOBDateToArriveAtWarehouse
 - It has the biggest F-value for EDISENT to CASE_CLOSED, as the Customs Risk Engine use Incoterms as a factor to assess the declaration.
- **Country of Origin** – Customs & Ocean freight segments
 - This factor appears to be significantly influencing everything except for:
 - Left Depot To Arrive At Warehouse
 - It has the biggest F-value for SOB to Cargo Delivered, as the Country of Origin influences not only the maritime leg of the journey, but also the way in which the Customs Risk Engine assesses the declaration.
- **Port of Loading** – Selection of supplier/service provider combination
 - This factor appears to be significantly influencing everything except for:
 - Discharge To Left Port
 - Left Depot To Arrive At Warehouse
- **Shipping Line** – Selection of service provider
 - This factor appears to be significantly influencing everything except for:
 - Left Depot To Arrive At Warehouse
 - It has the biggest F-value for SOB to ATA, which is as expected, as the Shipping Line is responsible for this leg of the journey.

The following section will elaborate on the descriptive analysis presented in Chapter 5, and provide an overview of the t-statistics value of individual categories outlined above.

6.4 T-statistics analysis

6.4.1 Introduction of the t-statistics analysis

This section presents an overview of the t-statistics analysis, which evaluates the dependent variable within each category. T-statistics is a type of inferential statistics used to compare the means of two groups, and is often used in hypothesis testing to determine whether a process or treatment has an effect on the population of interest or whether two groups are different from one another. T-statistics are used to determine which of the categories (for example, Spain, France, etc.) are significantly above and which are significantly below the population mean for each time lag. For a 5% level of significance, one uses t-stat > 2 or < -2 under the assumption of a normal distribution.

6.4.2 T-statistics results and findings

From the ANOVA, several segments within several categories presented a significant influence on time delays. However, since a vast array of segments showed to be significantly influencing

time delays, the largest F-values were used to determine which of the categories are significantly above and below the population mean for each time lag when calculating the t-statistics. Therefore, these include the following:

- Customs clearance segment for VOCs
- SARS infraction segment for OGAs
- Customs clearance segment for Customs' response
- SARS infraction segment for Incoterms
- The ocean transport leg for the country of origin
- The ocean transport leg for the shipping line

The following tables will summarise the results and findings of the t-statistics based on the segments above.

Table 6-2: Voucher of corrections: Statistical summary of the customs clearance process⁶³

Is VOC?	Size	Average	t-stat
No	37 664	0.07	-32.76
Yes	5 245	0.59	16.25

Source: Author's own compilation.

For observations without VOC ("No" category), the average processing time is 0.07 days, with a statistically significant difference from the overall average time (a t-statistic of -32.76, indicating that no VOC significantly reduces the time taken to complete the customs process). In the "Yes" category (VOC present), with 5 245 observations, the average processing time is 0.59 days, significantly longer than the overall average (a t-statistic of 16.25).

The following table provides a summary of the cargo being stopped by OGAs in terms of total time delays, from EDI SENT DATE to SARS CASE CLOSED:

Table 6-3: OGA stops: Statistical summary of a SARS infraction process

OGA stop	Description	Size	Average	t-stat
1	SAPS	36	-11.97	-1.94
2	NRCS	0	-	-
NULL		2 990	1.84	3.56

Source: Author's own compilation.

⁶³ EDI Sent to CUSRES.

For OGA code “1” stops (South African Police Service Stops), there are 36 observations with an average time of -11.97 days and a slightly less significant t-statistic of -1.94. The direction is as expected; however, the impact is less-pronounced.

The following table summarises the customs response after lodging an entry, which determines the influence of Customs’ response and their administrative and risk assessment processes in assessing declarations made:

Table 6-4: EDI CUSRES codes: Statistical summary of the customs clearance process

EDI CUSRES CODE	Size	Average	t-stat
1 – Release	35 050	0.01	-86.38
2 – Physical inspection	1	4.20	-
3 – Conditional release	8	15.09	-
6 – Reject declaration	876	0.26	2.36
9 – Already on system	2	1.27	0.92
13 – Supporting documents required	325	1.49	13.62
27 – Accept amendment	4 325	0.04	-19.20
28 – Accept cancellation	14	5.89	7.64
31 – Request additional supporting documents	226	2.55	15.84
33 – Supporting documents received	2 023	1.71	30.20
35 – Reminder for outstanding documents	13	3.46	13.99
36 – Booking confirmation	1	4.20	
49 – Provisional payment liquidated	45	1.55	16.36

Source: Author’s own compilation.

A total of 82% of all entries were released (code “1”) immediately after being submitted, the t-statistic of -86.38 showing there is a statistically significant difference between the overall average customs process time and the observations. For all the other SARS Customs’ responses, only code “27” (when the amendment is accepted) positively impacts performance, with a t-statistic of -19.20. For the rest, the most significant negative impact on the customs process occurs when supporting documents are requested and then received (code “33”), with a high t-statistic of 30.20, indicating that the difference between the average time for this category and the overall average time is statistically significant with an average of 1.71 days across the 2,023 observations.

The following table provides a summary per Incoterm in terms of total time delays from EDI SENT DATE to SARS CASE CLOSED:

Table 6-5: Incoterms: Statistical summary of a SARS infraction process

Incoterm	Size	Average	t-stat
CFR	0	-	-
CIF	0	-	-

CIP	509	1.68	0.06
EXW	1 819	2.18	7.14
FCA	0	-	-
FOB	698	0.35	-3.52

Source: Author's own compilation.

For CIP, the average time delay is 1.68, with a t-statistic of 0.06. The low t-statistic suggests that the difference between the average time delay for CIP and the overall average is not statistically significant. For EXW, the average time delay is 2.18, with a high positive t-statistic of 7.14. This indicates that the average time delay for EXW is significantly higher than the overall average, implying potential delays associated with this Incoterm. For FOB, the average time delay is 0.35, with a negative t-statistic of -3.52. The negative t-statistic suggests that the average time delay for FOB is significantly lower than the overall average, indicating potentially more efficient processing associated with this Incoterm.

Table 6-6: Country of export: Statistical summary maritime transport leg

Country	Products exported	Average	t-stat
United States of America	10 253	42.79	10.62
Thailand	8 403	36.39	-45.7
Italy	5 927	43.81	26.36
Spain	5 437	32.94	-61.05
France	3 879	39.28	-7.67
Poland	3 510	50.76	58.26
India	1 031	35.44	-20.6
Netherlands	974	33.78	-29.25
Germany	879	40.95	1.62
Belgium	735	37.83	-7.45
Romania	523	67.64	38.99
Portugal	479	26.42	-63.58
Brazil	269	34.6	-7.96
Slovenia	163	61.12	21.52
Georgia	161	41.67	3.1
Sri-Lanka	40	52.45	0.94
China	20	39.8	-0.91
United Arab Emirates	17	87.35	8.18
Hungary	3	53	1.75
Singapore	2	49	-
Czech Republic	1	25	-
Ireland	1	41	-

Source: Author's own compilation.

From the table, all countries of export (exporting more than 40 products) had a t-statistic of > 2 or < -2, except for Germany. The United States of America had a positive t-statistic of 10.62, as did

Italy with 26.36. Thailand, at a significantly large negative t-statistic of -45.7, were also notable, as were Spain, France, and the Netherlands.

Table 6-7: Shipping lines: Statistical summary maritime transport leg

Shipping Line	Products exported	t-stat
Mediterranean Shipping Company	6 285	13.07
Ocean Network Express	4 054	-10.38
Maersk Line	2 865	-29.30
CMA-CGM Group	2 695	-12.94
Gold Star Line	1 356	-55.57
Cosco Shipping Lines	444	9.99
Evergreen Marine Corporation	134	247.49
Safmarine Container Lines	127	3.03
OOCL	126	-22.29
Hapag-Lloyd	113	24.81
COSREN	93	6.84
Dal Deutsche Afrika-Linien	61	9.34
Pacific International Line	7	4.26
Hamburg Sud	5	-2.47

Source: Author’s own compilation.

Mediterranean Shipping Company had a positive t-statistic of 13.07. Ocean Network Express, Maersk Line, CMA-CGM Group, Gold Star, and OOCL had significantly negative t-statistics varying between -55.57 and -10.38. Whatever the reading, these figures show how these categories influence time delays, warranting further investigation into them through a TEC model.

6.4.3 The relationship between ANOVA and t-statistics

This section briefly describes the relationship between ANOVA (that evaluates the impact of a categorical variable on the dependent variable) and t-statistics (that evaluates the dependent variable within each category). This relationship indicates which of these factors should be included in the TEC model.

The ANOVA analysis showed the various combinations of factors and their influence on time delays, and indicated that several factors have a statistically significant influence on logistics time delays and cost. This is because different cargo categories use these factors as categorical variables, and therefore display time delays that are different from the population. These included country of origin, shipping line, and port of loading (in order of significance based on the influence of the respective process segments).

The t-statistics show that there are many instances where the dependent variable values are significantly above or significantly below the population mean for each time lag. Indeed, the t-statistics’ results confirmed many of the findings of the ANOVA results, including the most

significant factors (country of origin and shipping line) that have the most significant impact on time delay.

Therefore, the TEC will compare the different supplier routes (or trade lanes) with the objective of finding the best combination of shipping lines that are best served to import goods from these respective ports into South Africa. Consequently, the following section will use these combinations and investigate the TEC model to translate time variation into cost.

6.5 Total economic cost model

6.5.1 Introduction of the TEC model

This section presents a TEC model that transforms logistics time delay performance into effective logistics cost, based on the datasets described in Chapter 5. The TEC model is a comprehensive measure that includes both direct and indirect costs, such as interest on investments in stock, stock shrinkages, and losses due to out-of-stock situations. The TEC presented builds on previous work on the same subject (Hoffman *et al.*, 2013; Hoffman, 2019; Minken & Johansen, 2019, and most notably, Hoffman *et al.*, 2023) – incorporating several logistics cost elements outlined throughout the thesis.

Hoffman *et al.* (2023) applied the TEC model to a comparison between different transport corridors serving landlocked countries (LLCs) in the SADC region. They used Lusaka, Zambia, as a proxy for all Southern African Development Community (SADC) LLCs, to determine the preference of commercial cargo owners who have to select a transport corridor based on economic considerations. The results indicated that variability in time delays contributes much more to the total cost experienced by cargo owners than direct transport costs. In the case of ineffective corridors, such as the Beira corridor, the costs resulting from variability in time delays can be as high as 80% of total corridor costs. This may cause corridor costs to exceed 25% of the cost of the goods being transported, which is much higher than the global average of less than 10%. Although Beira Port is the closest to Lusaka, it enjoys the smallest share of cargo traffic of the three competing corridors. This can be largely explained by the fact that the TEC for the Beira corridor is higher than that of other corridors.

The TEC presented here aims to use the direct cost components from the perspective of the LSP outlined throughout the study (including freight and landside, storage, transport, etc.), and merge them with indirect costs mentioned in previous studies. In summary, the TEC model includes all the logistics-related costs as well as the externality costs, and, as such, the following TEC components are included:

1. Direct transport and logistics costs, including:
 - a. Freight and landside charges
 - b. 3PL charges (such as customs clearance, communication, agency fees, etc.)
 - c. Storage
 - d. Inbound road transport
 - e. Cargo dues (and other terminal handling fees)
 - f. Customs and OGA stops
2. Indirect transport and logistics costs resulting from time delays, including:
 - a. Cost of interest on cargo in transit
 - b. Shrinkage costs
 - c. Stock holding (i.e., buffer stock) costs
 - d. Loss of sales suffered should cargo not arrive in time to replenish buffer stock
 - e. Loss of goodwill through unreliable service (calculated as the fraction of sales lost multiplied by the gross margin)
3. Storage, including:
 - a. Terminal and depot storage
 - b. Inventory storage
4. Costs on inventory
 - a. Interest rate on investment in stock
 - b. Inventory stockholding cost per annum as a fraction of stock value
 - c. Average shrinkage in stock per day of stockholding

6.5.2 Objective of the TEC model

The objective of this section is to compare the different supplier routes (or trade lanes) in terms of a TEC model that includes bottlenecks related to the movement of trade, for example, shipping delays, customs delays, port delays, quality of services, and other related delays experienced by the cargo in the dataset in question. As the process analysis results presented in Table 5-22 indicated, the ocean transport leg took on average 35.97 days, whereas the total physical process took on average 40.40 days. Therefore, as will be explained throughout this chapter, the ocean transport leg – and by implication, the country of export-shipping line combination – is the most important consideration when attempting to minimise the total physical time delays, and as a result positively impact logistics performance based on time and cost.

6.5.3 TEC methodology

As mentioned earlier, the TEC presented builds on previous work on the same subject (Hoffman *et al.*, 2013; Hoffman, 2019; Minken & Johansen, 2019, and most notably, Hoffman *et al.*, 2023)

– incorporating several logistics cost elements outlined throughout this thesis. The TEC model includes all the direct logistics-related costs as well as the externality costs outlined above, as it quantifies the consequences of time delays and variability in time delays both on a wide array of logistics service providers (including shipping lines, terminal operators, transporters, and the like), and on cargo owners, regardless of the underlying causes of such time delays. Consequently, the following steps were taken to expand on the existing TEC model developed by Hoffman *et al.* (2023):

1. Determine the average number of shipment combinations per annum for the destination of the cargo that connects the country of origin with the destination (see the respective countries of origin presented in Table 5-11) through the use of the respective shipping lines (see the respective shipping lines presented in Table 5-13 and Table 5-14).
 - a. To simplify the comparison, the “cargo delivered” destination is used, whichever warehouse or distribution facility is referred to (although the vast majority of the cargo in the dataset was delivered to the same warehouse facility).
 - b. Nevertheless, since all warehouses and distribution facilities in the dataset are in and around the Gauteng economic hub, the slight variation in time delays between these facilities is negligible in the greater scheme of things.
2. Determine the actual figures of the direct transport and logistics cost categories (as mentioned in Table 5-17) for a standard 40 ft container to be transported from origin to destination, i.e., Gauteng hub.
3. Construct a model of direct transport costs based on distance and time, to determine what the charges for a standard 40 ft container from each port to the Gauteng hub should be if the competitive playing field is level for logistics service providers operating along all origin-destination pairs.
 - a. Direct transport costs were already accounted for in the dataset; however, several other costs to operate vessels and trucks as an economic asset over their economic life were added, including driver and operator costs, fuel and handling costs, financing costs, and others (see Table 6-8).
 - b. Values were assumed for the different cost parameters to calculate the monthly cost to own and operate a truck, a vessel, and a freight forwarding operation.
 - c. By using the total round trip time delays for each origin-destination pair, the cost was converted into an ownership cost per trip.
 - d. To calculate the TEC for all possible time delays between origin and destination, percentiles were calculated for all time delays, and the time-dependent costs were calculated for each percentile to allow an average time-dependent cost to be calculated.

- e. This process was repeated for different buffer stock policies (by varying the size of buffer stock as a fraction of annual consumption over a range of values), and the buffer stock size that produces the minimum total cost was determined for each trade lane.
 - f. These costs were added to the direct transport and logistics cost categories within the dataset, to arrive at a TEC cost incorporating both explicit and implicit costs.
4. Determine the TEC from the perspective of cargo owners who must select a specific origin-destination pair (or trade lane) by constructing a model that incorporates direct charges from the respective port in origin via the ocean freight transportation leg to the final destination in the Gauteng hub.
 - a. The total trade lane from the origin port to the destination was considered, comparing different options by using different shipping lines, different land-based transporters, etc.
 - b. As mentioned above, the indirect costs were also considered, such as the interest costs on investment in cargo in transit, shrinkage costs, stock holding costs, as well as the costs suffered by the cargo owner due to disruptions in operations, should cargo not arrive by the time that buffer stocks have been depleted.
 - c. The calculation of these indirect costs requires the quantification of the variability in delivery times caused by the various segments mentioned in Table 5-6 to Table 5-8, whether the delays were caused by ocean freight, customs, port, inbound transport, etc.
5. The time variability of moving cargo from the first trigger point in the destination country (i.e., shipped on board) was captured by the timestamp data throughout the datasets mentioned in Table 5-1.
 - a. Therefore, similar to the previous sections in Chapters 5 and 6, the time delays were divided into segments (or waypoints) where specific procedural activities occurred (including shipping on board, customs processing, container discharge, etc.).
 - b. However, as will be explained, the key segments were further divided into:
 - i. Ocean – SOB to ATA
 - ii. Port – ATA to Left Port
 - iii. Land – Left Port to Cargo Delivered
 - iv. Total – SOB to Cargo Delivered
 - c. Since the datasets provided access to detailed, product-level data, the statistics of delay times per respective segment for the total trade lane could be calculated.

- d. This approach allowed for not only calculating the contribution of the origin-
shipping line pairs, but also for each trade lane element (such as shipped on board,
customs processing, container discharge, etc.).
 - e. The results will enable the identification of factors forming part of the trade lane
logistics performance, which has the biggest impact on costs experienced by cargo
owners.
 - f. Moreover, the results will enable the identification of factors which are in the control
of the freight forwarder, as mentioned above in Table 5-22.
6. Lastly, the cost resulting from variability in delivery times will be impacted by the buffer
stock policy implemented by the cargo owner.
- a. It is assumed that the cargo owner is rational in terms of minimising total costs and
that buffer stock levels are optimised to minimise total costs.
 - b. Higher buffer stock levels will result in higher interest charges and higher stock
holding costs, but will reduce losses due to disrupted operations, and vice versa
for lower buffer stock levels.
 - c. Therefore, the total costs for a wide spectrum of buffer stock periods (the period
that buffer stock will last before it is depleted should there be no new stock
deliveries) were calculated and used.
 - d. Higher variability in transport and logistics delays will result in policies that use
higher buffer stock levels, and therefore higher total costs, compared to a case
where the variability in time delays is smaller.
 - e. As the optimal buffer stock level is determined in each case based on actual
historical trade lane time delays, it can be accepted that the calculated costs reflect
the true impact of trade lane operations on costs and the resulting decisions of
rational trade lane users who try to minimise their costs.

6.5.4 TEC model specification

The equations appearing in this section indicate how the various cost parameters were used in the calculation of TEC.

6.5.4.1 Direct costs

The following two tables showcase the cost parameters that were used in the cost calculations. The majority of the cost parameters come from the datasets used in this thesis, whereas the other costs build on the work by Hoffman *et al.* (2023):

Table 6-8: Direct transport and logistics cost parameters

Cost category	Cost parameter
Cargo dues per container (per TNPA schedule)	R3 730 per container
Customs (per HS code)	R141 677 per container
Ocean freight ⁶⁴ (depending on Incoterms and time - \$420 to \$7 100)	R50 863 per container
Landside charges	R1 439 per container
3PL charges	R712 per container
Storage	R615 per container
Land transport	R9 736 per container
Monthly interest rate on truck financing (@12% per annum)	1.0%
Number of monthly instalments (over a 6-year period)	72 months
Average cost of truck (~\$200 000)	R1 800 000 per truck
Monthly instalment (~\$3 911)	R74 309 per month
Average fuel consumption (km/l)	1.5
Cost of fuel per litre	R15.56 per litre
Cost of driver per month (~\$1 000)	R19 000
Other costs per trip (~\$180)	R3 420
Toll fees – N3 road per trip	R1 080

Source: Adapted from Hoffman et al. (2023).

Table 6-9: Cost parameters used in the TEC model

Cost category	Cost parameter
Annual Interest Rate on investment in stock	12%
Gross Margin	50%
Inventory stockholding cost ⁶⁵ per annum (% of stock value)	40%
Average shrinkage in stock per day of stockholding	1%
Average customs value of container load of cargo	~R2 270 000 per container
Average time duration for maritime transport	35.973 days

Source: Adapted from Hoffman et al. (2023).

The following equations describe how direct costs were calculated:

$$RTD_i = 2 \times TD_i + 4 \quad (1)$$

where RTD_i = round trip delay in days for the i -th trade lane and TD_i = trip delay from origin to destination.

$$DC_{trip,i} = \frac{DC_{monthly} \times RTD_i}{30} \quad (2)$$

⁶⁴ Depending on the Incoterm used, freight insurance (i.e., when goods move) is included in the freight charges.

⁶⁵ Inventory stockholding cost includes property and contents insurance (i.e., when goods are stationary).

where $DC_{trip,i}$ = driver cost per trip for the i-th trade lane and $DC_{monthly}$ = monthly cost to employ a driver.

$$FC_i = \frac{2 \times Dist_i \times FuelCost}{FuelEcon} \quad (3)$$

where FC_i = fuel cost for trade lane i, $Dist_i$ = distance from the origin to destination for trade lane i, FuelCost is the cost of fuel per litre, and FuelEcon is the fuel economy in km/litre.

$$DTC_i = DC_{trip,i} + FC_i + N3T + OC \quad (4)$$

where DTC_i is the direct trip costs, N3T is the N3 toll fees, whereas OC is other costs (e.g., subsistence for the driver).

$$NumTripspm_i = \frac{30}{RTD_i} \quad (5)$$

where $NumTripspm_i$ is the number of trips per month for the i-th trade lane.

$$TCpm_i = NumTripspm_i \times DTC_i + Instpm \quad (6)$$

where $TCpm_i$ is the total cost per month per truck for the i-th trade lane, and $Instpm$ is the monthly instalment per truck.

$$TranspCost_i = \frac{TCpm_i \times RTD_i}{30} \quad (7)$$

where $TranspCost_i$ is the total cost per trip for the i-th trade lane.

The transport cost for each trade lane was then calculated as a fraction of the cost of cargo for retail cargo or tyre imports, as is the case in this sample.

6.5.4.2 Variable time delay costs

By implementing a specific buffer stock level policy, the cargo owner will try to minimise the overall cost of their operation. As this policy remains constant after optimal buffer stock levels have been determined, it may still happen for each cargo delivery that an above-average delay time will lead to a stock-out situation, which will result in economic losses. To determine the actual TEC, it is, therefore, necessary to calculate the costs for the total spectrum of possible time delays, taking into consideration the likelihood of each possible time delay. For this purpose, the percentiles of time delays for each trade lane are calculated, and then the expected TEC for each percentile is calculated. By adding all these contributions, the total expected cost for all cargo deliveries could

be calculated based on the actual spread of time delays, as determined from measured cargo and truck time delays.

In addition to the above direct transport costs, the following indirect costs were identified from importing cargo as part of their operations, using the same approach as Hoffman (2019):

1. *Impact of varying time delays:* As time-dependent costs increase with an increase in the period that stock is in transit, the total cost should be calculated by integrating over all possible time delays:

$$TotCost = \int_{t=0}^{\infty} Cost(t)p(t)dt \quad (8)$$

where $Cost(t)$ is the cost incurred for time delay t and $p(t)$ is the probability distribution for all possible time delays. Since the true probability distribution of time delays is unknown, the best alternative is to take the average over all percentiles for stock time delays:

$$TotCost = \frac{\sum_{i=1}^{100} Cost_i}{100} \quad (9)$$

where $Cost_i$ is the cost incurred corresponding to the i -th percentile of time delays. This approach was applied to all time-dependent costs calculated below. For simplicity, the summation is not explicitly shown in each case.

2. *Interest paid on investments in stock-in-transit from origin to points of consumption, calculated as a fraction of the value of cargo:* Depending on the Incoterm used, the importer must pay for goods once it leaves the origin premises or is shipped on board at the port of origin (as it is in ~88% of instances in this thesis, with EXW and FOB Incoterms), and consequently the importer must invest in stock-in-transit for the time duration as from cargo being shipped until final delivery. This cost can be expressed as a fraction of the value of the goods:

$$CI = \sum_{i=1}^{100} IR \times VGIT_i \quad (10)$$

$$VGIT_i = \frac{VAC \times TD_i}{365} \quad (11)$$

Therefore:

$$\frac{CI}{VAC} = \frac{IR \times TD_i}{365} \quad (12)$$

where

CI = Cost of interest p. a.

IR = Interest rate p. a.

$VGIT$ = Value of Goods In Transit

VAC = Value of Annual Consumption

TD_i = Transit delay in days for the i – th percentile

3. *Shrinkage of stock in transit:* As shrinkage losses increase with an increase in the period that stock is in transit, the total shrinkage was calculated by summing over all percentiles for stock time delays:

$$TotShrinkage = \frac{\sum_{i=1}^{100} Shrinkage_i}{100} \quad (13)$$

$$Shrinkage_i = Shrinkagepd \times (1 - Shrinkage_{i-1})(TDPercCorr_i - TDPercCorr_{i-1}) + Shrinkage_{i-1} \quad (14)$$

where $TotShrinkage$ is the total shrinkage for all stock, including all possible time delays, $Shrinkage_i$ is the shrinkage for the i -th percentile, $Shrinkagepd$ is the daily shrinkage fraction, and $TDPercCorr_i$ is the time delay in days for the i -th percentile. The equation above considers that after each day in transit, there is less stock left that is still exposed to further shrinkage.

4. *Losses in sales or production, should an out-of-stock situation occur, as a fraction of the value of cargo:* These losses will occur if the actual delivery is delayed beyond the normally expected delivery time (as per “delivery expected” to “cargo delivered”). If a buffer stock is maintained to prevent these losses, then an actual loss will only occur if the unexpected delay is longer than the period covered by the buffer stock (Hoffman, 2019).
- *Retail:* For any retail operation – as is the case with this model – it is assumed that losses in sales will occur when the buffer stock is depleted before the next delivery is made:

$$\frac{LRI}{VAC} = FSL \times GM \quad (15)$$

where

$$FSL = \frac{OTL}{ADT} \text{ if } OTL > 0, FSL = 0 \text{ otherwise} \quad (16)$$

$$OTL = ADT - SDT - BSP \quad (17)$$

$$BSP = \frac{BSS}{UR} \quad (18)$$

where

LRI = Loss in Retail Income

FSL = Fraction of sales lost

GM = Gross Margin

OTL = Operational Time Loss

ADT = Actual Delivery Time

SDT = Standard Delivery time

BSP = Buffer stock period

BSS = Buffer stock size

UR = Usage Rate

5. *Storage costs paid for buffer stocks as a fraction of the value of cargo:*

$$\frac{SC}{VAC} = \frac{SR \times MIS}{VAC} \quad (19)$$

$$MIS = (BSP + SDT - MDT) \times UR \quad (20)$$

therefore

$$\frac{SC}{VAC} = \frac{(BSP + SDT - MDT) \times SR \text{Frac}}{\text{One Year}} \quad (21)$$

where

SC = Storage Cost p. a.

SR = 1 Year Storage Rate per unit

SRFrac = 1 Year Storage cost as fraction of unit value

MIS = Max Inventory Size in units

MDT = Min delivery time

Equations 1 to 21 above allow the total cost resulting from transport and other logistics delays to be expressed as a fraction of the total value of goods purchased:

$$TEI = CI + SC + LRI \tag{22}$$

where

TEI = Total Economic Impact

It was previously mentioned that TEC will be calculated for the optimal value of the buffer stock period *BSP* where TEC reaches its minimum value. Since the effect of *BSP* on TEC must be obtained by integrating all possible values of actual time delays, and as an analytical expression for the probability distribution of actual time delays is not available, it is not possible to find an analytical expression for the optimal value of *BSP*. Instead, this value is determined through numerical means by first averaging TEC over the measured percentile values for total time delays, and then repeating this calculation over a sufficient range of possible *BSP* values, allowing the investigation to find the optimal value for *BSP*.

6.5.4.3 Sensitivity of TEC with respect to cost parameters

The equations above demonstrate that the TEC, from the perspective of the cargo owner, is influenced by several cost parameters. To explore this dependency, the TEC was calculated by varying the values of these parameters across a range of values, as specified in Table 6-10 below.

Table 6-10: Range of values used to determine the sensitivity of TEC with respect to cost parameters

Cost category	Minimum value	Maximum value
Interest rate	1% p.a.	20% p.a.
Gross margin	10%	90%
Annual inventory cost as a fraction of the customs value of the goods	10%	100%

Source: Adapted from Hoffman et al. (2023).

6.5.5 Results and findings

This section elaborates on the results and findings of the TEC presented in the preceding sections.

