Risk Profile of Port Congestion:

Cape Town Container Terminal Case study

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Abstract

Supply chains, both complex and simple, are often exposed to various levels of risk stemming from different sources. These risks, whether minor or critical, require a certain level of management to mitigate and control frequency and overall impact. The South African maritime industry suffers from a number of risks, with the most prominent source of risk stemming from vessel and vehicle congestion within port terminals. In most cases, this is due to a lack of port capacity, lack of operator productivity, severe weather conditions and/or system-related challenges.

In South Africa, one of the most important ports – the Port of Cape Town – faces two risks associated with port congestion, namely, severe weather and system delays. These two risks place pressure on port management and can cause inefficiencies in both port operations and the operations of international shipping companies.

This study focuses on developing risk profiles of current and future port congestion within the Cape Town Container Terminal, with the primary objective being to highlight the importance of managing weather- and system-related port congestion within the container terminal. The secondary objective of the study is to suggest areas for future research on port congestion in other South African ports.

Overall, the purpose of this study is to offer some insight into port congestion as a risk to efficiency for the benefit of both South African ports and international shipping companies.

The research conducted for this study was done in two phases, namely, exploratory secondary research followed by self-conducted primary research. The secondary literature research provided background information on the maritime industry, the Port of Cape Town, and port congestion in the World and in South Africa specifically. In addition, the primary data collected was used to analyse current port congestion within the container terminal, create forecasts of future congestion, and finally develop risk profiles of port congestion within the Cape Town Container Terminal specifically.

The findings of this study indicate that vessel related congestion, specifically anchorage congestion, is the main risk within the Cape Town Container Terminal, while landside port congestion is likely to become a less severe risk over time. This is, however, likely to be influenced by truck queuing time and the 2015 truck ban, which were not included in this study. The findings of this study indicate that maritime-side risk is of greater concern, and that risk mitigation strategies should be considered in the present and the future.

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In conclusion, it is recommended that further research be conducted on the cost implications of port congestion, to determine the need for long-term financial investments, and on the impact of vehicle queuing and the proposed truck ban.

Furthermore, it is suggested that a similar study be conducted on port congestion within the Durban Port container terminal, as research indicates that this terminal is also prone to port congestion issues.

Keywords:

Cape Town Container Terminal; Container trucks; Ocean carriers; Operational risk; Port congestion; Risk profile; Weather and system-related port congestion.

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Opsomming

Voorsieningskettings, beide kompleks en eenvoudig, word gereeld aan verskeie grade van risiko uit verskillende bronne blootgestel. Hierdie risiko's, hetsy klein of krities, benodig 'n sekere vlak van bestuur om die frekwensie en algehele uitwerking te versag en te beheer. Die Suid-Afrikaanse maritieme industrie ervaar 'n aantal risiko's. Die mees prominente bron van risiko is die opeenhoping van skepe en voertuie binne hawens. In die meeste gevalle is dit as gevolg van 'n tekort aan kapasiteit, lae arbeidsproduktiwiteit, swaar weersomstandighede en/of stelselverwante uitdagings.

Een van Suid-Afrika se belangrikste hawens – Kaapstad-hawe – staar twee risiko's verwant aan hawe-opeenhoping in die gesig, naamlik swaar weersomstandighede en stelselvertragings. Hierdie twee risiko's plaas druk op hawe-bestuur en kan ondoeltreffendhede in beide hawebedrywighede en vir internasionale skeepsmaatskappye veroorsaak.

Hierdie studie fokus op die ontwikkeling van risikoprofiele van huidige en toekomstige opeenhoping binne die Kaapstad-houerterminaal, met die primêre doel om die belangrikheid van die bestuur van weer- en stelselverwante opeenhopings binne die houerterminaal te beklemtoon. Die sekondêre doel van die studie is om toekomstige navorsing in hawe-opeenhoping in ander Suid-Afrikaanse hawens voor te stel.

In die algemeen was die doel van hierdie studie om insig te kry in hawe-opeenhoping as 'n risiko tot doeltreffendheid, tot die voordeel van beide Suid-Afrikaanse hawens en internasionale skeepsmaatskappye.

Die navorsing vir hierdie studie het in twee fases plaasgevind, naamlik, ondersoekende sekondêre navorsing gevolg deur self-uitgevoerde primêre navorsing. Die sekondêre literatuurnavorsing verskaf agtergrondinligting oor die maritieme industrie, Kaapstad-hawe en hawe-opeenhoping in die wêreld en spesifiek in Suid-Afrika. Primêre data is gebruik om die huidige hawe-opeenhoping binne die haweterminaal te ontleed, vooruitskattings vir toekomstige opeenhoping te maak, en risikoprofiele van hawe-opeenhoping binne spesifiek die Kaapstad-houerterminaal te ontwikkel.

Die bevindinge van die studie dui daarop dat skeepverwante opeenhoping, meer spesifiek vasmeerplekopeenhoping, die vernaamste risiko in Kaapstad-houerterminaal is, terwyl landopeenhoping oor tyd 'n mindere risiko sal word.

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Hierdie sal egter moontlik deur voertuigtoustaantyd en die 2015-trokverbod beïnvloed word wat nie in hierdie studie in berekening gebring is nie. Die bevindinge van hierdie studie dui daarop dat maritieme risikoverligtingstrategieë huidiglik en vir die toekoms oorweeg moet word.

Ten slotte word daar aanbeveel dat verdere navorsing oor die koste-implikasie van hawe-opeenhoping gedoen moet word om die behoefte aan langtermyn finansiële beleggings te bepaal, en om die impak van voertuie wat toustaan en die voorgestelde trokverbod te bepaal. Daar word ook voorgestel dat ‘n soortgelyke studie op hawe-opeenhoping binne die Durban-hawehouerterminaal gedoen word, aangesien navorsing daarop dui dat hierdie terminaal neig na hawe-opeenhopingsprobleme.

Sleutelwoorde:

Kaapstad-houerterminaal; Houervragmotors; Skeepsrederye; Operasionele risiko’s; Hawe-opeenhoping; Risiko profiel; Weer- en stelsel- verwante hawe-opeenhoping.

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Last but not the least; I would like to thank my parents, my close friends and my devoted partner for their continuous support and motivation throughout the writing of this thesis and every other aspect of my life.

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List of Acronyms

3PL's	Third Party Logistics Providers
CTCT	Cape Town Container Terminal
DHCA	Durban Harbour Carriers' Association
FPT	Fresh Produce Terminal
GUI	Graphical User Interface
GVM	Gross Vehicle Mass
JIT	Just In Time
MAD	Mean Absolute Deviation
MPT	Multi-Purpose Terminal
MSC	Mediterranean Shipping Company
PSCD	Port-related Supply Chain Disruptions
RMG	Rail Mounted Gantry
RTG	Rubber Tyred Gantry
SADC	South African Development Community
SPARCS	Synchronous Planning And Real-time Control System
SSE	Sum of Squares for Forecast Error
TEU	Twenty-foot Equivalent Unit
TFR	Transnet Freight Rail
TNPA	Transnet National Ports Authority
TOS	Terminal Operating System
TPT	Transnet Port Terminals
TTAT	Truck Turnaround Time
VAT	Vessel Anchorage Time
VBT	Vessel Berthing Time
VWT	Vessel Working Time

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Chapter 1: Introduction

Maritime ports as a source of risk has long been an area of interest to both academics and those entities reliant on ports for trade purposes either internationally or coastally. The most prominent sources of risk specific to South Africa result from a lack of capacity, lack of productivity, severe weather conditions and port congestion (Richer, 2010:12).

This study centres on developing basic risk profiles of port congestion in South African ports and focuses on congestion within the Cape Town Container Terminal (CTCT) as a case study. The risk profiles focus on current port congestion, based on analysis of historical data, and future port congestion, based on five year forecasts. The purpose of the profiles is to highlight the importance of managing port congestion for the benefit of South African ports and international shipping companies.

This chapter briefly discusses background literature explaining the rationale behind the study and outlines the research problem statement and research objectives. Also discussed, is the significance of the study to the academic community, Transnet National Ports Authority (TNPA) and international shipping companies. Lastly, this chapter defines the scope and limitations of the research, including assumptions made and gives a brief outline of the chapters to follow.

1.1. Background Rationale for Study

Risks stem from various sources in the supply chain and all organisations, be it sole proprietors or large international companies, require a certain level of risk management to mitigate and control these risks. The risk management techniques used can contribute to the overall success of organisations as major supply chain disruptions are avoided (Young, 2014:12).

Risks stemming from internal supply chain activities and the external environment can be either controllable or uncontrollable. These risks can also be domestic or foreign depending on the type of organisation. One such risk that international companies, such as shippers, dealing in imports and exports should consider relates to maritime ports. Maritime ports are a vital link in the international supply chain as they perform two important functions, namely their function as a gateway for global trade, and their position as logistics nodes linking maritime trade to inland transport modes.

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South African maritime ports, such as the Port of Cape Town and the Port of Durban face a number of risks relating to capacity, productivity, port security, weather conditions and port congestion. All these risks place pressure on port management and can cause inefficiencies in both port operations and the operations of international shipping companies.

One of the most prominent risks experienced by South African ports is port congestion (Birkenstock, 2015; Davids, 2015 & Schultz, 2015:3). Unlike capacity, productivity and port security; port congestion is not taken as seriously during the risk management process. It is considered more a common daily occurrence than as a risk that could possibly be reduced. Port congestion is subsequently often not addressed in detail when port improvement and expansion plans are discussed as it is considered a “normal” daily occurrence.

In South Africa, the two most important ports are the Port of Durban and the Port of Cape Town, both of which experience port congestion at various times and due to various reasons. The Port of Cape Town is one of the most important maritime ports in South Africa as it facilitates the majority of trade within the Western Cape and acts as a multi-cargo port, servicing West Africa (De Wet, 2014:49). The majority of vessels serviced by the Port of Cape Town are container vessels, and these vessels must be serviced by a specialised container terminal (Transnet National Port Authority, 2013/14).

The container terminal at the Port of Cape Town faces two prominent risks, namely, severe weather conditions and port congestion. These two risks are, however, interlinked with port congestion resulting from the maritime-side (vessel related congestion) and the landside (container truck related congestion), which can cause major delays to both incoming and outgoing shipments. On the maritime-side, port congestion generally stems from severe weather conditions. These severe weather conditions include strong wind speeds, dense fog and large swells and are usually dominant over summer (December – February) and winter (June – August) months. However, as weather patterns are relatively unpredictable, one cannot plan based on this presumption, thus making maritime-side congestion relatively difficult to manage. With regards to the landside of the terminal, congestion is generally related to the movement of container trucks inside and outside the terminal as well as system-related challenges within the terminal. Container trucks are often subject to system delays and may face additional delays if the 2015 proposed truck ban[1] is implemented in the future. Therefore, port congestion experienced on the maritime-side and the landside of the terminal should be considered in more depth during the risk management process.

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[1] The proposed truck ban is discussed in further detail in section 5.4.2.

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1.2. Research Statement and Research Goals

The primary problem statement of this study is defined as follows:

> *To investigate the scheduling impact and frequency of maritime-side and landside port congestion experienced within the Cape Town Container Terminal in order to develop basic risk profiles of current and future port congestion.*

This research problem statement serves as a guide for the study and indicates the variables analysed, namely, maritime-side (vessel) congestion, landside (container truck) congestion, and congestion scheduling impact and frequency. The context of the study is also mentioned, with the case study taking place within the Cape Town Container Terminal (CTCT).

1.3. Objectives of the Study

To satisfactorily answer the problem statement, the study has been subdivided into objectives. The primary objective of the study is to solve the research problem statement, but in addition, more detailed secondary objectives are required to assist in achieving this goal.

These secondary objectives are as follows:

I. To investigate the current frequency of weather- and system-related congestion experienced by ocean carriers and container trucks.
II. To investigate the current scheduling impact of weather- and system-related congestion experienced by ocean carriers and container trucks.
III. To investigate the future frequency of weather- and system-related congestion likely to be experienced by ocean carriers and container trucks.
IV. To investigate the future scheduling impact of weather- and system-related congestion likely to be experienced by ocean carriers and container trucks.
V. To develop basic risk profiles of current and future port congestion.
VI. To briefly investigate the implications of the 2015 proposed truck ban.

All these secondary objectives are conducted within the context of the CTCT. The profiles are based on present and forecasted data, which should increase the accuracy of the profiles and allow for the basic template of port congestion risk to be used for other South African ports.

1.4. Significance of the Case study

Increasing volumes passing through the container terminals of many ports around the world continue to place pressure on both the capacity and operations of ports (Richer, 2010:12). In the case of the Port of Cape Town, current throughput volumes are ever increasing due to the expanding economy of the Western Cape (Transnet National Port Authority, 2013/14). This increasing demand for containerised goods places further strain on the terminal and its overall efficiency.

In addition to increased volume through the container terminal, the Port of Cape Town experiences severe weather conditions and system-related challenges, which impact the operational efficiency of the container terminal. These challenges relate to safety within the port, terminal operational efficiency, vessel congestion and vehicle congestion. These weather and system-related challenges have, according to David Davids[2] from Transnet Port Terminals (TPT), become inherent working conditions of the terminal and are deemed an increasing risk to port efficiency by TPT (Davids, 2015).

Solutions to these challenges include terminal expansion, diversion of vessels, and terminal equipment adjustment amongst others. However, it is important to note that these solutions come with certain limitations and drawbacks. Terminal expansion, for example, is not currently a viable option due to the infrastructure of the port and surrounding city, although plans have been developed (Birkenstock, 2015).

Current infrastructure limits access to ports such as the Port of Cape Town and, along with weather- and systems related challenges can result in traffic bottlenecks and congestion. The potential implementation of the 2015 truck ban will likely exacerbate congestion further with queuing bottlenecks outside the port (Freight and Trading Weekly, 2015:12). These bottlenecks can negatively influence the efficiency of both port operations and the operations of international shipping companies reliant on the container terminal. Future expansion plans have been suggested to alleviate the current capacity constraints. These plans are currently underway at the Port of Durban; however, plans for the Port of Cape Town are set for the distant future. In the meantime, weather- and system-related port congestion remains an ever present risk to operational efficiency in Cape Town’s container terminal (Transnet National Port Authority, 2013/14).

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[2] The current Key Account Manager for shipping lines at the Cape Town Container Terminal

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1.5. Scope and Limitations of the Study

For this research to be fully understood the scope and limitations of the study are discussed so as to avoid any misunderstandings regarding the size and context of the research.

This study was conducted within the container terminal of the Port of Cape Town for a number of reasons. Firstly, time and financial constraints on the researcher made the Port of Cape Town a more appropriate selection. The port is both accessible physically and has several individuals representing TNPA and TPT, willing to provide quantitative data and participate in qualitative interviews.

In addition to time and financial constraints, the Port of Cape Town was selected as future expansion plans for the container terminal are not set to begin until 2040. Durban port, however, is currently under expansion. The lack of expansion in the Port of Cape Town, in addition to increasing volumes of containers, places increased pressure on terminal facilities. This subsequently increases the likelihood of container truck bottlenecks and ocean carrier bunching.

The definition of port congestion used in this study focuses on weather- and system-related challenges which impact certain port operations and thus the turnaround of ocean carriers and container trucks. Port operations, in the case of this study, refer to those operations within the terminal such as berthing, loading, unloading and stacking of containers. These operations are divided between TNPA and TPT, and are discussed in further detail in section 5.2 of Chapter 5. Furthermore, this study emphasises the link between weather- and system-related issues and vessel/vehicle congestion, disregarding other factors which may influence congestion, such as human error or incompetence.

This study is further limited by the data collected during the course of the study. These limitations, along with methodology-related limitations are discussed in section 2.2.6 of Chapter 2.

The last consideration with regards to the scope and limitations of the research is timing. As discussed in section 1.1, the Port of Cape Town most commonly experiences severe weather conditions, and thus congestion, during specific times of the year. However, to develop a reliable and accurate risk profile, weather-related congestion experienced within a full one year period must be forecasted, thereby illustrating trends within weather-related port congestion forecasted for the future. System-related congestion challenges are similarly experienced sporadically. Thus this study was conducted to not only include peak periods of congestion, but also congestion experienced throughout the course of a full business year.

1.6. Assumptions in the Research

Along with the scope and limitations of the research it is important to clarify the assumptions made during the course of the research. This section highlights certain assumptions made with regards to key terminology and literature. Assumptions relating to the methodology of this study are discussed in section 2.2.6 of Chapter 2.

For the purpose of this study certain assumptions were made regarding specific definitions in literature. This included the two core concepts of the research - risk and port congestion. Risk and port congestion have a number of definitions derived by various academics and researchers, which can be seen in sections 3.1 and 4.1 of the literature review chapters. However, for ease of understanding, specific definitions were selected for this study and are described below.

Risk, for the purpose of this study, can be defined as *the consequences and benefits organisations encounter when making business decisions within an environment of uncertainty* (adapted from Purdy, 2010:882). These risks can be classified as either controllable or uncontrollable, with their degree of controllability determining the level of risk management required. Controllable risks can be managed through strategies designed for risk avoidance or elimination, while uncontrollable risks can only be managed if and when they occur with mitigation strategies.

The risks assessed and profiled in this case study are weather- and system-related port congestion. Port congestion in this case is deemed a manageable uncontrollable risk, as the occurrence of weather- and system-related issues are relatively unpredictable, whilst their impact is relatively constant and thus manageable. Chapter 3 discusses the theory of risk assessment, with specific reference to two measures, namely, risk frequency and risk impact. For the purpose of this study, the frequency of port congestion refers to the number of occurrences of weather- and system-related port congestion within the CTCT, whilst risk impact, or scheduling impact, refers to additional time spent in the CTCT due to weather delays or system delays. This is defined further to include the scheduling delays experienced by ocean carriers and container trucks.

With regards to this case study, port congestion can be defined as *bottlenecks, delays and other supply chain disruptions caused by several different factors.* These factors include insufficient capacity and productivity; bunching of vessels; vessel and vehicle scheduling clashes; severe weather conditions; and labour strikes (adapted from Schwitzer, Martens, Beckman & Sun Yoo. 2014).

This definition of port congestion is adapted further to disregard those factors not relating to weather- and system-related challenges and the movement of ocean carriers and container trucks. Therefore, other port congestion factors such as insufficient capacity and productivity, and human error and incompetence, are ignored. The CTCT currently operates at 70-80% capacity to ensure adequate space for the movement of containers into and out of the terminal, which minimises capacity-related congestion (Birkenstock, 2015).

This study was subsequently conducted under the assumption that port congestion within the CTCT is caused by weather- and system issues and results in delays in the turnaround time of ocean carriers and container trucks.

1.7. Reading Guide

The presentation of this thesis is given chapter by chapter below and briefly describes the contents of each individual chapter.

Chapter 2: Research Design and Methodology

Chapter 2 outlines the proposed research design used and the specific research techniques and methods utilised to answer the research objectives discussed in section 1.3 with the intention of answering the problem statement. In addition, this chapter includes the sampling techniques, research instruments, and data analysis techniques used to analyse current and future port congestion. This assisted in the development of the general risk profiles of current and future port congestion within the CTCT.

Chapter 3: Initial Literature Review

Chapter 3 introduces literature on general concepts discussed in the study for the purpose of background and further understanding. These concepts include risk, international trade, shipping and containerised trade in both an international and a South African context.

Chapter 4: Port Congestion and Risk

Chapter 4 follows on from Chapter 3 with literature defining port congestion in general, and the potential sources of port congestion. The chapter also discusses how port congestion is a risk to efficient operations and closes with an introduction to port congestion in South African ports.

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Chapter 5: Case study context - Port of Cape Town

Chapter 5 follows on from chapters 3 and 4 with literature pertaining to the context of the case study, namely, the history and current affairs of the Port of Cape Town. The chapter also takes a closer look at weather- and system-related port congestion experienced in the CTCT.

Chapter 6: Descriptive Data Analysis

Chapter 6 begins the data analysis portion of the thesis study with the analysis of current port congestion. The chapter includes a detailed descriptive analysis of the data collected, focusing specifically on the frequency of congestion and the scheduling impact of congestion. The chapter leads into the five year forecast of the future frequency and impact of port congestion.

Chapter 7: Forecasting Results and Discussion

Chapter 7 begins with a short introduction to the forecast analysis of future port congestion. The chapter goes on to introduce the five year forecasts of congestion in the context of the study. The chapter closes with a discussion of forecasted frequency and scheduling impact of port congestion expected to be experienced within the CTCT.

Chapter 8: Risk Profile and Discussion

Chapter 8 builds on Chapter 7 with a brief introduction to risk profiling and its significance to risk management. The chapter goes on to develop the risk profiles of port congestion based on current and forecasted data. The chapter briefly describes how the profile was developed and discusses the risk ranking which should be associated with current and future port congestion in the context of the study.

Chapter 9: Conclusions, Implications and Recommendations

Chapter 9 includes a brief summary of the findings of the research and discusses general conclusions regarding the main findings of the study. The chapter also details any implications the research may have and discusses recommendations for Transnet and shipping companies. The chapter closes with final remarks regarding the research and the study as a whole.

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Chapter 2: Research Design and Methodology

The research of this study was done in two phases, namely exploratory secondary research followed by self-conducted primary research. This chapter is subdivided into two sections representing these two research phases. The first section briefly identifies the key concepts and academic literature used to outline the scope of the study and the rationale behind the problem statement. The second section focuses on the primary research required to answer the research problem presented in section 1.2 of Chapter 1.

2.1. Secondary Research

The secondary research of this study includes the introduction and discussion of various concepts central to the understanding of the research. These concepts assist in highlighting the significance of the study and in the understanding of the results. For the purpose of this study, the secondary research, or literature review, is subdivided into three chapters for ease of reading and understanding.

The first literature chapter, Chapter 3, includes the initial literature review which introduces and defines concepts such as risk, supply chain risk, operational risk, international and containerised trade, and the shipping industry. The primary purpose of the chapter is to explain the importance of risk assessment and management, as well as discuss the significance of maritime ports with regards to international trade and shipping. The main argument of the chapter emphasises maritime ports as a source of risk and introduces the South African context, which leads into the next literature chapter on port congestion.

The second literature chapter, Chapter 4, continues the literature review with a discussion on port congestion, in the world and South Africa specifically. The chapter includes a discussion surrounding the definition of port congestion and identifies sources and consequences of congestion in maritime ports. The main argument of the chapter emphasises the significance of port congestion to the maritime-side and the landside of the port. The chapter concludes that port congestion can cause major time delays and thus negatively impact vessel and vehicle scheduling.

The final literature chapter, Chapter 5, focuses on the context of the case study, namely, the Port of Cape Town and the CTCT. The chapter includes a discussion on the significance of the Port of Cape Town to both global trade and the Western Cape economy.

This section is followed by a discussion focusing on the CTCT and its facilities and operations. Lastly, the chapter discusses port congestion on the maritime-side and landside of the container terminal.

The arguments developed in the literature review chapters emphasise the merit of primary research to develop risk profiles of current and future port congestion within the CTCT. The aim of the case study is to identify areas of improvement for the efficient operations of the CTCT and suggest a means to profile port congestion in other South African ports.

2.2. Primary Research

Primary research was required for this study due to the lack of prior research conducted on risk and port congestion. Thus, there was not sufficient literature available to answer the research problem of this study. In addition to the lack of literature, this study required raw data pertaining to the impact and frequency of port congestion, which could only be acquired from those entities directly influenced by congestion, namely, TNPA, TPT and various shipping companies.

"Methodological triangulation[3]" was used to conduct the primary research portion of this study. Quantitative data was used to determine the scheduling impact and frequency of port congestion and was subsequently used to forecast the scheduling impact and frequency over a period of five years.

Qualitative data derived from interviews was used, along with the forecasted results, to develop basic risk profiles of current and future port congestion within the context of the container terminal. The primary research methodology of the study was divided into three stages.

The first stage involved descriptive data illustrating the current scheduling impact and frequency of weather- and system-related congestion within the CTCT. The second stage included the development of a five year forecast and the descriptive analysis of the forecast, whilst the final stage investigated the development of risk profiles of current and future port congestion.

The following sections of this chapter outline the research methodology used to conduct the primary research element of the study.

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[3] Involves the use of multiple research methods, both quantitative and qualitative, to improve the accuracy of understanding (Blumberg *et al.* (2011:194).

Sections 2.2.1 to 2.2.3 discuss the sampling methods used to identify study participants; the research instruments implemented to collect the relevant data; and the different descriptive data analysis techniques used to derive meaning from the data collected. Sections 2.2.4 and 2.2.5 discuss the theory behind the five year forecast and the basic risk profiles of current and future port congestion within the CTCT; while section 2.2.6 outlines the assumptions and limitations encountered in the research methodology due to the nature of the study.

2.2.1. Sampling

Prior to the development and implementation of the appropriate research instruments required for data collection, the method of identifying willing study participants was determined. The sampling methods used for this study were chosen specifically with the scope and limitations of the study in mind.

Due to the limited availability of study participants and the narrow scope of the study, a non-probability sampling design was selected. As this study examines both the port perspective, and the shipping perspective (ocean carriers and container trucks), of port congestion, both viewpoints required adequate representation in the sample. Therefore, a combination of different non-probability sampling techniques was used. The combination of techniques used include judgement sampling, convenience sampling and snowball sampling. These techniques were used simultaneously to identify study participates who met the appropriate criterion and were willing and able to assist.

Judgement sampling, according to Blumberg *et al.* (2011:194), involves the identification of sample individuals based on certain appropriate criteria. For the purpose of this study, the criteria used for identification included the following:

1. Individuals or entities directly influenced by weather- and system-related congestion within the CTCT.
2. Individuals or entities representing either the port or shipping perspective of port congestion.
3. Individuals or entities both willing and able to contribute to either the qualitative or quantitative aspects of the study.

Convenience sampling, according to Blumberg, *et al.* (2011:194), is considered the least reliable form of non-probability sampling. However, for the purposes of this study, convenience sampling allowed the researcher the freedom to identify those individuals both willing and able to assist in the research as previously mentioned in the third criterion of judgement sampling.

Lastly, the snowball sampling technique allowed for easier identification of study participants as the technique allows the originally identified participants to identify and locate others adhering to the judgement sampling criterion mentioned previously (Blumberg, *et al.* 2011:196). The combination of judgement, convenience and snowball sampling techniques resulted in the identification of several individuals and entities.

For the port perspective of weather- and system-related port congestion, Transnet was approached as Transnet owns and manages all the ports in South Africa. However, for the purpose of this study, individuals from both TNPA and TPT division were required in order to obtain a more holistic view of port congestion within the CTCT. Interviews with TNPA individuals were required to obtain an overall view of congestion within the entire port, whilst interviews with TPT individuals were required to provide a more specific view of congestion within the CTCT.

For the shipping perspective of port congestion, various ocean carrier and trucking companies were approached to assist with the study. However, due to time constraints and a lack of willingness to participate, only a small sample was obtainable. Maersk Line, in association with Safmarine; Berry & Donaldson Shipping/Trucking; and Mediterranean Shipping Company (MSC) were among the few companies that responded to the request for assistance.