6.5.5.1 Direct transport and logistics cost

The following table displays the direct transport and logistics cost model for each origin-destination pair, as well as the average fraction that direct transport cost represents the value of

the cargo itself. Furthermore, the table also displays the average distance from each port to Durban, the transport cost for each origin-destination pair based on the direct transport cost model, as well as the actual charges captured by the dataset.

Table 6-11: Direct transport and logistics cost parameters for inbound road transport

Cost category	JHB
Ocean leg distance ⁶⁶	12 197
Distance (km)	539
Round trip duration (days)	1.959
Number of trips per month	10.139
Cost of driver per trip (ZAR)	1 873.952
Cost of fuel per trip (ZAR)	5 591.349
Costs per truck per month (ZAR)	74309
Transport cost per trip (ZAR)	64 267.301
Transport Cost Fraction for Retail	2.831%
Costs charged by freight agents (ZAR)	712

Source: Adapted and calculated from Hoffman et al. (2023).

6.5.5.2 TEC model costs

In the respective origin-destination via shipping line combinations, percentiles for time delays were calculated, encompassing separate calculations for ocean, ports, and land segments for each trade lane, as well as for the total trade lane. The contribution of each of these elements towards the total costs, as experienced by cargo owners, was quantified. When measuring TEC for one part of the logistics chain (ocean), the model uses the average values for port and land rather than their actual values, so that their percentiles all remain constant. This approach causes port and land to make a smaller contribution to TEC, because with this assumption, there is no uncertainty in port and land's delivery time (which speaks to the service reliability of inbound transporters). With this approach, only the ocean segment significantly contributes to variations in delivery time. However, it is important to keep in mind that with less uncertainty in delivery time, smaller buffer stocks still do not cause significant losses in sales.

Figure 6-1 below displays these segment percentiles. It can be observed in the top figure that the ocean freight transport leg has by far the most significant impact on time delays, which highlights the importance of selecting the best-performing supplier-shipping trade lane combination. This

⁶⁶ A basic gravity model was created to determine the average distance (in nautical miles) between the port of loading and the port of Discharge (Durban) based on the number of goods shipped out of these ports of loading. The distance was then converted from nautical miles into kilometres for ease of reference.

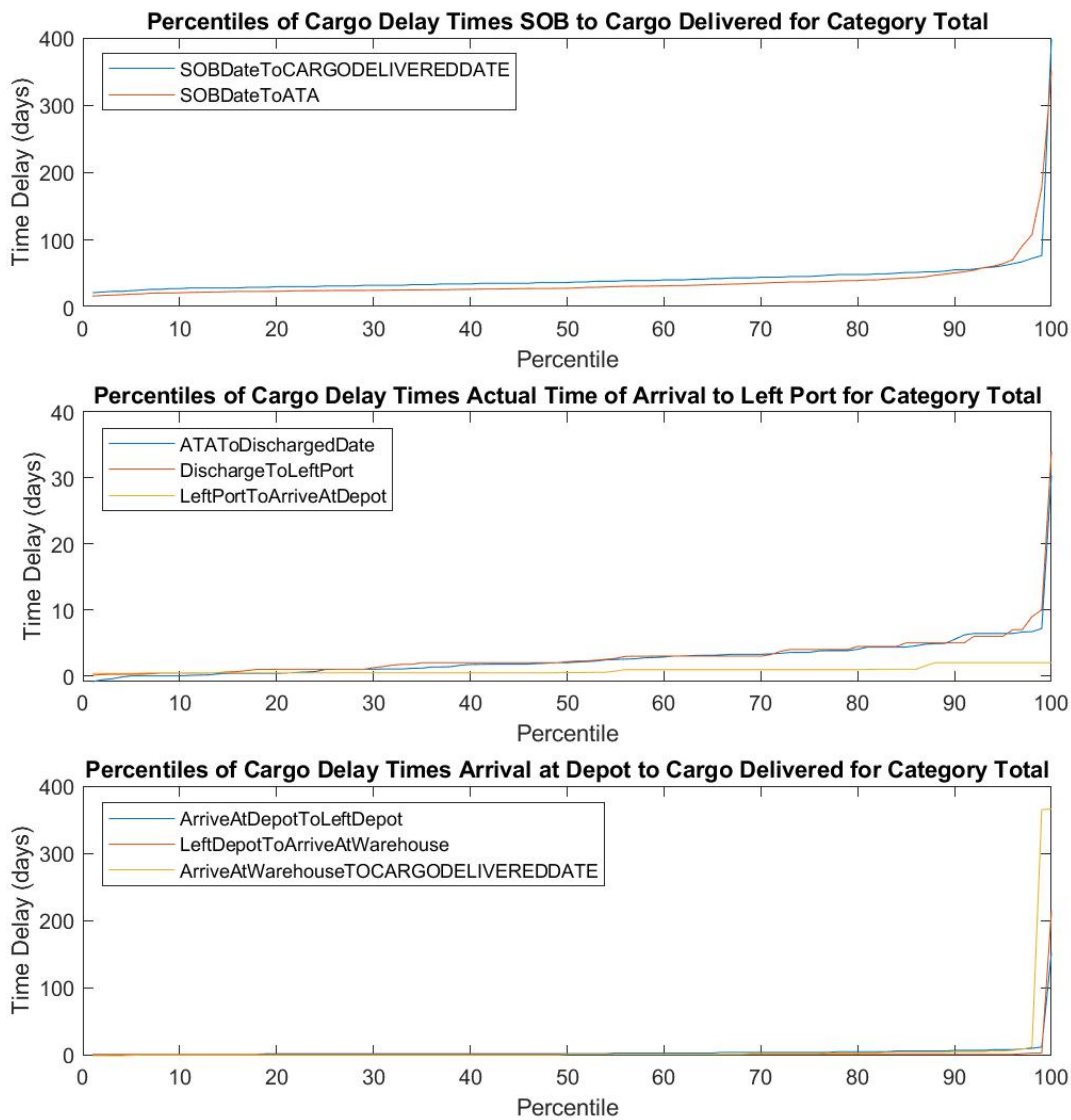
phenomenon is not surprising, since, as mentioned in Section 6.5.2, the ocean transport leg took on average 35.97 days, whereas the total physical process took on average 40.40 days.

The second middle graph in Figure 6-1 below shows that the waterside performance (ATA to discharge) and the landside performance (discharge to left port) have approximately the same impact on time delay. These results indicate that the relative performance of TPT equally impacts the time delay of cargo movement – whether it is the performance of the ship-to-shore cranes or the straddle carriers working on the landside.

The bottom graph in Figure 6-1 below shows that the inbound road transport segment has the least significant impact on time delay. However, there are significant delays experienced in the 96th percentile onwards, suggesting that when the cargo movement gets delayed, the delays are typically substantial and run into many days. Furthermore, there is some indication that the current inbound strategy of short haul-long haul can potentially be investigated further, since there are several instances of cargo spending a significant amount of time in either depots or warehouses. Often, the choice of where to leave cargo at rest relates to buffer stock levels and the related storage costs.

As such, the following section provides insights into the respective buffer stock scenarios, and delineates the relationship between TEC and the buffer stock period, demonstrating a characteristic pattern. Initially, TEC exhibits an elevated profile concomitant with a diminished buffer stock, attributable to a heightened frequency of lost sales resulting from instances of stockouts. Subsequently, TEC experiences a decline concurrent with an augmentation in buffer stock. Lastly, TEC undergoes a subsequent reduction following the cessation of sales losses, juxtaposed with an increase in the cost of stock as the buffer stock expands.

Figure 6-1: Percentiles of segment delays

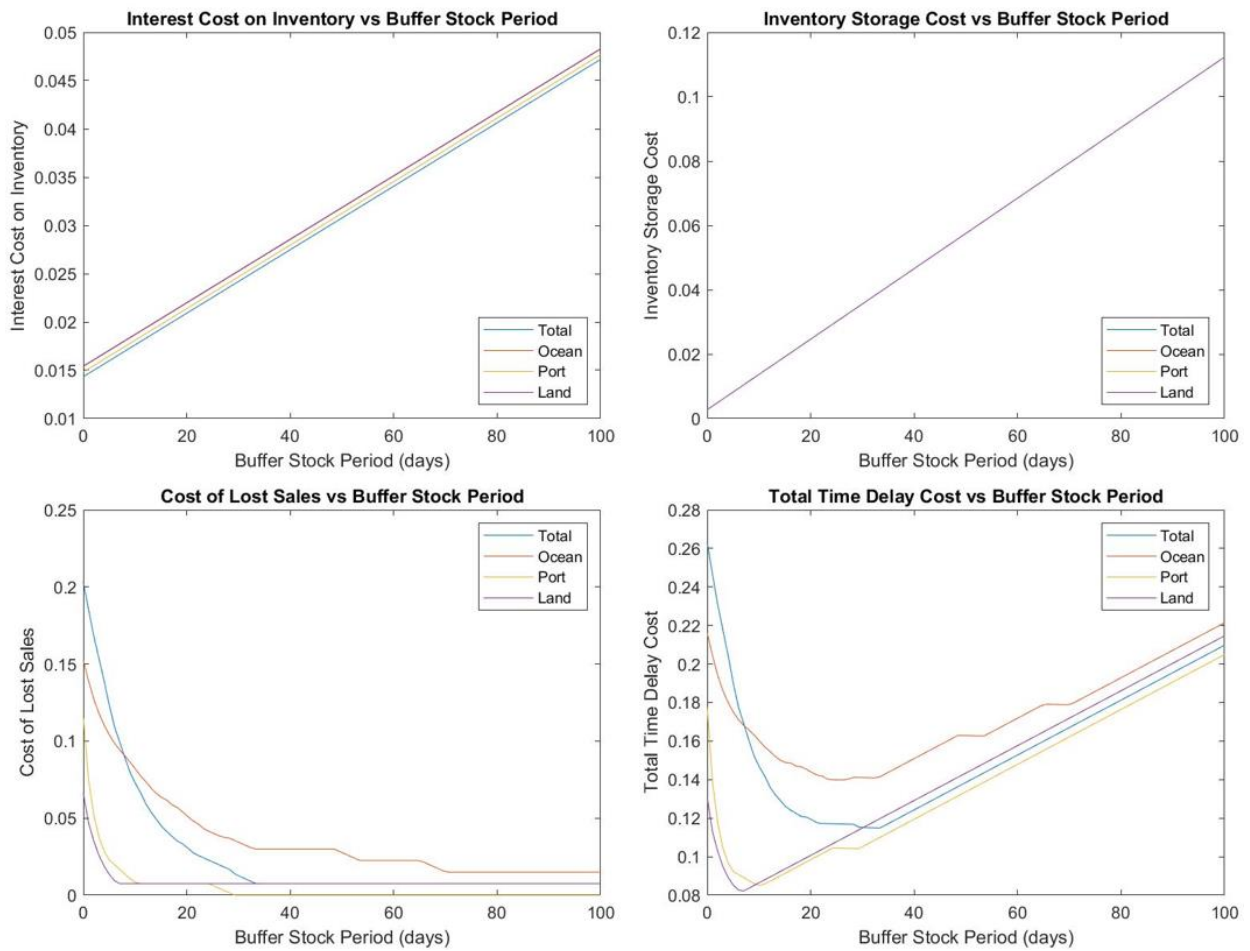


Source: Author's own compilation.

In Figure 6-2 below, the variations in contributions towards logistics cost are observed as a function of the buffer stock period. These variations are sorted (clockwise from the top left) in terms of interest cost on inventory, inventory storage cost, cost of lost sales, and total time delay cost versus buffer stock period. With an increase in buffer stock period, the cost of interest and storage costs rises, while the cost of lost sales decreases. Both the interest cost on inventory (top left in Figure 6-2) and the inventory storage cost (top right in Figure 6-2) have a direct positive, linear relationship with the buffer stock period, as expected.

For the cost of lost sales, the ocean leg is once again responsible for the most delays, with loss of sales only being negated with a buffer stock of around 70 days – significantly more than what most retailers will carry at any given period.

Figure 6-2: Contributors to cost resulting from time delay variability per trade lane

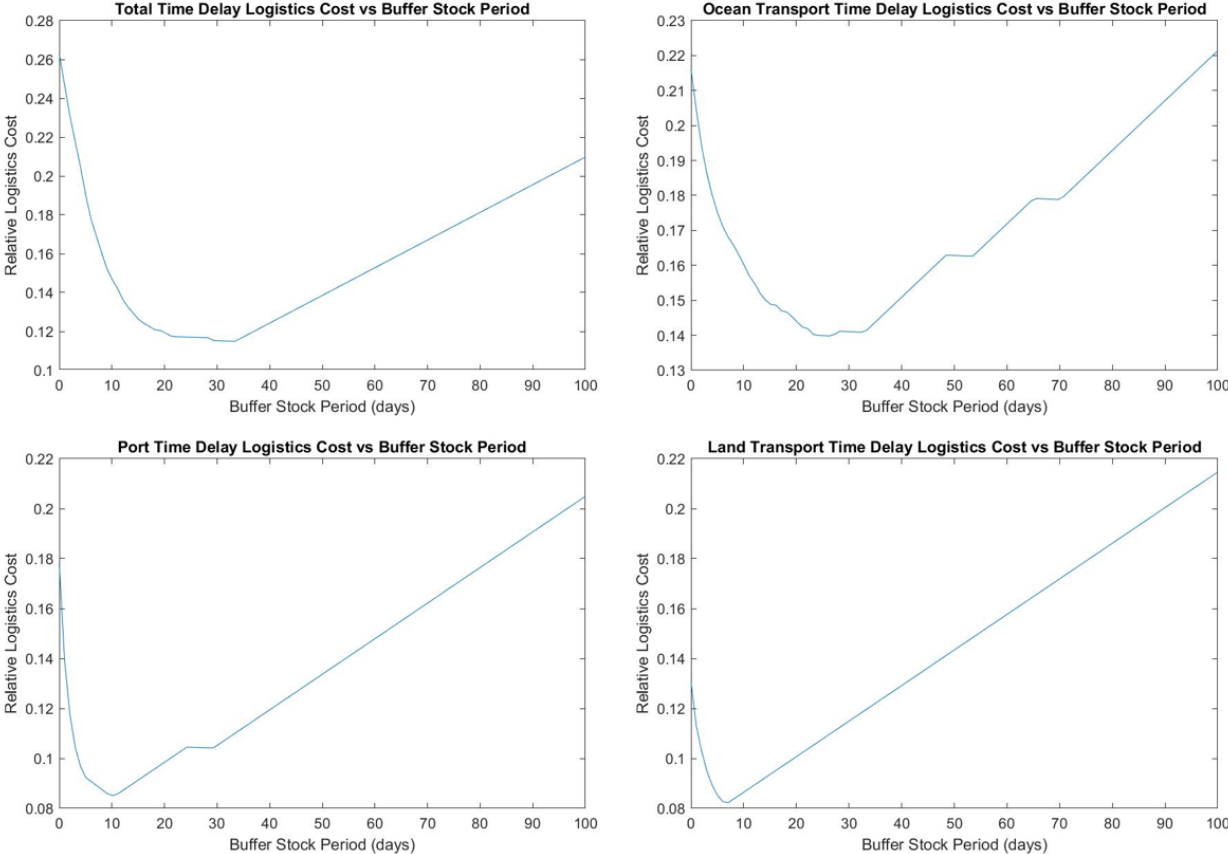


Source: Author's own compilation.

Figure 6-3 displays how total logistics costs fluctuate concerning the buffer stock. The curves illustrate an optimal value for the buffer stock period, where the total cost reaches its minimum value. For the total time delay, the optimal value of buffer stock to keep is around 34 days, which is roughly the average time of the ocean transport leg.

Subsequent TEC valuations were conducted using this optimal buffer stock value for each segment, with the minimum values approximately corresponding to the average time of each respective segment. However, as is the case with the total time delay, the ocean freight leg is again the most significant contributor. Ultimately, as mentioned above, it is important to keep in mind that with less uncertainty in delivery time, smaller buffer stocks still do not cause significant losses in sales.

Figure 6-3: Total logistics costs as a fraction of the cost of cargo for different buffer stock periods per trade lane



Source: Author’s own compilation.

Table 6-11 below displays the different elements contributing towards TEC for all trade lanes. Since the performance of the individual trade lane elements comprising the total trade lane also varies significantly, these calculations are repeated by taking into consideration only the time delay and variability caused by a specific trade lane element. In such a case, it is assumed that only one trade lane element showed variable time delays, while assuming that all the other trade lane elements produced their respective average time delays. This allowed for the quantification of the contribution of each separate trade lane element to TEC.

When the contributions towards costs resulting from the variability of delay times are broken down, it is observed that the ocean transport leg is by far the most responsible for time delays in importing cargo to South Africa.

The following table summarises the variability of transport and logistics costs as a fraction of the value of cargo per trade lane. The table takes the top 14 countries of origin (as per Table 5-14) and the top 10 shipping lines (as per Table 5-12):

**Table 6-12: Total time delay cost for origin-shipping line combinations
(% of value)**

Combination	BE	BR	FR	DE	IN	IT	NL	PL	PT	RO	SL	ES	TH	US
CMA-CGM	-	6.7%	8.8%	-	-	-	-	-	-	13.4%	14.0%	-	8.8%	12.8%
Cosco	-	-	3.9%	-	-	-	-	-	-	-	-	-	13.3%	-
Evergreen	-	-	-	-	-	-	-	-	-	-	-	-	24.5%	-
Gold Star Line	-	-	-	-	-	-	-	-	-	-	-	-	7.4%	-
Hapag-Lloyd	5.3%	6.3%	4.9%	-	-	8.5%	-	-	10.4%	12.5%	10.6%	-	6.0%	-
Maersk	8.1%	17.8%	6.5%	10.8%	6.9%	5.7%	5.1%	10.0%	-	-	-	5.9%	6.2%	8.0%
MSC	7.5%	8.3%	12.2%	7.4%	-	13.9%	10.0%	15.2%	6.0%	9.3%	21.1%	14.4%	8.4%	12.5%
ONE	7.2%	-	9.7%	16.1%	8.4%	8.4%	18.3%	8.6%	-	-	-	11.2%	9.9%	9.8%
OOCL	-	-	-	-	-	-	-	-	-	-	-	-	6.0%	-
Safmarine	10.6%	-	8.0%	7.5%	4.7%	-	6.1%	9.9%	-	-	-	9.1%	4.2%	10.1%

Source: Adapted and calculated from Hoffman et al. (2023).

From the table, several key observations can be made. For example, for France, the best Shipping Line is Cosco (with TEC due to time delays = 3.9% of cost value), and MSC the worst with 12.1%, which is a significant difference, given that the total direct logistics cost is about 9.2% of the total product value⁶⁷. The reason for this example is obvious: Cosco's average ocean transport leg (SOB to ATA) is 22.6 days, and that of MSC is 38 days.

Furthermore, the table provides additional insights, notably the respective connections offered by the shipping lines, which is interesting. For example, MSC offers connections to all but one market, with Maersk connecting to eleven and ONE servicing ten markets. Also, all lines connect to Thailand, which is the country most well-served and has the widest range in total time delay – ranging from 4.2% to 24.5%. The insights gleaned from these results indicated just how much the freight forwarder can positively influence logistics performance by matching the shipping line with the country of origin to shipped goods.

The following table indicates the minimum buffer period required for the respective shipping line and country of origin combinations:

**Table 6-13: Minimum cost buffer stock period for origin-shipping line combinations
(days)**

Combination	BE	BR	FR	DE	IN	IT	NL	PL	PT	RO	SL	ES	TH	US
CMA-CGM	-	23.68	-	-	-	-	-	-	-	18.95	33.16	-	28.42	-
Cosco	-	-	-	-	-	-	-	-	-	-	-	-	9.47	-
Evergreen	-	-	-	-	-	-	-	-	-	-	-	-	4.74	-
Gold Star Line	-	-	-	-	-	-	-	-	-	-	-	-	9.47	-
Hapag-Lloyd	-	-	-	-	-	-	-	-	-	9.47	9.47	-	9.47	-
Maersk	-	14.21	9.47	4.74	4.74	4.74	4.74	14.21	-	-	-	4.74	4.74	9.47
MSC	14.21	9.47	23.68	9.47	-	23.68	33.16	28.42	9.47	14.21	23.68	18.95	18.95	28.42
ONE	4.74	-	33.16	37.89	28.42	18.95	23.68	9.47	-	-	-	23.68	33.16	4.74
OOCL	-	-	-	-	-	-	-	-	-	-	-	-	9.47	-

⁶⁷ Note, to derive the total direct logistics cost plus the time delay for the respective shipping line and country of origin combinations from the table, 9.2% can simply be added to each combination.

Safmarine	33.16	-	14.21	18.95	-	-	4.74	14.21	-	-	-	14.21	18.95	18.95
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Source: Adapted and calculated from Hoffman et al. (2023).

From the table, several interesting remarks can be made. First of all, any combination indicating (-) shows that the combination is not served and is thus irrelevant. However, for the markets that are well-served, shipping with MSC appears to require cargo owners to carry a significant amount of minimum buffer stock, ranging from 9.47 days for cargo originating from Germany and a considerable 33.16 days for cargo originating from the Netherlands.

6.5.6 Conclusion and recommendations based on the TEC model

This section presented a TEC of logistics time delay performance. The TEC model compared the different supplier routes (or trade lanes) in terms of a TEC model that included bottlenecks related to the movement of trade. The TEC model demonstrated that it is a comprehensive measure that includes both direct and indirect costs, such as time delays, stock shrinkages, and losses due to out-of-stock situations. Ultimately, the TEC built on previous work on the same subject (Hoffman et al., 2013; Hoffman, 2019; Minken & Johansen, 2019; Hoffman et al., 2023) and incorporated several logistics cost elements outlined throughout the thesis.

The results showed that a wide range of time delays is evident among different cargo consignments, ranging from a few days to more than 100 days in some instances. This result confirms the importance of assessing the impact of variability in time delays on TECs to the cargo owner. Therefore, the freight forwarder should critically assess which supplier-shipping line combinations to choose for which product combinations, as there are significant variations in time delay performance, which directly impacts the total economic cost of moving goods.

6.6 Conclusion

This chapter contained an empirical analysis of the logistics performance for South African imports through the use of data analytics. The analysis was presented in two key parts: firstly, that of an ANOVA and t-statistics analysis determining which of the categories and which process segments are statistically significantly different from the population; and secondly, developing a total economic cost model in investigating the time delay variability in several key segments of moving goods into South Africa.

As has been the case throughout the empirical sections in this thesis, the aim was to see what potential level of influence the freight forwarder could exert in improving the flow of imported goods to South Africa. As such, the results identified several areas of potential further investigation into logistics performance, notably the choice of trade lane combinations and the

need for efficient and correct customs clearance processes to avoid goods incurring customs and OGA infractions.

The ANOVA analysis showed the various combinations of factors and their influence on time delays, and indicated that several factors have a significant impact on time delays, resulting in some categories experiencing time delays that are statistically significantly different from population time delays. These included (in order of significance based on the influence of the respective process segments) country of origin, shipping line, and port of loading. Other factors also showed significant statistical significance, notably (in no order) EDICUSRES, Incoterm, OGA, tariff, and VOC. These were further investigated using the TEC model.

The TEC model analysis reveals significant insights into the impact of various factors on logistics performance and cost. The ocean freight transport leg emerges as the most influential contributor to time delays, underscoring the critical importance of selecting optimal supplier-shipping trade lane combinations. With the ocean transport leg averaging 35.97 days, it significantly influences the overall time delay, which averages 40.40 days.

Port performance is dissected into waterside (ATA to discharge) and landside (discharge to left port) components, both demonstrating nearly equal impacts on time delay. The relative performance of Terminal Port Terminal (TPT) influences time delays, regardless of whether it pertains to ship-to-shore cranes (waterside) or straddle carriers (landside).

Inbound road transport has the most negligible impact on time delays, but noteworthy delays occur in the 96th percentiles onward, suggesting that when delays occur they are substantial, extending over many days. The study implies that the current inbound strategy of short haul–long haul warrants further investigation, as instances arise where cargo spends significant time in depots or warehouses, often influencing buffer stock levels and related storage costs.

Buffer stock scenarios exhibit a characteristic pattern, with elevated time event chain (TEC) profiles initially associated with diminished buffer stock, reflecting increased instances of lost sales due to stockouts. Subsequent TEC decline corresponds to increased buffer stock, with a subsequent reduction in lost sales ceasing, concurrent with expanding buffer stock. The cost of interest and storage costs rises with the buffer stock period, while the cost of lost sales decreases.

The cost of lost sales, heavily influenced by the ocean leg, requires a buffer stock of around 70 days to negate sales losses. Total logistics cost varies with buffer stock, showing an optimal value of around 34 days, approximately the average time of the ocean transport leg. Analysing the top 10 countries of origin and shipping lines reveals significant variations in TEC due to time delays. For instance, the choice of shipping lines, such as Cosco versus MSC for France, can result in

substantial differences in TEC values. Shipping lines also differ in their market coverage, with MSC connecting to all but one market, while Maersk services 12 (out of 15) and ONE serving 11 markets.

Buffer stock considerations highlight the need for effective matches between shipping lines and country of origin. Zero buffer stock implies efficient service, while negative values indicate irrelevant combinations. Shipping lines with long time delays and high levels of variability (for this study, MSC, in particular) require cargo owners to carry significant minimum buffer stock, ranging from 9.47 to 33.16 days for cargo originating from Germany and the Netherlands, respectively.

These findings provide valuable insights for freight forwarders seeking to optimise their logistics performance by making informed decisions about trade lane combinations and buffer stock strategies, based on country of origin and shipping line choices. Furthermore, the varying buffer stock strategies provide significant insights into the relationship between buffer stock and interest cost on inventory, inventory storage cost, cost of lost sales, and total time delay cost.

In essence, the underlying objective of logistics is simple: the faster goods move through the supply chain, the better. As WB has previously shown, a day's reduction in the transit time of goods is associated with an increase trade volume by at least one per cent and by as much as seven per cent for time-sensitive goods (Djankov *et al.*, 2010). Similar findings have been made in this chapter, as the results prove that further substantial improvements can be made through the use of data analytics in the physical and documentation flow of goods and information – which also results in significant cost reduction on the bottom line of cargo owners and logistics services providers alike.

CHAPTER 7: SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

7.1 Introduction

Efficient logistics is a critical factor in moving merchandise goods – whether locally, regionally, or internationally – as quickly, as cheaply, and as reliably as possible (Liu, 2009; Munim & Schramm, 2018; Lan *et al.*, 2017). This is true for all economic actors at all levels of analysis (Arvis *et al.*, 2018; Hausman *et al.*, 2013; and Müller *et al.*, 2012). Improving logistics performance has been widely studied in the past – from firm to national level, from one actor to the entire system (Quium, 2019). Despite the widespread interest in the subject, the available literature and evidence do not demonstrate empirical, quantitative, and bottom-up measurements of the performance of a logistics system in South Africa in terms of time, cost, and service reliability. The lack of empirical operational-level work on logistics performance is valid for the case of South Africa, as it is true globally.

Moreover, the research bridges a significant gap in the literature, including the lack of research to assist in understanding the operational performance of logistics systems at the national level across all actors. Furthermore, the gap extends to the allocation of performance in those systems between domestic and external factors. Both are essential to documenting and improving performance at whatever level the diagnostics determine.

This thesis has conceptually and empirically shown how, in an operational, logical, step-by-step process-driven manner, logistics performance for South African imports from the perspective of the primary orchestrator of international trade – the freight forwarder – can be improved. The object of this chapter is to summarise the content of the thesis and capture the essence of the research.

The structure of the chapter is as follows: Section 7.2 summarises the study according to the content presented in each respective chapter. Section 7.3 then provides the policy and practical recommendations based on the results from Chapters 5 and 6. Section 7.5 will then conclude the study with remarks, and Section 7.5 will suggest potential areas for future research.

7.2 A summary of the study

To provide the groundwork upon which logistics networks function in the extended supply chain, **Chapter 2** includes a literature review of the current international trading environment. The aim

of the chapter was to fast-track the history of trade and trade theory, to ultimately discuss the changing nature of global trade in recent times.

From Adam Smith's absolute advantage theory to Paul Krugman's new economic geography, the background and evolution of the most important trade theories to date were conferred to explain why countries trade in the first place. As discussed, the performance of logistics systems in facilitating global trade became extremely important, most notably when the effect of the standardisation of containers was realised with the commencement of the container era.

Moreover, in the chapter, the interconnectedness of the modern world is explained, with terms such as "globalisation" and "global value chain" being at the forefront of the international trading sphere. Modern trade mostly takes place in terms of intermediate goods, with specialisation becoming more and more important. In the present day, the ICT revolution is the main driving force behind the world's economy. Indeed, the opportunity to measure the performance of the logistics system has been created owing to the advancements of modern technology, especially in terms of the immense generation and flow of readily available data.

Chapter 2 was concluded with a focus on technology and the 4IR, along with the possibility of making more data-driven decisions in trade, transportation, and logistics. As with the previous industrial revolutions, the 4IR is expected to have an extremely positive impact on global trade, as technological innovations will continue to affect improvements in trade logistics and lower trade transaction costs, as was showcased in this thesis. Ultimately, technological innovations will continue to be investigated in order to make advancements in productivity and efficiency in the long term, as empirically demonstrated throughout the work presented in Chapters 5 and 6.

Chapter 3 included an in-depth investigation of all the relevant literature on global supply chains in general, and logistics systems in particular. Both concepts were viewed first from a global perspective, after which a South African perspective was provided. The chapter continued by investigating the role and evolution of ICT in the broader supply chain context, but also in the narrower logistics context – ultimately showing how the use of data analytics on supply chain and logistics can be implemented and leveraged to improve performance.

Worth reiterating is the fact that logistics is the vehicle of international trade, with the freight forwarder acting as the primary driver. Facilitating the constant flow of goods through global supply networks cannot happen without minimum friction in logistics networks. Indeed, we can understand this vehicle better by turning to definitions, noting that logistics is "*the planning, execution and control of the movement and placement of people and/or goods, and of the supporting activities related to such movement and placement, within a system organised to*

achieve specific objectives” (ELA, 2005:54). Improving the performance of logistics systems relates to the overall aggregate performance of the interconnected elements [processes] and sub-systems connected with each other in specific relations, as measured in terms of time, cost, and service reliability. This definition holds true whether at individual and/or local (actors), and collective and/or global levels (scales). Certainly, the literature confirmed these definitions to be valid.

However, the lack of research on logistics performance from a South African perspective was evident when the literature review was conducted. In fact, after a comprehensive literature review, not one study could be found that focuses purely on firm-level logistics performance from a practical, step-by-step, process-driven perspective.

After setting the scene concerning supply chains and logistics from a global perspective, at the end of Chapter 3 the study shifted specifically to logistics performance in South Africa. Therefore, before investigating how to improve the flow of goods to and from South Africa, the aim of **Chapter 4** was to provide an overview of trade, transport, and logistics in South Africa to first gain a better understanding of the trade context.

The chapter started off by providing a macroeconomic overview of the country’s economy, including emphasising which products South Africa trades most often and to which countries they come from and go to. Moreover, several trends and challenges were discussed, which could potentially influence trade and ultimately the logistics performance. South Africa – being a spatially challenged country – has a significantly high transport demand. The economic and trade hubs of the country (such as the economic hub of the Gauteng province and the mining locations extracting key mineral commodities) are situated far from the commercial ports, handling the vast majority of merchandise trade. Therefore, to satisfy this high demand, South Africa needs a multimodal approach to transport and logistics. As such, the respective transport modalities were discussed, including the transport infrastructure, the role players facilitating trade, and the main activities performed in both import, export, and transshipment cargoes.

Therefore, the focus of Chapter 4 went to the key performance measurements used in assessing logistics performance. These, of course, revolved around time, cost, and service reliability. These measurements were investigated from a micro and a macro perspective, and included all the academic literature presented on various levels of analysis (which could be collectively grouped under either firm or country-level) and across many variables.

Moreover, Chapter 4 provided a substantial amount of insight regarding the current set of activities that logistics service providers control in the end-to-end value chain and how the performance of

these activities are measured. Therefore, to aid the investigation of the use of data analytics towards improved logistics performance for South African imports, the aim of **Chapter 5** was to provide a descriptive and exploratory data analysis of firm-level data used to investigate logistics performance.

Three datasets were used to investigate the logistics performance from the perspective of the freight forwarder, describing the documentation, physical, and financial processes. The key was to investigate which process steps the freight forwarder controlled and where it could exert the most significant level of influence, and ultimately improve the performance thereof. These steps particularly pertained to the processes of creating the files, framing the entry, customs clearance, arranging inbound transportation, invoicing, and auditing. These process steps were particularly important to investigate the time variable of logistics performance.

Finally, **Chapter 6** provided an empirical analysis of the logistics performance for South African imports through the use of data analytics. Following Chapter 5, the analysis is presented in two parts: that of an ANOVA and t-statistics analysis and that of the development of a TEC model. The results identified several areas of potential further investigation into logistics performance, notably the choice of trade lane combinations and the need for efficient and correct customs clearance processes to avoid goods incurring customs and OGA infractions. Furthermore, the varying buffer stock strategies provided significant insights into the relationship between buffer stock and interest cost on inventory, inventory storage cost, cost of lost sales, and total time delay cost.

The ANOVA analysis showed the various combinations of factors and their influence on time delays, and indicated that several factors could have a significant impact on these delays, causing some categories to experience time delays that are statistically significantly different from the population time delays. These included (in order of significance based on the influence of the respective process segments) country of origin, shipping line, and port of loading. Other factors also showed substantial statistical significance, notably (in no specific order) EDICUSRES, Incoterm, OGA, tariff, and VOC. These were further investigated in the TEC model.

The results from the TEC model indicated that the ocean freight transport leg has by far the most significant impact on time delays, which highlights the importance of selecting the best-performing supplier-shipping trade lane combination. Shipping lines also differ in their market coverage, with Maersk and ONE serving all top 10 markets, while MSC connects to nine markets. However, performance varies significantly, with the total cost caused by time delays ranging from 4.2% to 24.5% of total cargo value.

Ultimately, concluding the empirical analysis, the results presented in Chapter 6 indicated that there is significant potential room for the improvement of logistics performance for South African imports from the perspective of the freight forwarder.

7.3 Recommendations from the findings of this study

The in-depth analysis that this research provided, identified factors that pose both opportunities and threats for the logistics systems of South African firms in the future. Since trade comprises such a large share of South Africa's GDP, the optimum performance of the system poses overwhelmingly more opportunities than threats. Within a geographical region such as South Africa, where competition is relatively low, it is paramount for logistics to facilitate trade. Although practical and policy recommendations were not the primary motivations of this study, several important recommendations can, however, be highlighted.

1. This research underscores the significance of implementing a comprehensive logistical process analysis in business operations, as demonstrated in the empirical investigation outlined in Chapter 6. Given the increasing accessibility of detailed, low-level data within an industry characterised by numerous data generators but limited technological adoption, it becomes imperative to leverage the opportunities presented in this research for the evaluation and potential improvement of logistics performance. Such a fundamental approach is poised to provide freight forwarders with an enhanced understanding of their processes, which could serve as a diagnostic tool and facilitate the identification of areas for sustained improvement. Moreover, this methodology holds promise for application across diverse business cases within the broader end-to-end logistics network, as and where these logistics service providers plug into the process outlined in this thesis.
2. As outlined in the methodology chapter (Chapter 5), the underlying operational flow of information at the freight forwarder is captured by three distinct sources of data, namely the documentary flow, the physical flow, and the financial data flows. However, as is the case for any operation making use of multiple data sources, these sources must communicate with each other and streamline operational performance. Therefore, an effort to integrate digital platforms used by the freight forwarder is crucial for enabling multiple platforms for several reasons, including (1) efficient data access, (2) improved decision-making, (3) enhanced business process integration, (4) real-time access to insights, and (5) scalability and efficiency. Augmenting the potential use of the previous suggestion in not only using the data generated but also a concerted effort to integrate various data sources will also significantly aid data analysis and reporting, which in turn will allow freight forwarders to gain insights, identify patterns, and make decisions based

on reliable and accurate data much faster. This is critical in the fast-changing landscape of international merchandise trade.

3. The freight forwarder ought to exercise direct supervision over the internal management of purchase orders or, at a minimum, possess comprehensive visibility into the process. This approach ensures strategic planning and effective execution of forwarding activities across the entire operational spectrum (upstream/downstream of activities). From the standpoint of decision-makers, typically the cargo owners, the primary goal is the minimisation of overall logistics costs. A lack of transparency regarding ordering patterns, particularly the reorder point, introduces a substantial disconnect between lead times, carrying costs, and potential stock-out scenarios. This reality was evidently presented in the variability of buffer stock periods presented in Figure 6-3. This discrepancy may lead to the inadvertent accumulation of excessive inventory and associated costs, especially for items categorised as "slow movers."
4. The freight forwarder is to have a deferment account with SARS Customs. Customs VAT and duties are payable at different times (keeping in mind that when you are liable for the VAT and duties and when they are due can differ). If it is a duty-paid entry and the agent/importer does not have an account (deferment) with SARS, it is payable before the client can receive a SARS release. Therefore, without a deferment account, goods can potentially be delayed for a significant period before being released. However, if it is a duty-paid entry and the agent/importer has an account (deferment) with SARS, then it is immediately put on the deferment, and the goods are released immediately by SARS, avoiding any time delays. The deferment is paid at the end of the month at a fixed time, depending on the arrangement between the agent/importer and SARS Customs.
5. The freight forwarder needs to consider categorising and issuing invoices according to activities as and when they happen so that they directly relate back to time. Currently, the data captured on invoices are consolidated and issued for activities across the board.
6. In addition to the recommendation above, it is advisable for the freight forwarder to expeditiously issue invoices for rendered services, given the existing significant disparity between the competence and issue dates. Likewise, in situations necessitating obligatory payments (e.g., settlement of cargo dues orders), freight forwarders should attempt to adhere to the prescribed standard operating procedures of relevant authorities at the latest opportunity possible. This adherence is essential not only to (1) circumvent penalties associated with belated payments, but also to (2) prevent untimely disbursements leading to cash-out-of-pocket scenarios. Notably, the TNPA allows a three-day window for settling cargo dues post-vessel departure. However, prevailing practices reveal that, on average, freight forwarders remit cargo dues approximately eight days prior to the vessel's arrival, resulting in an unutilised period of approximately eleven days.

7. The freight forwarder is advised to minimise, to the greatest extent feasible, the manual entry of data fields. The examination, organisation, and analysis of data revealed numerous errors, particularly in relation to the physical movement of goods, with a notable focus on the inbound transportation leg. As is customary, certain data fields, often mandated by legal requirements, are system-generated and exhibit minimal error occurrences. However, a considerable number of non-mandatory data fields, subject to manual input, are susceptible to inaccuracies. Therefore, it is recommended that freight forwarders institute rules-based, system-generated process flows to mitigate errors associated with data entry.
8. Lastly, the freight forwarder should be a lot more conservative concerning planned performance versus actual performance, which spills over into service reliability. Often, the proposed performance, according to SLAs, is somewhat unachievable and dependent on externalities outside of the control of the freight forwarder, including the performance of other parties (such as the shipping lines, customs, and others). For example, the planned delivery versus the actual cargo delivered differs on average by almost two days (1.94 days to be exact).

7.4 Contribution to the literature and concluding remarks

This study makes significant inroads into the complex research field of logistics performance, and can be used by various parties interested in LSCM, from national policymakers to multilateral agencies, economic actors, and logistics service providers. The novel research, which presented a detailed approach to a bottom-up, process-driven framework for logistics performance, makes a significant contribution to investigating logistics performance based on time, cost, and service reliability from the perspective of a freight forwarder.

Furthermore, the study serves as a diagnostic tool to identify specific areas where improvements can be made in the logistics process.

By starting with individual components and building up to the more extensive system, a bottom-up approach can ensure that all individual components are appropriately addressed and executed, leading to more flexibility and adaptability to changing requirements and feedback. This approach can be instrumental in managing complex logistics projects with many components, which are driven by many different role players but amalgamated and orchestrated by the freight forwarder. Additionally, a process-driven perspective can help to identify bottlenecks and inefficiencies in the logistics process, allowing for targeted improvements to be made, especially considering the various factors of uncertainty inherent in a complex international logistics system.

Worth reiterating is the fact that national logistics systems are the providers of infrastructures and spatial connectivity, whereas business logistics systems are the users. As a result, national logistics systems focus on developing and providing infrastructures, whereas business logistics systems focus on optimising supply chain decisions based on the infrastructures provided by national logistics systems. Although the research presented focussed on the logistics performance from the perspective of the freight forwarder – the user of the logistics network – the performance of the system can serve as a valuable diagnostic tool as to where the system performs poorly, along with the potential influence of improvements that the providers of infrastructures and spatial connectivity – the state – can exert to improve the overall flow of merchandise trade to contribute to socio-economic growth and development.

At the outset of this study, the following research questions were identified:

1. What is the role of ICT in LSCM globally, and what opportunities have the advancement of ICT technologies created in improving logistics performance?
2. What is the process flow of the logistics system for South African imports from the perspective of a freight forwarder?
3. What role does data analytics play in the logistics system for South African imports?
4. What are the most important performance criteria within the logistics system for South African imports, and which of the factors within the identified performance criteria can freight forwarders control to improve logistics performance?
5. How can the identified performance criteria be used to act as trigger functions in designing an improved logistics system for South African imports?

These five questions were answered by means of the research methods summarised throughout this chapter. In summary, the answers to these five questions are as follows:

Research question 1: What is the role of ICT in LSCM globally, and what opportunities have the advancement of ICT technologies created in improving logistics performance?

As comprehensively discussed in the literature chapters, the ICT revolution has significantly impacted data management, leading to a rapid expansion of data within global supply chains. This expansion has created opportunities for measuring and managing various actions and handover points throughout the supply chain, facilitating the utilisation of data science, predictive analytics, and big data in supply chain management. Scholars highlight ICT's critical role in integrating supply chains, ensuring real-time information flow, reducing uncertainty, and enhancing overall supply chain performance. Governments globally are recognising the importance of real-time information and knowledge in decision-making, prompting exploration into innovative ICT mechanisms for effective information delivery.

Furthermore, as comprehensively reviewed, a specific strand of literature has investigated the implications of big data on supply chain management, exploring its applications and potential benefits (such as Waller & Fawcett, 2013; Hazen *et al.*, 2014; Schoenherr, 2015; and Gunasekaran *et al.*, 2017). Another strand has focused on ICT's role in logistics and freight transportation, examining its impact on efficiency (Kache & Seuring, 2017, for example) and agility (Gunasekaran *et al.*, 2016, for example) within supply chains. The growing significance of ICT in supply chains underscores the necessity for optimal management, presenting substantial opportunities for disseminating information, reducing production and transaction costs, enhancing efficiencies, expanding market access, and ultimately increasing income.

In response to the challenges posed by data-rich but information-poor supply chains, this research endeavoured to bridge the information divide, aiming to improve the efficiency, cost-effectiveness, and reliability of moving goods within the global supply chain. Termed the "age of information," the 21st century witnesses a substantial influx of readily available data, driving intelligence that supply chain management can effectively leverage. The modern design of the supply chain necessitates the incorporation of all ICT facets and the analysis of various performances and models through multiple metrics, integrating data from diverse sources such as RFID, EDI, shipping lines, customer surveys, monetary transactions, and delivery notices.

This research further explored the opportunities arising from the emergence of data in supply chain management, advocating for the integration of data science, predictive analytics, and big data. The study proposes specific steps for researchers to combine supply chain management and data analytics, highlighting a myriad of research opportunities at the intersection of these domains. Overall, the advancement of ICT technologies presents multifaceted opportunities for enhancing logistics performance in global logistics networks, as was done throughout this thesis.

Research question 2: What is the process flow of the logistics system for South African imports from the perspective of a freight forwarder?

The data used throughout this thesis outlined the complexity, multi-faceted nature, and significantly fragmented data that flows across many different role players, and is presented on several levels in the end-to-end logistics network. The transaction-level flows between July 2017 and August 2023 (six years) – including (1) the documentary process flows, (2) the physical process flows, and (3) financial data showcasing the monetary flows – emphasised the need to simplify and clearly outline the process flow of the logistics system for South African imports from the perspective of the freight forwarder.

Certainly, these three datasets showed that there are many different process steps in the end-to-end logistics network of varying degrees of relevance. After several in-depth iterative processes, the thesis showed that there are 44 key steps in the process flow of the logistics system from the perspective of a freight forwarder. Furthermore, of these 44 steps, the freight forwarder is directly involved with the orchestration of 39 of these steps.

The process flow can be further divided into important event categories, notably purchase order management (and cartage from EXW to FOB – activities which the importer or freight forwarder typically does not have sight of), ocean freight (port to port activities), customs, customs/OGA stops, port/terminal activities, inbound transportation, and invoicing and auditing. A detailed – yet refined and understandable – process flow was documented in Figure 5-1, which showcased the typical import process flow per activity actioned by the respective role players. A comprehensive, step-by-step process flow – showing all activities, all documentation, and all requirements – including the risk involved with each step, is presented in the Annexure in Figure 9-12.

Research question 3: What role does data analytics play in the logistics system for South African imports?

The literature presented in Sections 3.4 and 4.4 highlighted and emphasised the immense opportunity that the advancement of technology broadly – and data analytics in particular – has presented to LSCM. The literature further highlighted the significance of big data analytics in enhancing business performance, emphasising the pivotal role of ICT in managing logistics functions, and positively impacting organisational performance. Indeed, in the digital era, ICT actively and continuously provides sustained competitive advantages in logistics. Moreover, the literature underscores that supply chain management practices, particularly logistics integration supported by ICT, contribute to overall efficiency in evolving logistics supply chain networks, which could ultimately improve performance based on time, cost, and service reliability.

However, as the literature also showed, a significant limitation still exists, as no research has demonstrated empirical, quantitative, and bottom-up measurements of the performance of a logistic system in South Africa (nor any other country) measured in terms of time, cost, and service reliability. The lack of empirical operational-level work on logistics performance is valid for the case of South Africa, as it is true globally. Where logistics systems have been studied, the literature has focused on vertical industries, such as the automotive, IT, and military (Dörnhöfer *et al.*, 2016; Caplice & Sheffi, 1995; and Barad & Sapir, 2003).

Ultimately, the research has answered this question by showing that data analytics does indeed play a role – and not only does it play a role, but we can also empirically test it, owing to the immense opportunity that advancements in data analytics have made in the field of LSCM.

Research question 4: What are the most important performance criteria within the logistics system for South African imports, and which of the factors within the identified performance criteria can freight forwarders control to improve logistics performance?

As with previous research on logistics performance, this thesis showed that the most important performance criteria are (1) the time taken to move cargo from origin to destination and (2) the cost incurred to move cargo from origin to destination. Furthermore, a third performance criterion can be added to measure the service reliability of the freight forwarder, i.e., the agreed performance (based on time) as per the service level agreements and the achieved performance as per the empirical results.

Moreover, logistics performance could be measured by using operational data from the point of loading at the origin to the final delivery at the destination – and each data point in between. These performance criteria are critical, as they feed into the following research question: not only is it essential to define the performance criteria, but also critical in order to ascertain how these criteria can be influenced by the freight forwarder so that the performance can be improved.

The results and findings discussed in Chapters 5 and 6 have presented an in-depth analysis of which identified performance criteria freight forwarders can control to improve logistics performance based on time, cost, and service reliability. Indeed, the results based on time showed that there is significant variability in the time delays experienced along each step of the process. However, as argued and discussed, some of these time delays are inevitable and cannot be influenced by the freight forwarder to any degree whatsoever.

The most important factors influencing performance within the logistics system for South African imports, based on the ANOVA analysis and TEC model, include country of origin, shipping line, port of loading, EDICUSRES, Incoterm, OGA, tariff, VOC, and the ocean freight transport leg. Freight forwarders can significantly control and improve logistics performance by strategically selecting optimal supplier-shipping trade lane combinations, considering factors like buffer stock policy, choice of shipping lines, and country of origin. Noteworthy areas for improvement include addressing delays in inbound road transport and investigating the current short haul–long haul inbound strategy.

These areas of performance – which include purchase order management delays at origin, time spent en route once goods have been shipped on board, and customs stops when no infraction

occurred, should be accepted and should not be investigated in much detail. However, the identified areas of performance – which include the selection of suppliers, shipping lines and other logistics service providers, the customs clearance process, and the arrangement of various process-driven functions such as inbound transportation, storage and warehousing – should continue to be investigated in detail, since these areas present significant room for improvement, as demonstrated throughout Chapters 5 and 6.

Furthermore, as the TEC showed, a significant level of time variability exists in the sample of the extended logistics network present in this research. Since several combinations of factors are chosen by the freight forwarder, the system's performance can be optimised by choosing the best combinations of the presented factors. Furthermore, as showcased, a significant level of uncertainty will inherently be present in moving goods. However, there remain many opportunities at various process steps to minimise the level of uncertainty.

Research question 5: How can the identified performance criteria be used to act as trigger functions in designing an improved logistics system for South African imports?

In complex systems such as a logistic system, performance criteria can be used as trigger functions to design an improved system by moving from a descriptive to a predictive model. The trigger functions identified include the various process steps – both happening in parallel and in series – investigated throughout this thesis.

In summary, the identified segments particularly relate to the documentary and legal requirements of each segment of the process flow, especially the successful customs clearance process and the interactions between the freight forwarder and other logistics services providers, such as the shipping lines, the terminal, and the inbound transportation.

As demonstrated, by analysing the performance data, trigger functions can be identified that can be used to predict when certain actions need to be taken to improve the system – especially those within the control of the freight forwarder in orchestrating international cargo movement.

In conclusion, this research shows that there is significant potential room for the improvement of logistics performance for South African imports from the perspective of the freight forwarder.

7.5 Suggestions for future research

The following three suggestions for future research on the subject (and related subjects) through the use of data analytics and other forms of ICT are made.

Firstly, to use the framework and approach presented in this thesis to investigate logistics performance in several other industries and countries. Although logistics performance – as presented in this thesis – involves the *overall, aggregate performance of the interconnected elements [processes] and sub-systems connected with each other in specific relations*, the variability and nuances of different industries in different countries will invariably be diverse. Nevertheless, the framework outlined in this thesis can very easily be replicated.

Secondly, to use the framework and approach presented in this thesis to extend the logistics system to incorporate the entire supply chain system. For example, including the sourcing and processing of goods from whichever level of processing or manufacturing, and extending the various logistics processes (including sourcing and processing – up until final distribution) will allow the research to determine the performance of the entire supply chain system. The proposed extended system can incorporate both the time performance measurement of the upstream and downstream activities of the supply chain, as well as the cost performance measurement by extending and refining the TEC model presented. As such, the TEC model could provide valuable insights for decision-makers to optimise processes, enhance efficiency, and ultimately drive competitive advantage in the dynamic landscape of international trade and logistics. By integrating the TEC's comprehensive cost assessment, companies can identify key cost drivers, make informed decisions on logistics strategies, compare scenarios, and track performance over time, facilitating continuous improvement and informed decision-making.

Thirdly, to use the framework and approach presented in this thesis to perform a detailed analysis of the factors (such as choice of supplier, choice of service provider, the customs clearance process, and others) which indicated the most significant performance variability, and therefore the most significant potential freight forwarder influence which can be exerted on these factors to improve performance.

Since a plethora of different factor combinations are worth studying, there is no end to the potential possibilities of investigating the use of data analytics to improve logistics performance from whichever role players' perspective at whichever level of analysis.

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ACSA see Airports Company South Africa.

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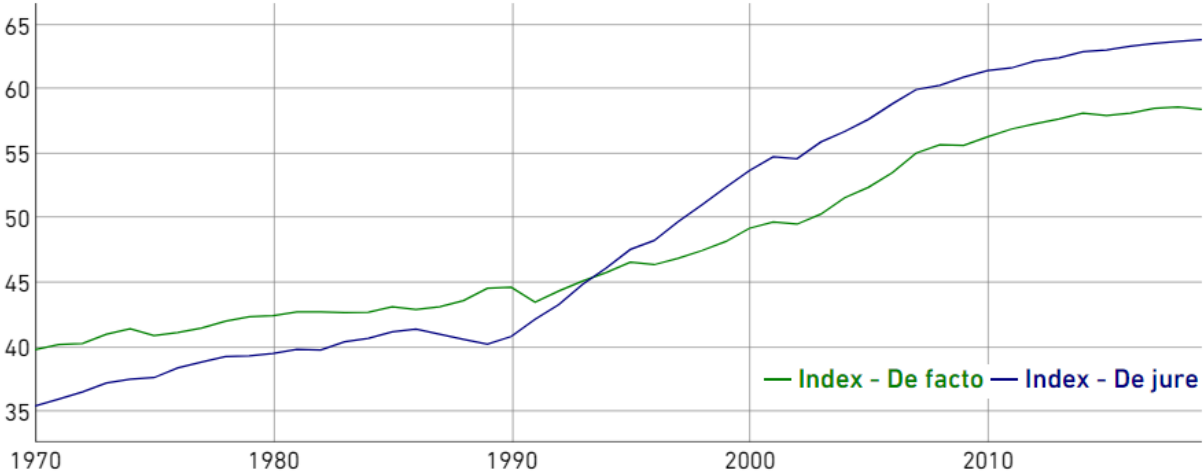
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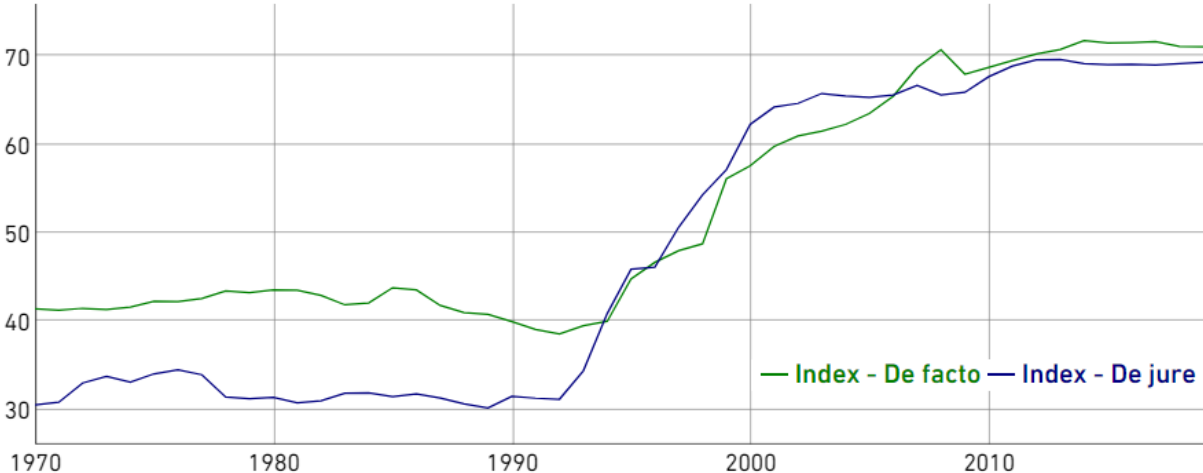
ANNEXURE: ADDITIONAL FIGURES AND TABLES

Figure 9-1: KOF globalisation index⁶⁸ (de facto & de jure), 1970-2019



Source: Gygli et al., 2019.