Data collection, in the form of research instruments, resulted in both qualitative and quantitative data from the previously mentioned study participants. This is discussed in the following section.

2.2.2. Research Instruments

The research instruments used for this study were chosen with the scope and limitations of the study in mind. Access to the willing study participants identified during sampling was also considered when developing the means of data collection. Due to the research design selected for this study, namely, “methodological triangulation”, more than one data collection instrument was required to maximise the accuracy and validity of the data collected.

The research instruments used for the qualitative portion of the primary research included personal interviews and email correspondences, whilst the quantitative research element was fulfilled through the collection of Excel data sheets from study participants pertaining to the movement of ocean carriers and container trucks, weather delays and system delays.

The data collection was conducted using two different interview templates (Addendum A and Addendum B) with general questions designed specifically for the different entities. The templates were aimed at addressing the two perspectives of port congestion, namely, the port perspective and the shipping perspective. These interview templates included questions designed to determine to what extent the Port of Cape Town and various shipping/trucking companies found port congestion a risk to efficiency. These interviews, either personal or via email, were used to supplement the literature and assist in developing the risk profiles of current and future port congestion. The interviews were also intended to broaden understanding of the importance placed on the scheduling impact and frequency of port congestion, thus assisting in the coding system of impact and frequency as discussed later in section 2.2.5.

The quantitative data collected came in the form of Excel data sheets. These data sheets were acquired from most study participants; however, certain of them could only provide qualitative data (refer to Table 2-1). Table 2-1 briefly outlines the study participants, the perspective of port congestion represented by each, and the data obtained.

Table 2-1: Study participant information

Study Participant		**Perspective of Port Congestion**	**Data Obtained**
Entities	**Representative**		
TNPA	Coen Birkenstock	Port of Cape Town: weather- and system-related congestion	Qualitative: Interview
	Lorraine Tabo		Quantitative: port/ terminal data Qualitative: Emails
TPT	David Davids	CTCT: weather- and system-related congestion	Quantitative: frequency and scheduling data Qualitative: Interview
	Pamela Yoyo		Qualitative: Telephonic Interview
	Shaun Julius		Quantitative: frequency and scheduling data Qualitative: Telephonic Interview
Safmarine	Kerry Melville	Shipping Company: ocean carriers	Qualitative: Interview
Maersk Line	Genio Marais	Shipping Company: ocean carriers	Qualitative: Interview
MSC	Rob Mcewan	Shipping Company: ocean carriers	Qualitative: Interview
Berry & Donaldson	Chris Lane	Shipping Company: trucking	Qualitative: Emails

Representatives from TNPA and TPT provided Excel data sheets containing frequency and scheduling data for the container terminal pertaining to vessel and truck movement. These data sets included truck turnaround time (TTAT), vessel anchorage time (VAT), vessel berthing time (VBT) and vessel working time (VWT). The TTAT data set pertained to the movement of container trucks inside the terminal and referred to the time taken from entry at the gate, to exit from the gate. The VAT, VBT and VWT data sets pertained to vessel movement from arrival outside the port, to rope-on/rope-off[4], and exit from the port.

This data was confirmed to be interval, time series data with the TTAT data spanning approximately five years (January 2011 – November 2015), and the vessel related data (VAT, VBT and VWT) dating from March 2011 to November 2015. This data collected was used to determine the current frequency and scheduling impact of port congestion. Examples of this data are illustrated in Addendums C and D.

In addition to these data sheets, TPT representatives were able to provide Excel data sheets containing the time impact (in hours) of weather- and system-related congestion within the CTCT specifically. This data was similarly identified as interval, time series data, with the weather delays data spanning a period of nine years (January 2006 – December 2014), and the system delays data spanning approximately six years (September 2009 – December 2014). Examples of these data sets are illustrated in Addendums E and F**.**

For the shipping perspective of port congestion, Maersk Line and MSC provided background knowledge with regards to the scheduling impact of port congestion on ocean carriers. This was linked to the data sets obtained from TNPA and TPT. In addition to the ocean carrier element of the shipping perspective, Berry & Donaldson provided background information with regards to the scheduling impact of port congestion on container trucks. This expert knowledge, similar to the ocean carrier information, was used in collaboration with the data sets obtained from TNPA and TPT.

The following section of this chapter discusses the descriptive methods used to analyse the above mentioned quantitative data to investigate current port congestion within the CTCT.

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[4] Also known as vessel berthing time (VBT), and refers to the time from when the port pilot secures the vessel for loading/offloading to when the vessel sets sail from the port.

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2.2.3. Descriptive Analysis Methodology

The descriptive analysis of the quantitative data focused on two elements of port congestion, namely, the frequency of occurrences and the scheduling impact. Frequency and scheduling impact were analysed separately using both graphical and numerical descriptive statistics.

The following sections discuss the statistics, measures and techniques used, and how each element was analysed individually. The results of the analysis are presented and discussed in Chapter 6.

❖ *Graphical and Numerical Descriptive Statistics*

The frequency and scheduling impact of port congestion were analysed using both numerical and graphical descriptive statistics. However, before frequency and scheduling impact could be analysed the individual data sets collected were analysed. All graphical and numerical statistics computed for the different data sets were done using Microsoft Excel. The VAT, VBT, VWT, TTAT, weather delays and system delays data sets were analysed as follows:

- Firstly, the observations of the different data sets were plotted on time series line charts to illustrate any trends[5] or patterns in the data.
- Secondly, the numerical descriptive statistics were used to compute a number of measures. These measures were required to describe the central tendency of the data, the variation of the data and develop further graphical statistics.
- Lastly, further graphical statistics were developed, such as frequency tables and histograms.

The first graphical statistics used to analyse the individual data sets were line charts. These were computed by selecting all the observations of the data set and inserting a line chart. Each line chart was then adjusted to have the time period (date) of the observations shown on the x-axis. In addition, trend lines were inserted into each chart to indicate the presence of any upward or downward trends in the data sets. Secondly, each data set was analysed using numerical descriptive statistics.

The Excel output of descriptive statistics was obtained by selecting Tools - Data Analysis - and then the "*descriptive statistics"* option. The measures calculated by the analysis tool are shown in Table 2-2.

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[5] The trends displayed are, however, only a guideline. The risk severity calculations done for each data set, later in this study, include more detail and are more accurate indications of trend.

Table 2-2: Output of “*descriptive statistics*” Excel tool

Descriptive Statistical Measures		
Mean	Sample variance	Maximum value
Standard error	Kurtosis	Sum
Median	Skewness	Count/Number of Observations
Mode	Range	Confidence Level (95.0%)
Standard deviation	Minimum value	

Of the statistical measures shown in Table 2-2, only certain measures were used to analyse the individual data sets. Before these measures can be discussed, however, certain statistical notation used must be explained. Table 2-3 presents the statistical notations used and what they represent.

Table 2-3: Description of Statistical Notations

Statistical Notation	**Representation**
$\bar{x}$	Sample mean
$\sum_{i=1}^{n}$	Sum of variables
x_i	Variable
n	Sample size
s^2	Sample variance
s	Sample standard deviation
k	Standard deviation in Chebysheff’s Theorem
CV	Coefficient of variation
y_t	Actual variable
F_t	Forecasted variable

The central tendency of the data was determined through the use of two statistical measures shown in Table 2-2; namely, the mean and the median. The *mean*, or average, is calculated by summing all the data observations and dividing by the total number of observations (Keller & Warrack, 2003:93).

Generally, the sample mean is denoted as $\bar{x}$ with the number of observations denoted as *n*. The manual formula for the sample mean is known as (Keller & Warrack, 2003:94):

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

The mean does, however, have one flaw. The mean can be influenced by extremely high or extremely low observations, known as outliers. To overcome this shortfall and improve the quality of the statistics another measure of central tendency, the *median*, was used.

The median refers to the data observation which falls in the middle of the data set after being placed in ascending or descending order. As this value is an actual observation found in the data set, it is not influenced by outliers and therefore may be a more accurate measure than the mean (Keller & Warrack, 2013:95, 98).

The measure of central tendency is an important measure in this study as it, in conjunction with other graphical statistics, is used to determine the shape of the data sets and the spread of the observations (Keller & Warrack, 2013:93, 98). Generally, the following applies (Nel, 2015):

$$\begin{aligned} &where: \quad && \bar{x} > median \quad && the\ data\ set\ is\ considered\ positively\ skewed \\ & && \bar{x} < median \quad && the\ data\ set\ is\ considered\ negatively\ skewed \end{aligned}$$

When a data set is said to be skewed, this implies that the majority of observations fall to either the left or the right of the histogram (Keller & Warrack, 2013:37). Positively skewed data sets fall to the right and often result due to unusually high values, while negatively skewed data sets fall to the left and result from unusually low values. In addition, where the mean does not equal the median, this can suggest that outliers exist. This can only be confirmed graphically using a histogram (Nel, 2015). The graphical statistics used to determine the shape and spread of a data set are discussed later in this section.

In addition to central tendency, it is important to determine the variation of the data collected (Keller, 2012:108). This can be determined through the use of a number of statistical measures, however, for the purpose of this study only two measures were used, namely, the standard deviation and the coefficient of variation (Keller, 2012:108). The *standard deviation* is the square root of the variance. The formula for variance, denoted by s^2, is:

$$s^2 = \frac{\sum (x - \bar{x})^2}{n - 1}$$

The variance is a more difficult measure to interpret as it is not presented in the same units as the sample. In addition, it provides a limited view of the amount of variation in the data. The standard deviation, however, allows for a more understandable interpretation of variation (Keller & Warrack, 2013:105) as it is computed in the same units as the sample. The standard deviation of a sample is denoted by s and is calculated using the following formula (Keller & Warrack, 2013:105):

$$s = \sqrt{s^2}$$

Depending on the shape of the histogram, found during the graphical analysis, the standard deviation can be interpreted to extract useful information (Keller & Warrack, 2013:106). For the purpose of this study, the Chebysheff's Theorem was used as it can be applied to histograms of all shapes (Keller & Warrack, 2013:107).

The Chebysheff's Theorem indicates the proportion of sample observations which lie within *k* standard deviation (mentioned in Table 2-3) of the mean for $k > 1$, or any positive number greater than one (Shafer, D.S & Zhang, Z. 2012:97). This value is, however, only the lower bound on the proportions contained in the data intervals (Keller & Warrack, 2013:107). The formula for the theorem is as follows (Keller & Warrack, 2013:107):

$$\left(1 - \frac{1}{k^2}\right) \times 100$$

The second measure of variation used in this study, but not featured in Table 2.2, is known as the coefficient of variation. This measure assists in determining the magnitude of the variation in the data set (Keller & Warrack, 2013:107). The coefficient of variation (*CV*) is computed by dividing the standard deviation of the data set (s) by the mean ($\bar{x}$). This value indicates the percentage of variation around the mean found in the data collected (Keller, 2012:115). The formula for sample coefficient of variation is (Keller & Warrack, 2013:107):

$$cv = \frac{s}{\bar{x}} \times 100$$

Following the numerical descriptive statistics, each data set was analysed using frequency tables and histograms. Frequency tables and histograms generally involve counting the number of observations that fall into a series of intervals (or classes), which cover the entire range of observations. The number of classes, sufficient for the observations within a data set, is determined by a formula known as Sturges' Formula, where n is the number of observations within a particular data set (Keller & Warrack, 2013:35). The formula is as follows (Keller & Warrack, 2013:35):

$$Number\ of\ classes = 1 + 3.3\log(n)$$

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After the determination of the number of classes, the width of the classes was determined. Class width is calculated using the following formula (Keller & Warrack, 2013:36):

$$Class\ width = \frac{range\ of\ data}{number\ of\ classes}$$

After the determination of the number of classes and class width the frequency tables and histograms were computed using the "*histogram*" function (with chart output) of the Excel data analysis tool.

From the frequency tables and histograms, the shape and spread of each data set was determined. As mentioned previously, data sets and histograms can be symmetrical, positively skewed or negatively skewed. Positively skewed histograms have long tails extending to the right, while negatively skewed histograms have tails extending to the left.

The resulting descriptive statistics computed for the data sets were subsequently used to determine the frequency of port congestion and the scheduling impact of port congestion. These elements of port congestion are discussed in the following two sections.

❖ *Frequency of Port Congestion*

The frequency of congestion was determined for a set period for each data set. The VAT, VBT, VWT and TTAT data sets were analysed from 2011 to 2015, while the weather delays and system delays data sets were analysed from 2011 to 2014. As mentioned earlier, each data set collected was analysed using graphical and numerical descriptive analysis techniques. The most prominent of these techniques included line charts, frequency tables and histograms.

The frequency of port congestion can be measured in a number of ways. For the purpose of this study, and specific to this case study, the frequency of port congestion was taken to refer to the number of observations (in percentage form) exceeding the trend line of the data. These percentages of incidences per year were considered relative to the average of all the years featured in the data series and were thus only an indication of the frequency of port congestion incidences. Therefore, it is important to note that there are likely more accurate and appropriate means of determining the frequency of port congestion. This method was, however, the most appropriate given the data collected in this study.

Table 2-4, shows how each data set was interpreted with regards to the frequency of port congestion within the CTCT.

Table 2-4: Interpretation with regards to the frequency of port congestion

Data Set	**Interpretation of Results**
VAT	Percentage of incidences experienced by ocean carriers during anchorage
VBT	Percentage of incidences experienced by ocean carriers during berthing
VWT	Percentage of incidences experienced by ocean carriers during offloading/loading of containers
TTAT	Percentage of incidences experienced by container trucks during offloading/loading of containers
System delays	Percentage of system delays experienced by ocean carriers and container trucks
Weather delays	Percentage of weather delays experienced by ocean carriers and container trucks

It is important to note that the above analysis was based on historical data and as a result is only representative of past experiences of congestion frequency. Therefore, a similar analysis was done on the forecast of congestion frequency. This is discussed in further detail in section 2.2.4.

- ### *Scheduling Impact of Port Congestion*

For the analysis of the scheduling impact of port congestion, the descriptive techniques were used to determine the amount of additional time or delays experienced by ocean carriers and container trucks within the CTCT. This included additional time experienced in the turnaround of ocean carriers and container trucks, as well as additional delays caused by system and weather-related congestion.

In addition to the mentioned graphical statistics, each data set was analysed using bar charts to illustrate the additional time or delays experienced over the past four years. This gave an indication of the scheduling impact on ocean carriers and container trucks. Table 2-5, shows how each data set was interpreted with regards to the scheduling impact of port congestion within the CTCT.

Table 2-5: Interpretation with regards to the scheduling impact of port congestion

Data Set	Interpretation of Results
VAT	Additional time experienced by ocean carriers during anchorage
VBT	Additional time experienced by ocean carriers during berthing
VWT	Additional time experienced by ocean carriers during offloading/loading of containers
TTAT	Additional time experienced in the turnaround time of container trucks
System delays	Delays experienced by ocean carriers and container trucks due to system-related congestion
Weather delays	Delays experienced by ocean carriers and container trucks due to weather-related congestion

It is important to note that, similar to frequency, the above analysis was based on historical data and is only representative of the past scheduling impact of port congestion. Therefore, a similar analysis was done on the forecast of scheduling delays. This is discussed in further detail in the following section.

2.2.4. Forecasting Methodology

The primary aim of this study is to develop risk profiles of current and future port congestion. These risk profiles were based firstly on the analysis of historical data (2011 - 2014 and 2011 - 2015), and secondly on the analysis of a five year forecast of the scheduling impact and frequency of port congestion.

The forecasted scheduling impact and frequency of port congestion was determined through the use of a specific forecast model, identified with the assistance of a statistical expert, Professor Daan Nel of Stellenbosch University. Together with Prof Nel's assistance the most accurate and appropriate forecast model was determined through a number of steps.

The first step involved the development of time series line charts or sequence plots of the data to be forecasted. The purpose of the time series line chart was to firstly visually represent the data set and, secondly, indicate whether certain behavioural components, such as trends and seasonality, exist. The presence, or absence, of trends and/or seasonality determined the selection of a forecast model for the production of the best possible forecast.

The second step of the forecast process involved the development of several competing forecasting models. These included the Moving Averages[6] method and Exponential Smoothing models such as Simple Exponential Smoothing[7], Holt's Exponential Smoothing[8] and Winter's Exponential Smoothing[9]. Certain of these models were immediately deemed inappropriate based on the presence and/or absence of trends and/or seasonality. These models deemed inappropriate included the Moving Averages method and the Simple Exponential Smoothing method as both methods are appropriate for stationary data, whilst the data in this study exhibited both trends and seasonality.

This left Holt's Exponential Smoothing method and Winter's Exponential Smoothing method, with Holt's method being appropriate for data exhibiting a trend and/or seasonality, and Winter's method being appropriate for data exhibiting both trend and seasonality. Each model was subsequently tested to determine which had the best accuracy measure and would produce the best possible forecast. This was done by a statistical expert (Prof Daan Nel from the Centre of Statistical Consultation at Stellenbosch University) and is not discussed in detail in this study.

Accuracy calculations used included the Mean Absolute Deviation (MAD) and the sum of Squares for Forecast Error (SSE). The MAD calculation averages the absolute differences between the actual values in the time series, and the forecasted values of the model (Keller, 2012:802). The formula for the MAD is as follows (Keller, 2012:802):

$$MAD = \frac{\sum_{i=1}^{n} |y_t - F_t|}{n}$$

The SSE calculation, on the other hand, is the sum of the squared differences and is used to avoid large errors as it penalises large data deviations more severely than the MAD calculation (Keller, 2012:802). The formula for the SSE calculation is as follows (Keller, 2012:802):

$$SSE = \sum_{i=1}^{n} (y_t - F_t)^2$$

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[6] Forecasting method applied to stationary data, involves averaging the closing value of a number of time periods and then dividing this total by the number of time periods (Wilson, Keating & John Galt Solutions, Inc., 2009:102).

[7] Uses past values to forecast weighted averages when there is no trend or seasonality present (Wilson, *et al*., 2009:107).

[8] Is an extension of simple exponential smoothing, as it adds a growth factor (or trend factor) to the smoothing equation to adjust for a potential trend (Wilson, *et al*., 2009:112).

[9] Is the second extension of the basic smoothing model, as it is used for data that exhibits both trend and seasonality (Wilson, *et al*., 2009:118).

The results of the above accuracy calculations done on the Holt's and Winter's forecasts, and the presence of both trend and seasonality, suggested that the most appropriate and accurate forecast model was a combination of the two methods, namely, Holt-Winter Forecasting (Nel, 2015). This was due to the presence of both trend and seasonality and to predict the most accurate forecasts possible (Nel, 2015). It is, however, important to note that Holt's method of forecasting does have one disadvantage, namely, that it generates forecasts with slight upward trends, which may influence the interpretation of the forecast (Nel, 2015). This weakness was, however, considered during the analysis of the forecasts in Chapter 7.

Following the selection of the most appropriate forecasting model, and prior to the prediction of the five year forecasts, certain model specifications were determined. These specifications included which variables to include, which seasonal periodicity to use and what parameter values to use for the forecast. For the purpose of this study, the variables included were the date of the observation and the value of the observation itself, whilst the forecast was done using a twelve-month periodicity (shown as L in the parameter and Holt-Winter forecast formulae).

The parameters required to compute the forecasts included an overall smoothing parameter, a parameter for smoothing the trend factor, and a parameter for smoothing the seasonal index (Wilson, *et al*., 2009:120). To compute these parameters, relatively long data series are required, which were not available for this study. Therefore, the *ForecastX* programme was used as it chooses the three best fitting parameters (it does not give the parameters explicitly[10]) and then produces the forecast based on the observed time series (Nel, 2015). Due to the nature of the data sets obtained in this study, it was determined that the multiplicative Holt-Winter forecasting method be used. According to Kalekar (2004:2), the multiplicative method is used when the seasonal fluctuations of the data set varies depending on the overall level of the series.

The manual formula for the Holt-Winter multiplicative forecasting method used in this study is shown below with the notation table contained in Table 2-6 (Wilson, *et al.* 2009:120):

$$\hat{Y}_{1+n} = (E_t + nT_t)S_{t+n-L}$$

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[10] Therefore, the parameters of the forecasts are not available and thus not featured in this study.

Where:

Overall smoothing parameter is: $E_t = \alpha\left(\frac{Y_t}{S_{t-L}}\right) + (1 - \alpha)(E_{t-1} + T_{t-L})$

Trend smoothing parameter is: $T_t = \beta(E_t - E_{t-1}) + (1 - \beta)T_{t-1}$

Seasonal index smoothing parameter is: $S_t = \gamma\left(\frac{Y_t}{E_t}\right) + (1 - \gamma)S_{t-L}$

Smoothing constants being: $0 \leq \alpha, \beta, \gamma \leq 1$

Table 2-6: Description of Statistical Notations

Statistical Notation	Representation
E_t	Deseasonalised level
α	Deseasonalised level smoothing constant, Alpha
Y_t	Actual variable
S_t	Seasonal index
β	Trend smoothing constant, Beta
γ	Seasonal index smoothing constant, Gamma
n	Forecast period (i.e. 1, 2 ….)
L	Seasonal periodicity
$\hat{Y}_{t+n}$	Forecasted variable

Although the selection of the Holt-Winters parameters are done automatically by *ForecastX* and are not reported in the program, the accuracy of the forecasts were considered acceptable by the statistical expert (Nel, 2015). The forecast accuracy measures for VAT, VBT, VWT and TTAT are shown in Addendum G - J.

The final step involved the prediction of the five year forecasts based on the historical data collected. According to statistical expert, Prof Daan Nel (2015), to predict a relatively accurate forecast, the forecast should be predicted using a minimum of 60 usable observations within the data set. Of the data sets collected, all adhere to this minimum requirement.

After the completion of the five year forecasts the forecasted results were analysed using descriptive analysis techniques similar to those done on the historical data discussed in section 2.2.3. This included frequency tables, histograms and bar charts of the forecasted congestion frequency and scheduling impact. The following section explains the methodology used in developing the risk profiles of current and future port congestion.

2.2.5. Risk Profile Methodology

The risk assessment process used in this study followed a number of steps which are covered in section 3.1.1 of Chapter 3. For the purpose of this study, however, certain of the steps were not included. The first step of risk assessment generally includes *risk identification* which, for the purpose of this study was not included, as the study focuses on port congestion as a risk factor. Therefore, this step was overlooked. However, the second and third steps of the risk assessment process, namely, *risk quantification and prioritisation*, and *risk evaluation*, form the basis of the development of the port congestion risk profiles and are conducted in detail.

The last step in the process, *risk treatment*, was also overlooked as the purpose of this study is not to develop solutions to port congestion. For this reason, the first step in the risk assessment of port congestion in this study involves the quantification and prioritisation of port congestion as a risk, and the second and final step involves the evaluation of port congestion as a risk.

The process for quantifying risks generally includes the estimation of the frequency and impact of the risk occurring and proceeds to prioritise the risk with regards to consequences. For the purpose of this study, the most common method is used, namely, the bow-tie method. The bow-tie method of risk analysis looks at the inherent risk, which is the level of risk without management strategies, and the residual risk, which is the level of risk remaining after management strategies are implemented. Figure 2-1 illustrates the theory behind the bow-tie method.

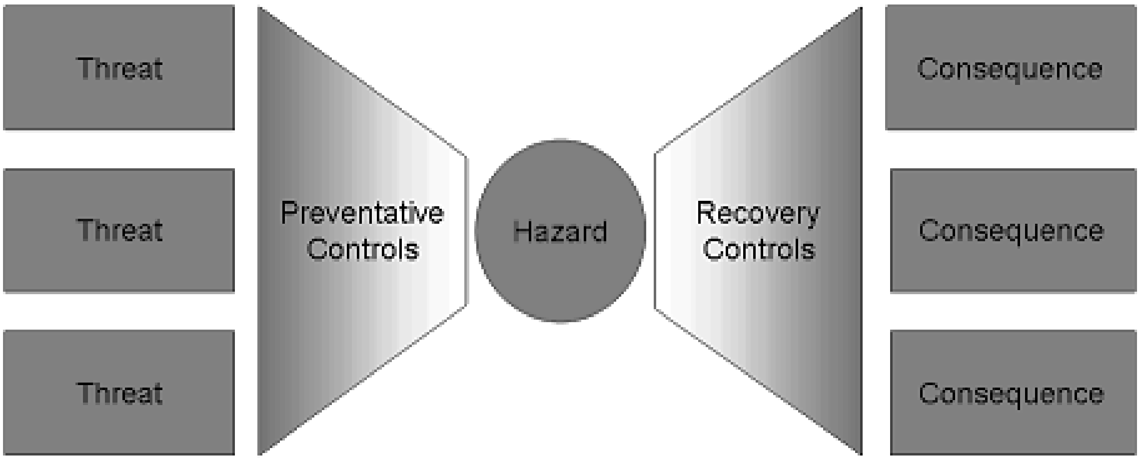

Figure 2-1: The bow-tie risk assessment method

Source: Book, 2007

It is important to note that for the purpose of this study certain elements of the model are excluded, namely, the “preventative controls” and the “recovery controls”. These elements were excluded as the purpose of the risk profiles were not to develop solutions, but rather to determine to what extent ocean carriers and container trucks suffer from port congestion. Therefore, the bow-tie models used in this study focused primarily on the triggers or causes of congestion, and the consequences thereof.

For the purpose of this study, two separate bow-tie models were constructed to analyse the maritime-side, and the landside of port congestion. These models are similar to Figure 2-1 with the exception of the elements specifically excluded. The primary purpose of these bow-tie models was to visually represent port congestion as a risk to ocean carriers (maritime-side) and container trucks (landside), with an emphasis on the causes and consequences.

In addition to the bow-tie models, as well as the data analysis of current and forecasted port congestion, the risk assessment process involved the quantification of port congestion. This was done through the use of two measures, namely, risk probability or frequency, and risk impact. These measures, according to Griffiths (2007), were then used to calculate the risk severity of port congestion experienced by ocean carriers and container trucks within the CTCT. The formula for the risk severity calculation is as follows (Griffiths, 2007):

$$Risk\ Severity = Risk\ Frequency\ \times Risk\ Impact$$

For the purpose of this study each data set collected was analysed separately in terms of current port congestion (2011-2014 and 2011-2015) and future port congestion (2015-2019 and 2016-2020). The risk severity calculations were based on the frequency and additional time (scheduling impact) bar charts presented in section 6.2 of Chapter 6 and section 7.2 of Chapter 7, and were therefore more accurate in identifying trends within the data over time. The risk severity calculations were documented in a specific format, as illustrated in Table 2-7, to assist in the development of a coding system.

Table 2-7: Template of risk severity calculations

	Current				**Forecasted**				
Year	Year *i*	Year *i*	Year *i*	Year *i*	Year *i*	Year *i*	Year *i*	Year *i*	Year *i*
Frequency %									
Impact									
Risk Severity									
Average Risk Severity									

Source: Created by author for the purpose of this study

The risk severity tables were essentially created to assist in the quantification of weather- and system-related port congestion as a risk to the turnaround of ocean carriers and container trucks. This quantification of port congestion, however, requires interpretation using a coding system before the risk profiles could be developed (Grifiths, 2007). Therefore, specific coding systems were used for each data set analysed to produce accurate risk profiles of port congestion within the CTCT.