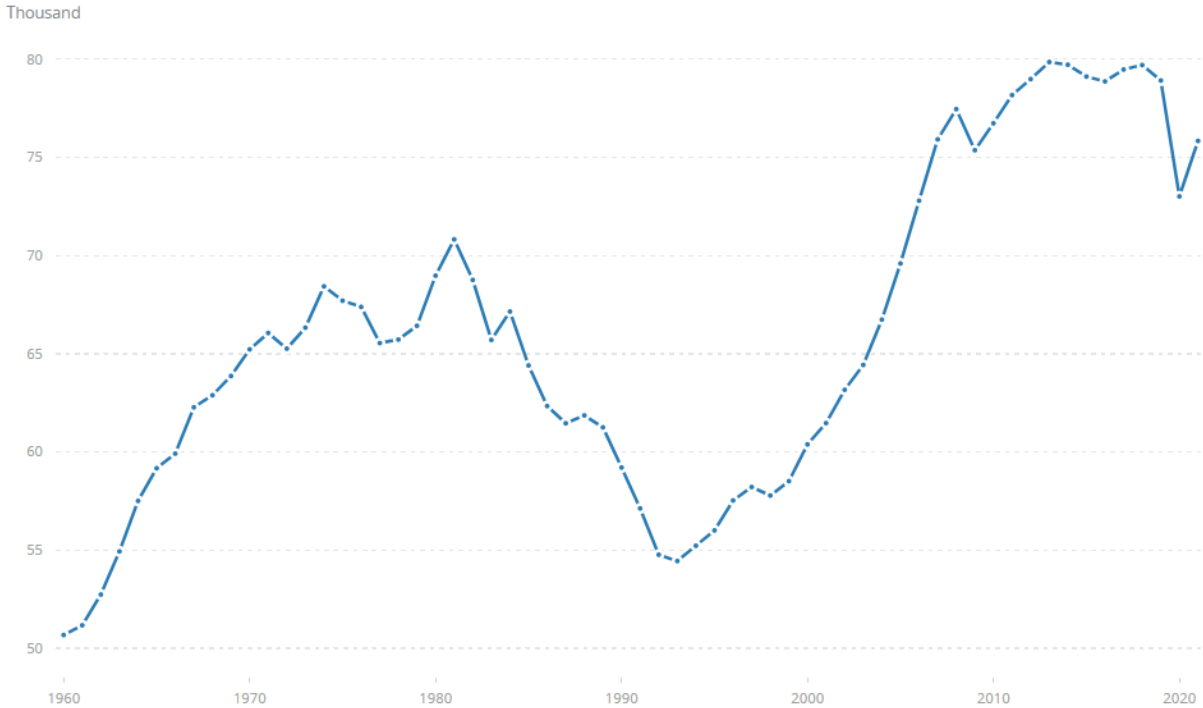
Figure 9-2: KOF globalisation index – South Africa (de facto & de jure), 1970-2019



Source: Gygli et al., 2019.

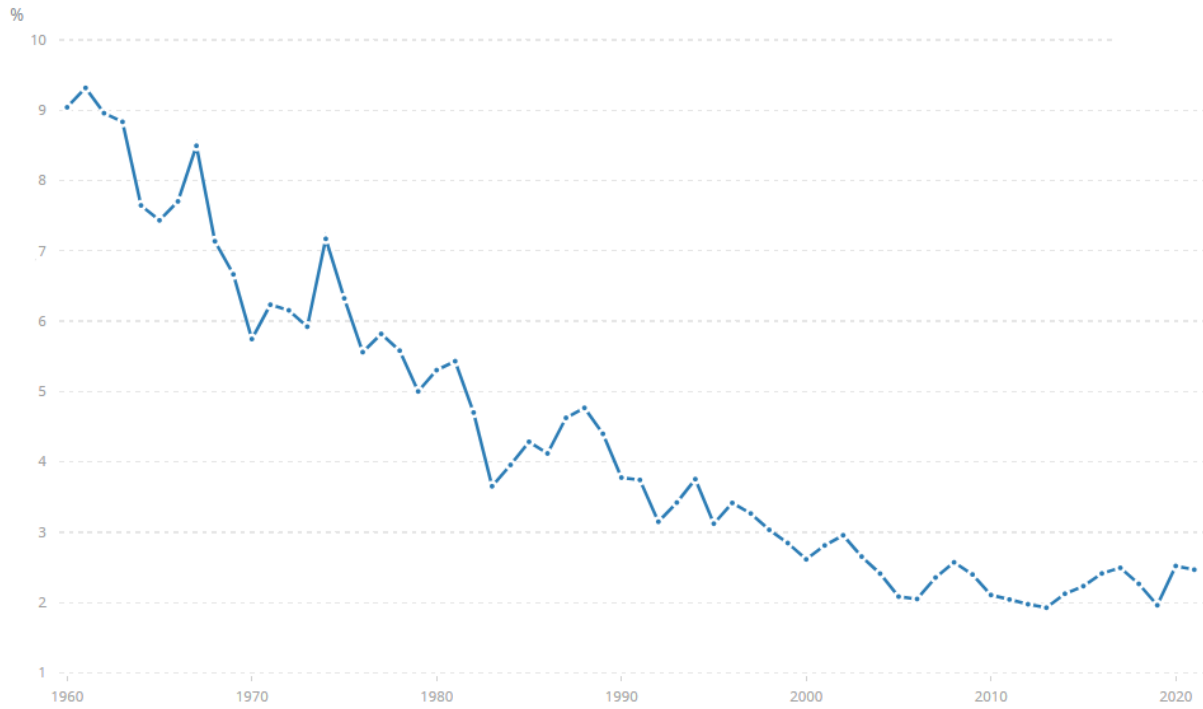
⁶⁸ The KOF Globalisation Index, a composite index measuring globalisation for every country in the world along the economic, social, and political dimension. The revised version of the KOF Globalisation Index distinguishes between de facto and de jure globalisation. While de facto globalisation measures actual international flows and activities, de jure globalisation measures policies and conditions that, in principle, enable, facilitate and foster flows and activities. (Gygli et al., 2019)

Figure 9-3: GDP per capita (constant LCU) – South Africa



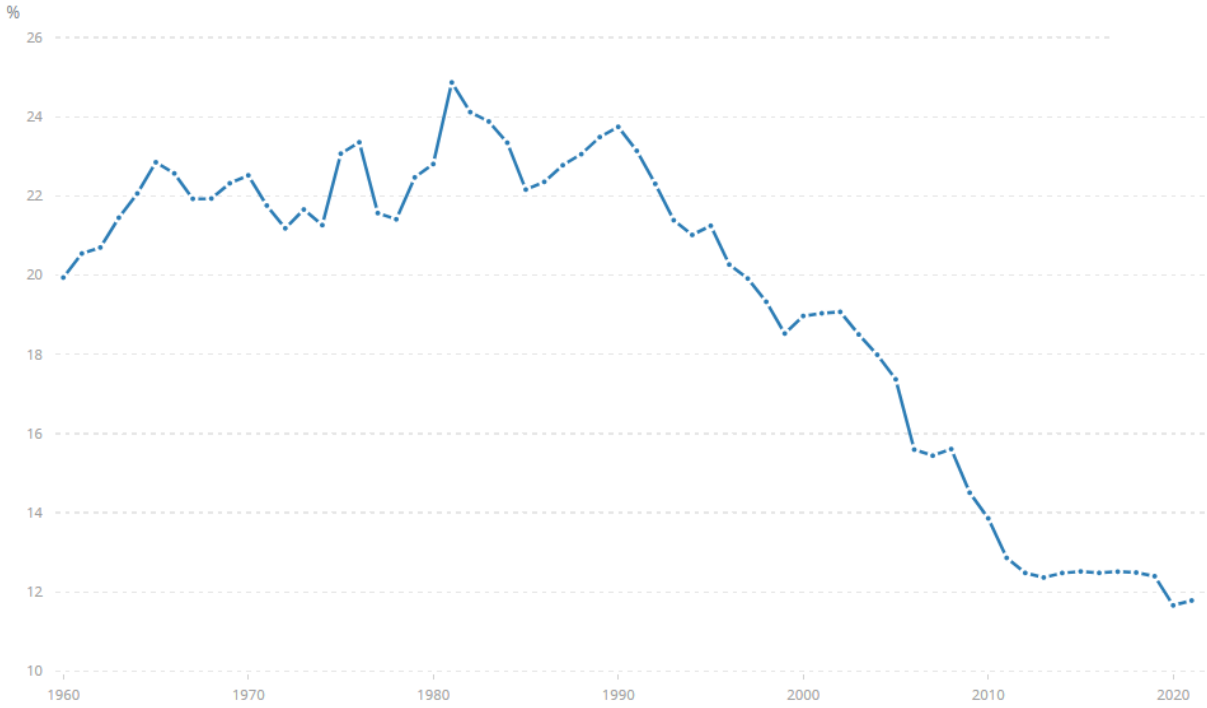
Source: WB, 2023c.

Figure 9-4: Agriculture, forestry, and fishing, value added (% of GDP) – South Africa



Source: WB, 2023c.

Figure 9-5: Manufacturing, value added (% of GDP) – South Africa



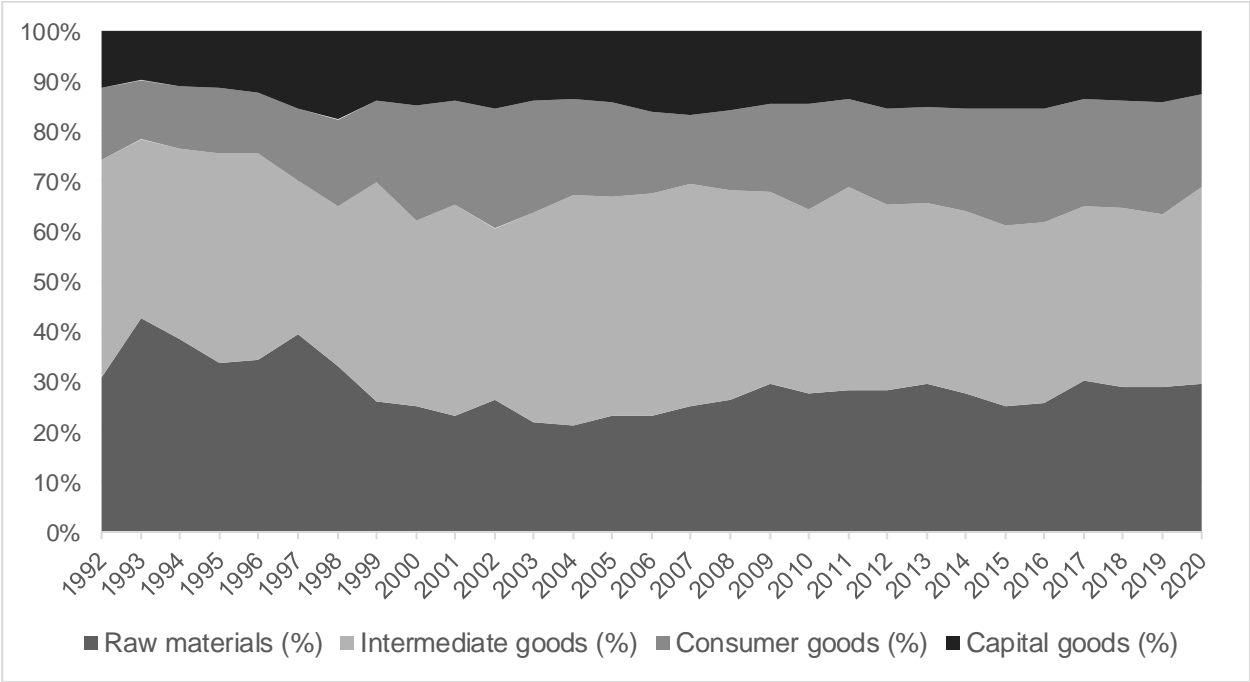
Source: WB, 2023c.

Figure 9-6: South African exports of miscellaneous manufactured goods (ZAR millions)



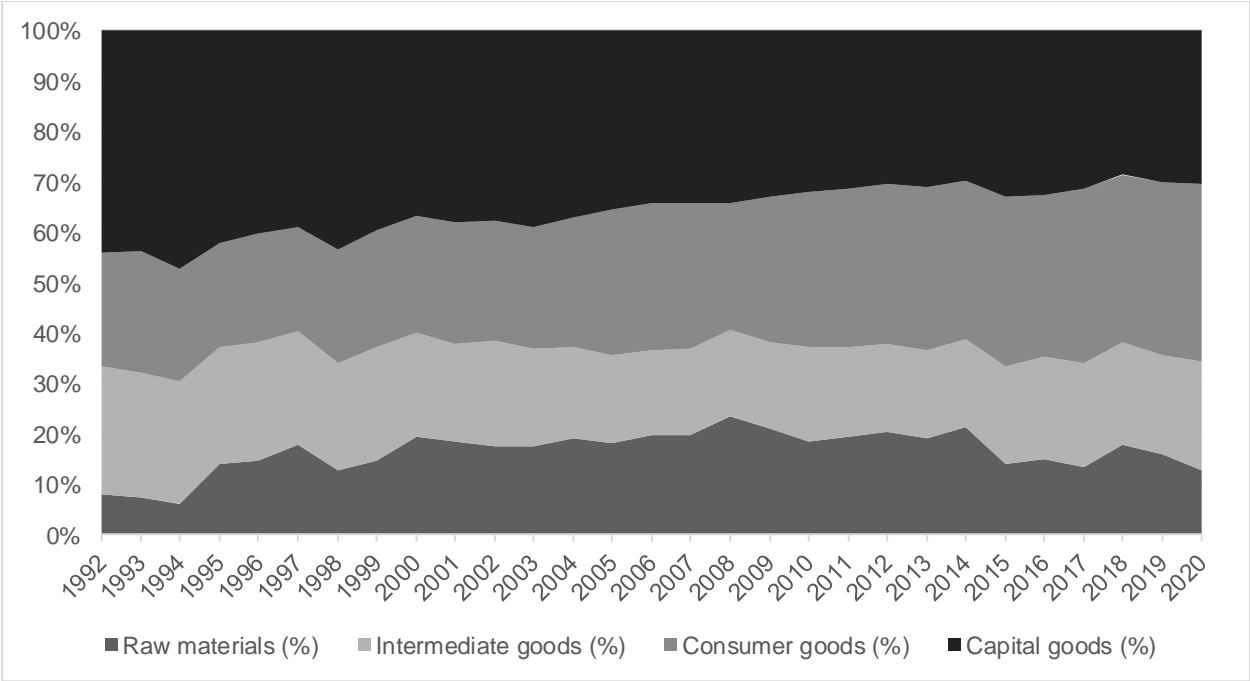
Source: SARS data via tradingeconomics.com, 2023.

Figure 9-7: South Africa: Export profile – share per product category



Source: Calculated and normalised from WITS, extracted from the WB development indicators, 2023c.

Figure 9-8: South Africa: Import profile – share per product category



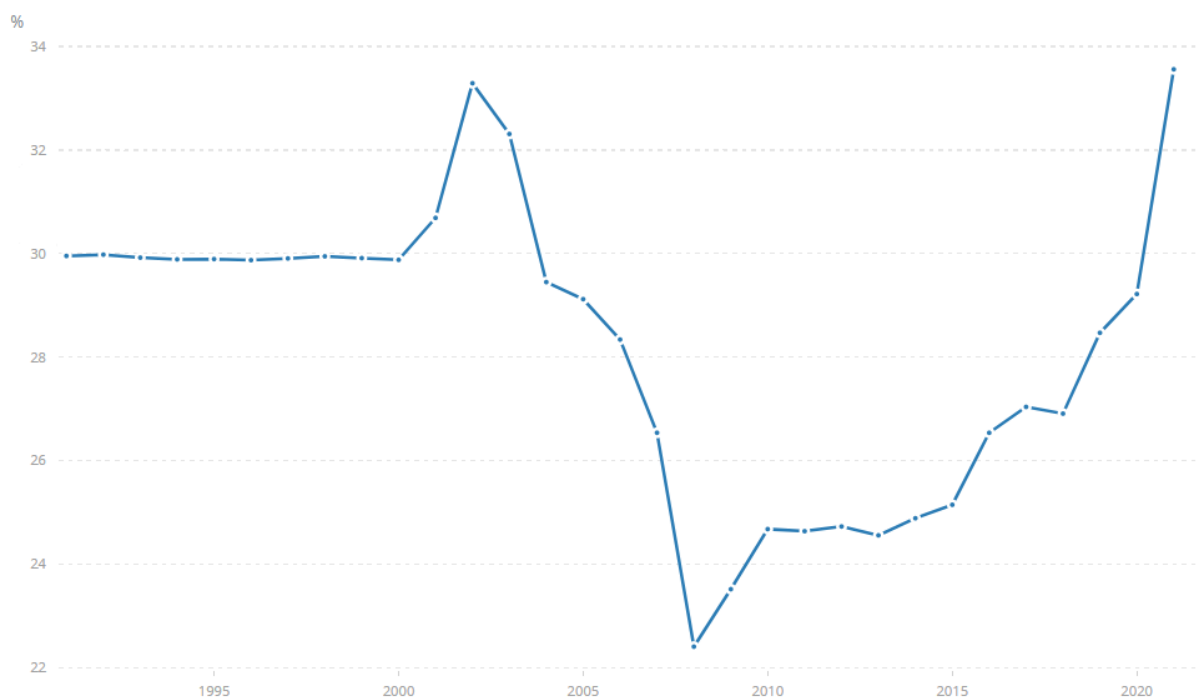
Source: Calculated and normalised from WITS, extracted from the WB development indicators, 2023c.

Table 9-1: Correlation analysis

	2018	2016	2014	Average:
LPI x WEF	81.98%	25.36%	36.08%	48%
LPI x HDI	58.64%	54.36%	62.15%	58%

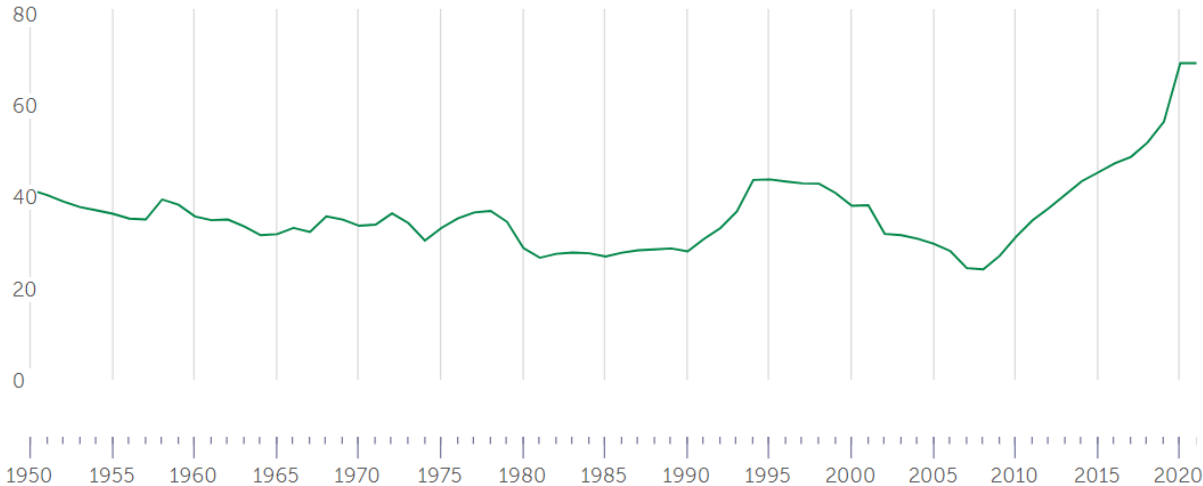
Source: Author's calculations from normalised WEF, WB LPI, and WEF GCI data (Eunomix).

Figure 9-9: Unemployment, total (% of total labour force) (modelled ILO estimate) – South Africa



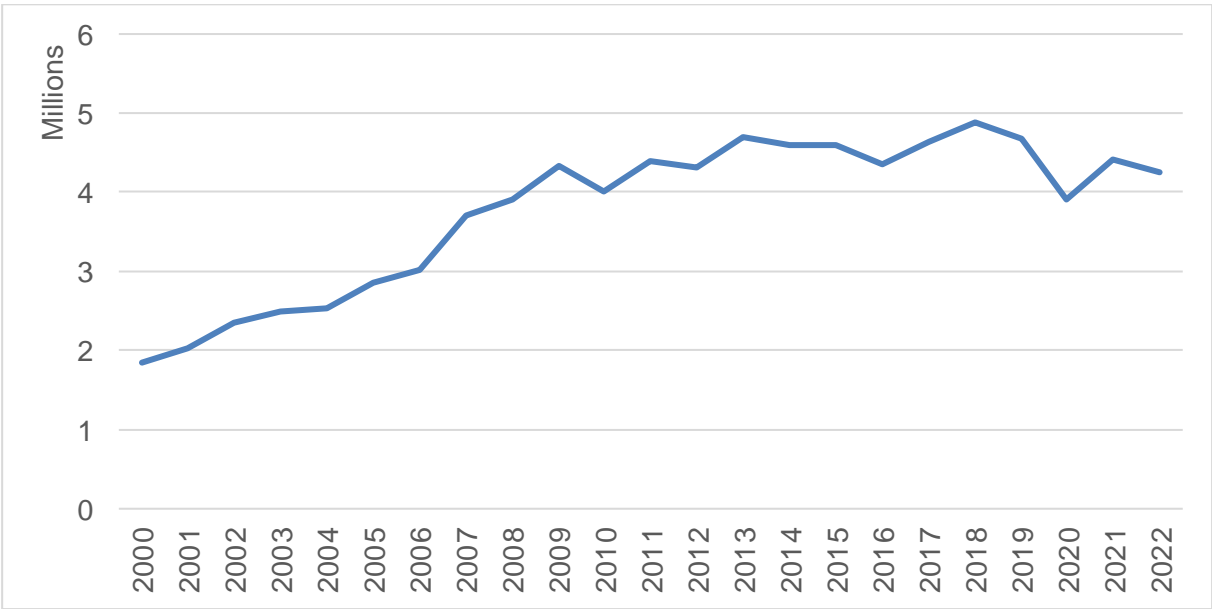
Source: WB, 2023c.

Figure 9-10: Central Government debt (% of GDP) – South Africa



Source: IMF, 2023.

Figure 9-11: Total containers handled at South African ports (TEU millions, 2000-2022)



Source: Author’s calculations from TNPA, 2023.

Table 9-2: Process analysis (measured in days)

Segment	From	To	Count (n)	Average	Std Dev	Level of FF Influence
Documentary flow						
Date created	6. Invoice Date 1	11. Date Created	42 910	16.038	13.034	High
Entry framed	11. Date Created	13. Date Framed	42 910	21.657	49.456	High
Customs clearance	13. Date Framed	22. EDI CUSRES	42 910	2.345	9.273	High
Entry accepted	17. EDI Sent	22. EDI CUSRES	42 909	0.133	0.818	High

SARS infraction	17. EDI Sent	23. SARS Case Closed	3 026	1.673	5.390	High
Arrange inbound	24. Final B/E	36. Delivery expected	39 580	12.169	51.783	High
Date closed	36. Delivery expected	43. Date closed	39 403	6.542	31.125	High
Date created	6. Invoice Date 1	11. Date Created	42 910	16.038	13.034	High
File created	10. Documents received	11. Date Created	21 818	4.623	4.456	High
Created to framed	11. Date Created	13. Date Framed	42 910	21.657	49.456	High
Docs to framed	10. Documents received	13. Date Framed	23 040	28.952	58.106	High
Framed to system check	13. Date Framed	14. Assessment	32 280	1.857	2.124	High
Ready for QA	14. Assessment	15. Ready for QA	15 363	27.070	83.010	High
QA	15. Ready for QA	16. QA	42 908	0.776	1.289	High
Customs entry lodged	16. QA	17. EDI Sent	42 906	1.194	11.412	High
Framed to customs	13. Date Framed	17. EDI Sent	42 909	2.212	9.182	High
SARS received	17. EDI Sent	18. EDI Contrl	25 180	0.005	0.087	High
Customs response	18. EDI Contrl	19. EDI CUSRES1	10 851	0.168	0.919	Medium
Cleared	19. EDI CUSRES1	22. EDI CUSRES	3 522	3.331	19.897	Medium
Stop	20. Stopped	21. Embargo Released	6	2.696	0.471	Medium
Stop completed	20. Stopped	23. SARS Case Closed	0	N/A	N/A	Medium
Release after SARS stop	23. SARS Case Closed	24. Final B/E	3 026	-14.377	33.309	Medium
Customs release to OGA	24. Final B/E	25. OGA Start	188	1.277	5.758	Medium
OGA stop	25. OGA Start	26. OGA Stop	179	8.547	3.877	Low
Port Health	27. Port Health	31. Discharged	38	1 583.500	0.000	Low
Cargo Dues paid	29. CDO	31. Discharged	15 525	190.314	415.43 9	Medium
Discharge to planned	31. Discharged	37. Planned Delivery	12 322	4.851	46.600	High
Inbound reliability	36. Delivery expected	39. Cargo Delivered	39 545	3.371	51.372	High
Delivered to modified	39. Cargo Delivered	41. Last Modified	42 708	-6.111	51.478	Medium
FF invoice	41. Last Modified	42. Invoice Date 2	42 674	5.171	56.117	High
Closed	42. Invoice Date 2	43. First Date Closed	42 604	7.347	30.398	High
Audit cycle	43. First Date Closed	44. Date Closed	42 708	85.417	185.74 7	High
Physical flow						
Ocean Freight	9. SOB	30. ATA	18 460	35.973	25.917	Low
Waterside	30. ATA	31. Discharge	15 543	2.445	2.410	Medium
Terminal evacuation	31. Discharge	32. Left Port	8 392	2.775	2.558	Medium
Short Haul	32. Left Port	34. Arrive at Depot	69	0.820	0.512	Medium
Time in Depot	34. Arrive at Depot	35. Left Depot	9 587	3.363	3.308	Medium
Long Haul	35. Left Depot	38. Arrive at Warehouse	12 703	1.139	2.844	Medium
Last Mile	38. Arrive at Warehouse	39. Cargo Delivered	18 119	5.839	39.849	Medium
MT Turn-In	39. Cargo Delivered	40. MT Turn-In	8 377	5.802	21.396	Medium
Origin to delivery	9. SOB	39. Cargo Delivered	42 707	33.680	15.266	Medium
Time in port	30. ATA	32. Left Port	7 862	4.533	2.964	Medium
Short - to long haul	34. Arrive at Depot	38. Arrive at Warehouse	10 758	4.062	2.572	Medium
Origin to WH	9. SOB	38. Arrive at Warehouse	18 129	33.680	41.819	Medium

Port to WH	32. Left Port	38. Arrive at Warehouse	16 529	3.064	3.325	Medium
Port to delivery	32. Left Port	39. Cargo Delivered	18 083	4.140	5.620	Medium
Berth to WH	30. ATA	38. Arrive at Warehouse	15 860	6.083	3.101	Medium
File created to WH	11. Date Created	38. Arrive at Warehouse	17 907	29.743	12.349	Medium
Customs to WH	17. EDI Sent	38. Arrive at Warehouse	16 495	12.898	6.520	Medium
Customs to file closed	17. EDI Sent	44. Date Closed	42 707	96.394	181.286	Medium
Customs to system check	17. EDI Sent	14. Assessment	42 910	0.007	0.054	Medium
Financial flow						
Invoice	6. Invoice	29. CDO	38 502	31.302	12.070	High
CDO paid	29. CDO	42. Invoice Date 2	38 391	11.347	20.319	High
Invoices 1 to 2	6. Invoice	42. Invoice Date 2	42 640	43.738	24.144	High
Closed	42. Invoice Date 2	44. Date Closed	42 604	92.721	189.110	High
	Competence Date	Issue Date	46 915	10.983	509.028	High
	Competence Date	Due Date	46 915	23.164	509.048	High
	Issue Date	Due Date	46 915	12.181	3.418	High

Source: Author's own compilation.

Table 9-3: Port of loading: Comprehensive statistical summary

Port of loading	Size	Average	Variance	t-stat	Min	Max
Laem Chabang	8 376	36.37	65.24	-45.72	22	84
Charleston	8 278	40.58	583.21	0.66	24	398
Genova	4 475	45.86	78.86	41.06	23	93
Algeciras	3 653	28.81	38.51	-112.93	17	79
Le Havre	3 373	39.59	92.33	-4.97	15	84
Savannah	1 904	52.62	126.19	47.44	28	76
Gdynia	1 705	54.89	148.11	49.13	32	128
Bilbao	1 582	41.83	58.60	7.40	23	78
Gdansk	1 345	47.95	46.77	40.44	33	107
La Spezia	1 312	37.23	108.71	-11.03	26	68
Rotterdam	970	33.77	50.21	-29.18	21	61
Bremerhaven	845	41.22	99.98	2.36	25	81
Ennore	701	37.51	4.86	-34.81	31	51
Antwerpen	683	38.40	89.81	-5.55	16	76
Constanta	524	67.63	254.78	39.04	39	92
Fos Sur Mer	504	37.14	23.58	-15.10	1	63
Sines	478	26.20	12.05	-89.50	20	45
Null	308	42.01	22.31	5.96	25	50
Chennai (ex-Madras)	281	26.33	25.69	-46.54	20	31
Koper	163	61.12	150.99	21.52	41	100
Itagui	155	37.02	119.49	-3.86	19	77
London Gateway Port	135	41.38	21.19	2.45	33	49
Vado Ligure	127	38.80	76.47	-2.08	28	61
Olszyna	125	48.00	0.00		48	48

Valencia	112	39.40	80.03	-1.19	24	75
Rio de Janeiro	96	31.68	174.71	-6.47	14	55
Barcelona	88	36.09	86.70	-4.35	28	53
Antwerp	53	30.40	1.55	-58.52	30	35
Kattupalli Port	49	58.00	0.00		58	58
Colombo	40	52.45	6 580.25	0.94	13	394
Hamburg	35	34.46	8.14	-12.34	28	42
Bangkok	27	40.26	7.12	-0.29	31	41
Olsztyn	26	41.27	14.60	1.15	33	48
Grangemouth	22	43.00	59.90	1.57	36	73
Charles City	21	34.14	6.43	-11.32	32	37
Dalian	19	39.95	8.94	-0.67	33	46
Sepetiba	10	32.40	32.71	-4.43	25	41
Charlestown	9	35.00	0.00		35	35
Jebel Ali	9	109.00	0.00		109	109
Savanna	9	53.00	0.00		53	53
Abu Dhabi	8	63.00	0.00		63	63
Genoa	8	33.00	0.00		33	33
Torino	8	61.00	0.00		61	61
Greer	7	30.43	0.62	-33.56	29	31
Greer-Greenville APT	6	32.00	2.40	-13.30	30	33
Jacksonville	5	37.20	14.70	-1.87	33	40
La Spezia off-line PT	5	41.20	51.20	0.25	38	54
Antwerp Churchill Terminal	4	36.00	0.00		36	36
Rio de Janeiro-Santos Dumont APT	4	17.00	0.00		17	17
Santos	4	34.00	34.00	-2.20	26	40
Blavozy	3	42.67	1.33	3.39	42	44
Belfast	2	45.50	40.50	1.13	41	50
Budapest	2	48.00	162.00	0.84	39	57
Constanzia	2	78.00	0.00		78	78
Marseille	2	45.00	32.00	1.15	41	49
Singapore	2	49.00	0.00		49	49
Aranda de Duero	1	25.00	0.00		25	25
Columbus	1	59.00	0.00		59	59
Dundee	1	44.00	0.00		44	44
Durban	1	43.00	0.00		43	43
Grangemouth	1	37.00	0.00		37	37
London	1	46.00	0.00		46	46
Shanghai	1	37.00	0.00		37	37
Warszawa	1	46.00	0.00		46	46

Source: Author's own compilation.

Table 9-4: Comprehensive ANOVA results (p-statistic, F-values)

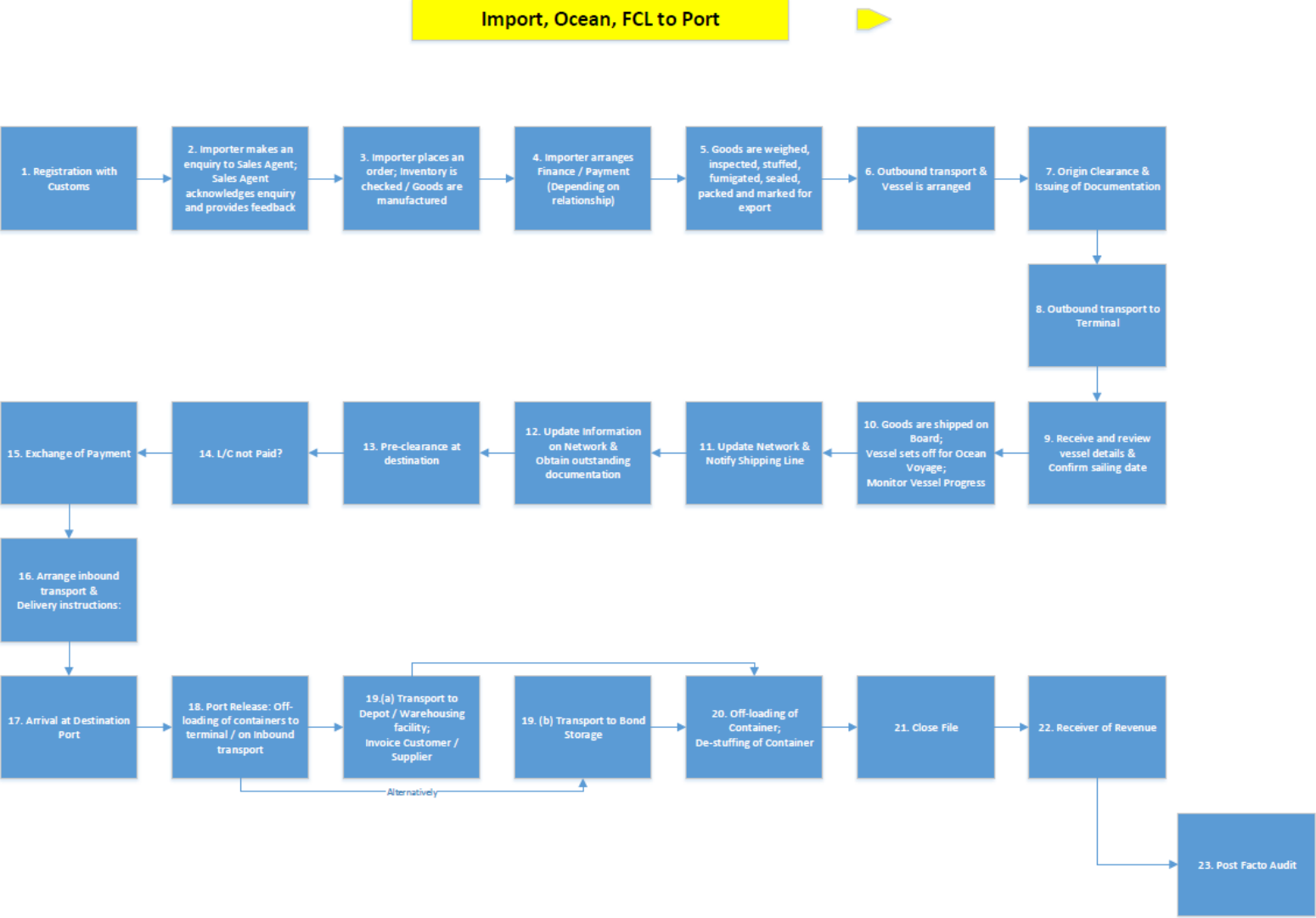
T-Stats																					Average T-Stats
VOC																					
N	-7.77	0.10	3.23	0.55	0.31	0.03	-0.95	4.67	0.35	0.39	1.94	1.66	5.60	4.71	10.45	3.48	-32.76	3.18	-25.12	1.67	
Y	7.35	-0.37	-11.63	-1.58	-1.10	-0.07		-27.49	-2.07	-2.14	-9.94	-6.82	-15.79	-13.27	-44.11	-9.53	16.25		4.60	-6.32	
OGASTOPENTITYCODE																					
1	0.55	9.86	4.04	0.49	5.59	3.47		-2.32	-5.37	-1.57	-0.70	-13.30	9.20	7.62	4.30	1.72	2.48	3.79	-1.94	4.47	
2	13.27															1.74				4.79	
NULL	-0.40	-0.10	-0.08	-0.02	-0.26	-0.12	0.00	0.03	0.01	0.03	0.01	0.02	-0.13	-0.28	-0.09	-0.18	0.04	-0.29	3.56	-0.16	
INCOTERMCODE																					
CFR	1.96	9.06	-1.78	-16.49	7.82	1.96		6.00		2.24	0.11	-38.27	3.97	-4.18	3.56	-66.29				-5.24	
CIF	-3.20	-2.98	-5.79	-3.71	-4.33	-4.46		1.60		0.51	0.96	-1.55	1.03	-8.34	-2.11	-7.63				-4.35	
CIP	-36.75	-0.11	-83.02	4.21	-12.06	-5.97	-7.31	-36.07	-33.15	-8.58	-3.66	-125.36	-14.18	-6.40	-8.40	-293.29	6.84	-0.46	0.06	-53.89	
EXW	7.00	-0.25	11.04	-2.02	3.71	3.84		1.37	8.45	1.34	2.07	4.01	4.26	7.74	3.20	4.80	5.52	-4.93	-4.51	5.39	
FCA																				0.00	
FOB	5.13	2.66	-1.18	13.78				-1.36		-0.06	-1.14		0.07	3.83	-7.89	49.09	13.18	10.59	-3.52	28.57	
EDICUSRESSTATUSCODE																					
1	-7.24	0.93	3.46	0.91	-0.67	-0.42	-0.95	4.41	0.47	0.41	2.16	0.89	5.17	4.96	9.88	1.15	-86.38	2.30	-2.62	1.12	
2																				0.00	
3																				0.00	
6	3.08	-2.62	-1.75	-6.25	3.95	0.82		1.16	-16.90	0.88	-2.71	2.54	0.22	-1.53	2.95	-9.66	2.36	-2.66	7.75	-1.67	
9	1.65	3.33	0.23	-0.56	1.11	0.45				0.31	-0.05		0.61	8.91	2.73	-20.12	0.92			1.09	
13	-0.46	-3.79	-7.88	5.56				-13.20		0.74	-10.89	-22.21	-12.39	-1.99		3.49	13.62	2.02	-1.81	0.02	
27	6.47	0.05	-7.56	-6.63	-0.61	0.67		-18.54	-0.87	-2.82	-3.45	-4.17	-10.44	-12.78	-43.81	-3.82	-19.20		-1.86	-4.10	
28	8.65		3.58													-18.25	7.64			3.17	
31	-5.30		2.23	13.62												6.02	15.84	-1.94		2.81	
33	0.98	-10.92	-23.83	9.32				-43.58		-0.09	-30.98	-66.60	-39.61	-5.57		4.54	30.20	2.42	0.70	-2.93	
35	-1.94															1.66	13.99			1.35	
36																				0.00	
49	-6.09	-12.30	-11.79	-7.86				-14.10		3.25	-13.64	-26.94	-15.95	-9.24		-51.69	16.36		-1.37	-10.32	
TARRIF_HEADING																					
4006.10																				0.00	
4011.10.01	-1.68	-0.43	-3.33	-5.37							-6.98	-7.62	-5.99	-3.36	-3.44	-2.71				-2.33	
4011.10.03	-2.10	6.55	1.45	-3.58	0.34	-2.68		-1.59	-23.52	4.20	2.69	-43.99	0.44	2.75	7.19	-6.36	-2.73		-3.13	-0.30	
4011.10.05	-9.08	0.42	-5.90	-6.69	5.65	0.98		-0.86	-6.73	0.02	7.91	-2.48	2.79	-5.64	-0.71	0.70				-1.99	
4011.10.07	-16.28	-4.34	-6.95	4.28	0.93	0.96		-15.83	-2.02	-10.38	-3.00	3.24	-8.60	-6.85	-9.89	-3.63	-29.81	-4.40	-37.34	-6.29	
4011.10.09	7.70	-3.10	-0.57	-5.49	3.80	0.34	2.65	-0.44	0.42	-2.40	-1.08	2.90	-1.84	-4.13	-4.15	-6.10	-31.74	-5.52	-8.47	-1.81	
4011.20.16	-3.82	-4.89	0.76	8.92					0.14	-3.54	6.66	-10.82	-4.63	-24.00	-37.38	-3.48				-5.63	
4011.20.18	2.18	-6.41	-5.62	-8.14	-13.32	-4.06	-3.10	-14.11	-0.83	-6.89	1.32	2.34	-6.84	-19.02	-4.64	19.31	-42.02			4.84	
4011.20.22	-8.97	4.49	-5.94	-4.17	0.68	-2.06		-0.68	-5.55	-6.62	-3.89	-23.38	-3.51	-4.68	0.93	0.72		-4.26		-1.81	
4011.20.24	-6.13	-1.99	-2.41	-6.11	4.36	-0.13	2.80	-2.70	0.94	0.28	0.48	1.41	-3.82	-4.78	-6.78	-0.82	-5.73	2.28	-12.49	-2.45	
4011.20.26	2.50	38.46	8.44	13.65	4.87	5.33	-11.98	9.85	-1.54	8.65	3.60	-38.98	9.41	25.00	6.86	-22.01	8.26	14.22	16.45	6.74	
4011.40	-26.68															-24.23	-150.34			-24.20	
4011.70.10	12.82	1.89	4.53	4.00	0.17	-0.99		-3.25	-0.13	-4.79	-5.38	0.03	0.47	7.20	-0.52	4.55	30.50		-32.56	4.82	
4011.70.20	2.04															-0.22				0.55	
4011.80.10	-12.09	-0.67	0.18	-7.19	3.30	-0.88		3.51	-7.33	2.21	-5.08	-4.24	1.77	-10.14	4.67	-2.95	2.51	3.00	12.80	-2.80	
4011.90.10	-8.24															2.91		2.16		1.39	
4012.90	-2.59	-0.25	-0.01	-1.65	1.19	-2.48		-1.77	1.39	0.96	-1.03	-0.39	-1.43	-2.59	7.36	-6.37	-14.88	-1.87		-1.83	
4013.10																				0.00	
4013.90																				0.00	
4016.10.90	-10.65	1.22	0.59	0.41	0.60	-3.55		-2.07	0.72	-1.77	0.68	-2.33	-0.38	-1.20	-2.87	-4.31	1.66	3.10	-1.89	-2.68	
4016.93.90	-2.86	-4.01	0.00	-1.76	2.12	2.23		0.71	-1.77	-2.05	-2.47	3.88	0.46	-2.11	0.65	-1.47				1.28	
4016.99.90	2.69	3.56	-0.36	-1.11	2.11	0.91				0.85	0.35	-57.89	1.32	1.84	2.40	-16.05				-0.15	
8481.80.09																				0.00	
8526.91																				0.00	

PortOfloading																				
ABU DHABI																			0.00	
ALGECIRAS	-112.93	-9.01	-9.81	-4.43	3.32	0.37	-10.36	6.35	-19.64	9.96	-1.02	-3.12	5.96	-48.63	1.39	-17.28	0.90	6.39	-1.41	-27.22
ANTWERP	-58.52	-35.07	-104.95	-38.94	30.60	34.94				-100.14	-152.84		43.92	-38.25	23.94	-278.74				-63.78
ANTWERP CHURCHILL TERMINAL																				
ANTWERPEN	-5.55	12.42	-4.00	-1.10	0.64	-2.14			-1.70	-27.70	-2.12	-4.04	-41.32	-5.05	0.25	9.81	-18.18	0.46		-2.36
ARANDA DE DUERO																				0.00
BANGKOK	-0.29		23.35																	10.83
BARCELONA	-4.35	2.32	-6.10	-35.18	0.81	-4.21		16.28		27.12	-3.74	-130.28	1.45	-8.36	-5.75	-350.88				-31.12
BELFAST	1.13																			0.28
BILBAO	7.40	11.70	3.26	-0.68	2.05	-3.20		-0.92	0.53	-0.75	-0.10	-6.68	-0.07	4.63	1.65	-3.40	2.98	19.16	-49.33	2.76
BLAVOZY	3.39	13.48	-0.14	-2.73		-1.16				-1.99			13.00	6.16	-70.06					-0.74
BREMERHAVEN	2.36	9.95	2.85	1.62	1.93	-4.54		-1.98	1.20	-0.72	-3.67	-44.77	-0.48	-1.33	-4.94	3.99		5.30		3.00
BUDAPEST	0.84																			0.27
CHARLES CITY	-11.32	-0.16	-7.47	-9.79				-1.00		4.87	1.73	-47.60	-6.60	-2.92		-10.99				-5.18
CHARLESTON	0.66	-7.49	-13.72	-95.69	-0.50	-10.55		1.81	-11.85	-6.50	16.28	5.09	-8.60	-30.05	0.94	29.30		-4.68		10.91
CHARLESTOWN																-6.01				-1.24
CHENNAI (EX MADRAS)	-46.54	-39.68	-67.89	-115.17	-0.39	-30.23					-9.42	-26.90	-49.38	-23.77	-20.27	-87.90				-46.50
COLOMBO	0.94	1.34	-1.32	-0.97	2.17	1.38		0.68		0.18	0.09	-3.96	1.79	-3.83	-2.16	-10.77				-1.57
COLUMBUS																				0.00
CONSTANTA	39.04	42.83	16.88	0.97	0.62	-34.07		2.65	-4.03	-0.11	-0.19	-16.59	-2.98	37.37	-13.45	-5.09	6.61		9.24	22.50
CONSTANZIA			37.87								-3.13	-5.28		-3.02	5.69	-1.20	-29.69			8.77
DALIAN	-0.67															-2.19				-0.58
DUNDEE																				0.00
DURBAN																				0.00
ENNORE	-34.81	23.32	-119.14	52.29	-11.96	0.68		15.70		21.18	34.31	-77.19	23.79	-25.60	32.28	-189.93				-35.96
FOS SUR MER	-15.10			2.55												-1.90	15.00	-1.63	14.04	-4.27
GDANSK	40.44	42.10	26.31	-4.33	-4.65	-6.65		3.99	-24.12	-1.10	-2.67	-67.92	-6.62	25.66	6.62	3.18	13.78	-6.49	-23.12	19.35
GDYNIA	49.13	57.73	24.72	6.94	-0.45	-5.56		6.87	0.43	4.87	4.02	-74.66	2.62	45.86	9.83	-34.69	10.85			29.72
GENOA																				0.00
GENOVA	41.06	48.22	13.93	20.04	-4.46	20.56		2.76	0.62	-1.77	0.00	-50.66	16.78	29.36	12.65	-9.64	-16.71		-2.92	19.52
GRANGEMOUTH																				0.00
GRANGEMOUTH	1.57		-0.98	0.70																0.07
GREER	-33.56	-10.94	-24.93	-10.09						-8.45	-15.98		-8.07	1.46	4.23	-66.95				-19.45
GREER-GREENVILLE APT	-13.30	-2.66	-8.96	-10.64	-5.26	-127.26				-8.21	-13.31		-13.98	2.23	3.67	-61.80				-12.42
HAMBURG	-12.34															-1.07		1.76		-2.19
ITAGUAI	-3.86	5.44	3.09	1.70	-3.50	-3.97		0.95	-0.03	1.00	-2.07	-92.50	2.57	1.84	0.75	3.11				2.34
JACKSONVILLE	-1.87																			-0.05
JEBEL ALI															-1.64	-57.77				-1.63
KATTUPALLI PORT																				0.00
KOPER	21.52	17.88	4.66	-1.03	3.51	1.47		-2.58	-0.80	-0.77	-0.80	-16.08	-0.33	6.83	-0.85	-1.51				8.28
LA SPEZIA	-11.03	8.10	-18.29	-16.58	14.47	6.65	3.14	-11.25	-28.53	0.08	0.70	-123.06	-19.51	-6.19	-17.53	-159.51				-19.34
LA SPEZIA OFF-LINE PT	0.25	2.35	-0.69	-5.37				3.55		-1.66	-4.35		2.51	-1.65	1.36	-5.72				-0.24
LAEM CHABANG	-45.72	-7.70	-5.55	15.04	-17.12	-3.91	-1.58	-19.86	0.55	-5.33	-2.01	3.09	-7.06	-17.76	-22.45	-27.53	-17.57	-8.32		-19.65
LE HAVRE	-4.97	-4.50	-0.50	-0.54	4.42	0.59	0.08	-0.21	1.16	-0.33	-6.37	3.20	-0.36	-4.69	13.71	-2.39	7.43	-2.57	1.67	-1.49
LONDON																				0.00
LONDON GATEWAY PORT	2.45		-33.92																	-1.65
MARSEILLE	1.15															2.89				0.43
NULL	5.96			1.88												11.18	6.36			10.04
OLSZTYN	1.15	10.13	0.68	-9.40	-1.95	-8.81		-1.52		-1.42	-5.16		-2.98	14.15	5.40	-67.35	-1.18	0.84		-1.22
OLSZYNA															9.27	-21.55	3.88			-2.73
RIO DE JANEIRO	-6.47	10.65	5.19	-20.31	-0.84	-3.73		2.96	0.65	0.10	-3.86	-21.65	-1.35	4.53	1.65	2.65		-0.97		3.08
RIO DE JANEIRO-SANTOS DUMONT APT																				0.00
ROTTERDAM	-29.18	-0.16	3.03	-1.37	-3.01	-3.55		-0.40	0.14	-3.00	-9.08	-38.41	0.52	-6.50	-6.35	2.99	-11.56	-2.98		-2.75
SANTOS	-2.20															2.00				1.80
SAVANNA																				0.00
SAVANNAH	47.44	17.07	5.67	-69.91	15.88	3.54		-6.38	-8.06	-9.67	-38.52	7.06	21.70	12.45	23.31					22.12
SEPETIBA	-4.43		-2.66													1.45				0.41
SHANGHAI																				0.00
SINES	-89.50		-89.77	17.32												-66.57				-76.03
SINGAPORE																				0.00
TORINO																				0.00
VADO LIGURE	-2.08	-0.91	-5.40	-6.55	0.13	-2.45		0.26	-7.38	-3.14	-4.49	0.73	-3.27	2.40	1.86	-147.24				-14.26
VALENCIA	-1.19	-1.33	-1.48	-4.31	2.19	1.08		3.68	2.04	2.38	1.33	1.47	0.73	2.68	1.57	-28.36	0.05			-2.39
WARSZAWA																				0.00

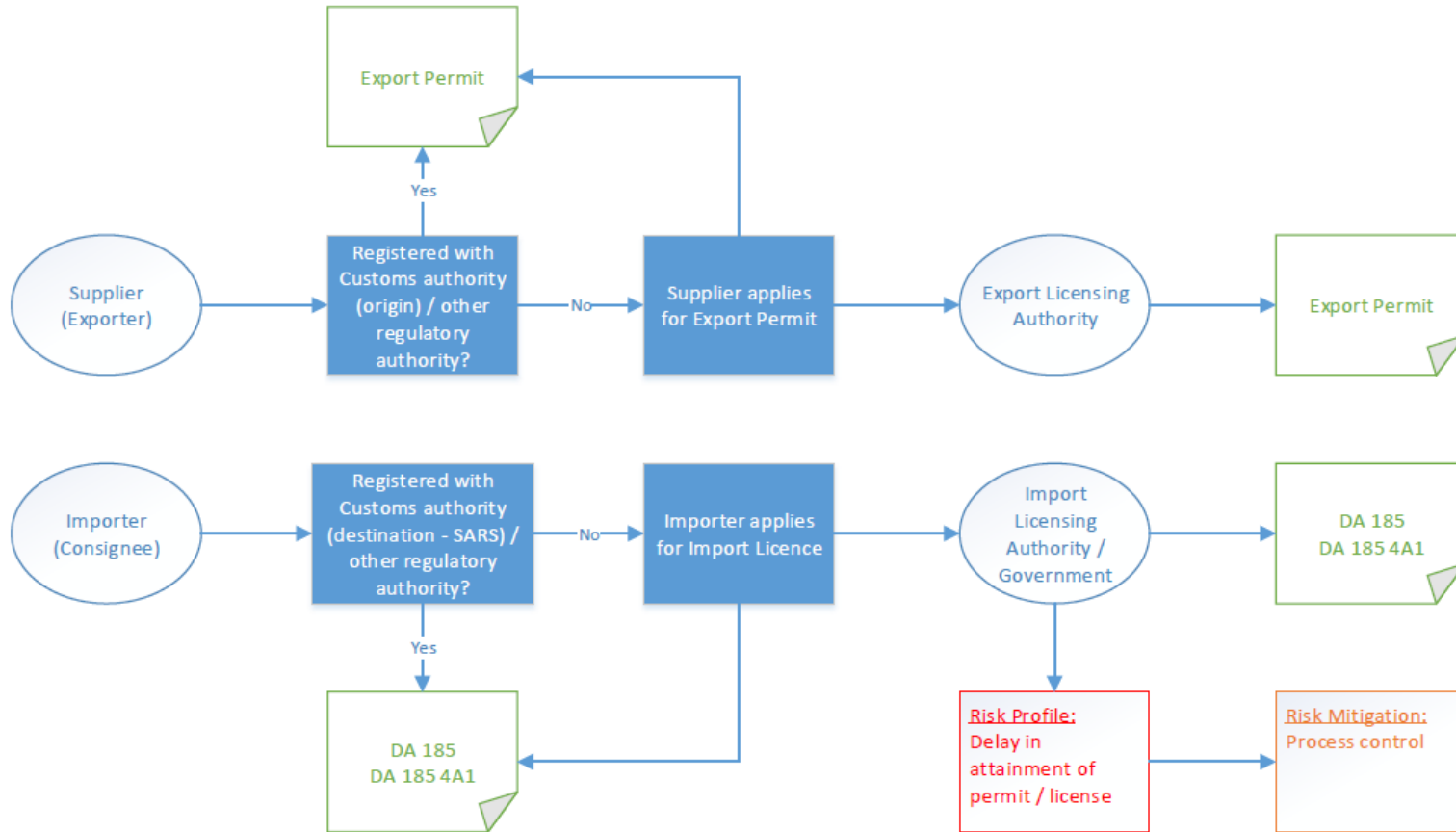
ShippingLine																			
ARENDAL SHIPHOLDING CO	-0.58																		0.00
CMA CGM SHIPPING	-15.66	-8.54	-12.94	16.09	-3.97	5.71	-1.94	0.35	1.04	5.60	2.60	6.44	3.55	-10.10	-15.61	-18.82	3.11		-0.23
CMA-CGM GROUP	0.38	-0.03	7.54						0.45	-4.90	-2.11	-8.40		-1.76	-12.42	3.23			-10.68
COSCO SHIPPING LINES (SO	12.27	28.00	9.99	22.46	-20.14	16.25				-18.57	-30.60	-31.09	-48.35	-188.95	5.30	8.83	-4.78		3.17
COSREN SHIPPING LINE	6.50	12.43	6.84							-12.63	-7.80	-49.86	-91.31	9.27	-186.98	-584.38			6.12
DAL DEUTSCHE AFRIKA-LINI	12.40	47.72	9.34							0.92	-7.55		-7.44	80.98	-30.35	-266.58			-25.58
DIAMOND SHIPPING S.A.																			6.89
DIAMOND SPV2 PTE LTD																			0.00
EVERGREEN MARINE CORPO	-21.56	-10.13	247.49	5.25							0.95			-111.63	-150.48	-95.12			0.00
GOLD STAR LINE	-22.72	8.14	-55.57	-5.18	-15.84	-17.35				-23.39	-9.32	-2.32	-0.46	-75.44	-11.31	-3.97	-9.74		133.77
HAMBURG SUD	16.84	-0.65	-2.47	0.22						0.45	-2.74	-4.99				-5.55	-0.44	14.43	-56.63
HAPAG-LLOYD	15.29	22.49	24.81	-8.67	4.31	-30.56				1.26	-1.50	0.03	3.02	-14.34	-1.51	16.80	-7.03	-60.55	9.42
HAPAG-LLOYD AFRIKA (PTY)	9.40	10.07								-6.09			-7.42	-15.52		12.30	-9.80	-0.54	13.12
IGNAZIO MESSINA & C (PTY)	5.67	7.10	5.31										-3.87	-12.32	-36.47	5.32	-7.61	-295.39	5.39
MAERSK LINE	-7.69	16.35	-29.30	14.45	-1.49	5.22				6.60	-4.52	12.05	10.16	-177.12	10.06	10.68	18.07	-53.23	-5.17
MAERSK LINE LIMITED	1.00	2.32	0.33	5.40						1.96	0.45	1.95	0.95		2.82	1.56	6.53	-100.15	-8.48
MEDITERRANEAN SHIPPING	-4.24	3.84	13.07	-10.22	7.77	2.68	2.52	3.23	0.42	-6.22	1.82	3.47	-0.35	9.50	19.68	6.36	-4.02		9.50
MITSUI OSK LINES	-9.00															7.92	-11.05		5.95
MOL SA PTY LTD																			6.04
MOL SOUTH AFRICA (PTY) L	-20.01																		0.00
MSC SOUTH AFRICA	13.11	16.06	7.52	-18.56	5.44	3.57				-15.43		-41.16	3.75	8.73		-5.49	12.68	11.11	0.17
NULL																			-9.24
OCEAN AFRICA CONTAINER LINE																			7.26
OCEAN NETWORK EXPRESS	-25.84	-7.09	-10.38	-14.01	3.38	-6.87	-7.31	2.02	0.99	6.11	-3.32	-7.94	-6.02	-31.07	-25.14	-3.45	-13.51	-17.49	5.33
ONE LINE	-0.53																		-11.32
ORIENT OVERSEAS CONTAIN	-31.81	-5.23	-22.29	-8.40	-0.09	-12.75				-11.58	-23.56		-25.46	-3.36	-10.47	-270.96			-2.76
PACIFIC INTERNATIONAL LI	4.27	8.83	4.26	-4.17	1.57	1.49		1.10		-0.09	-2.09		1.86	-2.15	-0.97	-68.25			-33.64
SAFMARINE CONTAINER LIN	35.94		3.03	14.60							-19.70			-154.17	-31.24	19.96	12.52	16.18	-29.40
SAFMARINE PTY LTD																			3.54

Source: Author's own compilation.