The development of the individual coding systems involved three elements, namely, the code itself (1 – 5), the interpretation of the code, and the interval ranges assigned to the individual codes. It was decided that a single coding system should be used for the frequency element of risk – as this element was measured as a percentage for all the data sets and forecasts analysed. The impact element of risk, however, required the development of separate coding systems for each data set/forecast analysed as each was measured differently and used different interval ranges (Griffiths, 2007).

Table 2-8 details the coding system used for the frequency element of port congestion seen in the four data sets, whilst Table 2-9 details the coding systems used for the time impact (scheduling impact) element of port congestion. The coding system created for the individual data sets/forecasts were developed based on expert knowledge[11] as well as the perceived severity of delays[12].

Table 2-8: Coding system used for frequency (all data sets)

Interpretation of Code	Coding	Frequency percentage
Rare	1	0 – 20%
Infrequent	2	21 – 40%
Fairly frequent	3	41 – 60%
Frequent	4	61 – 80%
Extremely Frequent	5	81 – 100%

Source: Created by author for the purpose of this study

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[11] Interviews conducted with shipping companies (Maersk and MSC) and trucking companies (Berry & Donaldson).

[12] Similarly based on interviews with industry experts, as well as knowledge acquired through literary research

Table 2-9: Coding system used for time impact (additional time) in each data set

Interpretation of Code	Coding	VAT	VBT & VWT	TTAT	Weather Delays	System Delays
Insignificant	1	0 – 5 hours	0 – 2 hours	0 – 2 mins	0 – 1 hour	0 – 0.2 hours
Minor	2	5.1 – 10 hours	2.1 – 4 hours	2 – 4 mins	1.1 – 2 hours	0.21 – 0.4 hours
Moderate	3	10.1 – 15 hours	4.1 – 6 hours	4 – 6 mins	2.1 – 3 hours	0.41 – 0.6 hours
Major	4	15.1 – 20 hours	6.1 – 8 hours	6 – 8 mins	3.1 – 4 hours	0.61 – 0.8 hours
Critical	5	More than 20 hours	More than 8 hours	More than 8 mins	More than 4 hours	More than 0.8 hours

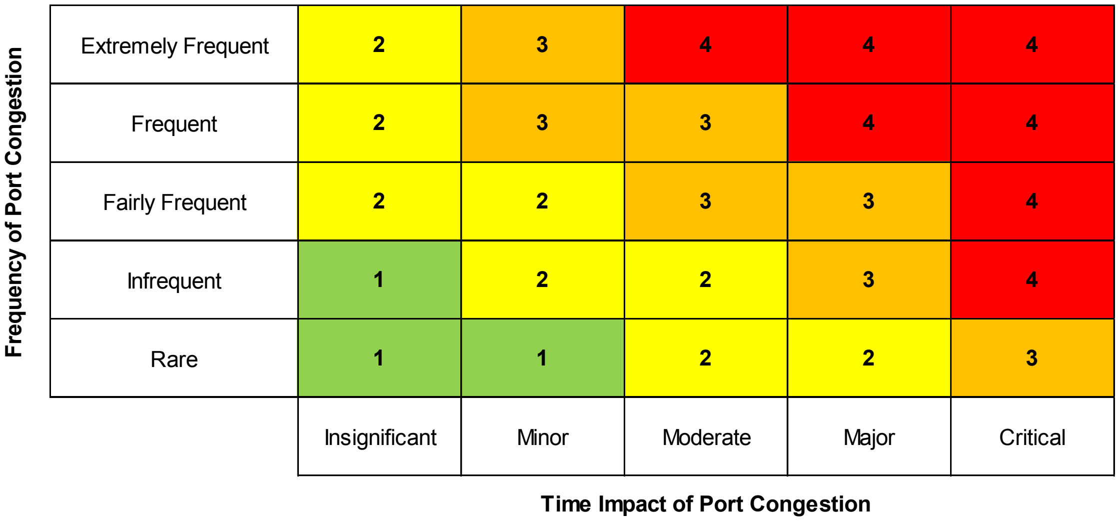
Source: Created by author for the purpose of this study

Overall, these coding systems were used to interpret the severity of port congestion as a risk to ocean carriers and container trucks. The risk prioritisation tables of the individual data sets/forecasts are contained in section 8.1.2 of Chapter 8, and were used in the next step of the risk assessment process – *risk evaluation*.

The *risk evaluation* step involved the development of several risk "heat-maps" to determine the level of risk port congestion currently, and is forecasted to pose to ocean carriers and container trucks within the CTCT. The objective of the risk "heat-map" technique was to evaluate port congestion through illustrating it on a model with frequency relative to time impact using the coding systems discussed previously.

For the purpose of this study four different "heat-maps" were developed, one for each data set/forecast analysed, to illustrate how port congestion has changed over the years in terms of frequency, time impact, and overall severity. These "heat-maps" were used in collaboration with the risk severity tables mentioned previously, to develop the overall risk profiles of port congestion within the CTCT.

To successfully develop risk profiles of both current and future port congestion the "heat-map" model was adjusted slightly to create a means of assigning the four risk rankings (minor – critical) more easily to port congestion as a whole per year analysed/forecasted. This means of ranking is illustrated in Figure 2-2: where 1 = minor risk (green); 2 = moderate risk (yellow); 3 = major risk (orange); and 4 = critical risk (red).



Frequency of Port Congestion	Insignificant	Minor	Moderate	Major	Critical
Extremely Frequent	2	3	4	4	4
Frequent	2	3	3	4	4
Fairly Frequent	2	2	3	3	4
Infrequent	1	2	2	3	4
Rare	1	1	2	2	3

Figure 2-2: Risk "heat-map" ranking system for port congestion

Source: Created by author for the purpose of this study; Adapted from Supply Chain Risk Leadership Council, August 2011

The results of the "heat-map" ranking system were subsequently consolidated into two tables, current port congestion versus future port congestion. This was used to calculate the overall risk rating to be assigned to port congestion as a whole per year. The template for the results of the "heat-map" ranking system is shown in Table 2-10.

Table 2-10: Template for results of "heat-map" ranking system

	Year *i*	**Year *i***	**Year *i***	**Year *i***	**Average risk ranking**
VAT					
VBT					
VWT					
TTAT					
Weather delays					
System delays					
Average risk ranking					

Source: Created by author for the purpose of this study

The "heat-map" ranking system and results tables were subsequently used to develop the risk profiles of current and future port congestion. The final risk profiles are discussed in section 8.2 of Chapter 8. The following section of this chapter discusses the limitations encountered during the development of the methodology of this study.

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2.2.6. Assumptions and Limitations of the Methodology

Due to the nature of this study, a specific case study, certain assumptions and limitations were encountered during the development of the research methodology. These assumptions and limitations pertained to the sampling, research instruments, and forecasting and risk profile sections of the study.

With regards to sampling, as mentioned in section 2.2.1, a relatively small sample of individuals/entities was acquired to participate in the research. This, however, is acceptable for the case study portion of the research, provided the findings are not applied to a container terminal, other than the CTCT. It is, however, important to note that the overall methodology behind the developed risk profiles can be applied to other South African ports, such as the Port of Durban, which also suffers from the risk of port congestion. In addition, the main assumption regarding the study participants pertained to the state of the data attained, namely, that it was complete and comprehensive.

An additional limitation, due to the nature of the interviews and data obtained from the study participants, stated that ethical approval and a non-disclosure agreement was required and subsequently obtained for the study. The ethical approval form, contained in Addendum K, ensures that no parties are harmed during the course of the research, while the non-disclosure agreement assures the sources of the data that the data will be handled with discretion (Addendum L).

Similar to the sampling aspect of the research, the research instruments used for data collection limited the scope of the study. As mentioned in section 2.2.2, study participants provided four data sets which were used to determine current and forecasted port congestion within the CTCT. These data sets contained the only data available to the researcher and subsequently limited the study to weather- and system-related port congestion experienced by ocean carriers and container trucks. Furthermore, the data collected pertained exclusively to the frequency of port congestion and the scheduling impact thereof. Therefore, the cost implications of port congestion could not be ascertained from the data and was thus excluded from the scope of this study.

Furthermore, the quantitative data received was assumed to be both reliable in terms of consistency and accuracy, and valid in terms of relevance to the study. The data was also assumed to be appropriate for forecasting and risk analysis based on a consultation with a statistical expert, Prof Daan Nel[13], during the course of this study.

With regards to the percentage of incidences, discussed in sections 6.2.1 and 7.2.1 of this study, an assumption was made regarding the meaning of 100% incident percentage. For the purpose of this study, and based on interviews with TNPA and shipping companies, 100% incident percentage was defined as the point where the majority of ocean carriers and/or container trucks moving through the CTCT within a particular year (current or forecasted) experience delays of varying severity (this can range from as little as a few minutes to several hours).

The last element impacted by assumptions and limitations was the risk profile aspect of this study. Due to the nature of the data collected, namely, four separate data sets/forecasts, a unique method of risk profiling was developed based on existing models.

As discussed in section 2.2.5, the risk "heat-map" model was adapted so that the four data sets could be assigned risk rankings. This adapted model was then used to develop current and future risk profiles of weather- and system-related port congestion within the CTCT.

2.3. Closing Remarks

The purpose of this chapter is to outline the methodology behind the various elements of this research study. Elements such as the research method used, sampling techniques, research instruments used, descriptive data methodology, forecasting methodology and the risk profile methodology used.

The overall research method selected is "methodological triangulation", which makes use of both quantitative and qualitative research methods. These methods were described clearly in the use of personal interviews and Excel data sheets as research instruments for data collection. Non-probability sampling was used to determine which entities to approach as study participants for the research study. These entities were selected by means of simultaneous use of judgement, convenience and snowball sampling techniques.

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[13] A consultant from the Centre for Statistical Consultations in Stellenbosch

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The data collected, as mentioned earlier, is both qualitative and quantitative in nature. The Excel data sheets obtained added to the limitations of the study with the data indicating that weather- and system-related port congestion is more commonly experienced by ocean carriers and container trucks within the CTCT.

The chapter discusses the descriptive data analysis methods used for the analysis of current port congestion data and forecasted port congestion. The descriptive analysis included both graphical and numerical data, which is used to analyse current and future port congestion frequency and scheduling impact, as mentioned in section 2.2.3. In addition to the general descriptive analysis, analysis of the two elements of port congestion is done using bar charts. These bar charts indicate the percentage of congestion incidences, and the amount of additional time experienced, by ocean carriers and container trucks per year.

In addition to the analysis of current port congestion (2011-2014 and 2011-2015), the chapter discusses the methodology of the forecast aspect of the research. Based on the line charts developed in the descriptive analysis phase of the study, Holt-Winter Forecasting with 12-month periodicity is done on the four data sets. Five year forecasts are subsequently generated to analyse how port congestion will change over the next five years (2015-2019 and 2016-2020). The forecasts are also used to develop a risk profile of future port congestion within the CTCT.

The final aspect of the study, the risk profiles of port congestion, is conducted through an adaption of the risk assessment process. Bow-tie models, and risk severity calculations and rankings, are used to quantify port congestion as a risk, and prioritise it according to risk severity. These models and calculations are then used to develop risk “heat-maps” for each data set/forecast.

The “heat-map” model is then adjusted to code the four different risk rankings (minor, moderate, major and critical), and is used to develop “heat-map” ranking tables for each data set/forecast. Finally, these “heat-map” ranking tables are used to develop the risk profiles of current and future port congestion within the CTCT. The last section of this chapter outlines and discusses the different assumptions and limitations encountered during the course of the research.

The following chapter starts the literature review of the study, and is followed by two additional literature chapters on port congestion (Chapter 4) and the case study context (Chapter 5).

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Chapter 3: Initial Literature Review

The previous chapter mentioned that a discussion of literature would form part of the secondary research element of this study. This chapter introduces some of the concepts relating to the study, namely, the risk concept, international and containerised trade, and the shipping industry. The chapter also serves as an introduction to further literature chapters.

3.1. The Risk Concept

The concept of risk and risk management is continuously changing as further research is done in the field. It is, therefore, important for organisations to understand the most recent definition of risk before implementing risk management strategies or developing risk profiles.

According to a recent study conducted by Young (2014:2), risk is often perceived as either a potential threat or a potential opportunity for gain. This suggests that there are two sides to risk. According to Young (2014:2), the one side attempts to prevent loss through minimising the risk, whilst the other side takes on the risk with the aim of attaining some benefit. Both sides entail a level of uncertainty, with high uncertainty resulting in higher risk and less uncertainty resulting in lower risk.

Uncertainty can be defined, according to Brindley (2004:7), as the lack of information pertaining to a decision situation and the need for judgement in evaluating the impact and probability of the situation. This implies that in extreme circumstances, uncertainty could be defined as situations where the risk and its likelihood are unknown and thus cannot be measured. There is, however, a significant difference between uncertainty and risk. This difference is the principle that all risk events involve a conscious decision of uncertainty that may result in a worthwhile reward, but subsequently exposes the business to a potential loss.

This definition of uncertainty leads to Young's definition of risk which states that risk can be defined as an event of uncertainty resulting in a loss or a positive outcome (Young, 2014:2). A less recent study done by Purdy (2010:882) similarly defines risk as the consequences firms face in an uncertain environment when pursuing goals.

These recent definitions sketch a similar, but more comprehensive version of an older study done by Fleisher (1990), which defines risk as the involvement of both the chance of loss and the opportunity for gain. This comprehensive version developed was subsequently adapted for this study, with risk defined as the *consequences and benefits organisations encounter when making business decisions within an environment of uncertainty.*

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In addition to the various definitions of risk, risk and uncertainty can be measured and interpreted in various ways. These methods of measurement and interpretation are dependent on the industry in which the risk event occurs.

The following section discusses the importance of risk assessment, as well as the various methods which can be used. Section 3.1.2 discusses the various ways risk can be categorised and section 3.1.3 focuses specifically on risk in the supply chain.

3.1.1. Risk Assessment and Profiling

Various reasons exist for why organisations are forced into conducting risk assessments. The foremost reason being the need to consider a range of possibilities rather than a single answer (Koller, 2005:13). An additional reason for risk assessment is the degree of uncertainty associated with many business related decisions and ventures.

According to Young (2014:3), risk management can be defined as the process of managing exposures to risk with the aim of preventing loss or minimising negative effects. Young (2014:3) goes on to state that in order to successfully manage risk, the risk must first be measured. This recent definition agrees with an earlier study by Brindley (2004:20), which states that the risk management process generally focuses on understanding the specific risks and how their impact and probability can be minimised.

Brindley (2004:20) goes further, stating that the stages of the risk management process range from risk identification or analysis to risk assessment or evaluation. Young (2014:3) argues that an effective risk management program generally should include intensive and on-going risk identification and assessment. This identification and assessment should distinguish between which risks to include in the assessment, and which to exclude.

The first step in the risk management process involves, as mentioned previously, the risk analysis or identification step. This step is significant as it follows the principle that decision-makers made aware of an identified risk, are better prepared to address said risk. Therefore, it can be concluded, that the primary focus of this initial step is to identify current and potential risks in order for the firm to respond proactively (Brindley, 2014:21).

Aside from identifying potential risks in step one, there is a need to quantify and prioritise risks in terms of probability and impact (Brindley, 2014:21-22). The quantified definition of risk defines the risk event in terms of the likelihood of the event occurring and the consequences of the risk event if it does occur (Garrick, 2008:18).

According to Garrick (2008:18), this involves compiling an exhaustive list of possible risk scenarios; calculating the probability or likelihood of each risk scenario; and describing the impact of the risk scenario in terms of damages or losses. For the second step, likelihood can be expressed as either the probability of the risk occurring, or the frequency of the risk occurrence.

Probability generally refers to scenarios that are not recurrent and thus the likelihood of the scenario occurring should be measured. Frequency, however, generally refers to scenarios which are recurrent and how often the scenario occurs should be measured. This frequency is expressed in measurements such as per hour, per day or per year (Garrick, 2008:20). With regards to the third step, impact can either be quantitative or qualitative in nature. Quantitative losses could impact the financial standing of an organisation, whilst qualitative losses may influence the reputation of an organisation.

The frequency and impact of a risk scenario can be estimated through the use of various methods. The most common method, according to the Supply Chain Risk Leadership Council (2011:15) being the "*bow-tie method*". Figure 3-1 illustrates the bow-tie method.

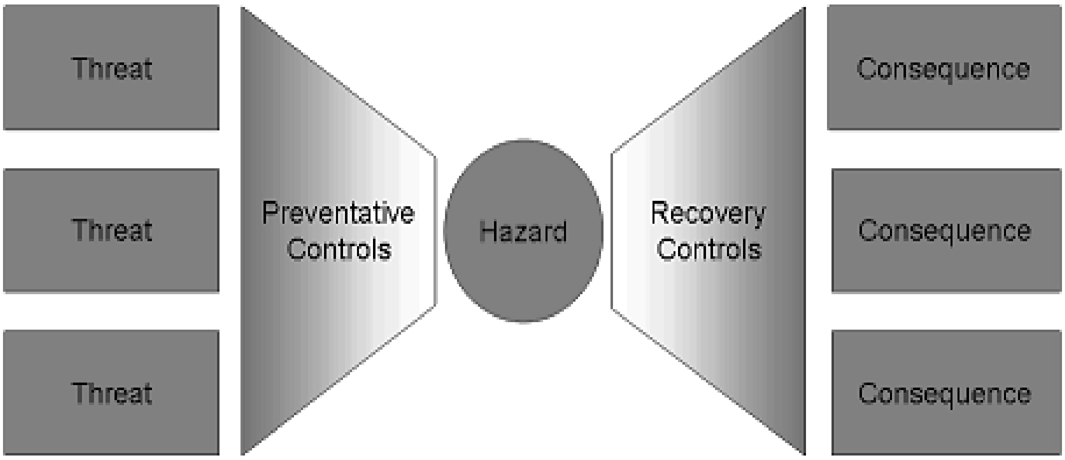


Figure 3-1: The bow-tie risk assessment method

Source: Book, 2007

The "threat" refers to the risk scenario or inherent risk, whilst the "consequence" refers to the impact of the risk scenario or the residual risk. Figure 3-1 also suggests that inherent risk can be managed through preventative controls, whilst recovery controls are appropriate in the management of residual risk.

Other risk assessment methods exist which focus on the assessment of working environment related hazards or risks. These methods include the Job Safety Assessment or JSA method and the Method-statement method.

The bow-tie method, however, focuses on all business related risks and assists in the identification of risks throughout an organisation's operations (Book, 2007:26). Section 2.2.5 in Chapter 2 presented the methodology behind the assessment of port congestion risk using the bow-tie method.

The quantification of risk scenarios using frequency and impact enables management to develop strategies and profiles to assess future risks. Furthermore, the illustration of risk scenarios in the bow-tie method diagram assists in determining where management strategies are required. The strategies subsequently developed generally include avoidance, reduction, transference or the sharing of risks.

The last step in the risk assessment process involves the evaluation of risk scenarios. This step generally rates the frequency and the impact of the risk before and after the implementation of management strategies. This evaluation can be done through the use of two different techniques, namely, the risk "frontier" map technique and the risk "heat-map" technique.

The first technique, known as the risk "frontier" map (seen in Figure 3-2), evaluates the risk by plotting the frequency of occurrences in relation to the impact of the risk on a graph ranging from high to low.

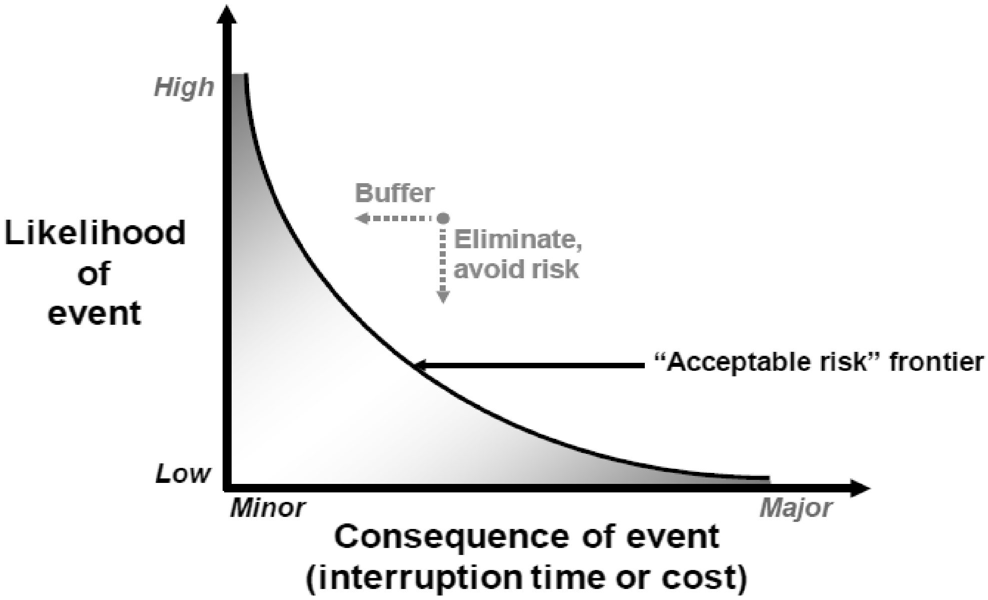


Figure 3-2: Risk "frontier" map method

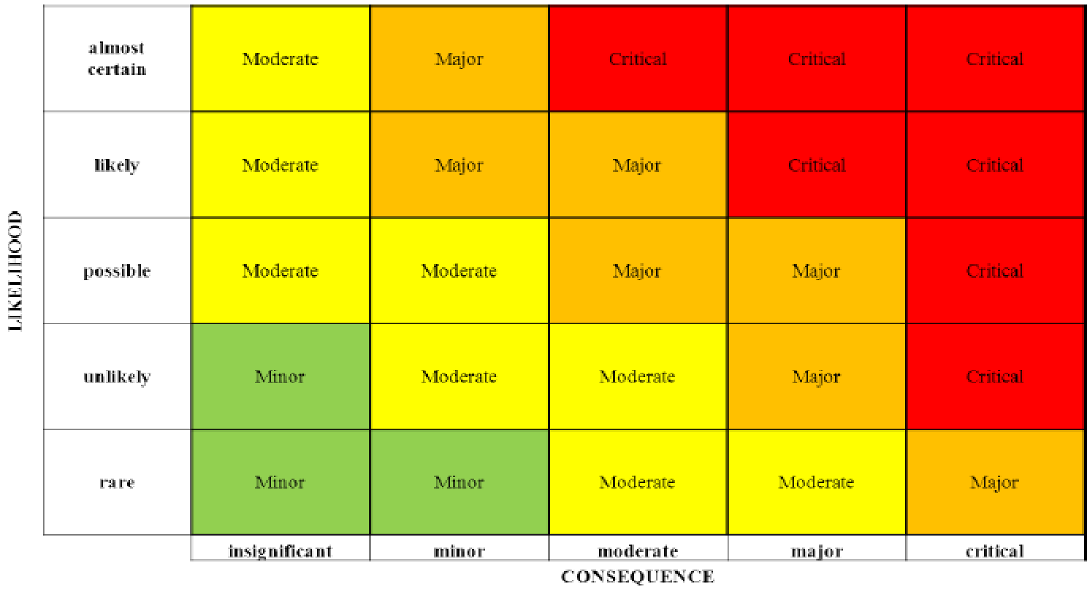
Source: Supply Chain Risk Leadership Council, August 2011

The risk "frontier" map illustrates the relationship between frequency, or likelihood and the impact or consequence, of the risk event. The "acceptable risk" frontier indicates the area in which risk impact can be buffered and risk frequency can be avoided or eliminated.

Any risk beyond this frontier would be difficult, if not impossible, to manage and is thus considered unacceptable.

The second technique is known as the “heat-map” method and evaluates the risk through illustrating the risk event on a matrix of frequency relative to the impact of the risk, ranging from minor to critical (Supply Chain Risk Leadership Council, 2011:16-18). These different levels of risk are allocated different colours corresponding to their level of severity. For example, minor risks are highlighted in green and critical risks in red.

A basic example of a risk “heat-map” can be seen in Figure 3-3. In addition to the colour allocation, the figure suggests that with an increase in likelihood and consequence, the severity of the risk scenario increases. The figure, however, also indicates that a critical consequence, but rare likelihood; results in a major risk, whereas an insignificant consequence with almost certain likelihood, results in only a moderate risk. This suggests that the impact of a risk scenario is of greater concern than the frequency at which it occurs and can be controlled through normal management strategies.



LIKELIHOOD

almost certain	Moderate	Major	Critical	Critical	Critical
likely	Moderate	Major	Major	Critical	Critical
possible	Moderate	Moderate	Major	Major	Critical
unlikely	Minor	Moderate	Moderate	Major	Critical
rare	Minor	Minor	Moderate	Moderate	Major
	insignificant	minor	moderate	major	critical

CONSEQUENCE

Figure 3-3: Risk “heat-map” method

Source: Supply Chain Risk Leadership Council, August 2011

Of the two techniques previously discussed, only the “heat-map” method was used in developing the risk profiles of this particular study. The various definitions of risk, and the various assessment methods, make the concept of risk difficult to define. This often results in the use of different definitions and assessment methods in different industries and supply chains. In addition, these different industries and supply chains often deal with various different types of risks, which subsequently influences the risk assessment methods used.

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3.1.2. Types of Risk

Many academics have determined various means of classifying types of risks that can be encountered in business. These classifications of risk types can refer to either general risk, or industry specific risk. For instance, Brindley (2004:9) argues that the types of risks can be categorised in terms of the context in which risky decisions are made. These decisions can relate to the environment, industry and/or the organisation.

Decisions made in a competitive environment expose the organisation to risks associated with technologies, economic trade and policies. Any changes within an industry could result in risks exposing all those organisations within that industry. Lastly, decisions to change organisational structure in reaction to competition can also result in various risk exposures. It is, however, important to note that often an individual organisation has limited influence over any risks resulting from these three sources, most notably the environment and the industry. However, an individual organisation can improve their influence over risks through the analysis and management of identified risks.

In addition, Brindley (2004:9-10) goes on to state that due to this lack of control and influence, it is necessary to classify risks in terms of the degree to which they can be avoided. Those risks which in most cases are unavoidable are known as systematic risks as they often occur due to environmental circumstances, whilst those risks which can be managed by the organisation, and often stem from the organisation’s operations are known as unsystematic risks.

In contrast to Brindley, a more recent study conducted by Young (2014:3) suggests that risks can be defined as either financial or non-financial. Financial risks can be defined as risk events that lead to a direct financial loss and have a negative impact on the organisation's profits. While non-financial risks can be defined as risk events that could potentially have a negative impact on organisation operations. This negative impact can be either quantitative or qualitative in nature and can indirectly impact the organisation's profits. Strategic risk, reputational risk, legal risk and operational risk fall under the non-financial risk category, whilst credit risk, market risk and liquidity risk fall under financial risks.

Figure 3-4 illustrates Young’s theory. The different risk categories result from different factors in and decisions made by an organisation. For example, reputational risk can stem from decisions made that could influence the reputation of the organisation, whilst market risk can stem from decisions made with regards to current or future markets.

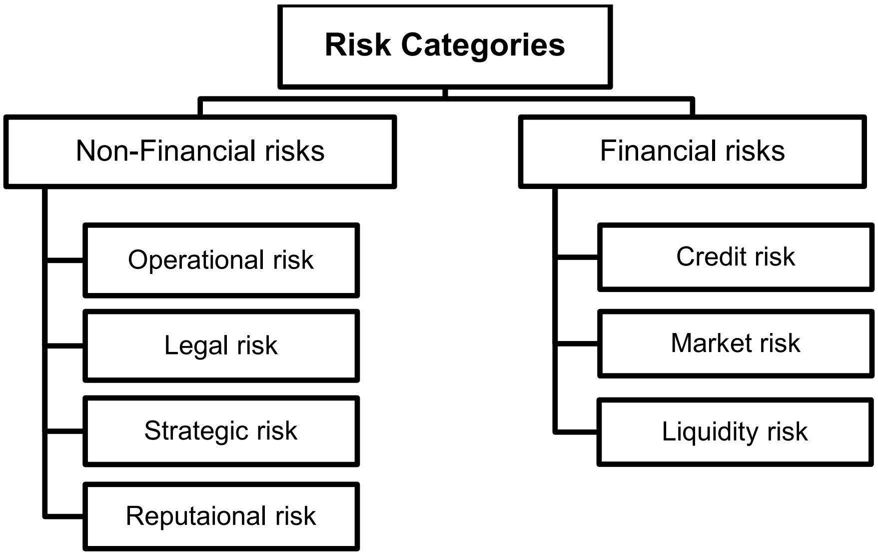

Figure 3-4: Risk Categories

Source: Young, 2014

Operational risk, on the other hand, stems from internal and external supply chain factors of an organisation. These factors are generally viewed in unison and must be considered simultaneously during the risk management process. Operational risk can be defined as the exposure of a company to losses resulting from failures in the execution of operations and processes (Young, 2014:17-21). These losses can stem from both internal failures of people, processes and systems, and from the external environment. Operational risk is largely related to the supply chain and supply chain activities of an organisation and is often referred to as supply chain risk.

3.1.3. Risk in the Supply Chain

The supply chain of an organisation is generally made up of two flows, namely, the outbound flow and the inbound flow. These flows are made up of various logistics activities, which also form part of the organisation’s supply chain. The domestic outbound flow of goods is known as physical distribution, whilst the flow of goods between international markets is known as exports.

Similarly, the domestic inbound flow is commonly known as materials management, whilst the flow from international markets is known as imports. Both the outbound and inbound flows of the supply chain encounter various risks known as supply chain risks.

Brindley (2004:20) defines supply chain risk as those risks that are directly related to the flow of materials and information in a firm's supply chain. This includes the different logistics activities associated with this flow. Brindley's definition suggests that supply chain risk is merely a part of overall risk faced by the organisation.

Figure 3-5 illustrates Stemmler's (2010:184-185) suggestion of how supply chain risk can be categorised into two different types of risks. Exogenous risks stem from interactions between the supply chain and its environment, whilst endogenous risks stem from interactions between supply chain partners. Both categories can be subdivided further, highlighting the various sources of supply chain risks.

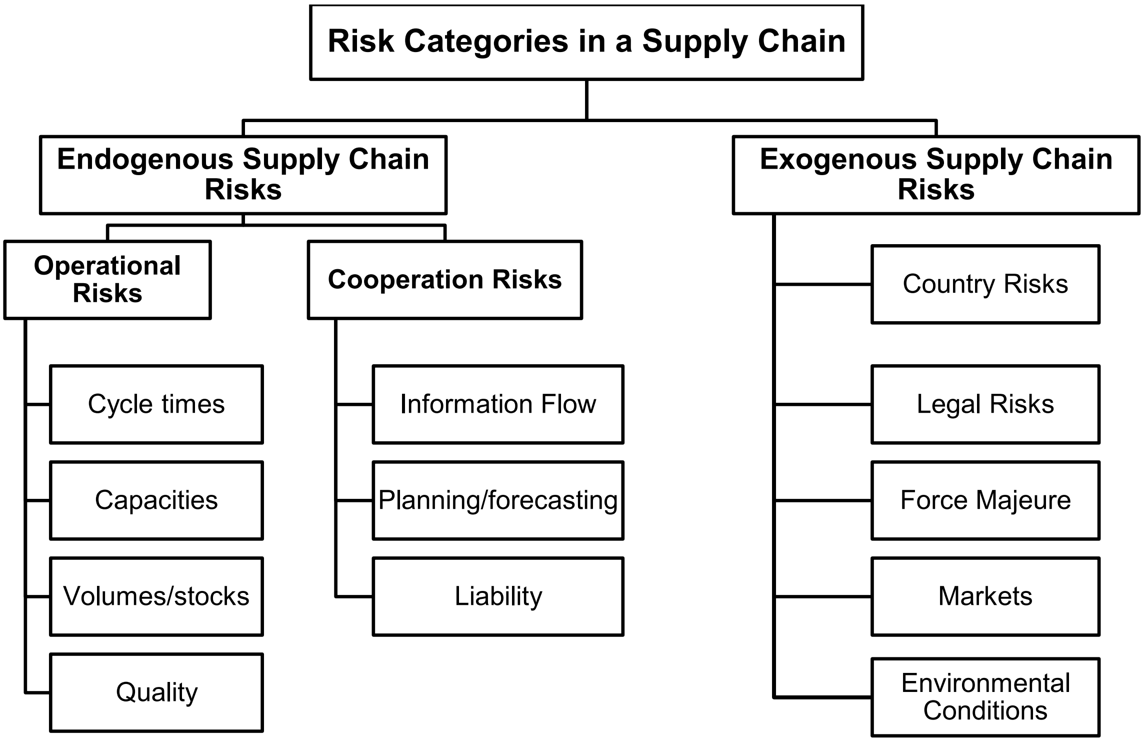

Figure 3-5: Supply Chain Risk Categories

Source: Adapted from Stemmler, 2010

According to Stemmler (2010:184-185) endogenous risks generally include organisational risks and risks stemming from integration, coordination and cooperation along the supply chain. Operational risks, as mentioned in the previous section, form a large part of internal supply chain risks and should be considered during the risk management process.

Supply chain related risks such as operational risk can, as mentioned previously, stem from either the inbound or outbound flow of goods and services. Operational risks are more common in the linkages between transportation modes, namely, transportation hubs, ports and railway terminals. Similarly, environmental conditions can also impact these links and nodes in the supply chain.

The domestic supply chain is generally more easily managed as it includes less complex risks. Domestic supply chain risks usually stem from supply chain partners or logistics activities, which are managed more effectively due to their close proximity to the organisation. International supply chain related risks are, however, a more complex management issue due to the increase in international and containerised trade, and the increased need for safe access points into countries.

3.2. International and Containerised Trade

According to Janse van Rensburg (1997:4) international trade can be defined as the flow of goods, services and finances between different trading nations. Reasons for international trade include non-economic and economic reasons. Non-economic reasons include the uneven distribution of natural resources around the world (Janse van Rensburg, 1997:4), where countries such as South Africa, which have large coal reserves, trades with Arab countries for oil. In similar situations, countries which lack the ideal climate to cultivate certain desired agricultural products trade with those countries with surplus.

Economic reasons include differences in country development and population distribution across the world (Havenga, 2015:1). Differences in the level of productivity in the production of different commodities result in trade as different countries specialise in the production of different goods (Havenga, 2015: 1-22). It is, therefore, cheaper to trade in these goods and economies of scale are achieved. Differences in population distribution result in trade as certain countries do not have the production capacity or specialisation capabilities to support the entire population.

These reasons for international trade have facilitated the growth of international trade, specifically containerised trade, over the past 50 years. International trade and containerisation have subsequently become the backbone of globalisation according to Fremont (2009:5) with containers being one of the fastest growing cargo segments of the industry (Fan, Wilson & Dahl, 2012:1121). This increase places pressure on organisations operating within the shipping industry and maritime ports, both of which are vital in facilitating the movement of goods between trading nations.

Containerisation has moved from a simple technical innovation to an intermodal tool that paves the way for further innovations in the transportation sector. Certain international trade activities are promoted by containerisation. According to Lun, Lai and Cheng (2010:220) container vessels replace less economically efficient traditional vessels.

This, according to Gubbins (1986:29), results in large cost savings as transport costs are reduced when standardised methods are used to carry and transfer goods between modes of transport.

Transport costs are reduced further as cargo handling efficiency is improved through containerisation (Gubbins, 1986:29). This cost-efficiency subsequently encourages economic development in both the shipping industry and the country of trade. In addition to cost savings, containers assist in reducing the time required to load, unload and transport cargos. In its entirety containerisation supports the growth of global production, distribution and consumption as it facilitates convenient and cost-effective cargo movements (Lun, *et al.* 2010:220).

International trade would not be possible without maritime shipping. Section 3.2.1, which follows, discusses the various aspects of the international shipping industry. The influence of containerisation on the shipping industry and maritime ports is also discussed briefly.

3.2.1. International Shipping Industry

One of the most prominent elements in the international transportation sector is maritime trade and the shipping sector. The term “shipping” can be interpreted in many ways. For some, “shipping” refers to vessels and maritime trade, whilst for others; “shipping” refers to any form of transport which moves goods between the producer and the consumer (Lun, *et al.* 2010:1). Shipping is, however, generally defined as the movement of goods between producers and end consumers irrespective of transportation mode. Regardless of the chosen definition, however, it can be said that shipping and maritime ports play an important role in the development of economies around the globe.

In addition to this role, Gubbins (1986:1) suggests that the most significant function of shipping is to allow trade between nations with surplus commodities and nations with a deficit in commodities. This function includes transporting raw materials from extraction sites to manufacturers, and manufactured products to consumer markets.

It can, therefore, be said that the primary objective of shipping is to move freight and passengers from one place to another in a manner that is safe, economical and reliable (Gubbins. 1986:2). Throughout the transportation process the maritime industry must interact with certain fixed infrastructures. The fixed infrastructure of the maritime industry refers to ports and terminals through which cargo is moved.

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Vessels and vehicles are the infrastructure used to move cargos between these fixed infrastructures. Industrial developments within the maritime industry have led to several changes in terms of specialisation. These changes have influenced both fixed infrastructure, and vessels and vehicles.

Vessels and vehicles have subsequently experienced various degrees of specialisation over time. Figure 3-6 illustrates the increase in specialisation in terms of the development of vessel types. The figure shows how vessel types have moved over time towards highly specialised ships designed to carry specific types of cargos. For example, cargo liners were specialised over time to handle containerised goods, palletised goods and automobiles on vessels known as Ro/Ro ships[14].

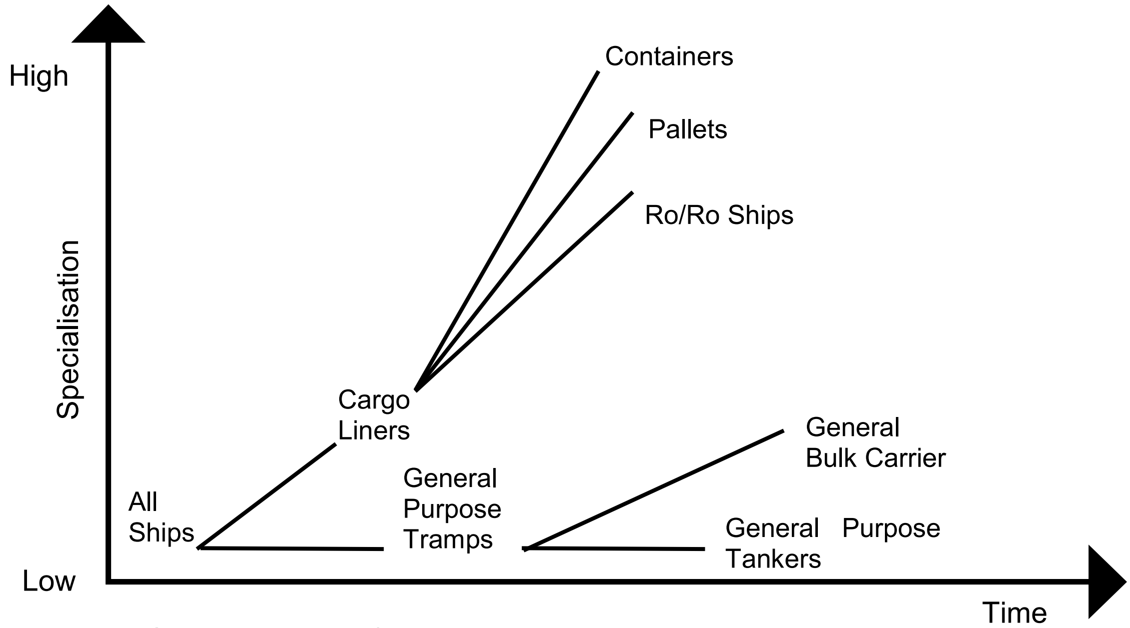

Figure 3-6: Specialisation of vessels over time

Source: Adapted from Gubbins, 1986

In addition to increased specialisation, vessel size has increased over the past 50 years to accommodate ever increasing volumes of cargos to meet increasing global demand.

Figure 3-7 illustrates the growth of container vessel size, with current maximum vessel size accommodating over 19 000 Twenty-foot Equivalent Units[15] (TEU's) and growth averaging 1 200% since 1968.

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[14] Acronym for Roll-on/Roll-off. Refers to vessels used to transport wheeled cargo such as motor vehicles.

[15] A unit of measurement for the carrying capacity of ocean carriers. One TEU is equal to that of a standard 20-feet shipping container (20-feet long and 8-feet in height).

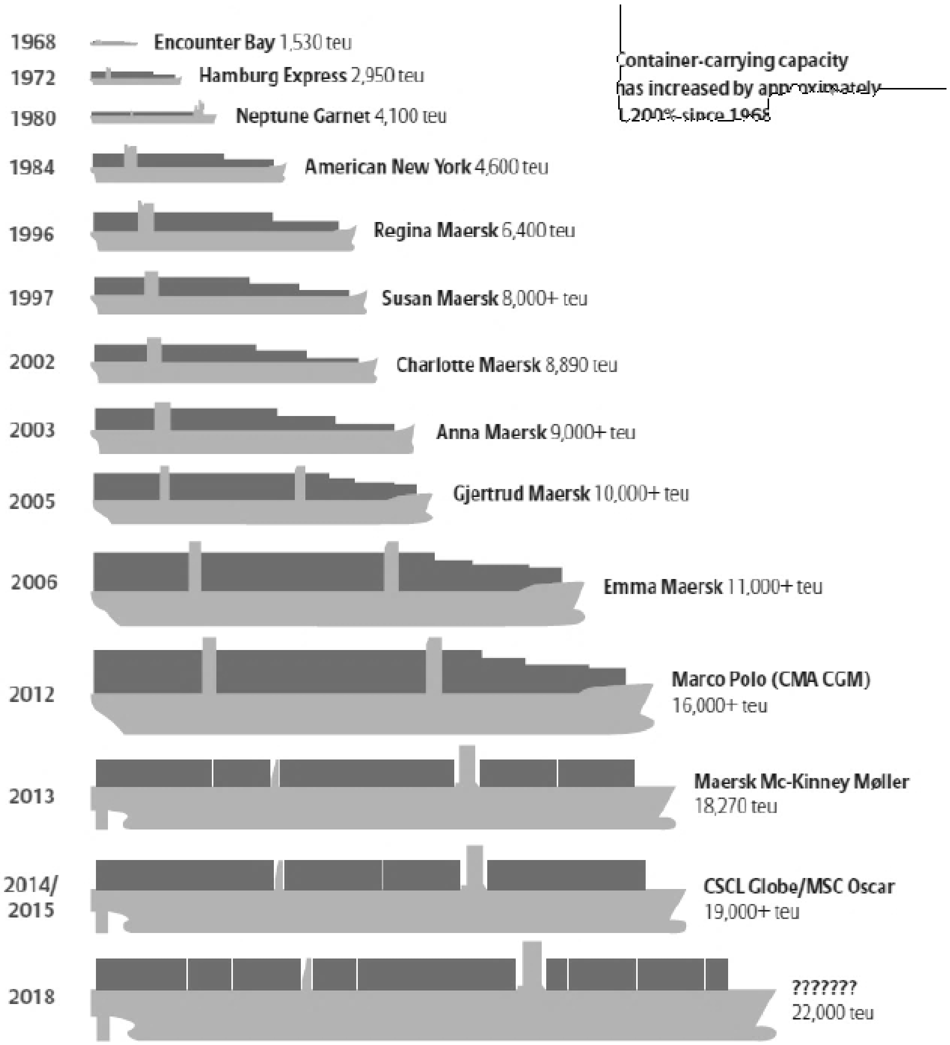

Figure 3-7: Container Vessel Growth, past 50 years.

Source: Adapted from Maritimecyprus.com, 2015

The introduction of container vessels, as a result of specialisation in the 1950's, has seen a high growth rate due to the advantages and opportunities offered by containerisation. One such opportunity offered by containerisation is the development of designs and operations of facilities and equipment. Vessels, trains, vehicles, barges, terminals and warehouses have adjusted designs and operations for the efficient handling of container cargo (Lun, *et al.* 2010:220).

In addition to opportunities, containerisation has many advantages and disadvantages for the maritime industry. According to Gubbins (1986:29-30), shipping companies can experience large productivity gains when implementing containerisation into the transportation of goods.

Furthermore, containerisation contributes to significant reductions in the time taken to transport goods between international trading nations (Gubbins, 1986:29-30). In addition, containerisation facilitates cost savings in lowering handling and overall transportation costs.

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The introduction and use of containers for transportation has, however, also resulted in a number of disadvantages. Gubbins (1986:31) argues that the initiation of a containerisation system requires sophisticated handling equipment. This equipment and the training programmes required to operate it requires a large financial investment. In addition, containerisation reduces the labour required. This results in fewer workers and lower labour costs, but suggests that a small number of strategically placed individuals can potentially bring operations to a halt. These interruptions in operations can negatively impact port terminals and port operations.

3.2.2. Maritime Ports and Port related Risks

Maritime ports form an important part of a supply chain as ports can potentially influence operating costs, profitability and responsiveness to consumer demand (Lun, *et al*. 2010:205). Furthermore, maritime ports are a vital part of the global transport infrastructure as ports act as nodes in logistics chains linking inland transport modes with international trade. In addition, ports and port activities represent a significant portion of total chain costs.

Originally, ports simply provided the convenience of cargo storage, but over time port services expanded to include bulk and conventional cargo distribution, packing and processing. According to Loh and Thai (2014:99), this second generation, led to the emergence of a third generation of ports which act as facilitators of cooperation and information sharing. Ports thus play a vital role in the exchange of information between supply chain partners. Overall, these three generations of port services saw changes in port ownership, port development and port activities. These subsequent changes lead to a change in port objectives, namely, a shift away from acting as a gateway to hinterlands, to rather a system providing value-added facilitation services.

This third generation of ports is, however, not sufficient in coping with the growing market uncertainty which is created by constant changes in the external environment (Paixão & Marlow, 2003:355). Thus it was suggested that ports should adopt a new logistics approach, namely, agility. This new strategy is only one of the many strategies available to assist ports in becoming more proactive than reactive in a rapidly changing economy.

Currently, ports facilitate the berthing of vessels and the handling of cargos between maritime and hinterland transportation services. Furthermore, the effectiveness of shipping is influenced by ports as they are situated where ships are often immobile while in ports and thus not being productive. The speed and efficiency at which the port operates can influence the productivity of shipping vessels.

Similarly, port efficiency and the role ports play in the supply chain can be influenced by a number of internal and external factors such as weather conditions, system delays, labour strikes, infrastructure constraints and port congestion.

According to Lun, *et al.* (2010:179), ports have four different roles. Firstly, ports act as places where vessels and cargos are handled. Secondly, ports provide operating systems for the efficient handling of vessels and cargos. Thirdly, ports are economic units which strive to handle vessels and cargos within an economically efficient framework. Lastly, ports are administrative units which strive to handle vessels and cargos within an efficient administrative and policy framework.

An earlier study by Janse van Rensburg (1997:35) states that port services can be divided into operational, commercial and industrial functions. Ports provide a protected berthing area and supportive services such as repairs and bunkering. In addition, ports strive to facilitate industrial development in terms of growth in manufacturing and the transport sector.

The most important function of maritime ports is the facilitation of trade between international markets and domestic markets for the economic growth of hinterlands and/or countries (Chapter 2: Port Development in Africa, 2010). The successful functioning of maritime ports subsequently contributes to economic wealth which leads to an increase in tourism and an overall increase in the standard of living (Janse van Rensburg. 1997:36).

Figure 3-8 suggests that ports lie at the heart of the logistics supply chain. Ports not only link the hinterlands to global markets, but also assist in the servicing of landlocked countries in continents such as Africa.

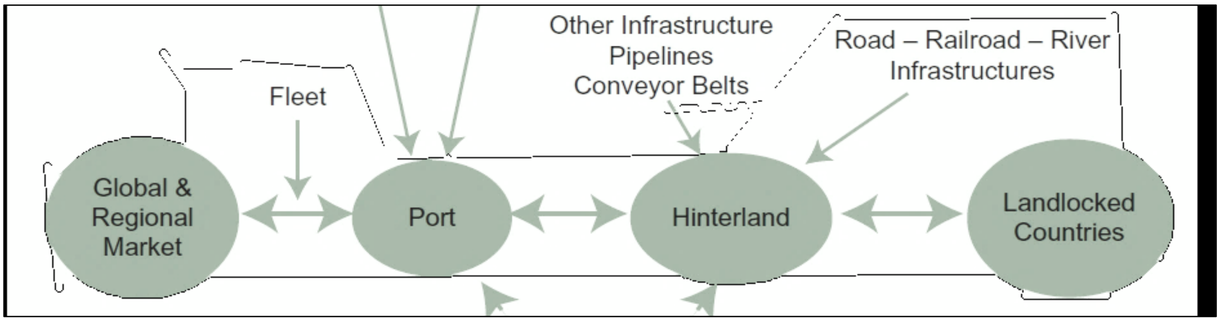

Figure 3-8: Ports at the heart of the logistics supply chain

Source: Adapted from African Bank, 2010

Consequently, both past and more recent studies acknowledge the importance of maritime ports and the terminal operations within ports. One such terminal operation which has experienced exponential growth over the past few years is container terminals (Fan, *et al.*, 2010:1121).

During the transportation of containerised goods, container terminals act similarly to ports as nodes linking maritime trade to inland transport (Lun, *et al.* 2010:219). According to Chadwin, Pope and Talley (1990:19) this linkage between nodes highlights the importance of container terminals to an intermodal transportation network.

This role of container terminals as nodes has been evolving from simple cargo handling to distribution centres with infrastructure serving as transportation hubs. Container terminals thus serve as the interface connecting key players in sea and land transportation, and the overall international container supply chain (Choo, Klabjan & Simchi-Levi, and 2010:98). This chain includes shippers, shipping lines and intermodal transport operators. The major role of a container terminal includes the performance of activities such as unloading import containers from shippers into container stacks; and loading export containers onto vessels for dispatch from the terminal (Choo, *et al.*, 2010:98). Additional functions include container staging before loading and after unloading, as well as short-term storage of containers in container stacks on the landside of the terminal.

Figure 3-9 illustrates this process and highlights the different functions of the terminal, namely, quayside activities and landside activities.

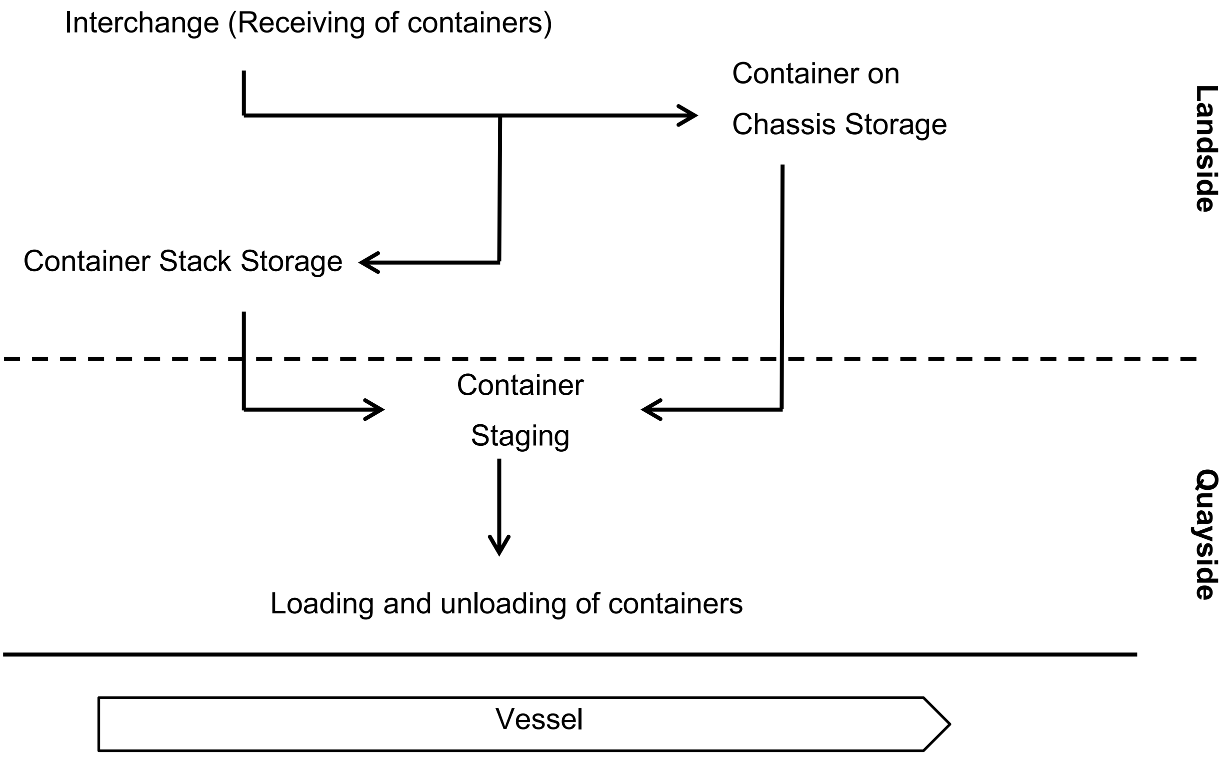

Figure 3-9: Container terminal layout showing different functions

Source: Adapted from Chadwin, Pope & Talley, 1990

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The previously mentioned functions of the terminal must be performed for all entering containers. This includes import containers entering the terminal via vessels and export containers entering the terminal via vehicles. The seamless administration of these functions, and various other services offered, is a widely sought after ability of maritime ports.