Figure 9-12: Detailed process flow of ocean freight imports, from the perspective of the freight forwarder

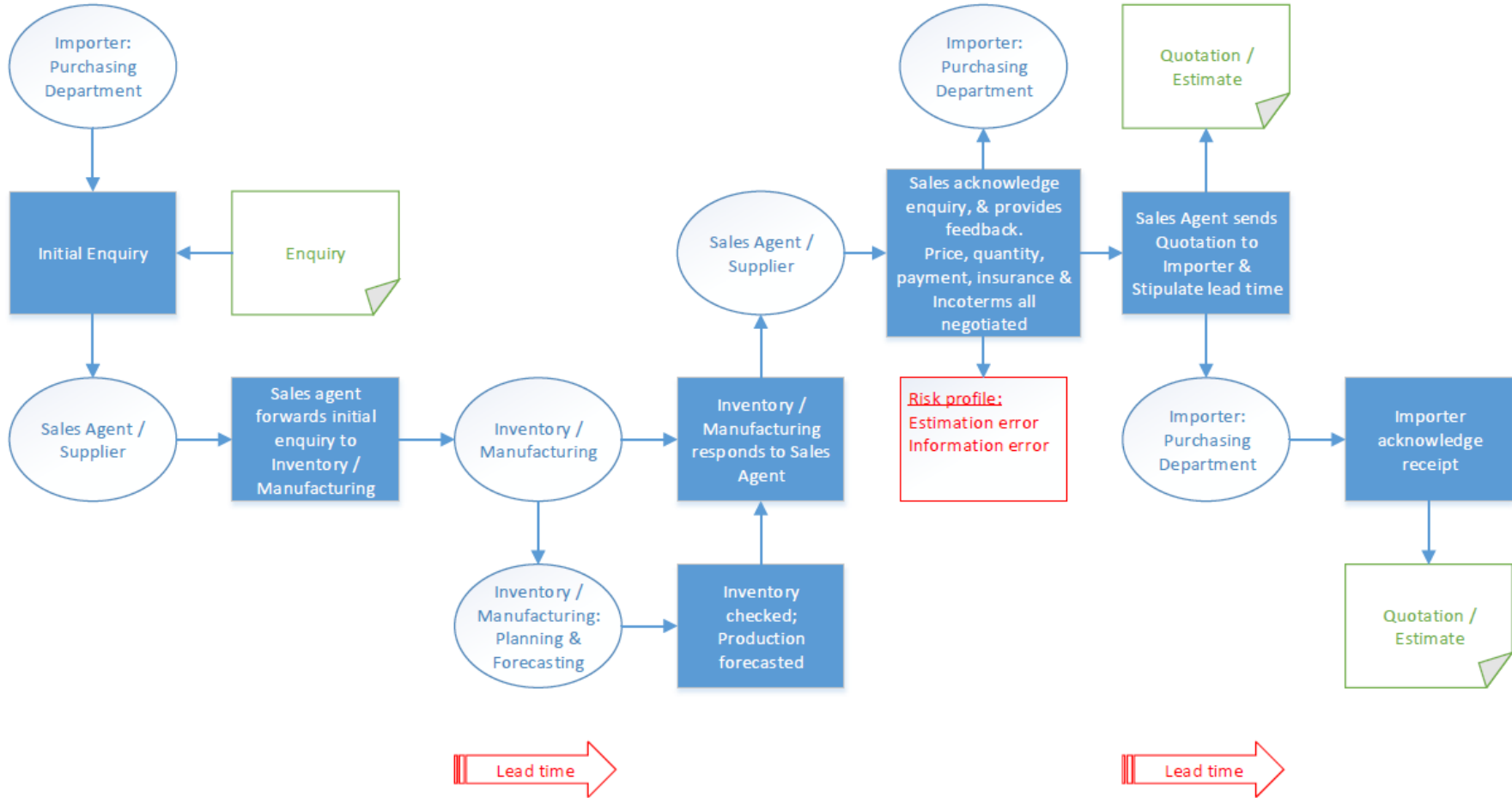


**Import, Ocean, FCL to Port:
1. Registration with Customs**



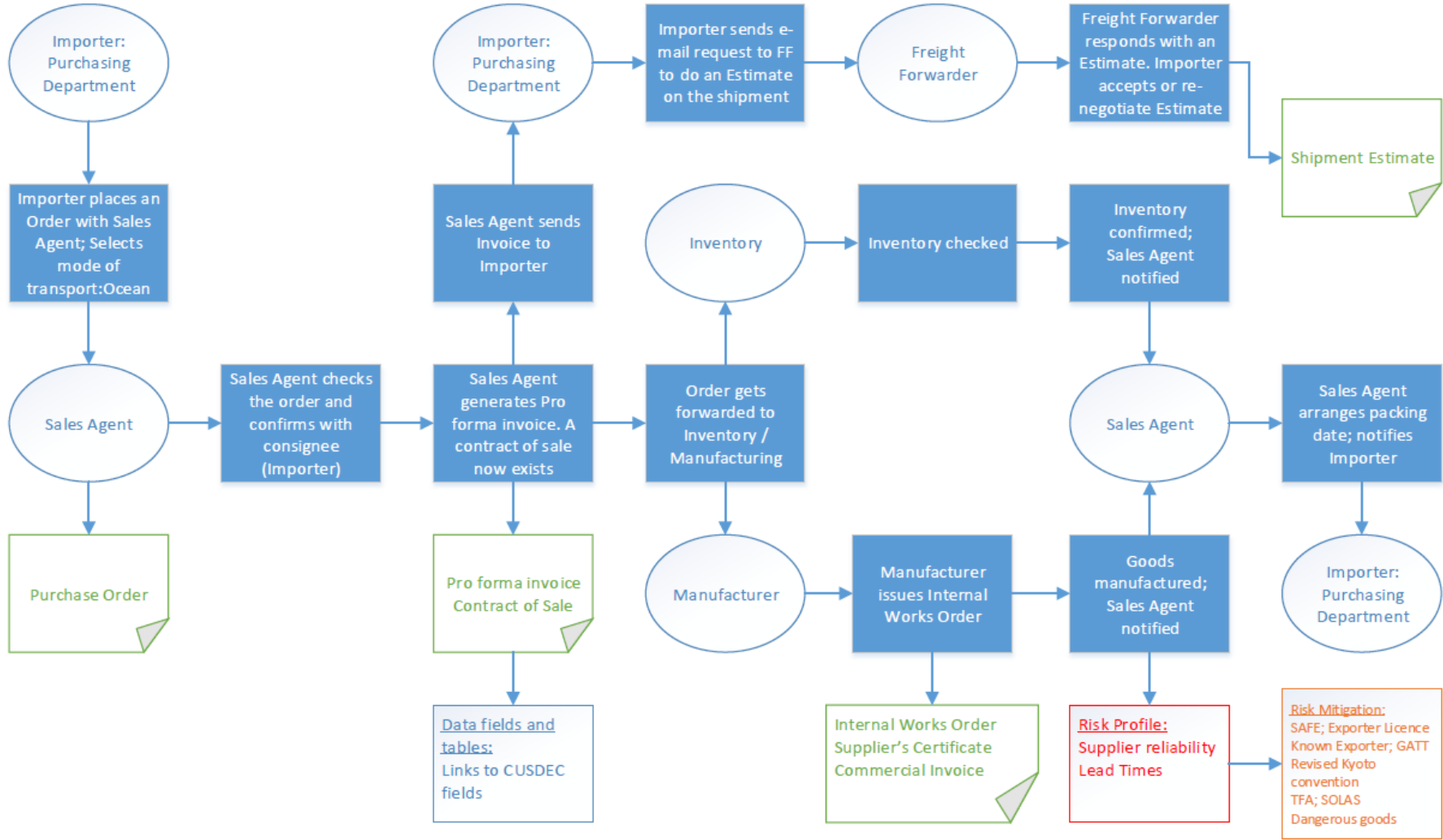
The turnaround time for Importer registrations is approximately 10 working days

**Import, Ocean, FCL to Port:
2. Enquiry**



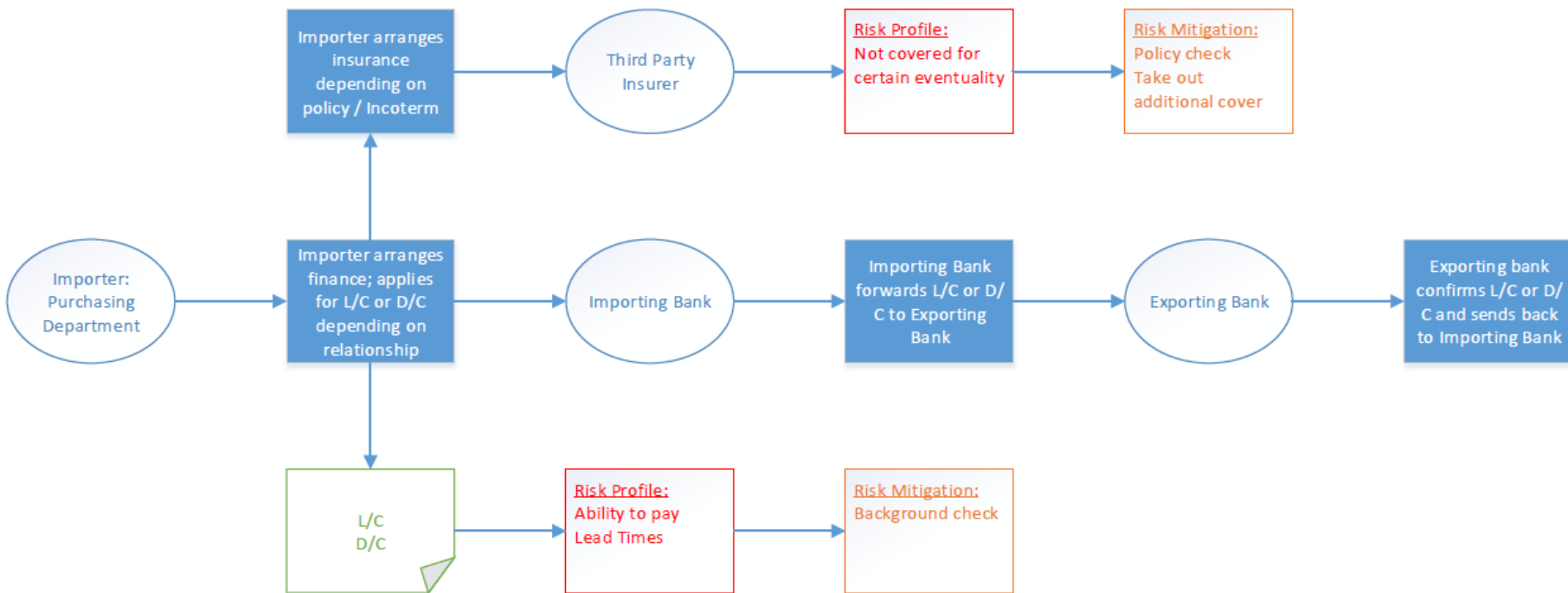
As per contracted lead time within company standard

**Import, Ocean, FCL to Port:
3. Order**



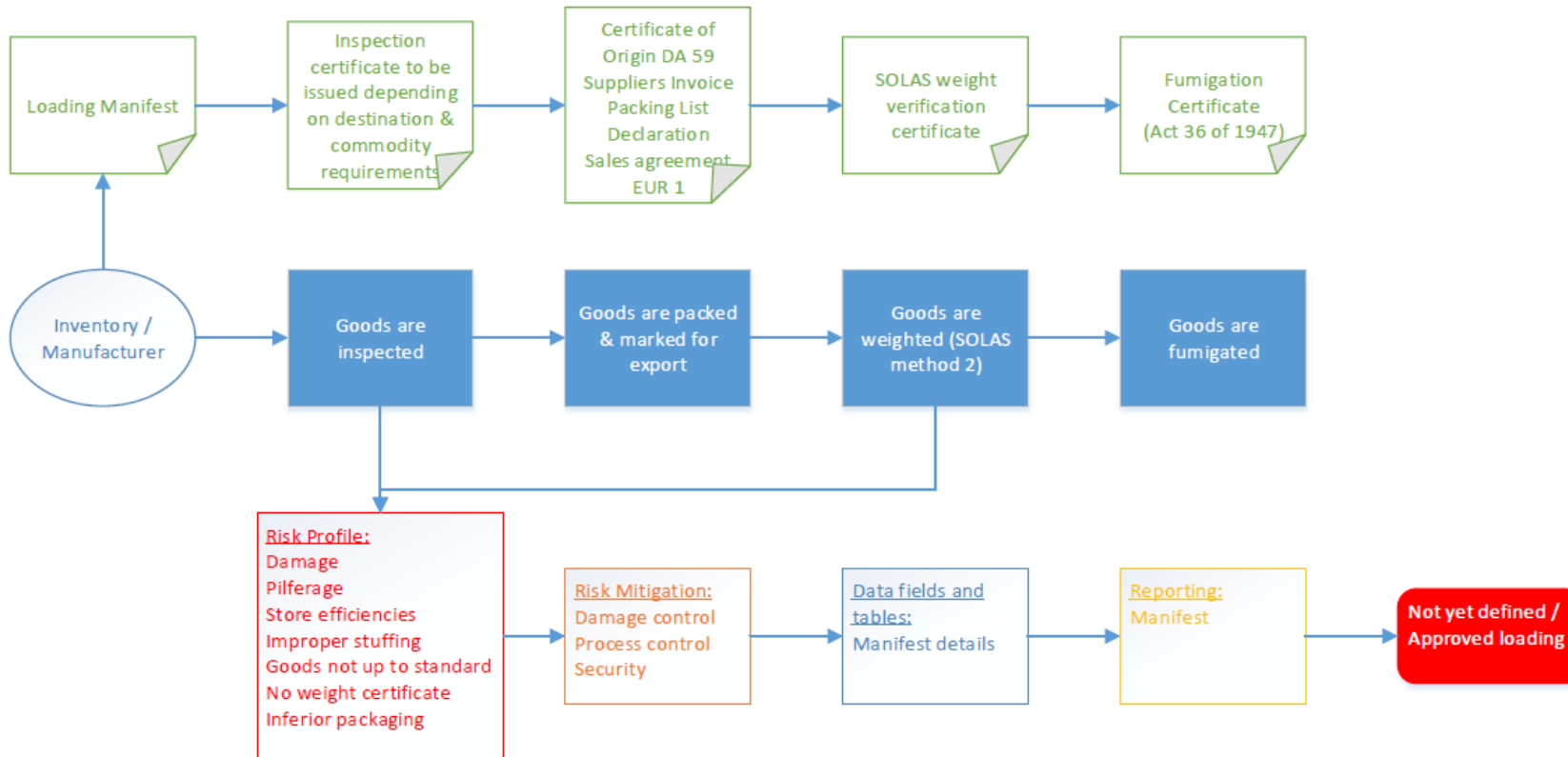
➔
 Manufacturer / Inventory to provide contract lead time

Import, Ocean, FCL to Port:
4. Finance (If not Cash in Advance / Open Account)



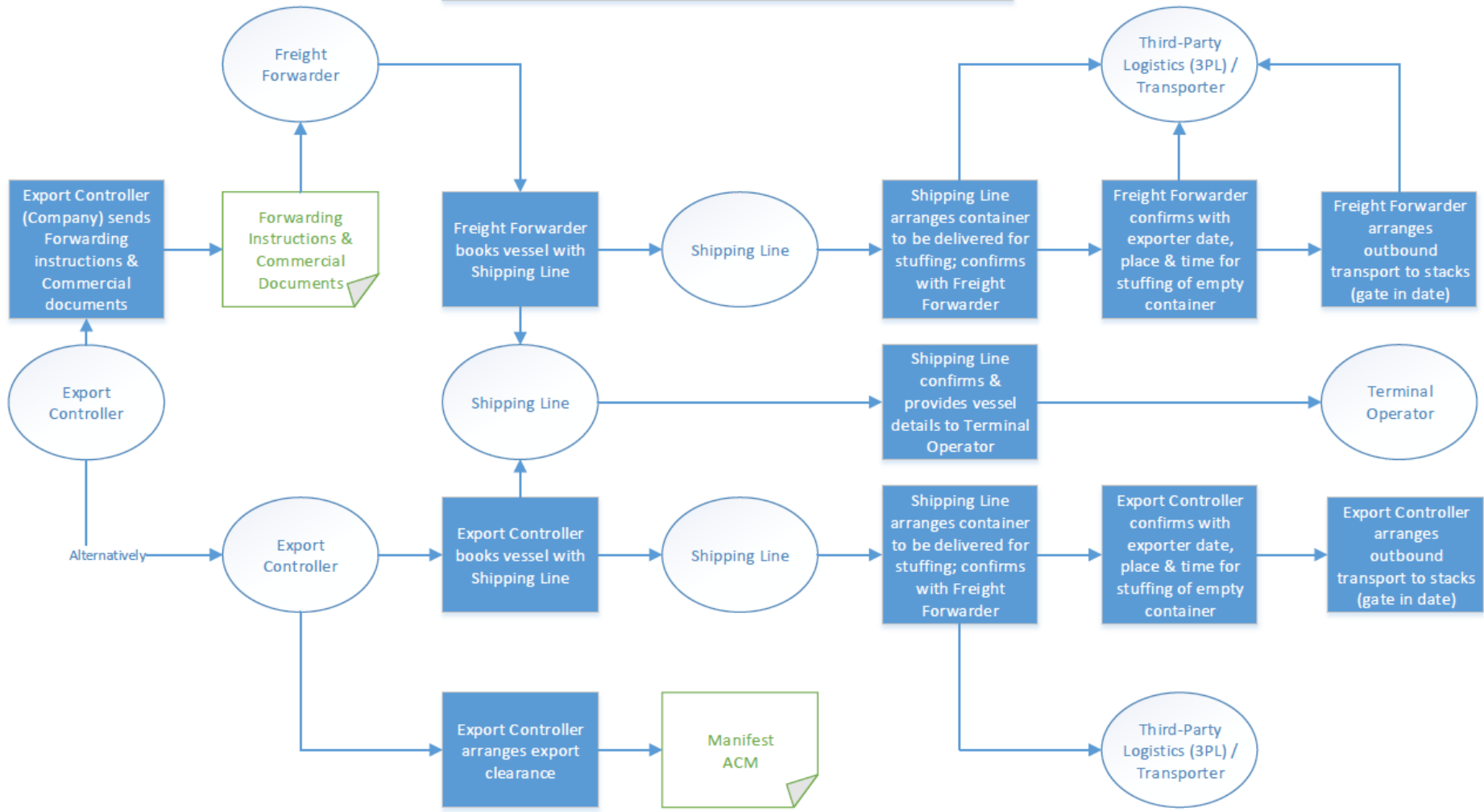
Lead times depending on relationship

**Import, Ocean, FCL to Port:
5. Packing & Marking**



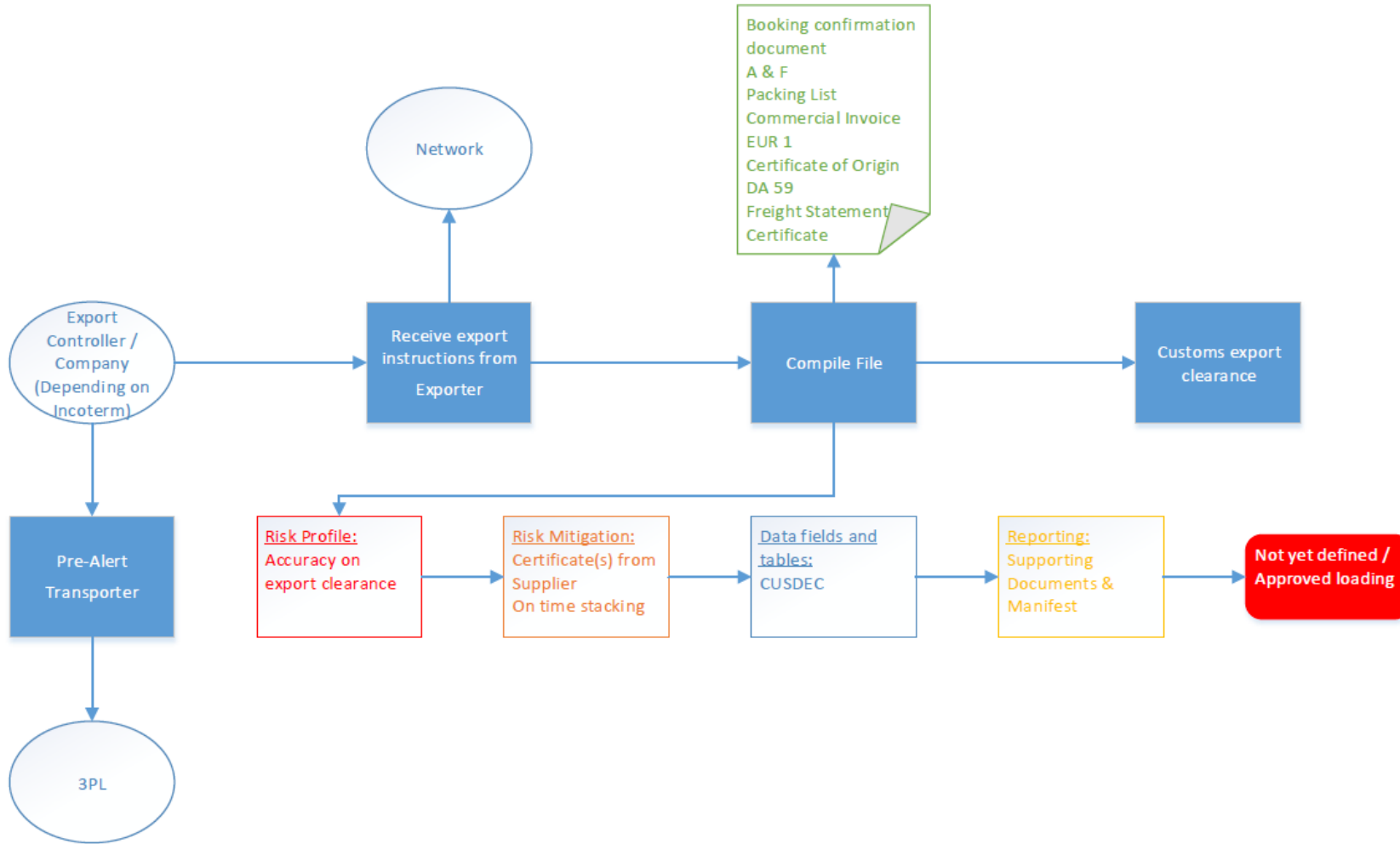
Links to L / C or Open Trading Terms & Stack Dates