Additionally, port activities are required to fit integrally into logistics chains. It is subsequently important to identify potential measures which can be implemented by port management to minimise the impact and frequency of port-related supply chain disruptions (PSCD).

According to Loh and Thai (2014:98), PSCD threats can be defined as operational risks commonly found in port operations, which are capable of disrupting the upstream and downstream flow of supply chains. The significance of ports to international trade increases vulnerability as PSCD threats can generate a ripple effect on the network of supply chains working through ports. This vulnerability of ports should, according to Loh and Thai (2014:97-98), be addressed to ensure functionality of port operations and to enhance overall supply chain resilience.

Port related risks can stem from a number of sources, as mentioned previously, such as a lack of infrastructure/equipment capacity, low productivity, severe weather conditions and congestion. The main consequence stemming from a lack of infrastructure/equipment capacity and severe weather conditions is congestion in the container terminal and the subsequent inability of the port to accept as many containers as it should (Richer, 2010:23).

Port capacity is directly related to the velocity at which freight moves through port terminals. This implies that the faster freight moves through the port, the more freight the port can handle within a set period of time. A lack of storage capacity results in shortened stack dates, which results in a shorter period in which shippers can bring in containers for loading. A lack of capacity relating to freight velocity, on the other hand, results in a decrease in freight velocity at sea, and through other port systems, and can result in congestion. Under normal circumstances container freight velocity at sea is 25 knots. However, if the vessel is delayed in a port somewhere along the logistics chain, the average freight velocity is reduced and the consumption of port resources such as berths, terminal yards, urban roads, container stacks and handling equipment increases.

Low productivity in a port can stem from a lack of appropriate handling equipment, a lack of trained crane operators, or severe weather conditions causing the shutdown of certain terminal equipment. Productivity is one of the more difficult factors to control due to the human factor (Richer, 2010:23-24).

The two less controllable port related risks, which are inherently linked, are port congestion and weather conditions (Richer, 2010:23-24). Both port congestion and weather conditions can cause inefficiencies in operations often in the form of major delays to shipments and can subsequently result in large financial losses if not taken into account during the risk management process (Richer, 2010:24). Port congestion is discussed in further detail in Chapter 4 of this study.

The following section briefly introduces an African, and specifically a South African, context of international, and containerised trade.

3.2.3. South African Context

Over 90% of Africa's imports and exports are moved via vessels through maritime ports. Thus, increased innovation and development is required to support ever growing maritime trade. According to research, Africa has a number of economically significant ports in terms of TEU's handled per annum.

Table 3-1 presents the top ten African ports according to TEU's handled during a recent survey in 2013. The table indicates that Egypt is home to three of the top ten African ports, while South Africa boasts only two: the Port of Cape Town is ranked seventh on this list, with the Port of Durban ranking second.

Table 3-1: Top ten major Africa ports according to TEU's handled annually (2013)

Ranking in Africa	Country Name	Port Name	Number of TEU's ('000)
1	Egypt	Port Said	3 910
2	South Africa	Durban	2 775
3	Morocco	Tanger-Med	2 600
4	Egypt	Alexandria	1 519
5	Nigeria	Lagos	1 155
6	Egypt	Damietta	1 000
7	South Africa	Cape Town	988
8	Angola	Luanda	913
9	Kenya	Mombasa	894
10	Ghana	Tema	842

Source: GAIN Regional Freight Demand Model (RFDM), 2014

The world's geography limits the basic features of sea transport as vessels are forced to pass through specific maritime passages, capes and straits. These routes are generally located between major economic zones such as Western Europe, North America and East Asia (Lun, *et al.* 2010:12-14).

These routes are evident on the map in Figure 3-10, which also illustrates cargo flows around the African continent, with some of these flows linking to the maritime ports mentioned in Table 3-1. Connecting the Atlantic-Ocean-orientated traders and the Indian-Ocean-orientated traders is South Africa, the southernmost country of Africa.

According to Table 3-1, the Port of Durban and the Port of Cape Town are the two most significant ports of South Africa, handling approximately 2 775 000 and 988 000 TEU's respectively in 2013 alone. Figure 3-10 also indicates that the Port of Durban and the Port of Cape Town are significant nodes on the trade routes between Europe and India (black line), and Brazil and Asian markets (red line).

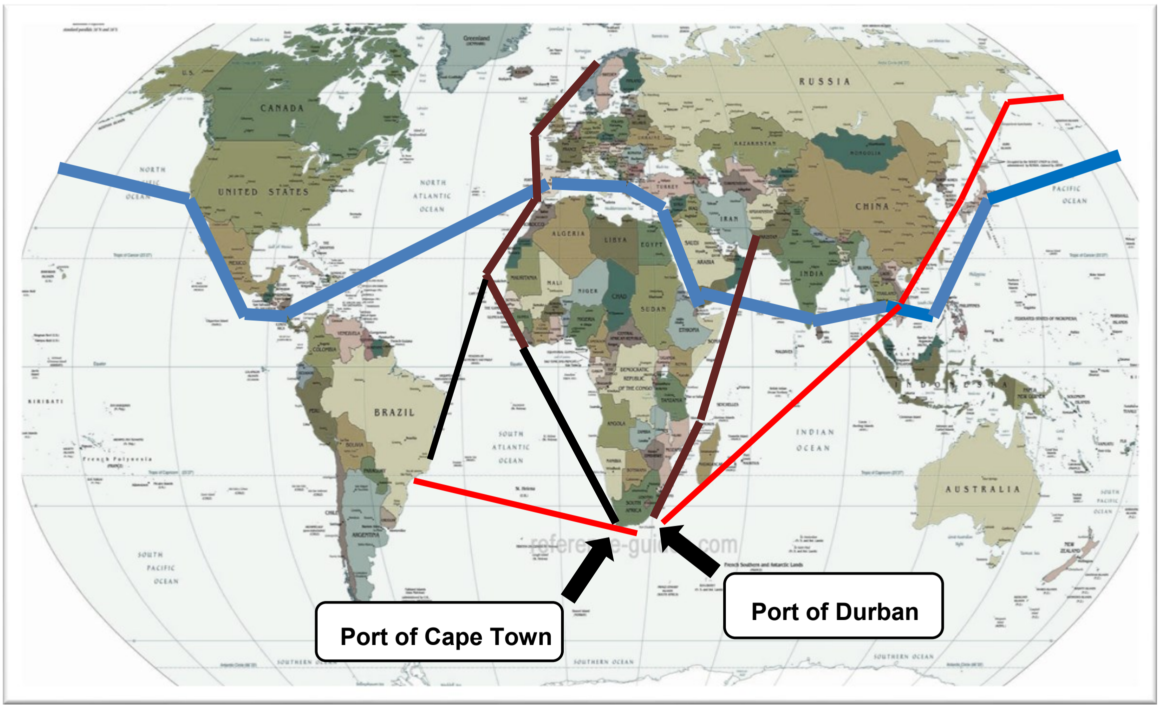

Figure 3-10: Cargo flows around Africa – A World perspective

Source: Transnet National Ports Authority, 2015

According to the Regional Freight Demand Model (RFDM) (GAIN Group, 2014/15), the Port of Durban is South Africa's largest and busiest multi-cargo port, handling approximately 56 million tons of cargo annually. Durban port is considered as South Africa's premier gateway for international trade as it is strategically located on the world shipping routes.

It is also the leading maritime port in the Southern African Development Community (SADC) region as it is one of the few ports in the world situated in close proximity to the central business district. Before the Port of Durban became the leader in promoting growth of the South African economy, the Port of Cape Town was one of the best strategically placed ports in South Africa.

The Port of Cape Town acted as a link between the Western global traders; the Americas and Europe; and the Eastern global traders; Asia, the Far East and Australia. However, since the widening of the Suez Canal, and the continual expansion of Durban port, it has lost some of its strategic importance for the country. The Port of Cape Town does, however, retain its importance to the Western Cape economy as a major link to global traders.

Table 3-2 lists the top ten export markets for the Western Cape for the year 2013. Importers contributing to export goods flowing through the Port of Cape Town include the European countries such as the Netherlands, as well as the United States and China. The United Kingdom ranked first, importing approximately 70 863 TEU's per annum, and the Netherlands ranked second, importing approximately 40 560 TEU's per annum.

Table 3-2: Top ten export markets for the Western Cape based on total TEU's (2013)

Rank	Importers	Total TEU's	Value (ZAR Billions)	% Share	% Growth 2012-2013
1	United Kingdom	70 863	6.66	8.89	25.04
2	Netherlands	40 560	6.74	9.00	-0.91
3	Germany	13 571	3.85	5.14	25.33
4	United States	10 815	3.49	4.65	4.38
5	Angola	5 051	2.54	3.40	11.83
6	China	3 712	2.12	2.84	49.39
7	Japan	3 339	2.65	3.53	117.68
8	Kenya	2 408	2.29	3.05	64.53
9	Singapore	1 612	2.70	3.61	9.17
10	Mozambique	842	3.78	5.05	148.62

Source: Transnet National Ports Authority, 2015

Similar to Table 3-2, Table 3-3 lists the top ten exporters contributing to the Western Cape's import market in 2013. Exporters to the Western Cape include Saudi Arabia, China, India and the United Kingdom.

Table 3-3: Top ten import markets for the Western Cape based on total TEU's

Rank	Exporters	Total TEU's	Value (ZAR Billions)	% Share	% Growth 2012-2013
1	China	51 858	28.01	15.01	39.27
2	Germany	16 386	8.10	4.34	65.45
3	United Kingdom	14 397	6.58	3.53	21.31
4	Italy	12 054	5.24	2.81	38.49
5	United States	11 985	4.71	2.52	13.80
6	Netherlands	7 661	4.64	2.48	-11.23
7	India	6 589	16.37	8.77	75.28
8	Saudi Arabia	2 096	37.67	20.19	-0.32
9	Singapore	333	7.54	4.04	75.42
10	Nigeria	29	13.59	7.28	-20.73

Source: Transnet National Ports Authority, 2015

Table 3-3 shows that China dominates exports with as much as 51 858 TEU's per annum, while Germany exports aproximately 16 389 TEU's per annum to the Western Cape. Similar to Durban, which is considered a premier gateway for international trade, the Port of Cape Town is often considered the gateway to South Africa and a number of landlocked African countries due to its strategic position and transport infrastructure.

The Port of Cape Town is also home to the second busiest container terminal within the country, with Durban port having the busiest. Both ports, along with most other South African ports deal in the import and export of several different cargo categories, namely, break bulk, dry bulk, liquid bulk, containers and automotive units.

Figure 3-11 illustrates the various categories of cargo, and percentage of tons, handled by the Port of Durban in 2014. Tons in containers and automotive tonnage are the dominant cargos handled with 27% share each, liquid bulk comes second with 21% share, while only 8% of imports and exports consist of dry bulk.

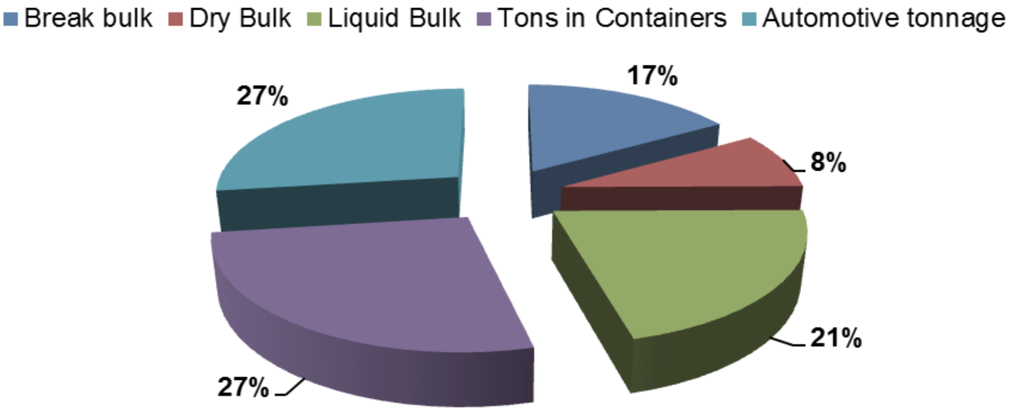

Figure 3-11: Percentage of tons per cargo category handled by the Port of Durban

Source: Adapted from GAIN Regional Freight Demand Model (RFDM), 2014

Figure 3-11 suggests that the most significant cargos passing through the Port of Durban are containers and automotive units. This suggestion is similar, yet different from that of the Port of Cape Town. Figure 3-12 illustrates the percentage of tons in terms of the same cargo categories handled by the Port of Cape Town in 2014.

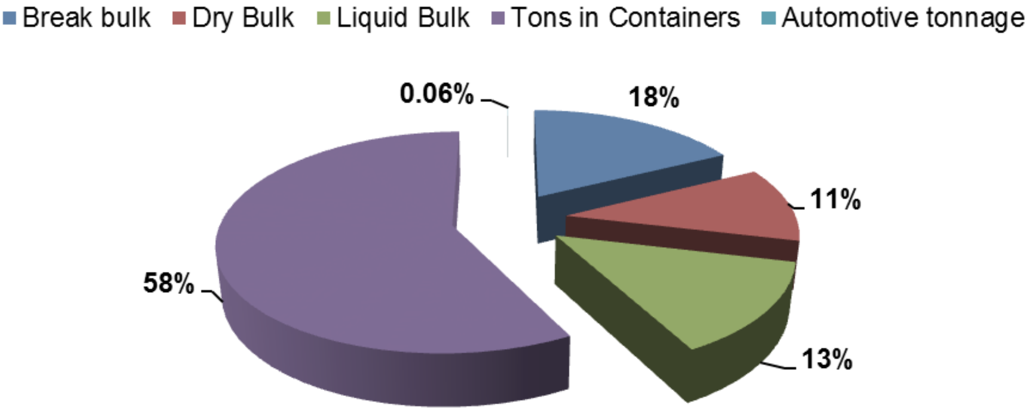

Figure 3-12: Percentage of tons per cargo category handled by the Port of Cape Town

Source: Adapted from GAIN Regional Freight Demand Model (RFDM), 2014

The figure shows that similar to Durban, containers are the dominant cargo handled with a 58% share, while automotive tonnage handled is the smallest cargo category with only a 0.06% share. Similar to Figure 3-11, Figure 3-12 suggests that containers are the most significant cargo category handled in the Port of Cape Town.

Together, the two figures (Figure 3-11 and Figure 3-12) suggest that containerised trade is one of the most significant cargo categories handled in South Africa with both ports handling large percentages. The Port of Cape Town, as the context of this study and the second most significant port in South Africa, is discussed in further detail in Chapter 5.

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3.3. Closing Remarks

In closing, this chapter discussed how the risk concept has evolved over time to result in a common definition. This common definition suggests that risk can be defined as an event of uncertainty which could result in a loss or a positive outcome. The chapter went further to discuss various risk assessment and profiling methods as well as the different types of risks present in organisations.

Operational risk, a type of risk common in supply chains was discussed and defined as the exposure of a company to losses resulting from internal and external factors such as failures in the execution of operations and processes. Operational risk can be experienced throughout the supply chain, but is most evident in linkages such as transport hubs and maritime ports.

The chapter discussed international trade, containerisation and the shipping industry. The discussion highlighted the importance of international trade to world economies and how containerisation has revolutionised international trade and the shipping industry through standardisation. Containerised trade has furthermore influenced the design and operations of maritime ports due to improvements in cargo handling and transportation.

The role of maritime ports in the success of international trade, containerised trade and the shipping industry was also discussed. In addition, port related risks such as a lack of capacity or productivity, adverse weather conditions and port congestion were briefly mentioned. The concept of port congestion is discussed further in the following chapter.

In conclusion, this chapter introduced the South African context of international and containerised trade, and identified the two most significant ports as the Port of Durban and the Port of Cape Town. One of the most prominent cargo categories handled was identified as containerised goods, with the Port of Cape Town handling a significant amount for the Western Cape economy. The Port of Cape Town, with specific focus on the Cape Town Container Terminal (CTCT), as the context of this study, is discussed in further detail in Chapter 5.

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Chapter 4: Port Congestion and Risk

Following Chapter 3, this chapter discusses the concept of port congestion in greater detail. It includes an introduction to port congestion, both globally and locally. The chapter identifies the various sources of congestion, and explains how port congestion is an operational risk to the efficiency of both ports and shipping companies. The chapter closes with an introduction to the South African context of the study.

4.1. Introduction to Port Congestion

Maritime ports, as mentioned in section 3.2.2 of Chapter 3, are widely renowned as critical logistics chain nodes in transportation and international trade. However, a common issue experienced by ports around the world is congestion resulting from controllable and relatively uncontrollable factors. These factors contributing to port congestion include a lack of infrastructure and equipment capacity, a lack of productivity, and adverse weather conditions (Meersman, Van de Voorde & Vanelsalnder, 2012:49). The occurrence of port congestion is a global PSCD as it not only impacts larger maritime ports, but also smaller ports worldwide.

According to Veloqui, Turias, Cerban, Gonsalez, Buiza and Beltran (2014:615-616), the continuous growth of maritime transport since 2011 has resulted in an increase in congestion in maritime ports, which has subsequently made congestion a common problem worldwide. In addition, the growth in container trade aggravates congestion (Fan, *et al.*, 2012:1121). The most significant impact of port congestion relates to port competition. Maritime ports operate within a “wide-open” marketplace. This implies that ports must deal with a large degree of competitiveness as shippers can choose from numerous available ports and logistics paths which best suit changing customer requirements. Shippers select ports of call based on a number of criteria.

According to Chang, Lee and Tongzon (2008:877) factors contributing to port selection include cargo volume capacity, terminal handling, availability of berths, and the location of the port, transhipment volume capacity, and the port’s hinterland connection network. In addition, the frequency of congestion in a port is also taken into consideration as shippers work to a relatively tight schedule and cannot afford time delays. This often results in shippers opting to “skip” congested ports for ports deemed as less congested.

Based on this, Veloqui *et al.* (2014:616) go on to suggest that congestion in ports may result in significant risks not only to the transport infrastructure, but also port competitiveness. Additional risks stemming from port congestion include delays in cargo delivery, loss of product value and increased port related costs.

A recent article in the Maritime Executive (2014) took a long-term look at port congestion around the world. The article suggested that port congestion should not be considered a short-term issue, but rather a persistent PSCD as an increasing number of maritime ports world wide experience congestion on a regular basis. However, it was further noted that certain world regions are at greater risk of persistent port congestion over the long-term due to the development of ever larger container vessels (Port Congestion: Look long term, 2014). Figure 4-1 from the article illustrates some of the main container ports around the world which reported congestion issues during 2014. The map suggests that congestion is not limited to any one part of the world and is not solely a developed or developing market issue.

Figure 4-1: Select container ports with recently reported port congestion

Source: Maritime-executive.com, 2014

Figure 4-1 indicates a relatively large number of popular maritime ports which experience congestion issues. As the sizes of vessels increase, along with the volumes of cargoes transported, shippers are likely to encounter an increasing number of ports with congestion issues. Therefore, to safeguard the growth of international trade for not only developed, but also developing markets, port congestion should be considered more seriously.

The successful management of port congestion should begin with an accurate and detailed definition. Although a significant amount of research has been conducted surrounding congestion, and specifically port congestion, a set definition has yet to be agreed upon.

A 1982 study conducted by Jansson and Shneerson (1982) resulted in the following definition of port congestion and congestion costs:

> "Congestion costs exist if the other short-run costs of port operations, per unit of throughput, are an increasing function of the actual capacity utilization. When actual demand exceeds capacity, extreme congestion costs arise, which we call queuing costs. *When a port is said to be congested, it is commonly meant that ships are queuing, waiting to obtain a berth*." [emphasis added].

This definition, with the emphasis added, suggests that with regards to maritime-side port congestion, a congestion cost is only levied once demand exceeds port capacity and results in vessel queuing or bunching. Ports are thus termed congested when vessels queue outside the port awaiting a berth to unload and load cargo.

Similar to the above definition, a study conducted by Meersman *et al.* (2012:51) argues that congestion generally implies that *a transport user, such as a vessel, delays another transport user*. This consequently results in a cost levied upon a third party, usually the customer. This cost increases as traffic levels increase, thus resulting in increased congestion.

Schwitzer, Martens, Beckman and Sun Yoo (2014:3) define port congestion more broadly as *bottlenecks, delays and other supply chain disruptions caused by several different factors.* These factors, similar to those mentioned previously, include insufficient capacity and productivity; bunching of vessels; vessel and vehicle scheduling clashes; severe weather conditions; and labour strikes (adapted from Schwitzer, Martens, Beckman & Sun Yoo. 2014).

This recent definition, in contrast to the older definitions suggested by Meersman *et al.* and Jansson and Shneerson, looks at a holistic view of port congestion to include causes stemming from both the maritime-side and the landside of a port. This general definition allows for further research and adaption. Thus, for the purpose of this study, this definition was adapted further to encompass those factors inherent to the context of the research. Subsequently, factors not relating to weather- and system-related challenges and the movement of vessels and vehicles were excluded.

This study, therefore, worked under the assumption (see section 1.6) that port congestion within the CTCT is caused by weather and system issues which result in delays in the turnaround time of vessels and vehicles.

This definition was selected for the purpose of this study due to the limitations and scope of the research mentioned in section 1.5 of Chapter 1, with the most significant aspect of scope being the context of the research, the Cape Town Container Terminal (CTCT). Congestion experienced in the Port of Cape Town, and its container terminal, is discussed in further detail in Chapter 5.

At this point it is important to note that congestion can be generated by a number of sources relating to port facilities and port activities. The next section discusses the various sources of congestion in further detail and refers specifically to maritime-side congestion and landside congestion.

4.2. Sources of Congestion

According to Meersman, *et al.* (2012:49), congestion appears in two forms. Congestion can be relatively hidden and appear as congestion costs, or it can visually appear in the form of vessel or vehicle queuing. A more common means of categorising port congestion is by the area from which it stems. According to De Wet (2014:65-67) port congestion primarily takes place in two areas of a port, namely the maritime-side and the landside.

A Maritime Executive (2014) article suggested that the causes of port congestion are numerous and varied, with many of the causes being short-term in nature. Table 4-1 suggests a number of examples of port congestion experienced by ports such as Rotterdam, Hamburg, Los Angeles/Long Beach and Hong Kong. The examples in Table 4-1 are categorised based on whether they stem from the maritime-side or the landside of a port.

Table 4-1: Examples of port congestion (maritime-side versus landside)

Examples of Maritime-side Port Congestion	**Examples of Landside Port Congestion**
Vessels off schedule	Trucker strikes
Closure of port due to weather conditions	Implementation of vehicle movement ban
Vessel bunching due to weather conditions	IT systems and equipment issues
Peaks caused by larger vessels	Terminal enhancement works
Impact of larger vessels and alliances	Railhead and road congestion

Source: Adapted from Maritime-executive.com, 2014

As suggested in Table 4-1, the most common maritime-side congestion issues result from either vessel movement or severe weather conditions. Landside congestion issues on the other hand generally result from IT or equipment related issues, labour issues or vehicle movement. These types of congestion issues are common to most maritime ports around the world.

In addition to the two forms of congestion that Meersman *et al.* (2014:49) suggested, Meersman *et al.* also suggest that congestion is commonly generated in port terminals, hinterland connection nodes and hinterland transportation modes. This subsequently suggests that most congestion problems stem from the landside of the port, due mainly to the complexity of developing solutions in this part of the logistics chain (Meersman, *et al,* 2012:50). However, it is important to consider the maritime-side of the port and the congestion issues which stem from vessel movement.

The following two sections discuss congestion on the maritime-side and the landside of a port in further detail. Specific reference to South Africa is covered in section 4.4 of this chapter.

4.2.1. Maritime-side Congestion

Due to the rapid increase in containerised trade and container cargo volumes the number of vessels calling at container terminals has subsequently increased. This rapid increase in vessels has caused greater congestion issues, which subsequently increase time delays in the port system and can result in serious financial and commercial issues for the shipping sector. In addition to inefficiencies due to a lack of infrastructure and equipment capacity, container terminals can experience weather- and system-related challenges, which result in further inefficiencies.

Literature on maritime-side congestion suggests a number of ways in which congestion can be classified or described. The following section discusses the various views on maritime-side congestion and concludes with a summary and collective definition. This is followed by a section discussing landside congestion in a similar layout.

❖ *Maritime-side Congestion Literature*

Meersman *et al.* (2012: 52) suggest that a vessel heading from open seas to a maritime port may experience congestion repeatedly in a number of places, depending on the structure and location of the port in the logistics chain. These places include maritime access routes, locks, berths, loading and unloading, storage, and customs inspection.

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In certain areas of the world, ports are linked to open seas by rivers or canals and congestion can occur due to tide dependences and capacity restrictions. Vessels in these cases often have to adjust speed in open seas to adapt to the expected slots of these maritime access routes. Certain of these ports lie behind a system of locks. This can result in congestion if the number of vessels scheduled to use the lock is greater than the capacity of the lock itself. However, under normal circumstances, vessels do not queue at the entrance of the lock, but rather adjust vessel speed to approach the lock to meet the expected slot (Meersman *et al.* 2012:52).

According to Meersman *et al.* (2012:52) congestion resulting from berth availability is a common issue in ports around the world. Congestion relating to berths occurs when certain berths are occupied by vessels which are not yet prepared for departure. In such instances the awaiting vessel must moor temporarily at another berth or wait outside the port. Linked to berth availability is congestion resulting from a lack of equipment capacity. Certain terminals have a limited number of berths for the loading and unloading of containers from vessels. Once all of these berths are occupied by vessels a shortage of loading and unloading equipment such as gantry cranes and straddle carriers can cause time delays and system backlogs (Meersman, *et al.* 2012:52).

Similar to a lack of equipment capacity, certain terminals lack sufficient storage space in port areas, which can result in congestion. Storage related congestion can also include additional waiting time for both containers and vessels due to either ineffective configuration or through unexpected moves made by equipment.

In all international maritime ports around the world customs clearance is required to enter or leave a country. Customs clearance is awarded once a thorough customs inspection of all cargo and containers has been conducted. Meersman, *et al.* (2012:52) argues that the time required to conduct these inspections can result in congestion issues such as time delays. Once customs clearance has been awarded, loading and unloading of containers from vessels can occur.

In contrast to Meersman, *et al*'s suggestion, De Wet (2014:65-67) argues that congestion resulting from the maritime-side of ports/terminals can be defined as *delays resulting from the movement and scheduling of ocean vessels entering and exiting the port of call*. This suggests that vessel related congestion can rather be attributed to a number of factors.

These factors include severe weather conditions, stoppages of vessels in and outside the harbour, inefficient intermodal transport systems, inefficient cargo handling within the container terminal, and customs clearance issues. These factors begin before the vessel enters the port, and continue while the vessel is in the terminal for loading and unloading.

A recent study conducted by Moon and Woo (2015:445) disagrees with both Meersman *et al.*'s and De Wet's descriptions of maritime-side congestion. Moon and Woo (2015) suggest that congestion occurs during a vessel's time in port. This time spent in port is defined as *the time duration between the vessel's arrival at the buoy and the vessel's departure from the same buoy*. The time in port includes waiting time, manoeuvring time, berthing time, productive time and idle time. Figure 4-2 illustrates these elements in a diagram.

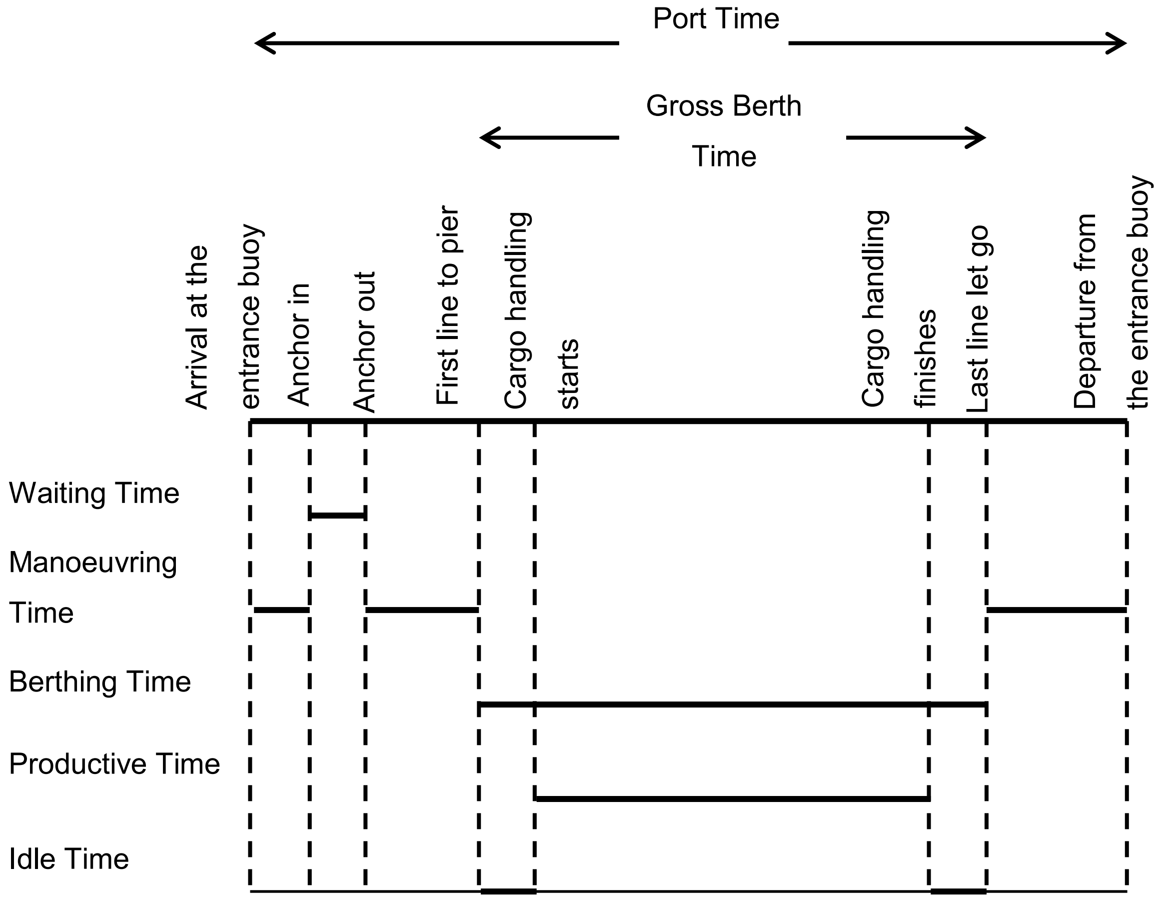

Figure 4-2: Illustration of vessel time in port

Source: Moon and Woo, 2015

Of the various activities shown in Figure 4-2, the two more important, in terms of their influence on port time, are 'waiting time' and 'berthing time'. Waiting time can range from a few hours to a number of days depending on weather conditions and capacity constraints of the terminal.

Berthing time can also range from less than an hour to several hours depending on congestion and accurate scheduling. Thus, it can be said that the vessel's time in port is a variable element as it is easily influenced by the amount of time spent on each activity mentioned in Figure 4-2.

The three arguments previously discussed regarding the definition or description of maritime port congestion are summarised in Table 4-2.

Table 4-2: Summary of maritime-side port congestion literature

Academic Researchers	**Descriptions/Definitions**
Meersman , Van de Voorde & Vanelsalnder (2012)	Maritime congestion can be experienced repeatedly in various places or corridors.
De Wet (2014)	Maritime congestion can be defined as *delays resulting from factors influencing the movement and scheduling of ocean vessels entering and exiting the port of call*.
Moon and Woo (2015)	Maritime congestion occurs during a vessel's time in port, which is defined as *the time duration between the vessel's arrival at the buoy and the vessel's departure from the same buoy*.

The above three descriptions of maritime congestion featured in Table 4-2 appear different, but each touches on an element contributing to maritime congestion experienced in ports worldwide. These descriptions can thus be used to develop a more intrinsic definition, which encompasses all elements, factors and activities contributing to maritime congestion.

Maritime congestion can thus be defined as follows:

> *…delays or additional costs which result due to external and internal factors relating to port/terminal activities during the course of vessel entry and exit from a port/terminal. These factors can occur repeatedly and at various locations during a vessel's movement along the logistics chain between ports.*

According to this definition, external factors refer to factors outside the control of the port system such as adverse weather conditions, and inefficient intermodal transport systems for example. Internal factors originate from within the port/terminal and are more controllable.

They include vessel stoppages in- or outside the port/terminal, inefficient cargo/container handling and customs clearance issues, for example. These factors relate to port/terminal activities such as waiting for a berth, and manoeuvring into the port and/or berth.

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The following section discusses the landside source of congestion and refers to several sources of literature to identify a common definition.

4.2.2. Landside Congestion

According to Wan, Zhang and Yuen (2013:418) the majority of container traffic is transported into and out of maritime ports via road vehicles. Therefore, congestion on public access roads and urban roads surrounding the port has become one of the more significant factors influencing port competitiveness and efficiency. Wan, *et al.* (2013:418) go on to suggest that the significant growth of international trade, as a result of containerised trade, has led to increased pressure on the intermodal transportation system of a number of countries. Bottlenecks in the transportation system result in delays, which subsequently increase transport times and fuel costs, whilst decreasing the overall reliability of commercial road transportation and increasing the probability of unsynchronised scheduling. The accumulation of these factors could consequently translate into additional costs and charges borne by those shippers electing to make use of intermodal transport to ship cargoes.

The definition of landside congestion is a difficult concept to define as it has both physical and relative dimensions. An additional aspect which makes defining road congestion difficult is the large number of different literary views and definitions available. The following section discusses literature surrounding the definition of landside congestion.

❖ *Landside Congestion Literature*

Landside congestion, often referred to as either road congestion or traffic congestion, can be defined in a number of ways depending on the literature consulted. The simplest version comes from the English Dictionary and states that road congestion is *an excessive or abnormal accumulation of traffic on rural or urban roads* (*The Oxford English Dictionary, 2015).*

According to ‘An Introduction to the Department for Transport’s road congestion statistics’ (2013:1), road congestion can be explained in its simplest form as *the interaction of more than one vehicle which results in the impeded progress of multiple vehicles.* This definition refers to the physical dimensions of road congestion and suggests that vehicle interactions can influence individual journeys.

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These vehicle interactions increase as road capacity decreases or road capacity is reduced by road works or closures. Road congestion is also influenced by uncontrollable factors such as weather conditions and unexpected traffic accidents (An introduction to the Department for Transport's road congestion statistics, 2013:1).

'An introduction to the Department for Transport's road congestion statistics' (2013:1) goes on to suggest that this physical definition of road congestion fails to acknowledge that congestion could have different definitions to different people. For example, individuals residing in predominately rural areas might regard severe congestion as unusually long traffic queues along their daily commute route, while individuals residing in metropolitan areas might experience the same amount of traffic along their commute route and consider it as being uncongested. Therefore, road congestion can be defined in relative terms as *the lack of alignment of actual road network performance and user expectations of traffic conditions on the road network*.

Similar to the above definition of road congestion, Stopher (2004:118) acknowledges that road congestion has different definitions for different people. For example, traffic engineers define congestion as *a phenomenon that occurs when traffic input volumes exceed road facility capacity.*

This definition suggests that congestion could be used as an indicator of maximum or excessive facility capacity. Another implication of this definition suggests that as traffic volumes increase, so does the density of traffic (density referring to the number of vehicles per lane per kilometre of road). Therefore, as traffic density increases, vehicle speed decreases due to the increasing proximity of other vehicles.

However, Stopher (2004:118) notes that traffic density can only increase to a certain amount. Once vehicles are "bumper-to-bumper", speed decreases to zero, thus resulting in a "traffic jam" of maximum traffic density and therefore maximum congestion. This "traffic jam" density (Stopher, 2004:118) is considered inefficient. However, a number of studies argue that the operation of the transport system at the point where traffic volume equals road capacity, and where traffic flow has not become unstable, represents the maximum use of road capacity infrastructure. It is, however, agreed that this suggestion may not signify the optimal use of the road network. The definitions previously discussed are summarised in Table 4-3.

Table 4-3: Summary of landside port congestion literature

Academic Researchers	**Descriptions/Definitions**
Oxford English Dictionary (2015)	Road congestion is *an excessive or abnormal accumulation of traffic on rural or urban roads*.
An Introduction to the Department for Transport's road congestion statistics (2013)	Physical Terms: Road congestion is *the interaction of more than one vehicle which results in the impeded progress of multiple vehicles.* Relative Terms: Road congestion is *the lack of alignment of actual road network performance and user expectations of traffic conditions on the road network*.
Stopher (2004)	Road congestion is *a phenomenon that occurs when traffic input volumes exceed road facility capacity.*

The descriptions summarised in Table 4-3 appear different, but each touches on an element contributing to landside congestion experienced in and around maritime ports worldwide. These different definitions can subsequently be used to develop an intrinsic definition, which includes all elements, factors and/or activities which contribute to landside congestion.

Landside congestion can thus be defined as follows:

> *…delays or additional costs which result due to either the lack of alignment of road network capacity and input traffic volumes, or other external factors, which subsequently influence overall vehicle volumes and movement on urban and rural road networks.*

This definition suggests that other external factors could influence road congestion. These factors include traffic accidents, severe weather, labour strikes, and road/lane closures due to road works.

The next section discusses the risks and consequences which result from unmanaged port congestion, highlighting the importance of risk management strategies for port congestion.

4.3. Risks and Consequences of Congestion

Port congestion, if left unmanaged is a risk which can result in numerous negative implications for not only ports themselves, but also the international shipping companies who operate through the ports.

As mentioned previously, port congestion can have a negative impact on road transportation costs. In addition to the short-term implications of port congestion such as scheduling time loss and additional fuel consumption, the long-term implications should be considered. For example, the time loss resulting from port congestion can generate large costs such as higher vessel operating costs and high investment costs. Measures and strategies to mitigate or avoid congestion subsequently decrease these costs and increase the efficiency of port activities (Meersman, *et al.* 2012:55).

It is, however, important to note that the mere presence of congestion in a port system suggests that the port is both a valuable and scarce good. This subsequently suggests that the solution to congestion should be relatively straightforward, with port authorities increasing port dues and thus benefiting from the scarcity of capacity. This is, however, not the case in practice. Most Port Authorities choose rather to keep port charges low, even in ports which are deemed congested. The reasoning for this decision generally involves the belief that higher port charges will cause a loss of vessel traffic and also result in higher prices for imported products (Meersman, *et al.* 2012:56).

In addition to the short-term and long-term implications of port congestion, it should also be noted that port congestion can cause a ripple effect in the supply chain. This ripple effect can extend from international companies to eventually influence the economic status of both that given companies' industry and the country's import/export industry as a whole. Based on this, it can be implied that a successfully conducted risk assessment and development of risk profiles could assist international companies which face the port congestion risk on a daily basis. Benefits could include identifying areas of inefficiency for improvement as well as the development of risk treatment strategies aimed at reducing inefficiencies and maintaining the firm's competitive advantage.

Based on this, it is recommended that when analysing port congestion, both the long-term and short-term implications should be considered to determine where congestion is more persistent and if congestion management is effective. One such congestion management strategy is to impose a congestion surcharge.

Figure 4-3, from a recent article in the Maritime Executive (Port Congestion: Look long-term, 2014), illustrates locations around the world where a number of ocean carriers have imposed a congestion surcharge over the last five years to transfer the bulk of congestion costs to the client. Carriers do not, however, keep a fixed congestion surcharge as most causes of congestion are not consistent throughout a business year.

Therefore, most carriers opt to rather add a congestion surcharge to the base rate ocean freight cost to reflect any additional expenses incurred when calling at congested ports (Marais, 2015). In Figure 4-3 for example, carriers in the US charge a congestion surcharge only when there is an increased likelihood of port shutdowns or stoppages.

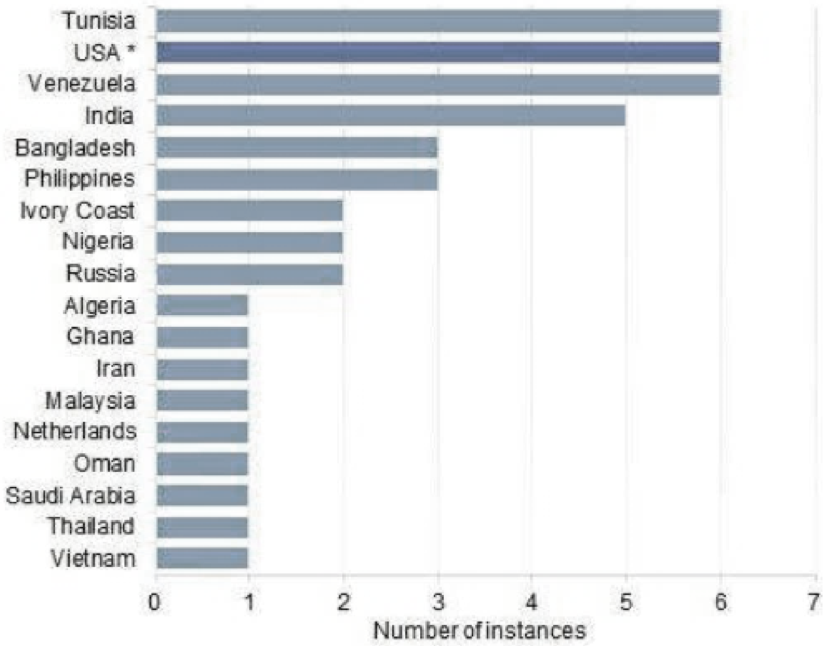

Figure 4-3: Countries with congestion surcharges imposed by selected carriers

Source: Maritime-executive.com, 2014

The implementation of a congestion charge has both benefits and drawbacks. The benefits are relatively clear. Firstly, congestion surcharges generate higher income for the maritime port as they are a source of funding for port expansion plans. Expanding either port infrastructure or services rendered will subsequently enhance port self-sufficiency and allow the port to be less dependent on subsidises supplied by the public. Furthermore, according to Meersman *et al.* (2012:55), congestion surcharges encourage more efficient use of available facilities at the port.

However, the drawbacks of a congestion surcharge should be considered. Demand for port services, and therefore port congestion, tend to fluctuate seasonally due to various factors and may contain random elements of influence such as weather conditions (Meersman, *et al.* 2012:56). Stronger shipping companies pass on congestion charges to third parties, often through a mark-up, which can consequently have an indirectly negative effect on the demand for maritime port services and result in unsatisfied customers. The risks and consequences stemming from port congestion can vary depending on the country and port.

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The South African context, with specific reference to port congestion in its two main ports (the Port of Durban and the Port of Cape Town), is discussed in the following section.

4.4. South African Context - Durban versus Cape Town

Section 3.2.3 of the previous chapter briefly discussed international trade with regards to South Africa. Table 3-1 illustrated the Port of Durban as South Africa’s most significant port, with the Port of Cape Town being second. Due to their significance to South Africa and its economy, PSCD which impact the Port of Durban and the Port of Cape Town should be considered seriously in the risk management process.

One such PSCD which is not considered in-depth is port congestion, however, it remains a daily issue for both the Port of Cape Town and Durban port. Despite not featuring on the map in Figure 4-1 shown in section 4.1, the Port of Durban and the Port of Cape Town have both reported increasing port congestion over the past five years (Birkenstock, 2015).

In South Africa, congestion resulting from maritime access routes and locks does not occur as all maritime ports are located on the coast and therefore have relatively high accessibility. South African container terminals do, however, experience congestion resulting from berths, loading and unloading, storage, and customs inspection. Generally, the Port of Cape Town and the Port of Durban experience congestion issues resulting from different factors, with congestion in the Port of Durban resulting from a lack of infrastructure and equipment capacity, and congestion in the Port of Cape Town stemming from weather- and system-related challenges (Birkenstock, 2015).

The congestion issues in Durban port have reached such levels that TPT recently underwent a partnership with supply chain solutions company Barloworld Logistics to ease congestion through an expansion of Durban harbour (Mkhize, 2014). The article featured in “Business Day Live” suggested that the project was aimed at easing container congestion and that further “capacity-creation” projects are underway across a number of TPT sites.

This suggests that TPT may have further plans to decrease congestion issues in ports such as the Port of Cape Town, which experiences congestion from a number of sources. To date, this does not include the implementation of congestion surcharges (Birkenstock, 2015). The Port of Cape Town, specifically the CTCT, is discussed in further detail in the following chapter.

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4.5. Closing Remarks

Port congestion is a PSCD experienced in numerous maritime ports around the world. This fact is concerning considering the importance of maritime ports to international and containerised trade, as discussed in Chapter 3. Port congestion is, however, a manageable, uncontrollable risk and management strategies to deal with the repercussions of congestion, such as delays and additional costs, can be developed.

This chapter discussed the concept of port congestion and highlighted its significance as a risk to port efficiency. Furthermore, the general definition of port congestion was discussed before the definition used for the purpose of this study was put forth, as mentioned in section 1.6 of Chapter 1. Following this general definition, the sources of congestion were discussed, which led to the distinction between maritime-side and landside congestion.

Section 4.2 discussed the literature behind both maritime-side and landside congestion, and introduced various sources before the development of an intrinsic definition of each. This section was followed by the risks and consequences generally resulting from port congestion, with the most prominent implications or consequences found to be time delays and additional costs. Time delays, including delays to port/terminal operations resulting in queuing, and schedule delays resulting in late collection and delivery of cargo. Additional costs resulting from congestion were found to be either short-term or long-term in nature.

The final section of this chapter introduced the South African context of port congestion, with specific reference to the Port of Durban and the Port of Cape Town. Durban port is said to experience mostly capacity related congestion, while Cape Town port suffers from weather- and system-related congestion.

Chapter 5, which follows, discusses the context of the case study, namely, the Port of Cape Town and the CTCT. There congestion is discussed further with specific reference to sources of congestion and the significant implications of congestion.

Chapter 5: Case Study Context – Port of Cape Town

Following on from Chapter 4, this chapter introduces general background and history on the Port of Cape Town and the CTCT. The chapter goes further to discuss the sources of port congestion in the CTCT and the implications to terminal efficiency and international shipping companies.

As one of the best strategically placed ports in South Africa, the Port of Cape Town forms a vital trade link between the Western global traders[16]; and the Eastern global traders[17]. In addition, the Port of Cape Town facilitates the majority of the trade within the Western Cape, linking the province to international trade and grounds several key economic sectors such as fishing, fresh produce exports, and retail consumer goods (De Wet, 2014: 49). According to the 2014 Transnet Long-Term Planning Framework, Cape Town is considered the limited gateway for time sensitive cargo from the west, destined for Gauteng (Chapter 4: Port Development Plan, 2014:125).

5.1. History of the Port

In terms of international trade, the significance of the Southern tip of Africa first came to light through the need for trade between Western Europe and the East Asian countries. This need for trade was evident by the fourteen hundreds and an eastern route via the Mediterranean Sea was not a viable option. This left only two alternatives, namely a Southern route around Africa or a Western route as done by Columbus (Janse van Rensburg. 1997:50).

The earliest mention of the Table Bay area was in 1486 by Bartholomeu Dias the Portuguese explorer. After its initial discovery the Dutch East India Company sent Jan van Riebeeck in 1652 to set up a way-station for passing Dutch ships. At this point, the Port of Cape Town was known as the Port of the Cape and consisted of relatively simple infrastructure needed to supply passing vessels. These passing vessels generally included Dutch, British and French vessels which called at the port for fresh water, meat, wood and other support services. The British travellers soon began referring to the settlements surrounding the port as “Cape Town”, which has remained the name of the city to this day (Port of Cape Town, 2015).

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[16] The Americas and European countries such as the United Kingdom, Netherlands, Germany and Italy.

[17] Asia (China, Japan, India and Singapore), Far East (Saudi Arabia) and Australia.

Figure 5-1 illustrates the original perimeters of the trading station during the 1650’s in purple. Passing ships would simply anchor in the bay and smaller vessels would transfer cargo to and from the shore.

Figure 5-1: Original Port of the Cape trading station in the 1650’s

Source: Adapted from Transnet National Ports Authority, 2015

In 1781 the Port of Cape Town experienced its first conflict as the British attempted to occupy the port for its strategic positioning on the trade route to the Far East. However, the attempt was unsuccessful as the French Fleet had built a garrison to assist the Dutch defenders. Following the arrival of the French, the Port of Cape Town experienced an increase in economic wealth and both the town and port expanded.

In 1795 Great Britain was successful in occupying the Port of Cape Town and the British Cape Colony grew throughout the 1800’s with several new towns originating in the surrounding areas (Port of Cape Town, 2015). The British upgraded roads and constructed an electric tramway to transfer supplies between the town and the Port of Cape Town.

The start of a new economic era began with the discovery of diamonds at Kimberley in 1867. This resulted in direct competition between the Port of the Cape and Port Elizabeth to obtain the majority of trade to Kimberley. The initial discovery of diamonds in 1867 was followed closely by the discovery of gold in 1884 at the Rand in the area then known as Zuid-Afrikaansche Republiek (Janse van Rensburg. 1997:51).

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The subsequent trade resulting from these discoveries was handled predominantly by the Port of Durban as it was the closest of the colonial ports. To share in the development of the country, the Port of the Cape, which could provide limited services at this time, was upgraded with the building of the first dock in 1860. Figure 5-2 illustrates the upgrades done to the Port of the Cape in 1860 in red. This included the construction of the first safe harbour to facilitate the increased volume of passing ships.

This dock was known as the Alfred Dock and included the construction of a simple breakwater to protect entering vessels from severe weather conditions. Despite the port being further away from the economic centres of those days (Kimberley and the Rand), the Port of the Cape continued to be the most significant port for passing ships.

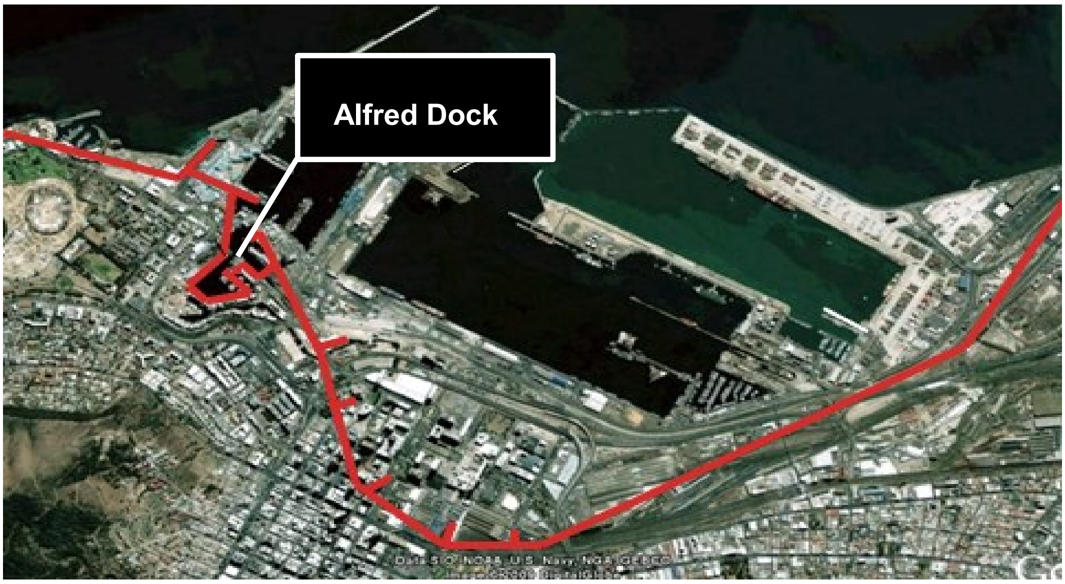

Figure 5-2: Upgrades to the Port of the Cape in the 1870's

Source: Adapted from Transnet National Ports Authority, 2015

The initial construction of the Alfred Dock in 1860 was closely followed by further upgrades to the port. The major changes to the port began with the foreshore reclamation, which eventually led to the port known today. The reclamation of the foreshore in 1920 and the construction of the Victoria Basin are illustrated in yellow on Figure 5-3.

Figure 5-3: Reclamation of the foreshore and construction of the Victoria Basin in 1920

Source: Adapted from Transnet National Ports Authority, 2015

The Victoria Basin as it is known today was then known as the Waterfront dock. Figure 5-4 shows the Waterfront dock and its new operating infrastructure in the early 1900's.

Figure 5-4: Historical photograph of the Waterfront dock, early 1900s

Source: Adapted from blackexpat.com, 2009

The construction of the Victoria Basin in the early 1900s was followed by the construction of an additional dock to accommodate increasing volumes of vessels. Figure 5-5 illustrates the construction of this dock in 1935 in green.

Figure 5-5: Further upgrades to the Port of the Cape in 1935

Source: Adapted from Transnet National Ports Authority, 2015

Within 10 years of the construction of the additional dock previously mentioned, further upgrades were done to the Port of Cape Town (Figure 5-6 in blue). These upgrades included the construction of the Duncan Dock, which included a tanker basin and a small craft basin.

Figure 5-6: Construction of the Duncan Dock and other basins in 1945

Source: Adapted from Transnet National Ports Authority, 2015

Figure 5-7 illustrates the upgraded port in the early 1940s, which allowed the facilitation of more vessels.