**Import, Ocean, FCL to Port:
6. Vessel & Outbound**



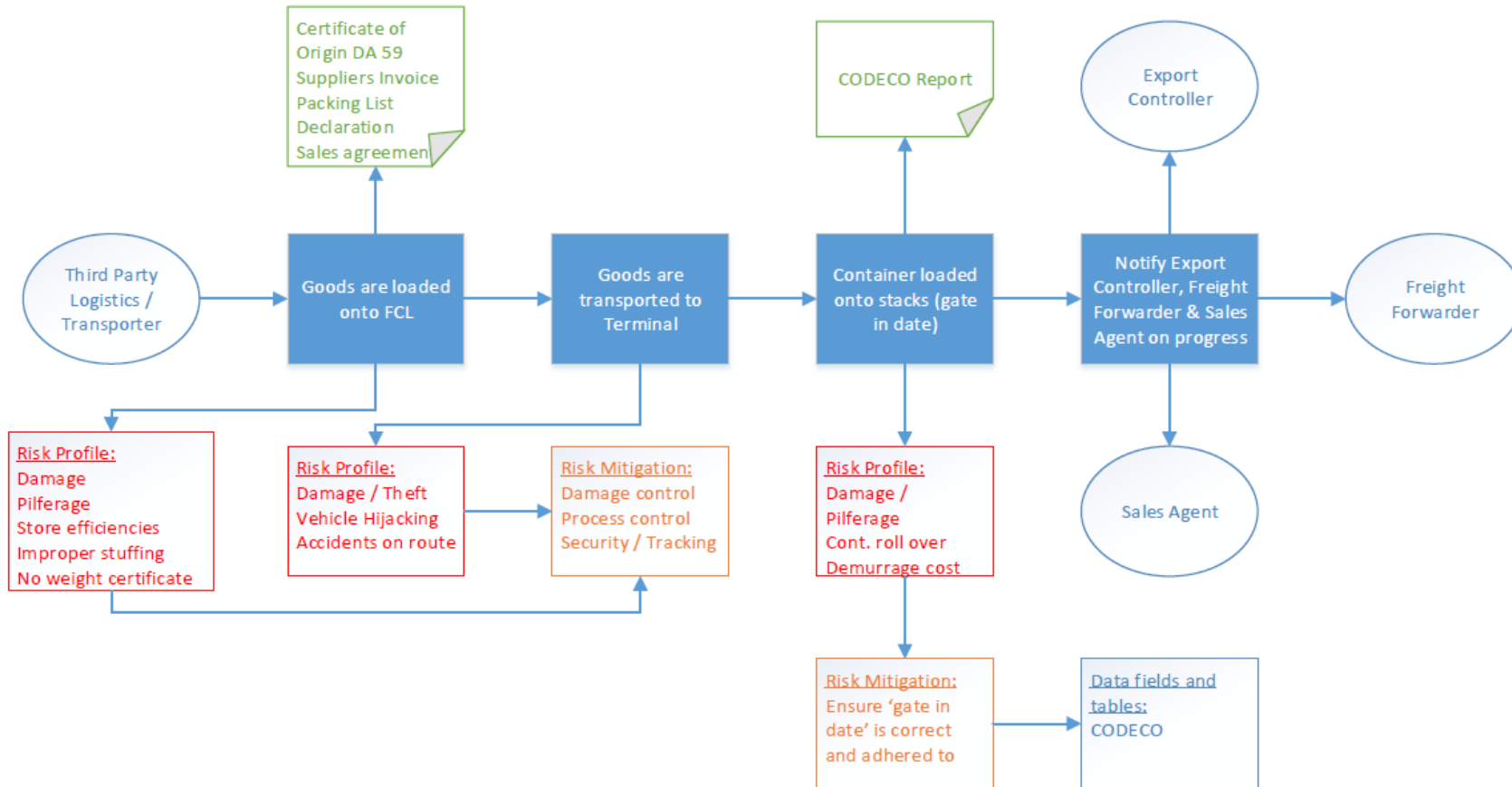
As per contracted lead time

Import, Ocean, FCL to Port:
7. Origin Clearance



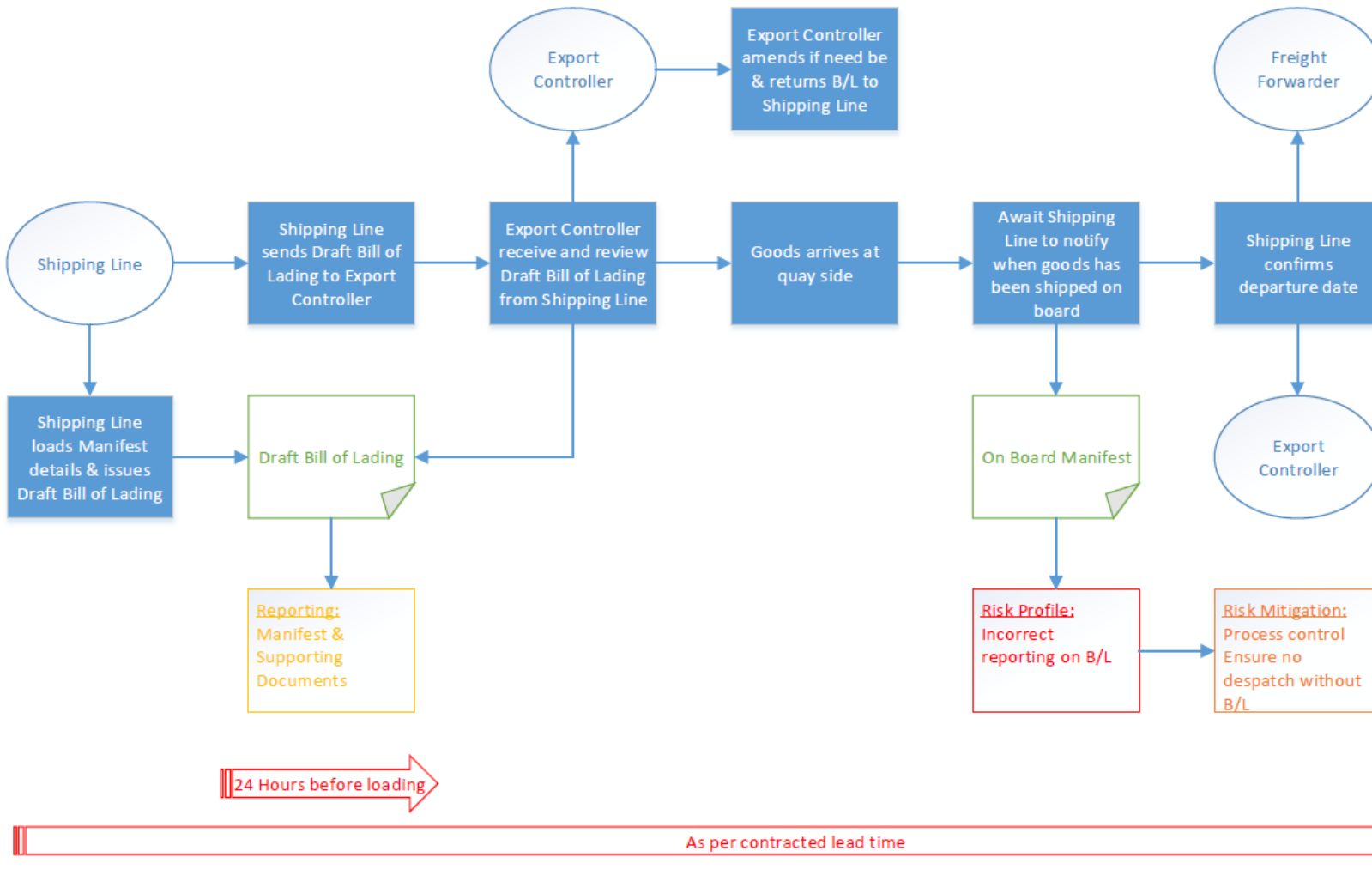
24/7 Rule

**Import, Ocean, FCL to Port:
8. Transport to Terminal**

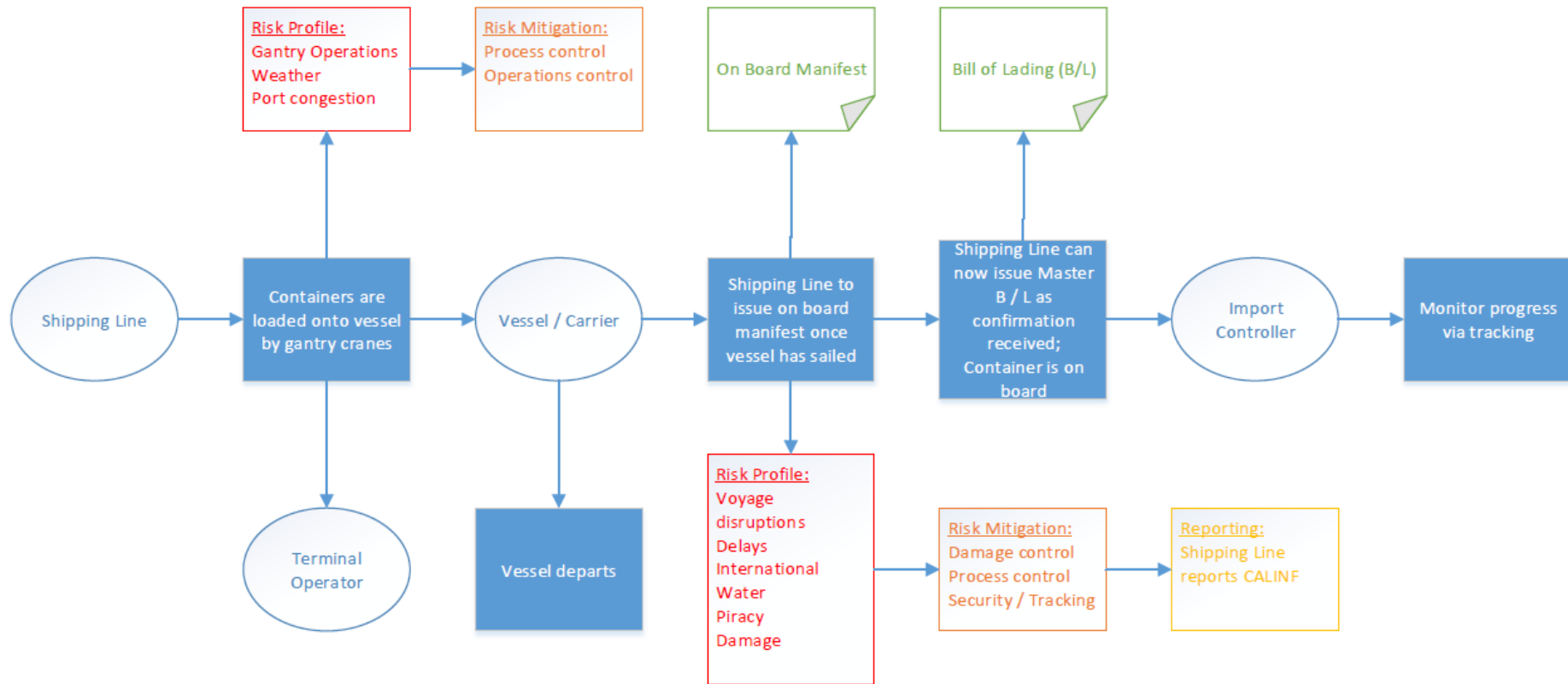


As per contracted lead time

**Import, Ocean, FCL to Port:
9. Review Vessel**



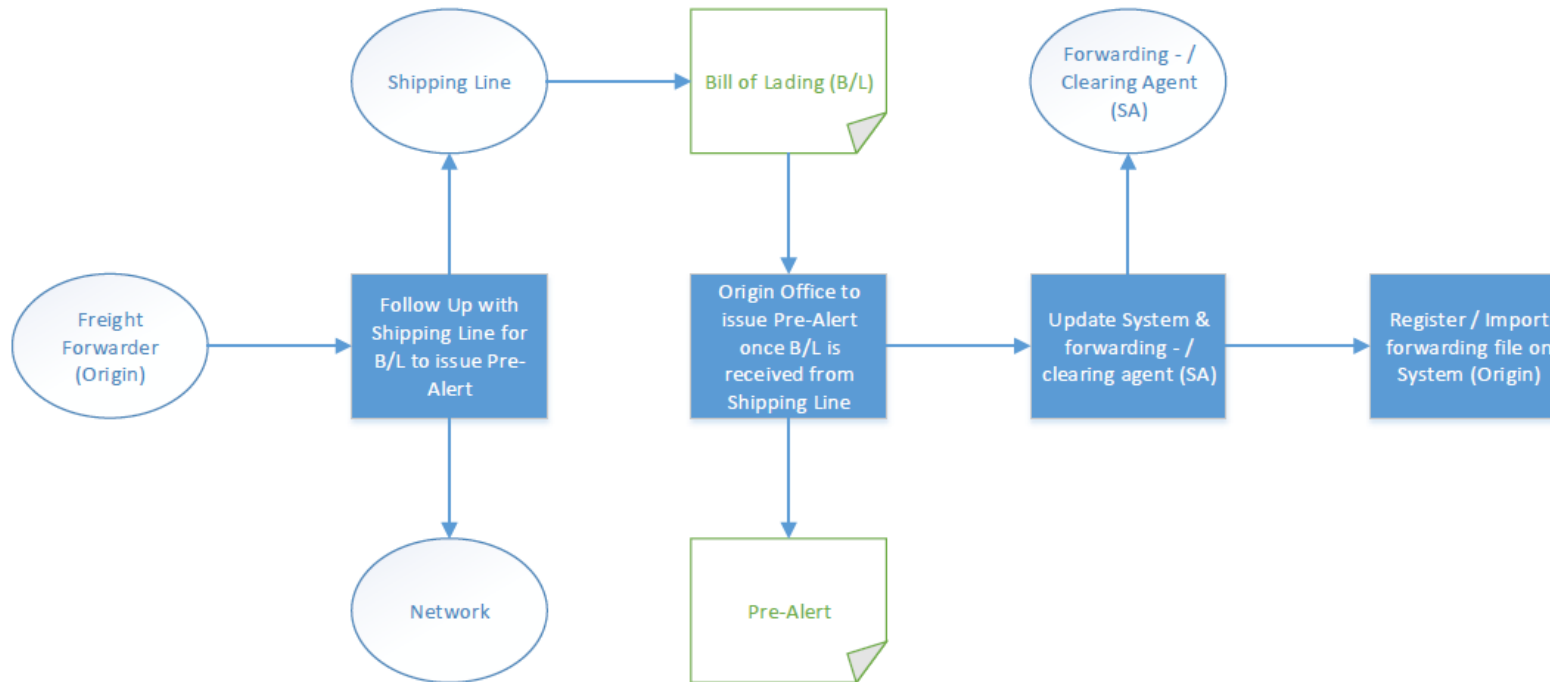
**Import, Ocean, FCL to Port:
10. Shipped on Board & Voyage**



10 days prior to arrival

As per contracted lead time

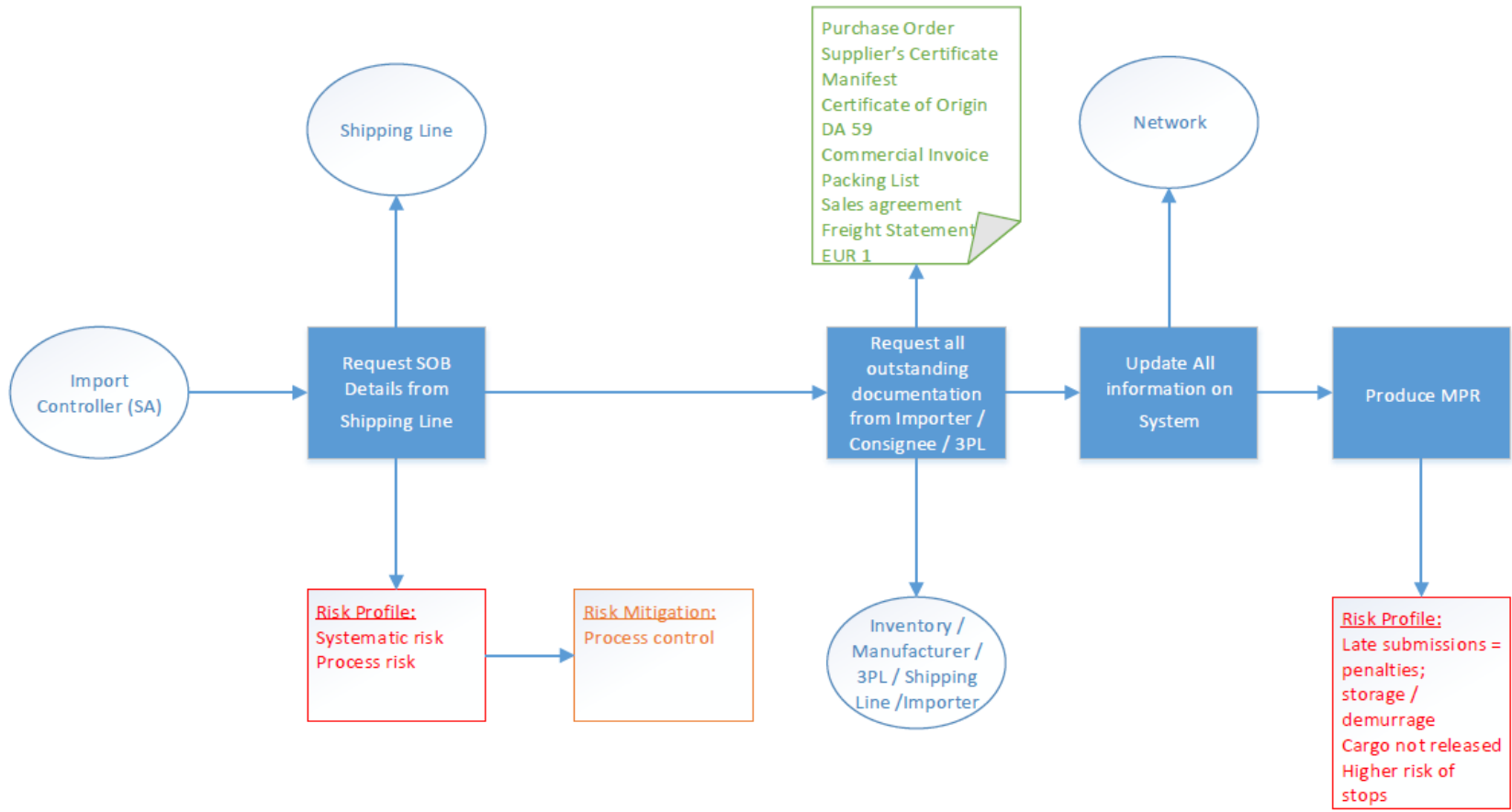
Import, Ocean, FCL to Port:
11. Network Update



After sailing confirmation

As per contracted lead time

**Import, Ocean, FCL to Port:
12. Update & Obtain**



72 Hours before vessel arrives

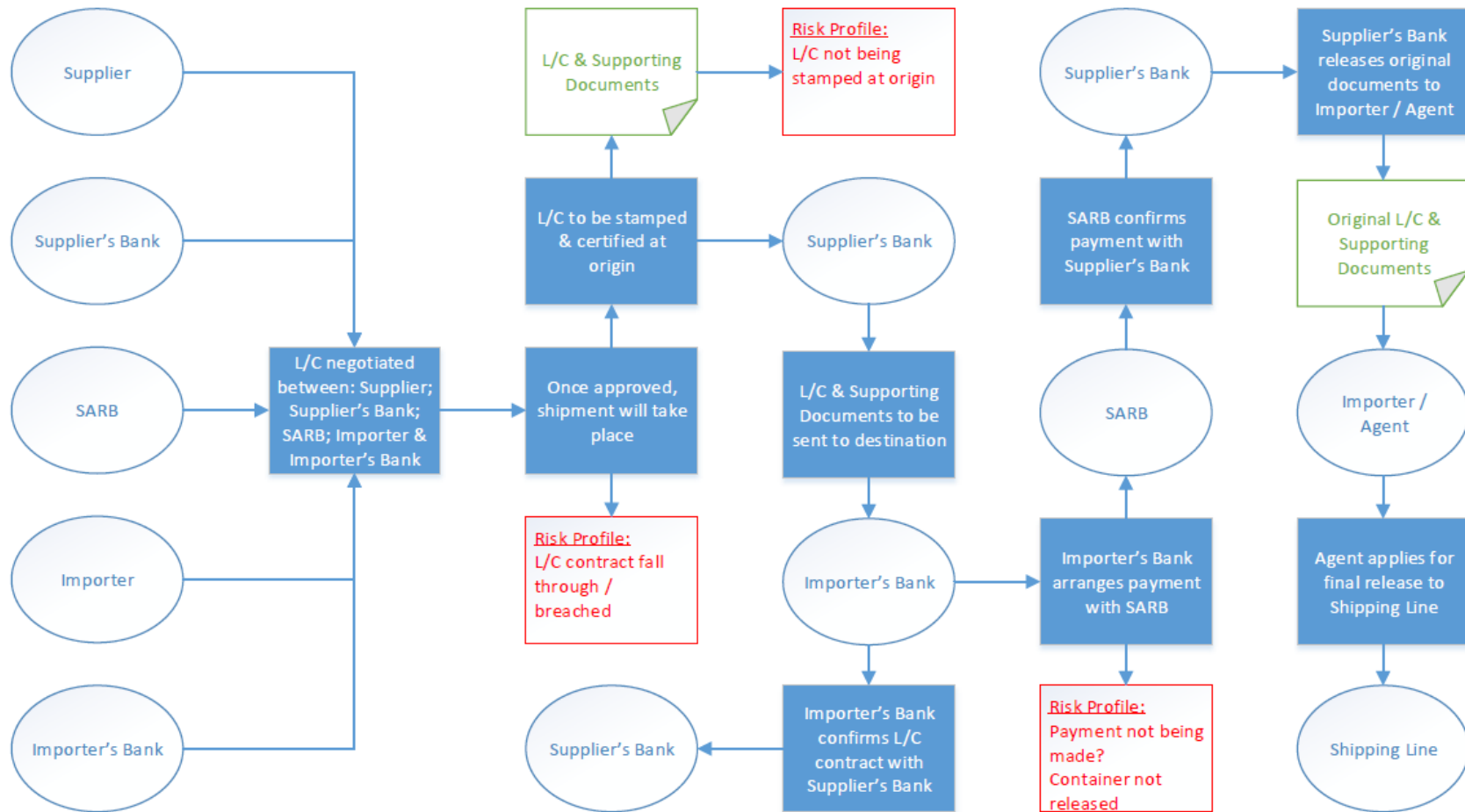
As per contracted lead time

**Import, Ocean, FCL to Port:
13. Destination Pre-Clearance**



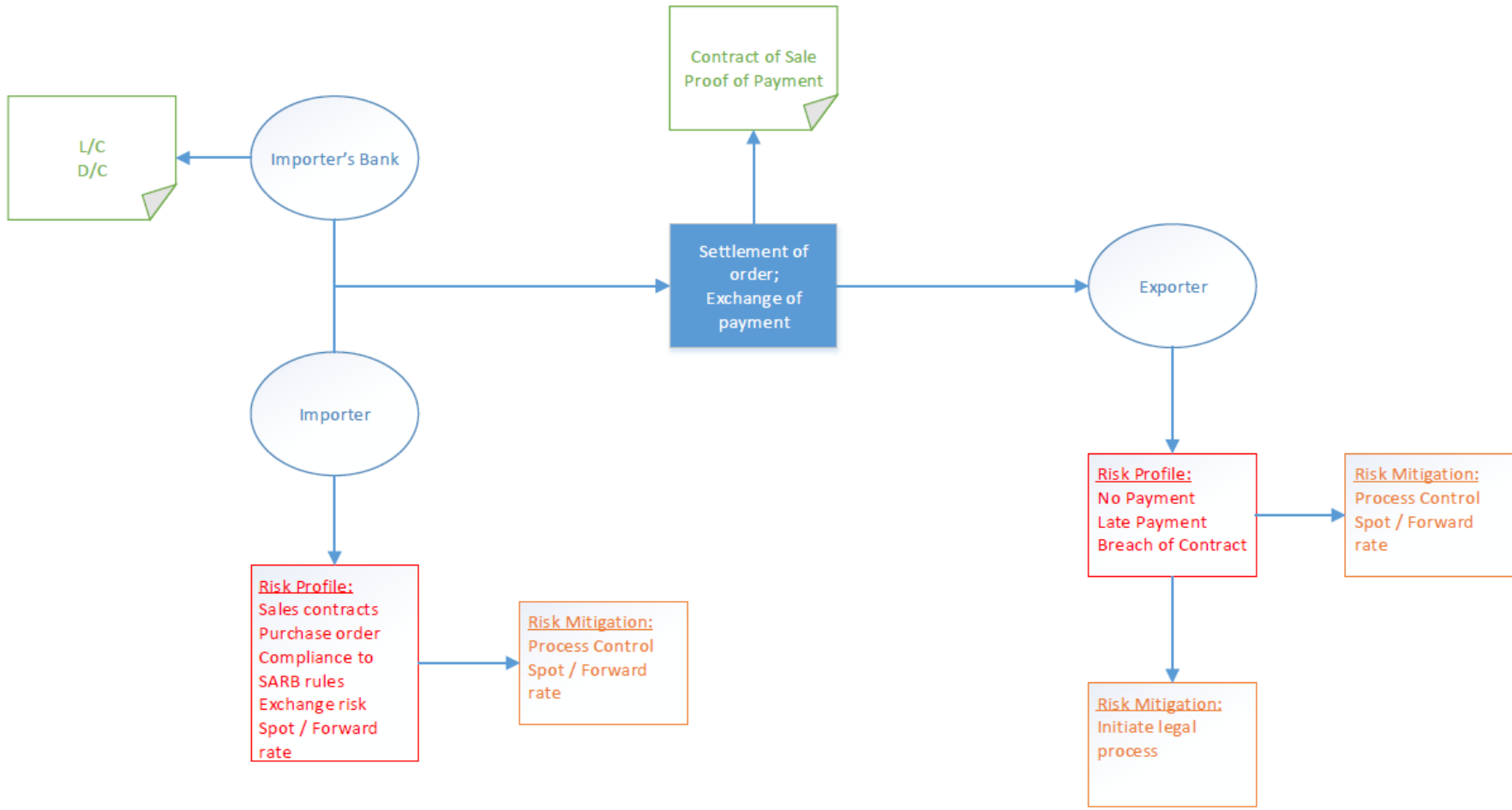
3 Days [72 Hour] before arrival at quay side; PCA: 3 years