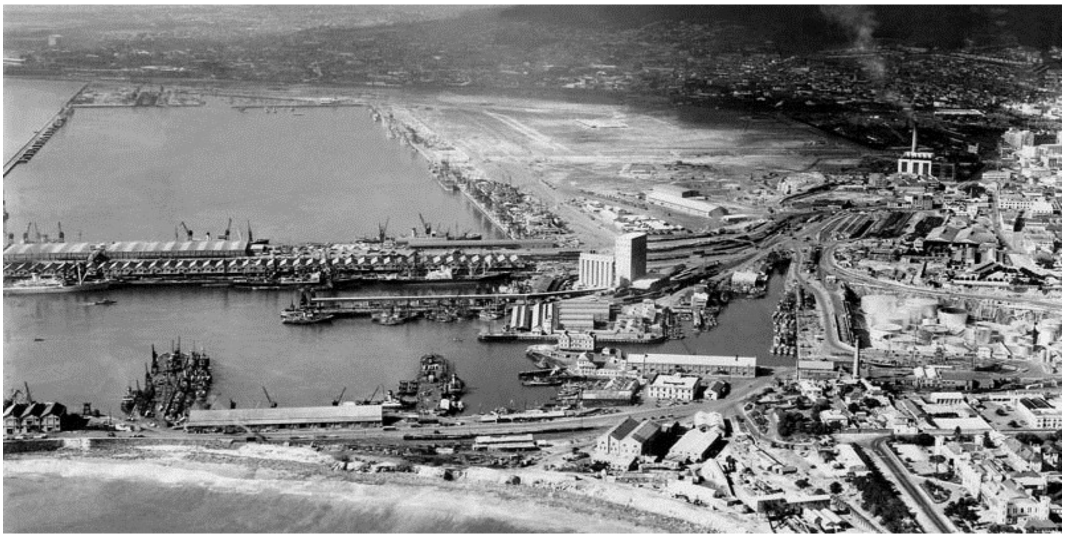

Figure 5-7: Cape Town foreshore in the late 1940's

Source: Taken from ViewfromAbove.com, 2004

The Port of Cape Town remained relatively unchanged until 1975, at which point the Ben Schoeman Dock was constructed to facilitate increasing volumes of container vessels. The dock constructed, which later became known as the CTCT, is illustrated in Figure 5-8 in orange. This addition to the Port of Cape Town was constructed on the seaward side and did not include further reclamation of the foreshore. Furthermore, the addition of the Ben Schoeman Dock is the most recent fixed infrastructure expansion done to the port.

Figure 5-8: Construction of the Ben Schoeman Container Terminal in 1975

Source: Adapted from Transnet National Ports Authority, 2015

The figures mentioned thus far are adapted from a figure provided by the TNPA, which illustrates the development of the Port of Cape Town over time. Each expansion or construction of an additional dock is illustrated on Figure 5-9. More recent upgrades done to the container terminal were less drastic in nature and did not involve direct alteration to the current port facilities. Upgrades done in from 2010 to 2013 included improvements of container handling equipment, quay refurbishment, basin deepening and container terminal reconfiguration.

Figure 5-9: Map illustrating upgrades done to the Port of Cape Town over time

Source: Transnet National Ports Authority, 2015

The completion of the latest improvements led to the current operational efficiency of the port today. Figure 5-10 is an aerial photograph of the present day Port of Cape Town and shows the two main docks, namely the Duncan Dock and the Ben Schoeman Dock.

Figure 5-10: Aerial Photograph of the Port of Cape Town

Source: Transnet National Ports Authority, 2015

The current facilities and operations in place at the Port of Cape Town are discussed briefly in the following section.

5.2. Current Port Facilities and Operations

In today's world the Port of Cape Town is an established maritime port providing container, bulk and general cargo handling services to the Western Cape hinterland. According to TNPA (Birkenstock, 2015), the Port of Cape Town renders a number of additional maritime services, namely, pilotage, towage, berthing, vessel traffic services, as well as fresh water, electricity and refuse removal. Due to its strategic positioning, the Port of Cape Town is the ideal way-station for a number of industries and foreign markets. The port is the preferred port for the export of fresh fruit as its position in relation to European and American markets reduces sea voyage times compared to Durban port.

The 2014 Transnet Long-Term Planning Framework indicates that Cape Town services approximately 2 400 ocean carriers per year, which is second to Durban, which services approximately 3 900 ocean carriers per year (Chapter 4: Port Development Plan, 2014:141).

The Port of Cape Town is also positioned strategically on the South Atlantic route around Africa, providing an alternative to the Suez Canal. This makes the port the popular East-West route for international trade as mentioned in section 3.2.3 of the previous chapter.

In addition to its strategic positioning on the South Atlantic trade route, the Port of Cape Town is the preferred port of call for passenger cruise ships on around the world tourist voyages (Transnet National Port Authority, 2013/14). This is mainly due to the large number of tourist attractions offered by the Western Cape Province such as the Winelands and Table Mountain. In addition, the Cape Town International Airport conveniently provides airline connections[18] to most parts of the world.

Furthermore, certain operational capabilities of the Port of Cape Town allow the port to service the emerging West African oil industry in support services, repairs and maintenance facilities (Port of Cape Town: Freight Transport Databank, 2015). The deep entrance to the port and its complete repair facilities and capabilities are especially useful to offshore drilling platforms, which require deep port basins and extensive maintenance facilities.

The Port of Cape Town consists of a total land area of 253 hectares, while the total body of water area is 9163 hectares. The port is partially protected from severe weather conditions by breakwaters which span 9.8km of the 20km distance surrounding the port. The port currently has 42 berths for import and export vessels to load and offload cargo, and must facilitate approximately 54 000 000 vessels per annum (Transnet National Port Authority, 2013/14). The current layout of the Port of Cape Town is discussed in terms of the sea and landside of the port.

The sea side of the port has the two basins, namely the Duncan Dock and the newest and largest dock known as the Ben Schoeman Dock, or the CTCT. The Duncan Dock is a multi-purpose dock which consists of general cargo berths and bulk liquid dolphin berths, while the Ben Schoeman Dock has predominately container berths. These container berths are specifically designed to be deeper to accommodate large container vessels.

These docks are operational 24 hours a day, 7 days a week, but are occasionally closed during the winter (June - August) and summer (December to February) months due to severe weather conditions. Strong South-Easterly gale force winds and large ocean swells interfere with vessel berthing and cargo handling. Generally, the port is sheltered from the prevailing South-Easterly winds and the breakwater extensions done to the port protect the outer container terminal without obstructing the entrance into the inner Duncan Dock. The eastern side of the Duncan Dock houses vessel repair jetty berths as well as the Sturrock dry-dock.

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[18] The majority of these connections are indirect through airlines such as SAA (via OR Tambo International Airport), KML (via Amsterdam Airport - Schiphol), Turkish Airlines and Emirates (via Dubai International Airport) for example.

The ports also houses basins, which have become too old for commercial use. These basins have been converted into the V&A Waterfront, which falls outside the perimeter of the port and are used for the berthing of tug vessels and admin crafts.

Various locations around the port are also allocated for the berthing of local and foreign fishing vessels, while recreational crafts are berthed in either the Yacht Basin or the Elliot Basin. Figure 5-11 illustrates these various docks and berthing areas. A larger version of the figure can be seen in Addendum M.

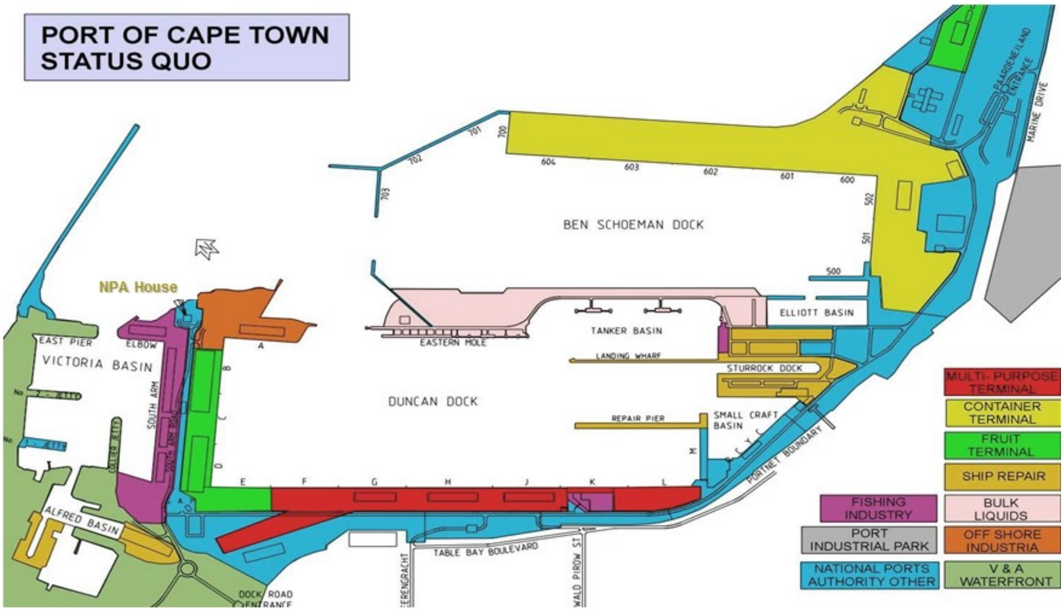

Figure 5-11: Current facilities of the Port of Cape Town, 2015

Source: Transnet National Ports Authority, 2015

In contrast with the sea side layout of the port, the landside of the port consists of 234 hectares of land. The container terminal and its operations occupy 69 hectares of the land, 45 hectares is allocated to bulk and break bulk cargo, while 25 hectares is occupied by ship repair facilities. Due to its age and geographical location, the Port of Cape Town has limited quayside land in relation to its berthing capacity. Furthermore, the port has limited opportunities for landward expansions due to the surrounding city infrastructure.

The previous discussion of port layout mentioned the various types of cargos handled by the port and suggests that the layout can alternatively be discussed in terms of these types of cargos. Table 5-1 provided by TNPA (Port of Cape Town, 2015) describes the port's layout in terms of the various cargo types; namely, containers, dry bulk, break bulk and liquid bulk. Furthermore, the table includes in-depth information on each cargo type. For example, the table shows that the break bulk terminal has the largest capacity at 4.2 million TEU's, whilst the container terminal has a capacity of only one million TEU's.

Table 5-1: Layout of the Port of Cape Town according to cargo type

Cargo type	Terminal	Berths	Usable berths	Terminal capacity (TEUs)
Containers	CTCT	601, 602, 603, 604	4	1 000 000
Dry bulk	MPT	G, H	2	1 400 000
Break bulk	MPT & FPT	B, C, D, E, F, J	6	4 200 000
Liquid bulk	Chevron , Grindrod, etc.	TB1 and TB2	2	3 400 000

Source: Adapted from Transnet National Ports Authority, 2015

In addition to terminal capacity, Table 5-1 indicates which cargo type is handled at which dock and in which berth at the port. This information used in conjunction with Figure 5-12 shown earlier (see Addendum M) offers a visual representation of where the various cargo types are handled in the port. For example, Table 5-1 indicates that containers are handled in the CTCT (yellow on the figure) at berths 601, 602, 603 and 604, while break bulk cargo is handled by either the Fresh Produce Terminal (FPT) (green on the figure) at berths B, C, D and E; or the Multi-Purpose Terminal (MPT) (red on the figure) at berths F and J.

The previous discussion of port layout highlighted the sea side and landside of the port, as well as the various types of cargo handled by the port. However, an equally important element to port layout is port capacity. Compared to other ports in South Africa, and as mentioned previously in section 3.2.3 of the Chapter 3, the Port of Cape Town handles only 2.2% of the country's break bulk cargo and 17% of all containerised cargo (Transnet National Port Authority, 2013/14). Of the vessels moving through the Port of Cape Town approximately 71.5% are container vessels, 14.5% are bulk cargo vessels and 6% are general cargo vessels. This suggests that the CTCT is the most active terminal at the Port of Cape Town and is therefore more likely to experience inefficiencies due to the high volume throughput it experiences annually.

Port operations and terminal operations are managed and controlled by two separate divisions of Transnet, namely TNPA and TPT. These two entities work together in ensuring the efficient operation of port and terminal activities. TNPA is responsible for the safe, effective and efficient functioning of the South African port system. TNPA provides the port infrastructure and the marine services for all ports in South Africa, including the Port of Cape Town.

In contrast, the TPT division is responsible for the commercial handling services of imports, exports and transhipments in containers, bulk, break-bulk and automotive industry. TPT operates terminals in seven South African commercial ports including the CTCT at the Port of Cape Town. Terminal operations include import and export operations across the following cargo sectors: containers, mineral bulk, agricultural bulk and Ro-Ro (roll on/roll off) cargo.

The CTCT, its facilities and operations are discussed, along with the container terminal TPT services, in the following section of the chapter.

5.3. The Cape Town Container Terminal (CTCT)

According to Lun, *et al.* (2010:185) a container terminal is a location where containers are loaded onto vessels, unloaded from vessels, and stored in stacks at which point the receiving and delivery of containers occurs. The container terminal at the Port of Cape Town is the second busiest container terminal, after Durban, and as mentioned previously, services approximately 71.5% of the vessels which enter the port (Transnet National Port Authority, 2013/14).

The containers handled by the CTCT are approximately 49.3% imports and 50.7% exports (Transnet National Port Authority, 2013/14). Figure 5-12 illustrates the container volumes moving through the CTCT from 2011 to as recent as 2014. The figure indicates that containerised trade through the Port of Cape Town was relatively low in 2011, which was followed by a rapid increase over the following two years, and the increasing trend is expected to continue (Birkenstock, 2015).

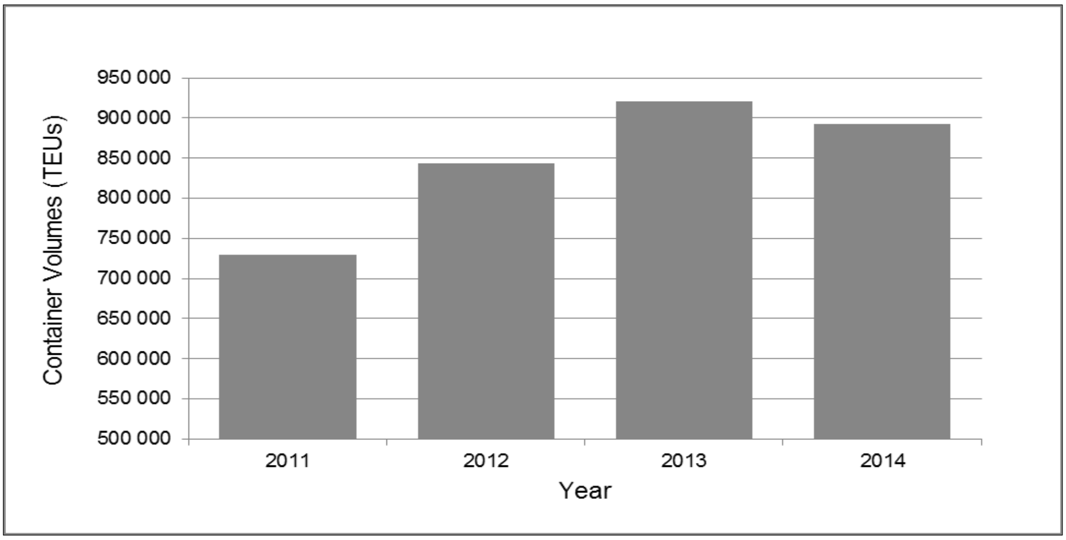

Figure 5-12: Port of Cape Town container volumes, 2011 - 2014

Source: Havenga & Van Eeden, 2011; Transnet National Ports Authority, 2013/14

The CTCT has two seasonal peak periods in cargo volumes, namely during the summer months due to the increase in fresh fruit exports and the winter months due to fish exports. The summer month peaks can begin as early as September and extend into March, while the winter months generally begin in June and end near the end of July (refer to circles in Figure 5-13).

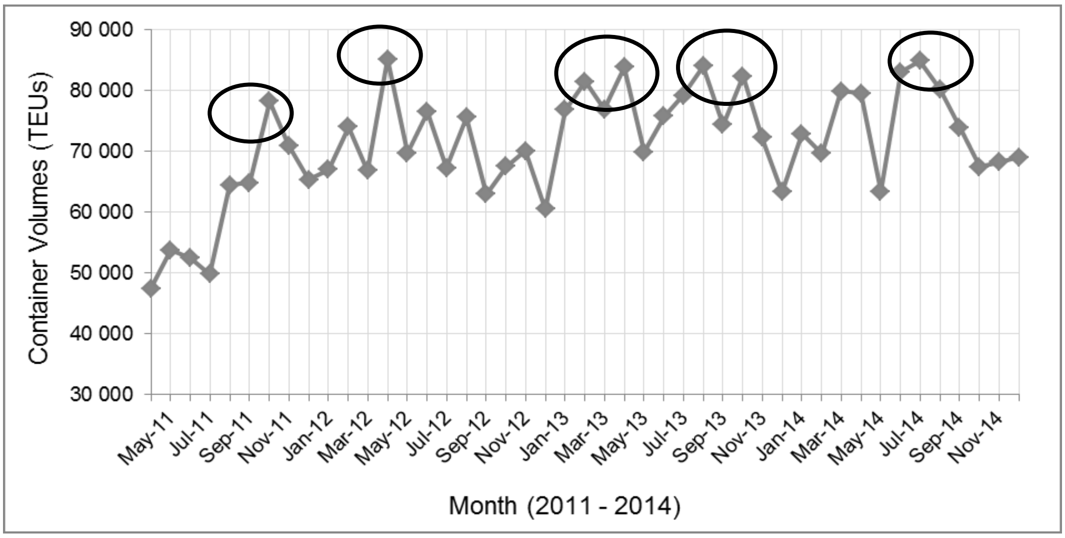

Figure 5-13: Seasonal container volumes for the Port of Cape Town

Source: Havenga & Van Eeden, 2011; Transnet National Ports Authority, 2013/14

When entering the container terminal, containers move through four main processes in the container terminal value chain. A simple version of this value chain involves containers flowing from the vessel through the container terminal to the inland transport modes. This simple chain is illustrated in Figure 5-14.

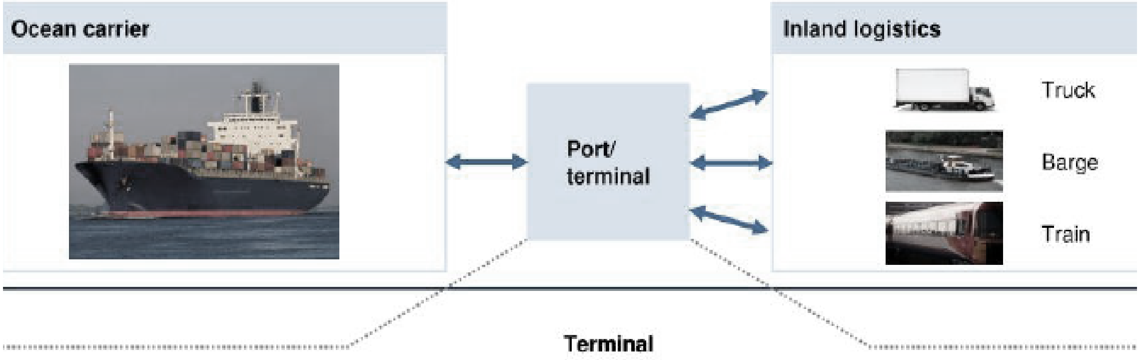

Figure 5-14: Simple container flow through a port or terminal

Source: Adapted from Gutzkow, 2013

The container value chain is, however, more complex than the illustration in Figure 5-14. The four main processes are evident in Figure 5-15. Containers are brought into the terminal via ocean carriers or vessels (labeled zero on the figure).

The containers are then either offloaded from the ship to the shore, or loaded from the shore to the ship (both labeled 1 on the figure). At this point the containers are transferred (2 on the figure) to the container stacks for termporary storage (3 on the figure). The final terminal process is delivery (4 on the figure) to the hinterland via truck, barge or train. It is important to note that the containers are considered transshipment cargo at point A on the figure and are only considered local cargo during the delivery process (point B).

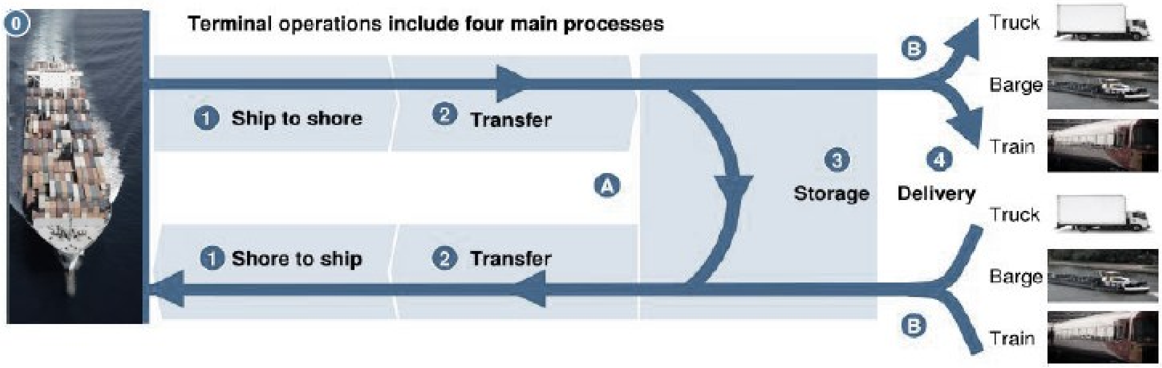

Figure 5-15: Container flow through the four main terminal operation processes

Source: Adapted from Gutzkow, P. 2013.

According to Lun, *et al.* (2010:183), and similar to Figures 5-14 and 5-15, the main processes in a container terminal can be divided into inbound processes and outbound processes. Inbound processes include the arrival of the vessel at the terminal, unloading of the cargo, transfer from quayside to container stacks, storage of containers, and finally the transfer of containers to intermodal transport modes.

The outbound processes are similar, yet in reverse, and include the transfer of containers from intermodal transport modes to the container yard operations, storage of the containers, transfer of containers from the stacks to quayside, loading of the containers and finally the departure of the vessel.

Figure 5-16 illustrates these processes.

[redacted]

Figure 5-16: Container terminal processes

Source: Lun, Lai & Cheng,. 2010

Lun, *et al.* (2010:188) goes on to suggest in Figure 5-17 that the network of nodes and links in the container transport value chain can be classified into four principle functions.

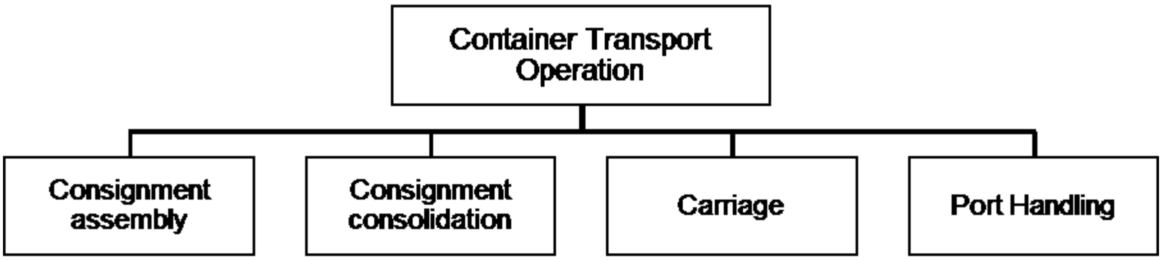

Figure 5-17: Container transport operations

Source: Lun, Lai & Cheng, 2010

Consignment assembly is the first stage in the physical movement of containers. For example, the movement of a full container load would involve the dispatch of an empty container from the container depot to the exporter for loading (Lun, *et al.* 2010:188).

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Consignment consolidation is the next step in the container transport value chain and includes a freight consolidation facility loading different consignments into less than container loads.

The carriage stage can involve both inland and sea transportation of containers. Inland transportation does, however, include shipping links and nodes for the transport of export and import goods to and from foreign markets. The physical movement of containers involves transport from shippers' premises to the terminal or from shippers' premises to a consolidation facility. Port handling occurs from the point of entry into the terminal until the point of departure.

The TPT division is responsible for port handling within the CTCT. Port handling includes value added services such as container stuffing and destuffing, handling and storage of uncleared and cleared containers, packing of export containers, reefer handling, the transferring of containers between transport modes, transportation of containers within the port and the movement of containers between stacks by cranes.

The facilities and operations of the CTCT are briefly discussed in the following section. Facilities refer to the fixed infrastructure of the terminal, whilst operations refer to the equipment used and the operations performed by the terminal equipment.

5.3.1. Terminal Facilities and Operations

Container terminals consist of main facilities, such as a quay, a container yard, a container freight station, an interchange area, a gate facility, a railhead and terminal management offices. The CTCT is located at the east end of the Ben Schoeman Basin, which is approximately 15.5 metres deep and consists of seven berths with different purposes. The current depth and width of the terminal, however, only allows for the accommodation of 300 – 325-meter container vessels (McEwan, 2015).

Five of the berths mentioned are for deep-sea container vessels, whilst the other two are coastal container berths. The length of the container quay is 1 132 metres and the terminal consists of 6 900 ground slots and 3 752 reefer points. These reefer points enable the short-term storage of refrigerated (reefer) containers carrying export products such as fresh fruit.

The orientation of the CTCT can be seen in Figure 5-18, which shows an aerial view of the terminal as it is known today.

Figure 5-18: Aerial photograph of the Cape Town Container Terminal

Source: Adapted from Transnet National Ports Authority, 2015

The CTCT makes use of equipment for the loading and unloading of vessels, and the movement of containers within the terminal. These various equipment types are subject to a number of limitations with regards to lifting capacity and working under severe weather conditions. The lifting capacity of each equipment type is discussed later.

To deal with the severe weather conditions experienced at the Port of Cape Town, all heavy duty equipment such as cranes, gantries and carriers are equipped with a device known as an anemometer. This device looks similar to a weather vane, but is designed specifically to measure wind direction and wind speed. The device makes use of four cups or pointers (illustrated in Figure 5-19), which not only indicates the direction of wind, but also accurately measures current wind speeds.

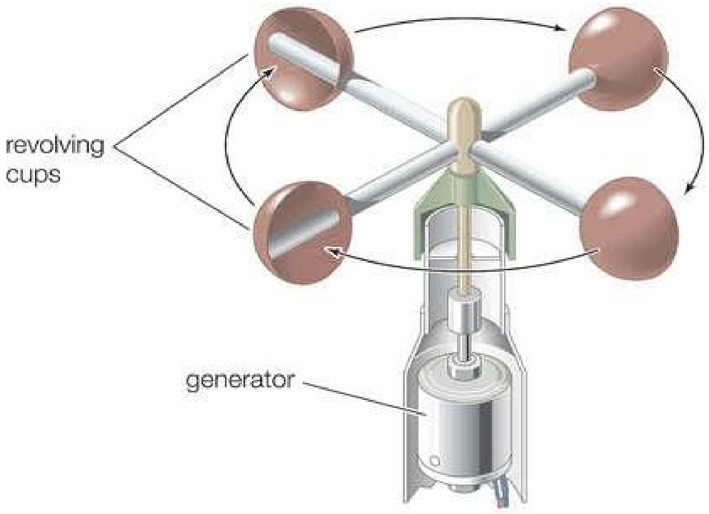

Figure 5-19: Basic diagram of an anemometer

Source: Adapted from global.britannica.com, 2015

When winds exceed 80-100kph, increasing the danger of equipment operation, the device sends electronic warning signals to the gantry or crane operator. The operator can then decide whether to continue operating, with the hopes that wind speeds will decrease, or discontinue equipment operation. If the operator elects to continue working, and wind speeds increase, the device will send a final signal to the gantry or crane system resulting in the automatic shutdown of the equipment until wind speeds decrease.