**Import, Ocean, FCL to Port:
14. L/C not Paid**



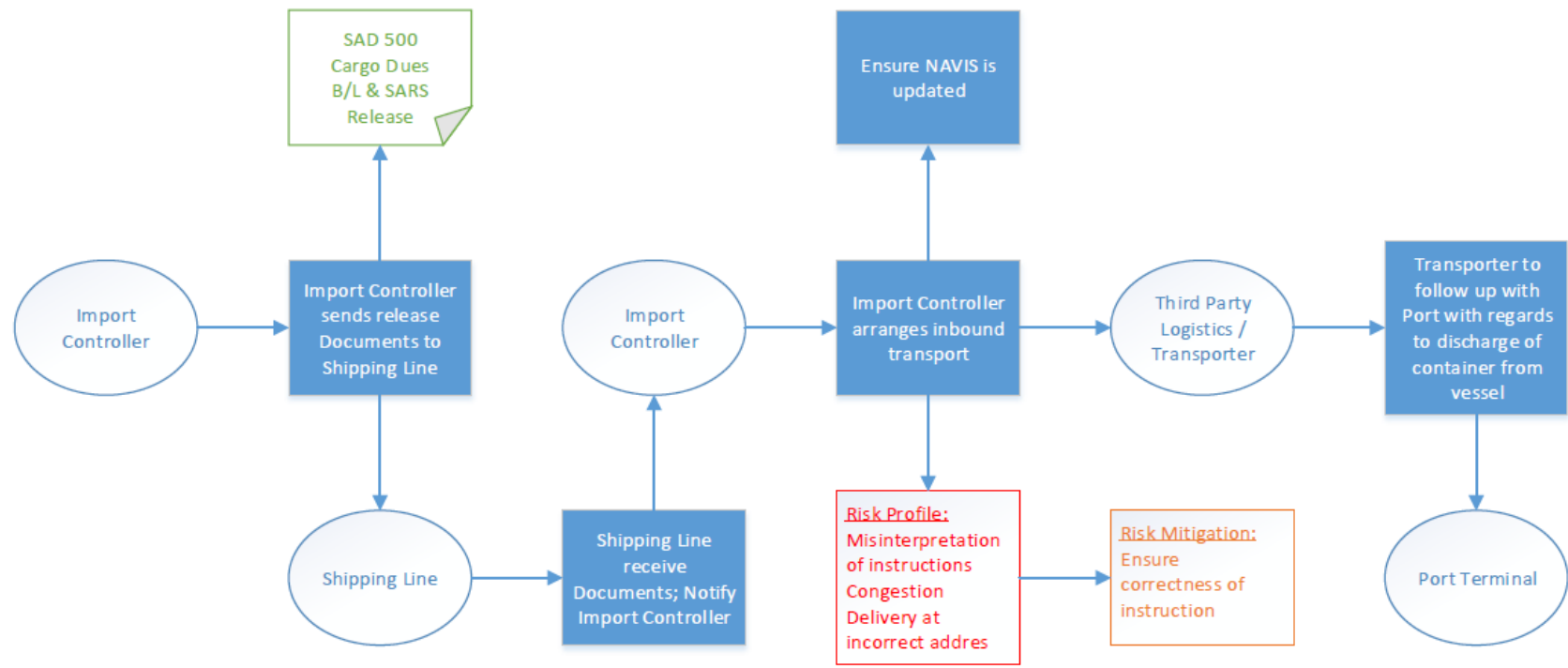
Per negotiation time frame

**Import, Ocean, FCL to Port:
15. Exchange of Payment**



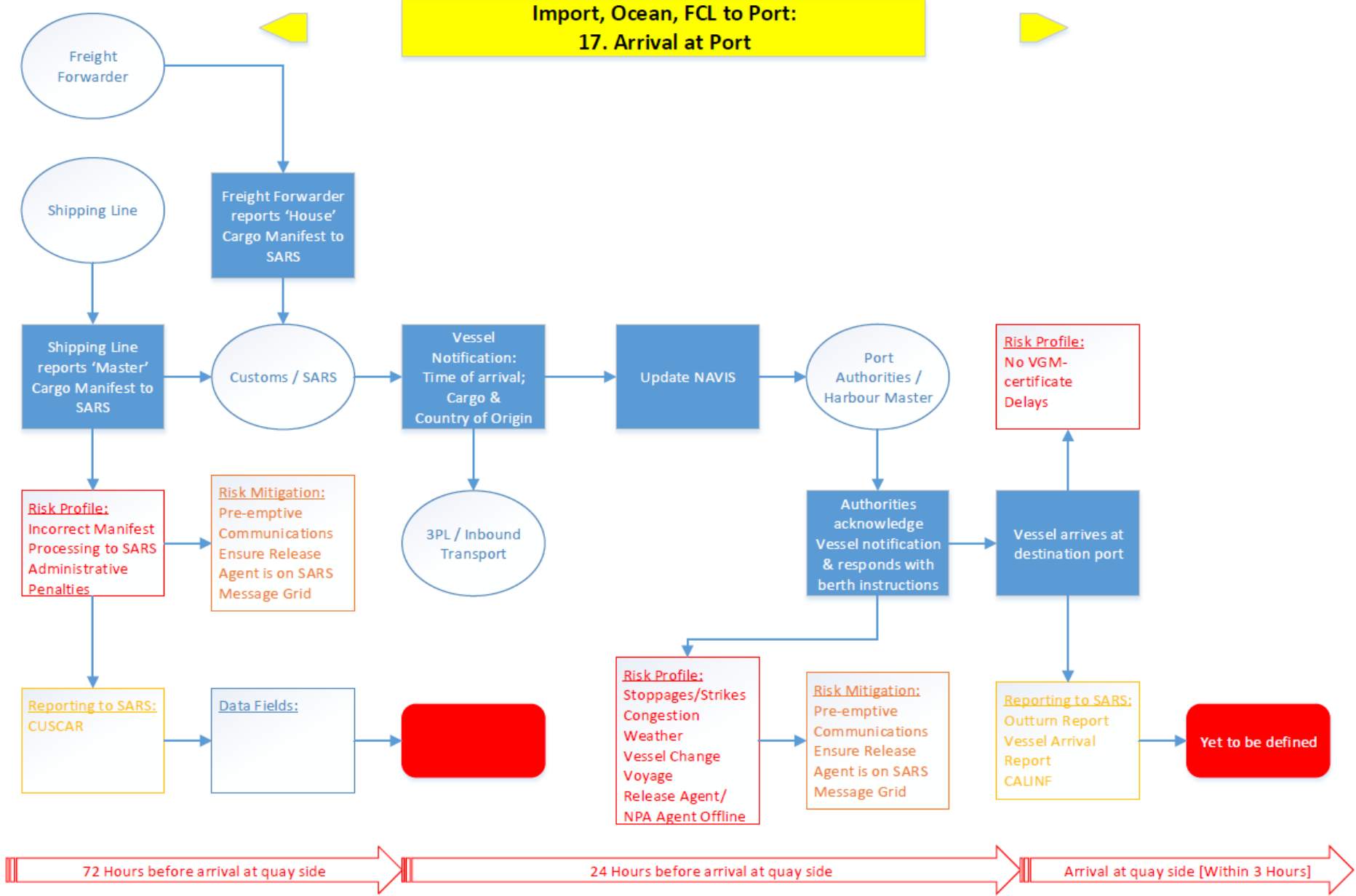
As per contracted lead time

**Import, Ocean, FCL to Port:
16. Inbound & Delivery**



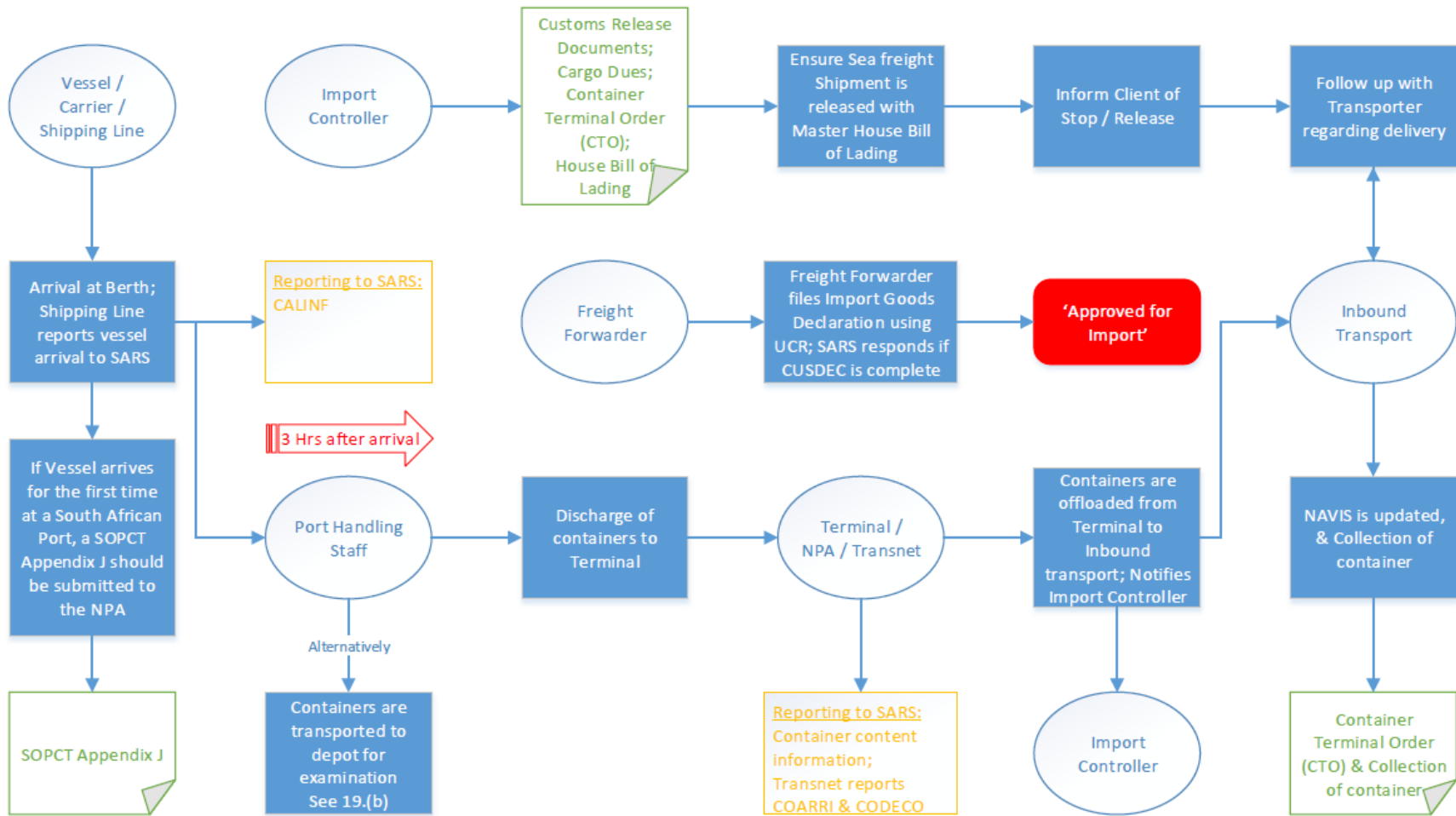
3 Days before arrival at quay side

**Import, Ocean, FCL to Port:
17. Arrival at Port**



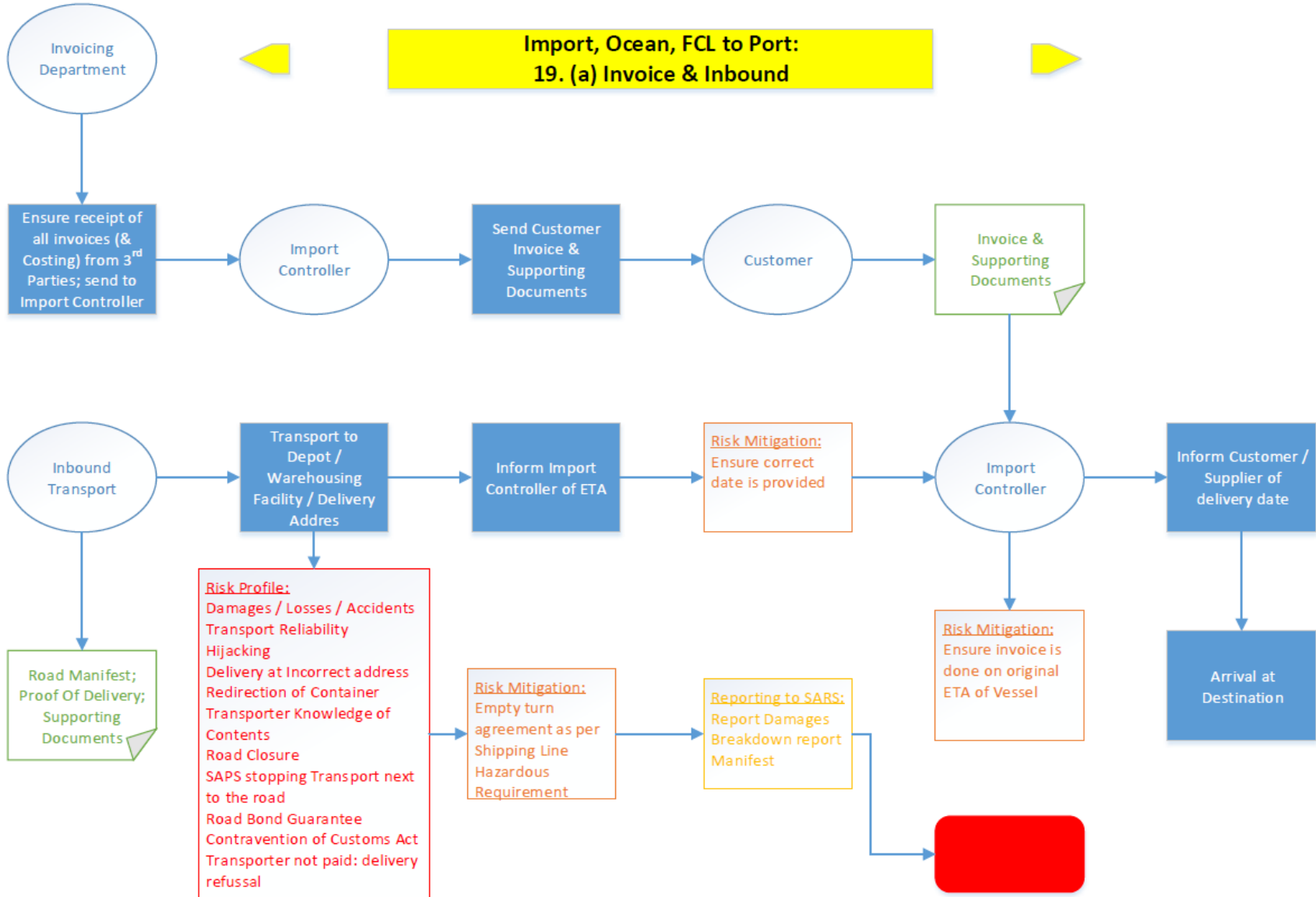
72 Hours before arrival at quay side → 24 Hours before arrival at quay side → Arrival at quay side [Within 3 Hours]

Import, Ocean, FCL to Port: 18. Port Release



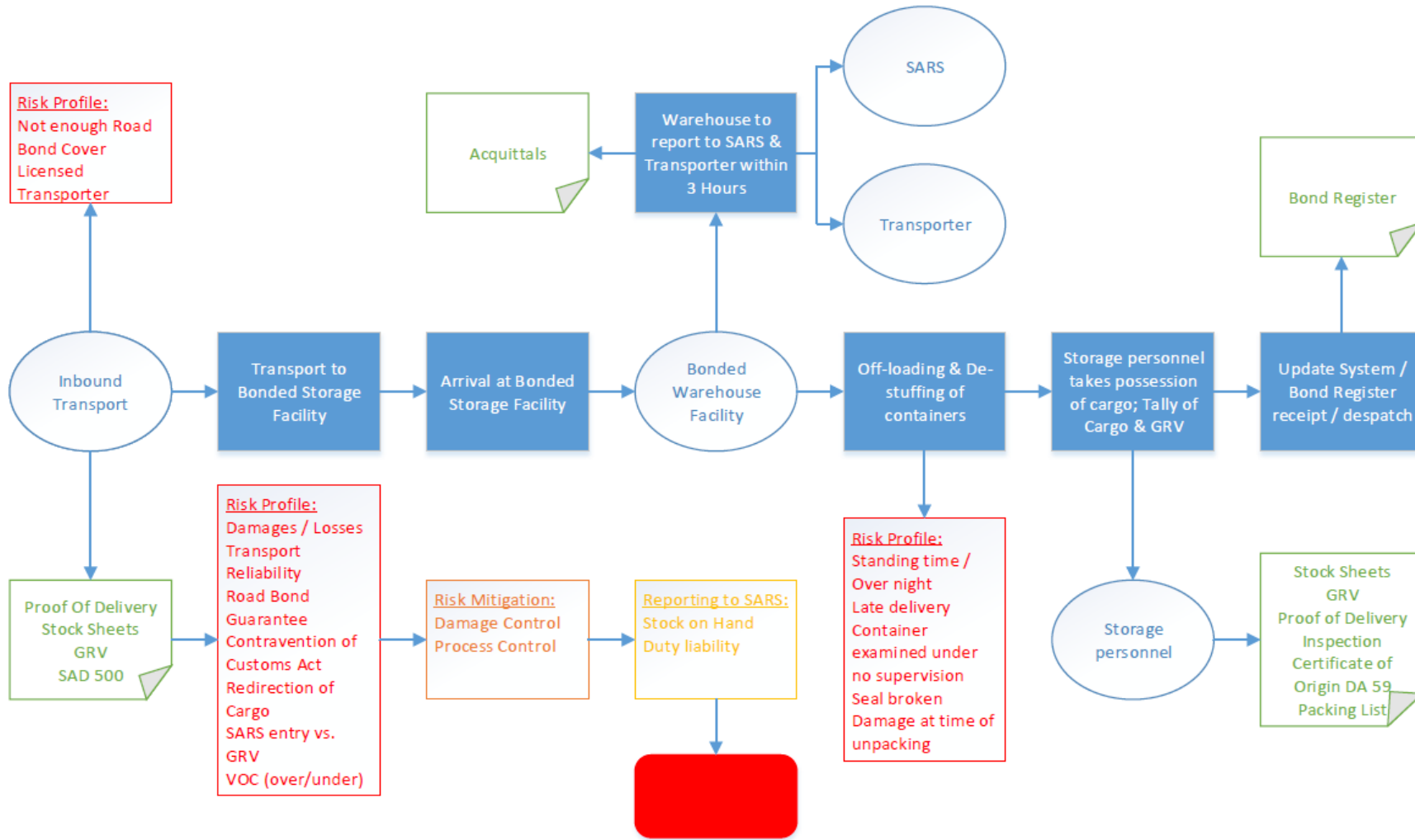
21 days before

Arrival at quay side



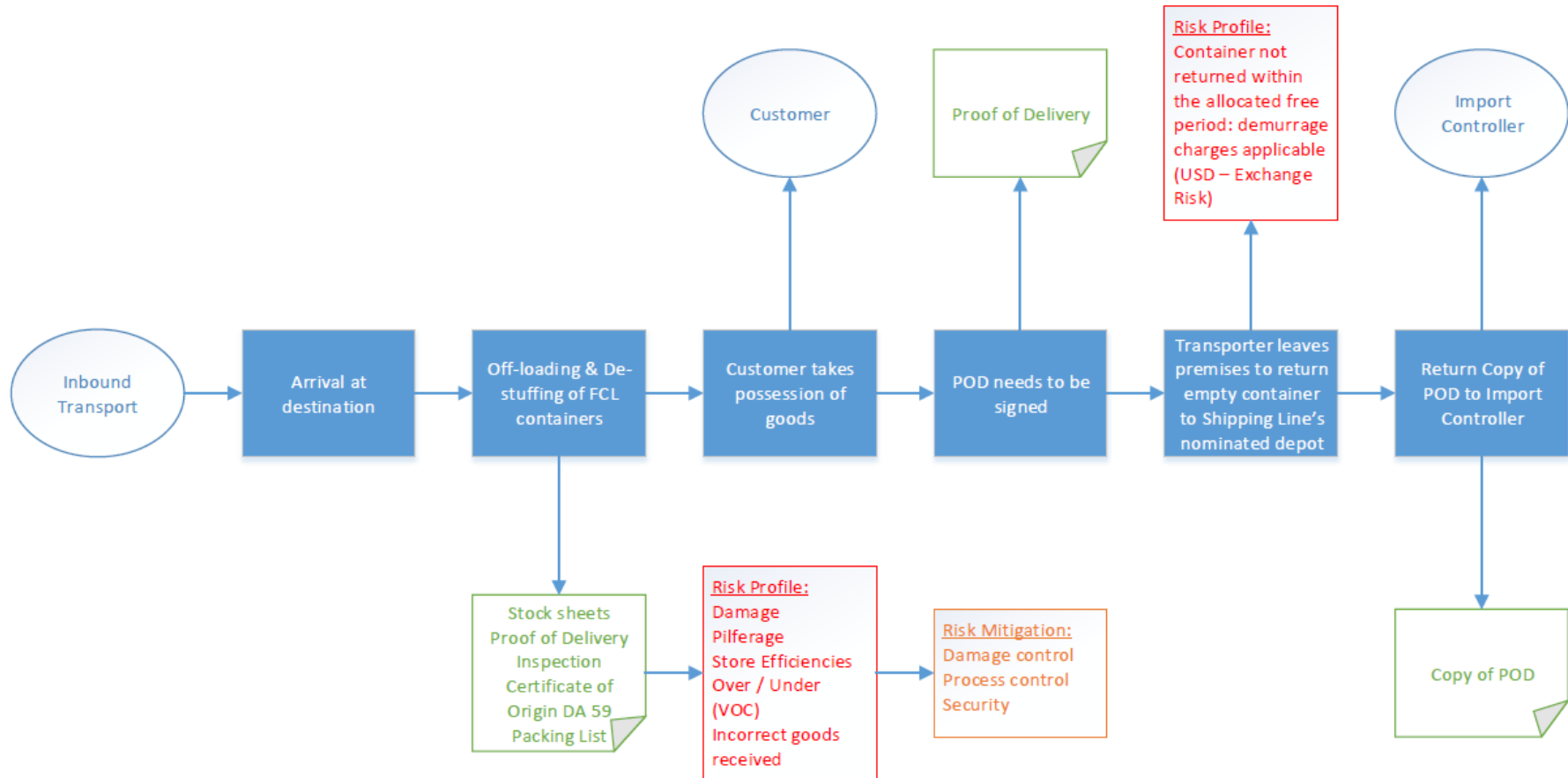
After Vessel discharge

**Import, Ocean, FCL to Port:
19. (b) Bond Storage**



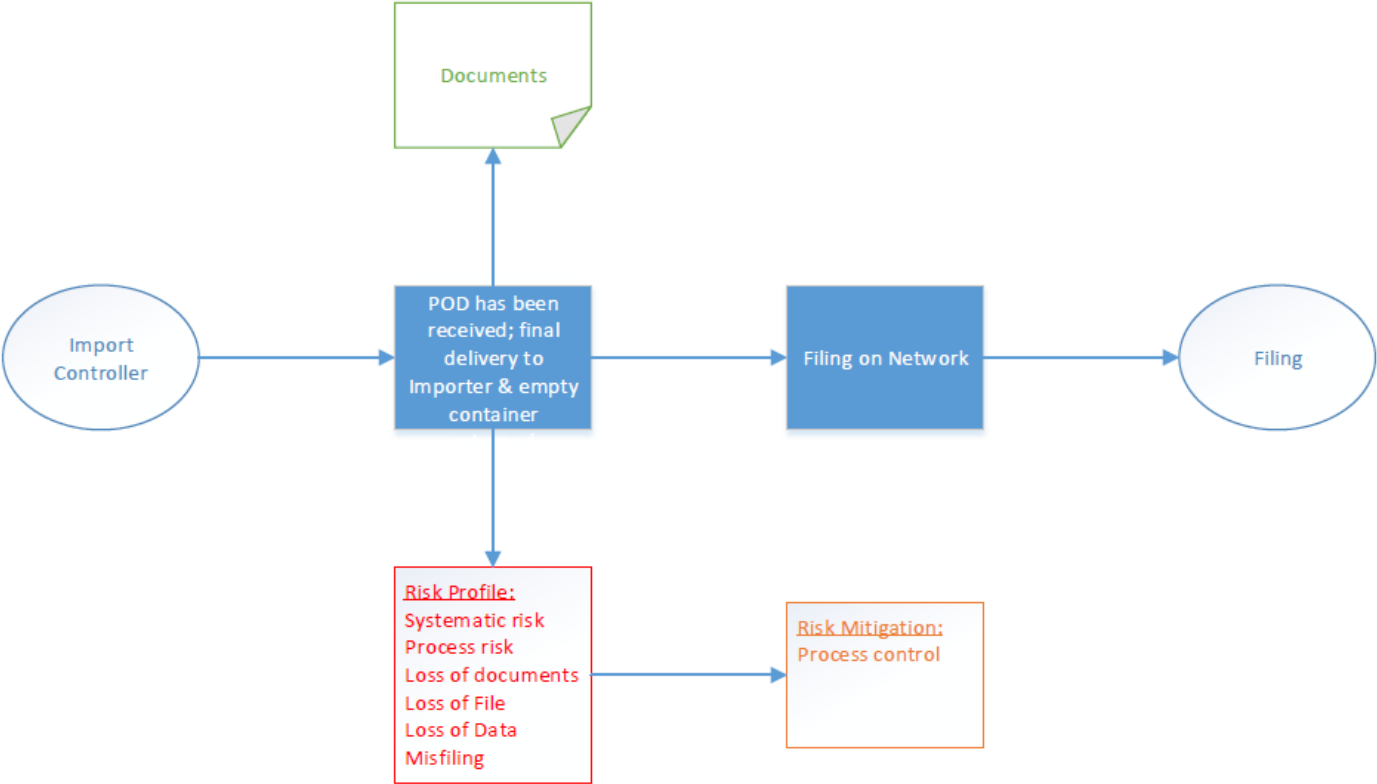
Acquittal 30 days; Bonded Storage 2 years

**Import, Ocean, FCL to Port:
20. Off-loading & De-stuffing**



Per Contract ETA

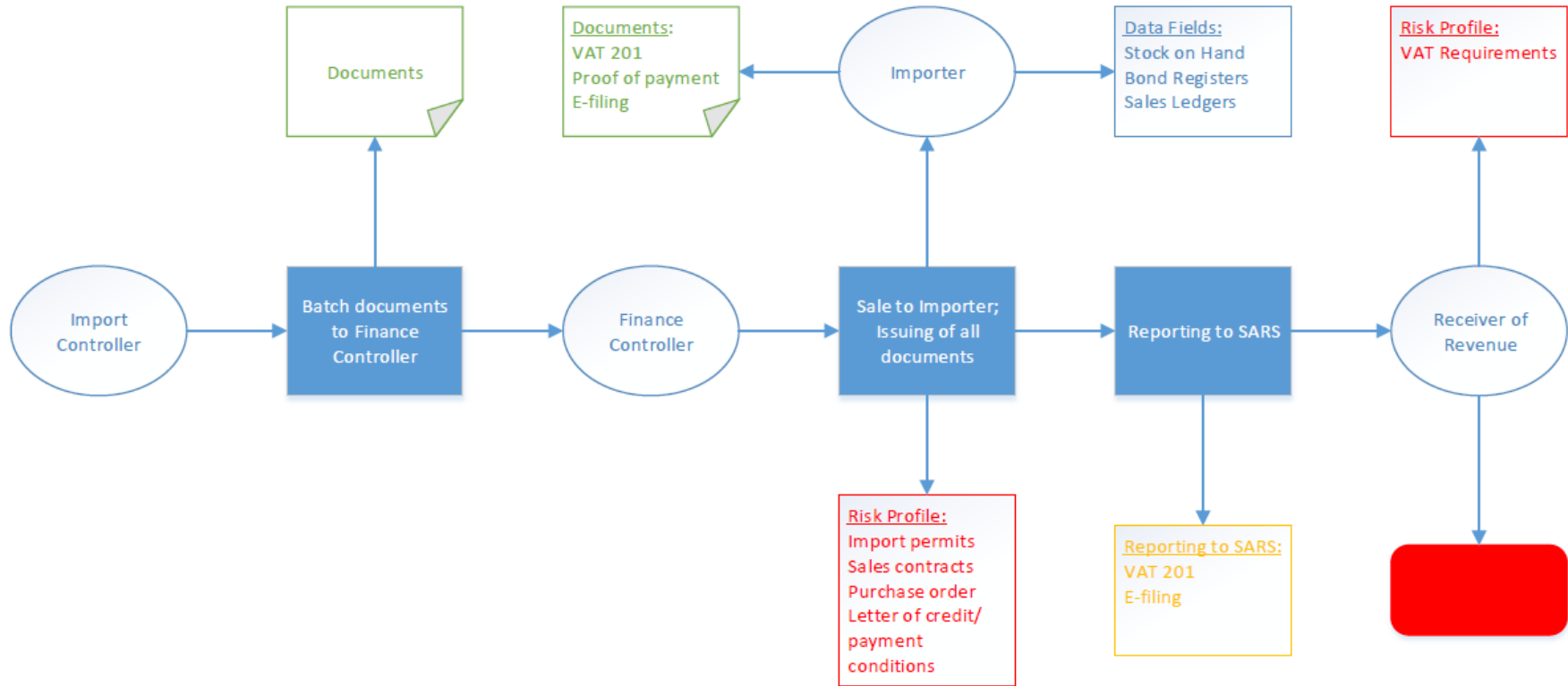
◀ Import, Ocean, FCL to Port:
21. Close File ▶



At close of order / Exchange of payment →

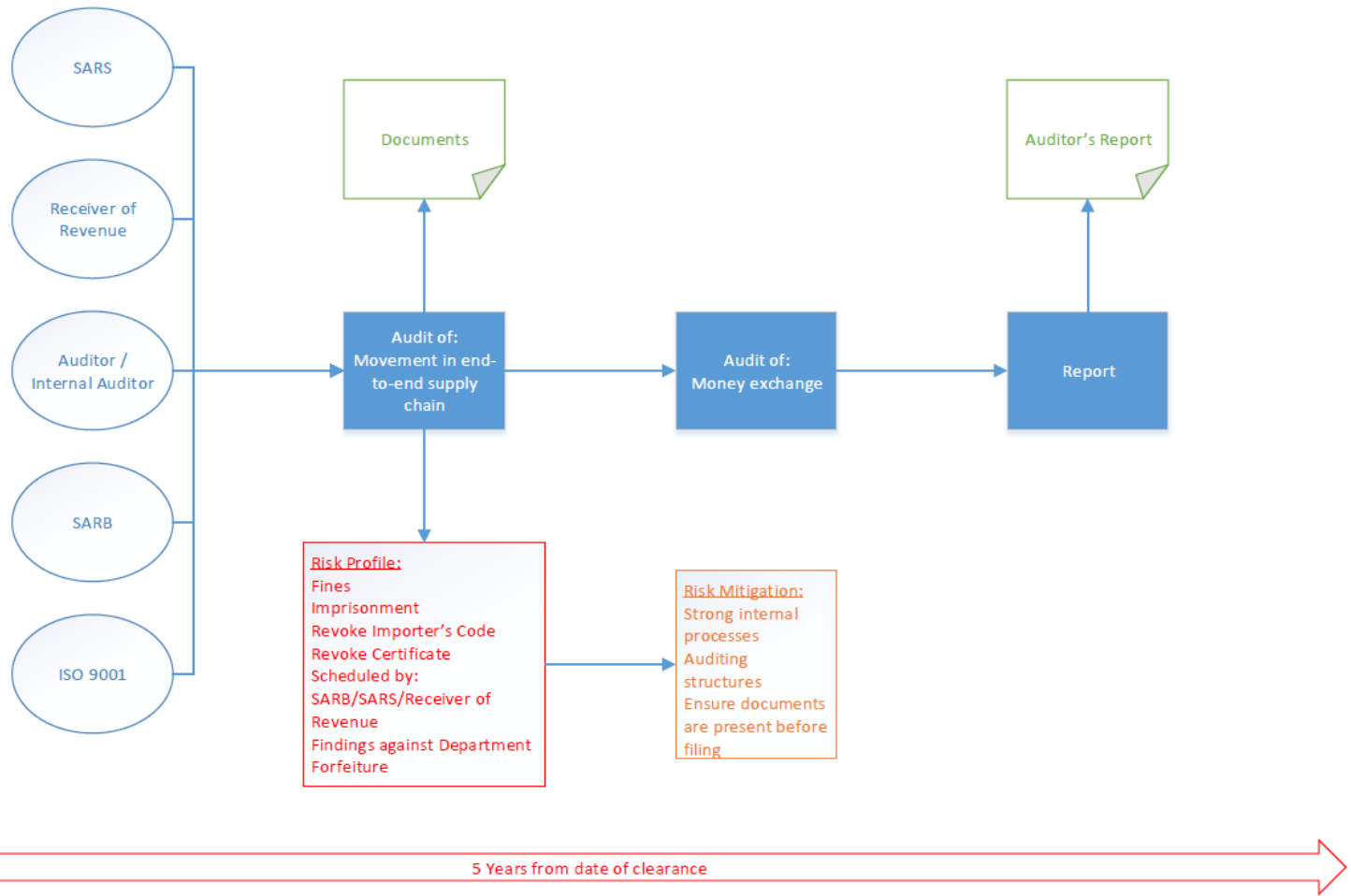
◀

**Import, Ocean, FCL to Port:
22. Receiver of Revenue**
▶



24/7 Rule
▶

**Import, Ocean, FCL to Port:
23. Post Facto Audit**



Source: Author's own compilation.