Certain gantries and cranes have a vibration plate built into the equipment in addition to the anemometer. This plate vibrates in the wind and will send warning signals to the operator when wind speeds increase past 80-100kph, which is deemed unsafe. If wind speeds exceed 80-100kph, and operation of the equipment becomes too dangerous, the vibration plate sends out a signal to shut down the equipment. These different safety mechanisms are vital in preventing accidents in the terminal; however, they are also contributing factors to port congestion.

Terminal equipment at the CTCT includes eight super-post-Panamax cranes, 28 rubber tyre gantries (RTG), one rail transfer gantry, four straddle carriers, two reach stackers, 47 internal haulers, 59 bathtub trailers, and five empty stackers (Port Overview, 2015:4). These different types of cranes, gantries, haulers and stackers are discussed in further detail to follow.

A container crane, also known as either a container handling gantry crane or a ship-to-shore crane, is designed to be installed on the dockside of a container terminal for the loading and unloading of intermodal containers from container vessels.

Container cranes or gantry cranes can generally be classified according to lifting capacity and the size of the container ships, which can be loaded and unloaded. The three most common types are Panamax cranes, post-Panamax cranes and super-post-Panamax cranes.

Panamax cranes are capable of moving containers from container vessels, which are able to pass through the Panama Canal due to a width of between 12 and 13 containers (or less). Post-Panamax cranes are able to move containers from container vessels, which are too large (approximately 18 containers wide) to pass through the Panama Canal. The largest container crane in production is known as the “super-post-Panamax” crane and is designed to move containers from container vessels with a width of approximately 22 or more containers. This modern crane is capable of lifting either four 20-foot containers (end to end) or two 40-foot containers, and has total load capacity of 120-tonnes.

Figure 5-20 shows super-post-Panamax cranes similar to those currently situated along the container quay of the CTCT for the servicing of berthed container vessels.

Figure 5-20: Super-post-Panamax cranes similar to those in the CTCT

Source: Adapted from safety428.rssing.com, 2013

The smaller version of a container crane/gantry crane is known as a rubber tyred gantry (RTG) crane as it runs on rubber tyres instead of rail tracks. These cranes are mobile gantry cranes used for stacking intermodal containers within the stacking area of the container terminal. RTGs are used at container terminals and container storage yards to straddle multiple lanes of rail/road and container storage, or when maximum storage capacity in the terminal is desired.

Figure 5-21 shows one of the RTG cranes at the CTCT. These cranes are able to lift two twenty-foot containers or one forty-foot container at a given time.

Figure 5-21: Rubber Tyred Gantry Cranes, CTCT

Source: Adapted from www.slideshare.net, 2009

Smaller sized cranes and terminal equipment include straddle carriers, rail mounted gantry (RMG) cranes, reach stackers, internal haulers, bathtub trailers, and empty stackers. These cranes are used for the movement of containers within container terminals and to transfer containers to and from inland transport modes.

A straddle carrier is a non-road going vehicle used in a container terminal for stacking and transferring containers within the terminal. The straddle carrier picks up and carries containers by straddling the load and connecting to the lift points of the containers via a container spreader (Container handling equipment, 2013:1). These cranes have the ability to stack containers up to four high and can move at a relatively slow speed of up to 30kph when laden with a container.

Figure 5-22 shows a typical straddle carrier used in South African ports, similar to the straddle carriers used in the CTCT. This carrier is able to stack one over two high, which means one container onto two stacked containers, and can lift approximately 50 tons.

Figure 5-22: Typical straddle carrier

Source: Adapted from www.porttechnology.org, 2014

RMG cranes are fixed infrastructure located at the node between the container terminal and the rail network. Figure 5-23 shows the rail mounted gantry crane at Coega port, which is similar to the rail transfer crane at the CTCT.

Figure 5-23: Example of rail mounted gantry crane (RMG crane) at Coega Port

Source: www.sa-transport.co.za, 2009

This crane facilitates the transfer of containers from the terminal onto rail flatbeds for transport to the hinterland, and can lift approximately 65 tons, either single or twin lifts of twenty-foot and forty-foot containers.

Reach stackers or loaded container handlers are able to transport containers over a short distance at a fast rate and stack the containers in various rows depending on the row's access. Reach stackers are popular equipment in container terminals as they are flexible and have a higher stacking and storage capacity compared to lift trucks (Container handling equipment. 2014:4). Figure 5-24 shows typical reach stackers, similar to those used at the CTCT.

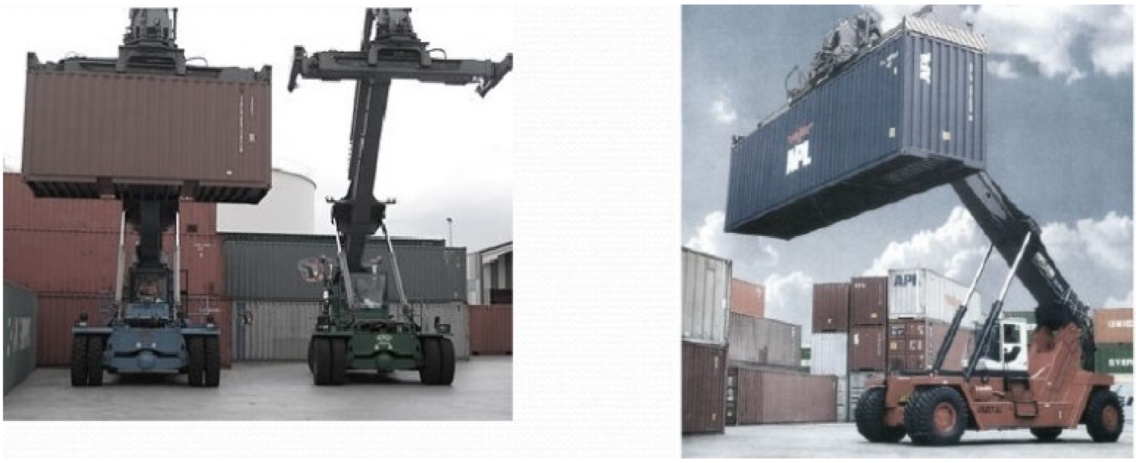

Figure 5-24: Typical reach stackers used in container terminals

Source: Adapted from www.slideshare.net, 2013

Reach stackers are able to stack containers five high and can lift up to 45 tons. The container stacks at the CTCT allow for five high stacking, however, this is not always possible during periods of high wind speeds. This greatly decreases stack capacity and is generally counteracted by TPT through increased working hours of reach stackers, straddle carriers and haulers. Empty containers are handled quickly and efficiently by empty stackers. These stackers are similar to reach stackers, with the difference being the purpose of the stacker. The CTCT currently has five empty stackers in operation.

Internal haulers facilitate the movement of containers within the terminal between ocean and inland transport modes and the container stacks. Haulers are used in conjunction with bathtub trailers and offer safer, faster handling and transport of containers within the terminal yard. Figure 5-25 shows a container being placed onto one of the bathtub trailers by one of the internal haulers at the CTCT.

Figure 5-25: Internal hauler and bathtub trailer at the CTCT

Source: Adapted from ports.co.za, 2010

The containers which are handled by the port equipment previously discussed contain various types of commodities intended for one or several destinations. Containers flow through the container value chain and can be handled in three states: namely, empty containers, full container loads and less than container loads. Full container loads refer to containers loaded with one single consignment for one single shipper, while less than container loads are loaded with multiple consignments from many different shippers.

In addition to the physical equipment required to operate a container terminal, terminals require a terminal operating system (TOS) to conduct day-to-day business activities. Originally, TPT made use of a paper-based system, which was quickly replaced with COSMOS, a computer-based green screen system. The latest TOS to be used in Transnet terminals is NAVIS, which is a “Graphical User Interface” (GUI) management system. The purpose of NAVIS is to assist in maintaining efficiency, adaptability, cost-effectiveness and scalability in the long-term. NAVIS also assists in enhancing terminal operational efficiency and support future volume growth whilst helping to reduce operational overhead costs (Navis, 2014).

NAVIS was originally implemented in the CTCT in September 2009, but further upgrades were made from March 2010 to 2011 which increased stability to over 97% (Van Schalkwyk, 2013). In April 2012 the NAVIS Synchronous Planning and Real-time Control System (SPARCS) was implemented and is still currently in use. NAVIS SPARCS N4 is essentially a web-based TOS which was developed to assist in the management of container logistics and operations.

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The primary purpose of NAVIS is to assist TPT and their clients in monitoring cargo along both land transport and terminal routes. Information from point of entry at the terminal, through the stacks, and finally to loading onto the vessel is updated regularly to improve visibility and streamline planning and scheduling of container movements. The section which follows discusses the different types of containers and their destinations.

5.3.2. Types of Cargo and Containers

International containers handled by the CTCT can generally be divided in terms of type of container, or by original/final destination. Containers come in various forms or types. The most common form, used for the transport of any normal cargo sorted on pallets or in boxes, is the "general purpose container". These containers can either be 20-foot or 40-foot in length. The second most used container type is the refrigerated (reefer) container.

These containers are used to transport temperature controlled cargos and can be either 20-foot or 40-foot in length. Both "general purpose containers" and reefer containers can be either standard or high-cube containers, which offer an additional foot in height compared to the standardised height. This makes these containers ideal for light, capacious cargo or bulky cargo. Other less popular types of containers include open-top containers, ventilated containers, tanker containers, hardtop containers and flat containers.

The destination of containers can be divided into three different categories. Firstly, containers shipped to or from ports situated on the Eastern and Western Coast of Africa, which are known as *Coastwise containers*. Secondly, containers shipped to or from ports other than those situated along the Eastern and Western Coast of Africa, which are known as *Deep-sea containers*. And lastly, shipments known as *Transhipped containers,* which are containers handled by the Port of Cape Town, but are destined for different ports in the country or around the world.

Table 5-2 illustrates the percentage distribution, from largest to smallest, of imported and exported cargo containers, which originate from these different categories. The table suggests that the majority of containers imported and exported through CTCT are intended for or from foreign ports and not East and West African ports.

Table 5-2: Types of containers and percentage distribution

Types of Containers	Import	Export
Deep-sea Containers	76.95%	79.71%
Transhipped Containers	16.32%	17.97%
Coastwise Containers	6.72%	2.31%

Empty Containers	37%	32.17%

Source: Adapted from Havenga & Van Eeden, 2011; Transnet National Ports Authority Annual Report, 2013/14

In addition to the import and export containers, the CTCT handles empty containers, which as seen in Table 5-2, account for approximately 37% of all imported containers and approximately 32.17% of all exported containers, according to the Transnet National Ports Authority Annual Report (2014/15). Import containers moving through the CTCT primarily carry commodities such as processed foods and transport equipment, while commodities such as agricultural goods, transport equipment and stone are examples of cargo carried by export containers.

The various sources of containers as well as the large quantities handled by the Port of Cape Town can result in a unique variety of risks relating to maritime ports, which may negatively influence the terminal's efficiency. However, all container types and sources are equally influenced by port congestion. The following section discusses port congestion in the context of this study.

5.4. Port Congestion in the CTCT

In the Port of Cape Town, port congestion initially became apparent in the 1990's when it was noted that the infrastructure of the port and its terminals could not handle the increasing number of containers moving through the port. At this time the port was owned and managed by Portnet, which is known today as TNPA and TPT (Schultz, 2015:3).

Portnet dealt specifically with shipping lines and therefore vessel related congestion, as landside activities such as container deliveries and collections were handled by Portnet's road transport section. This subsequently resulted in a lack of service provided by port operations.

Due to this lack of service provision the congestion issue at the port steadily worsened, putting Cargo Owners at risk and resulting in an increasing number of shippers opting to by-pass the Port of Cape Town for less congested ports such as the Port of Durban for example (Schultz, 2015:3).

Today, congestion issues remain for both the Port of Cape Town and the Port of Durban. The ports, however, deal with congestion issues stemming from different factors, as mentioned in section 4.4 of Chapter 4. Congestion in the Port of Durban results from a lack of infrastructure and equipment capacity, and the Port of Cape Town's congestion primarily stem from weather- and system-related challenges.

Port congestion resulting from weather and system issues can stem from two sources, as mentioned in section 4.1 of Chapter 4, namely the maritime-side of the port and the landside of the port. The following two sections discuss the sources of congestion issues experienced in the CTCT.

5.4.1. CTCT Maritime-side Congestion

Maritime-side congestion, as mentioned in section 4.2.1, can result due to a number of factors. For the Port of Cape Town and its container terminal, weather- and system-related challenges are the primary causes of vessel congestion. Adverse weather conditions common to the Port of Cape Town include large ocean swells, strong under water currents, high wind speeds and thick fog.

These weather conditions are inherent to Cape Town as a result of the city's geographical location. Situated in an area known as the Cape of Storms, the Port of Cape Town commonly experiences severe weather during summer (December – February) and winter (June – August) months of the year, which subsequently constrains the ability of the port and results in congestion (Birkenstock, 2015). Safe entry into the port and its terminals is often prevented by large swells and high wind speeds. This subsequently results in delays as the vessels drift outside the port. In addition, high wind speeds can cause further delays as certain terminal equipment (cranes and gantries) cannot be operated safely over 80/100kph wind speeds.

In the winter months (June to late August) Cape Town often suffers from severe storms linked to cold fronts and low pressure systems. These low pressure systems result in surface winds, which can reach maximum speeds of 100kph (Storms and High or Gale force Wind, 2014).

According to the Beaufort Wind Scale (seen in Table 5-3), this can result in structural damage and large ocean swells. Average wind speeds during winter months are, however, significantly lower (between 13.3 and 15.5kph) suggesting that severe storms occur sporadically throughout the season (Cape Town Weather Statistics, 2014).

Table 5-3: Beaufort Wind Scale

Beaufort Number or Force	Wind Speed	Description	Maritime-side Effects	Landside Effects
	Kph			
0	< 1	Calm	Water is "mirror-like"	Still, calm and smoke will rise vertically
1	1-5 kph	Light Air	Small ripples on water surface	Rising smoke drifts, wind vane inactive
2	6-11 kph	Light Breeze	Small wavelets develop, crests are glassy	Leaves rustle, wind noticeable, wind vanes begin to move
3	12–19 kph	Gentle Breeze	Large wavelets, crests start to break (some whitecaps)	Leaves and small twigs move, light weight flags extend
4	20–28 kph	Moderate Breeze	Small waves develop, becoming longer, whitecaps	Small branches move; raises dust, leaves and paper
5	29–39 kph	Fresh Breeze	White crested wavelets (whitecaps) form, some spray	Small trees sway
6	39–49 kph	Strong Breeze	Large waves form (whitecaps), prevailing spray	Large tree branches move, telephone wires "whistle", umbrellas difficult to control
7	50–61 kph	Moderate or Near Gale	Large waves develop, white foam blown from breaking waves	Large trees sway, becoming difficult to walk
8	62–74 kph	Gale or Fresh Gale	Moderately large waves with blown foam	Twigs and small branches broken from trees, walking is difficult
9	75–88 kph	Strong Gale	High waves (6 m), rolling seas, dense foam. Blowing spray recues visibility	Slight damage to buildings, shingles blown off roofs

10	89–102 kph	Whole Gale or Storm	Large waves (6-9 m), overhanging crests, sea becomes white with foam, heavy rolling, reduces visibility	Trees broken or uprooted, building damage is considerable
11	103–117 kph	Violent Storm	Large waves (9-14m), white foam, visibility further reduced	Extensive, widespread damage
12	118 + kph	Hurricane	Large waves (14+ m), air filled with foam, sea white with foam and driving spray, zero visibility	Extreme destruction, devastation

Source: Adapted from Marinewaypoints.com, 2015

In addition to winter wind conditions, the Cape Town area also experiences worsened wind conditions in the summer months (December – February). These gale-force winds can span several consecutive days and are known to residents as the “Cape Doctor” (Storms and High or Gale force Wind, 2014). Similar to the winter winds, the “Cape Doctor” can reach gale force strength or a Beaufort wind scale of nine or ten (see table 5-3). Despite maximum wind speeds reaching an excess of 80kph, average wind speeds during summer months range from between 22 and 23 kph (Cape Town Weather Statistics, 2014). This suggests that the “Cape Doctor” reaches maximum speeds relatively infrequently.

Most cranes and gantries in the CTCT cannot operate if wind speeds exceed a certain speed. Generally, straddle carriers can operate in wind speeds up to 85kph, while gantry cranes can operate in wind speeds of up to 100kph. However, when winds exceed these speeds, the loading and unloading of berthed vessels and container stacks are impacted.

Currently, the CTCT handles between 14 and 15 containers per crane per hour. The TPT’s target is 20 container moves per crane per hour; however, this is still below the international benchmark of 25 container moves per crane per hour. This less than optimal efficiency is primarily due to high wind speeds resulting in the shutdown of equipment.

Figures 5-26 and 5-27 illustrate the South-South Easterly ("Cape Doctor") and South-South Westerly winds which impact the operation of equipment in the CTCT.

Figure 5-26: South-South Easterly wind direction

Source: Adapted from McEwan, 2015

Figure 5-26 indicates that the "Cape Doctor", experienced in the summer months, has a larger impact on terminal operations. Generally, the wind is diverted across False Bay into the Table Mountain range where it increases in velocity by 2.5 before exiting and hitting the Port of Cape Town. This significantly reduces equipment operating hours as wind speeds often exceed the recommended speeds.

Figure 5-27: South, South Westerly wind direction diagram

Source: Adapted from McEwan, 2015

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Figure 5-27 illustrates the South-South Westerly wind often experienced in the winter months in Cape Town. The direction of this wind diverts it into the western side of the Table Mountain range, which is considered more forgiving to the Port of Cape Town as the mountain range reduces wind speed slightly. A further hindrance to terminal operations is thick fog. Although less common than high wind speeds, thick fog reduces visibility, which reduces equipment operation safety and accuracy.

Of the weather-related challenges faced by the CTCT, high wind speeds impact port operations to a larger degree than ocean swells and fog, as high winds cause stoppages throughout the year and often result in port closure. The maritime-side of ports, specifically the Port of Cape Town, is not the sole area impacted by weather- and system-related challenges. The landside of the CTCT is also impacted. The following section discusses landside congestion experienced at the CTCT.

5.4.2. CTCT Landside Congestion

Landside, or road congestion, is one of the main issues experienced by the Port of Cape Town, and more specifically the CTCT (Lane, 2015). In Cape Town, road congestion stems from the historical development of the metropolitan area, with the city infrastructure growing around the existing port. This has consequently resulted in the port and its terminals being surrounded by city infrastructures, which has limited the required growth of the CTCT to facilitate increasing container volumes.

In addition to infrastructure constrictions, increasing commuter traffic into the metropolitan area has similarly contributed to road congestion around the port (De Wet, 2014:67). Furthermore, there is a lack of coordination between the two entities responsible for port financing and decision-making, namely Transnet and the Cape Town Municipality. This results in a “red-tape” barrier preventing earlier port improvements (De Wet, 2014:67).

Generally, in the case of the CTCT, landside congestion can be experienced in two areas, namely, congestion at entrances to the port and congestion delays inside the port (Lane, 2015). Both sources of landside congestion are equally important to consider as they both directly influence container movement into and within the container terminal.

These areas of congestion not only obstruct the two entrances to the port, but also have a negative impact on transportation costs.

Landside congestion generally results in increased turnaround time of vehicles (Lane, 2015), which consequently leads to an increase of road transportation tariffs for cargoes as trucking companies attempt to maintain profitability. This, therefore, implies that a solution to road congestion could enhance the efficiency and competitiveness of the Port of Cape Town (De Wet, 2014:67). Currently, the Port of Cape Town has two main entrances with limited capacity, namely the Northern entrance to the CTCT via Marine Drive, Paarden Island and Container Road; and the Southern entrance, known as the Christiaan Barnard Entrance, to the Duncan Dock via Table Bay Boulevard and Duncan Road on the Foreshore.

Figure 5-28 illustrates a map of the two entrances relative to the City of Cape Town and the Port of Cape Town itself; whilst Figure 5-29 and Figure 5-30 illustrate the Northern and Southern entrances in closer detail (see circled areas). It is important to note that container trucks predominately enter the port via the Northern entrance, as this entrance is closest to the container terminal and the container stacks.

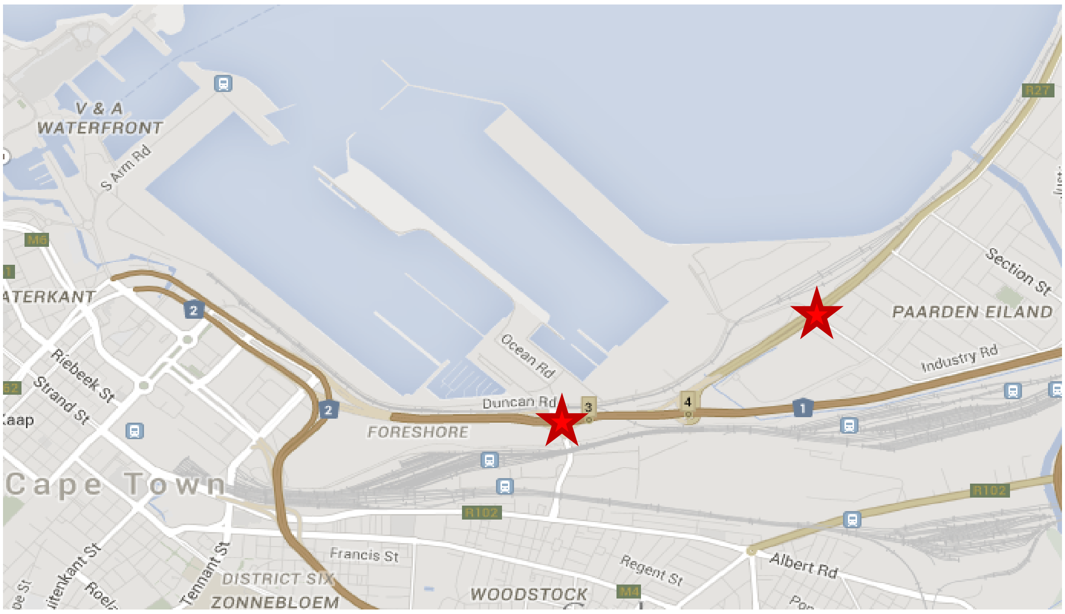

Figure 5-28: Map of the Port of Cape Town, with entrances indicated

Source: Adapted from google.co.za/maps, 2015

Figure 5-29: Northern CTCT entrance

Source: Adapted from google.co.za/maps, 2015

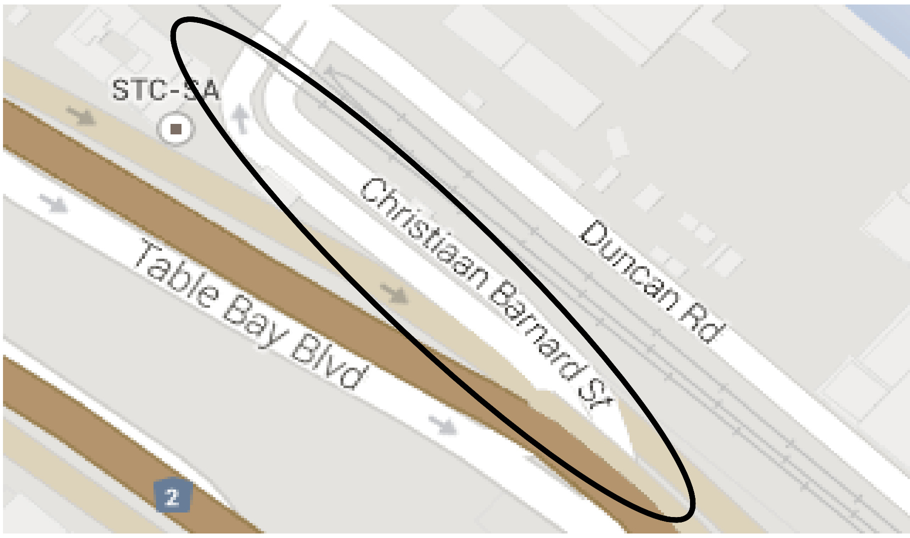

Figure 5-30: Southern Christiaan Barnard entrance

Source: Adapted from google.co.za/maps, 2015

Figure 5-28, Figure 5-29 and Figure 5-30 suggest that road congestion often originates outside the port before the ripple effect moves congestion inward into the port and its terminals. It is, however, important to note that landside congestion, as mentioned earlier, can also originate from within the port itself. This scenario will be discussed later in this section.

Each of the entrances illustrated in the previously shown figures include gate facilities where a number of functions are performed. According to Lun, *et al.* (2010:190), information regarding containers and consignments are checked against the shipper booking information. Once this information has been checked and cleared, the vehicle can proceed into the terminal and be unloaded into the stacks.

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At this point any subsequent movements of the container are controlled by the yard operators, not the shipper. Container movement and inventory information are continuously updated in the terminal system. Therefore, fast and accurate information flow can be achieved by the container terminal to facilitate the daily handling of thousands of containers.

In combination with poor access to the port and stringent gate facility protocols, current throughput volumes of the port causes vehicle delays of several hours as vehicles try to deliver and collect containers on schedule. This queuing of vehicles creates a ripple effect, which subsequently causes delays in commuter traffic between the city centre and the Atlantic Northern coast down the N1 main road, as seen in Figure 5-28.

The internal operations of the port and the movement of containers within the terminal can similarly cause congestion issues. Port operations and activities are influenced by a number of internal and external factors such as adverse weather conditions, labour strikes, container volume increases and equipment related challenges (Lane, 2015). However, as mentioned previously, this study focuses on weather- and system-related port congestion.

Adverse weather conditions, as discussed in the previous section on maritime-side congestion, include high wind speeds, thick fog, large ocean swells and strong underwater currents. Certain of these weather-related challenges impact container movement within the container terminal and thus impact landside transportation and congestion levels. This ripple effect from the port to the inland transportation of containers is best described in the form of scenarios or examples.

When severe weather conditions occur, the greatest impact is experienced by the container equipment. High wind speeds and thick fog hinder the safe loading and unloading of containers to and from vessels, vehicles and container stacks. This in turn delays the collection of containers, and impedes the delivery of containers due to capacity configuration in the terminal. This subsequently negatively impacts the schedules of container vehicles attempting to collect and deliver containers.

In the case of large swells and strong underwater currents, vessels entering and exiting the terminal are most severely impacted. However, this impact has a ripple effect which extends from the maritime-side to the landside of the port. Safe vessel entry into the Port of Cape Town is largely impacted by strong underwater currents near the entrance to the port. When these currents are too strong, vessels are prevented from entering the container terminal for loading and unloading.

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Vessels are subsequently forced to “drift” outside the port until conditions improve. This delay extends to the landside as vehicles similarly must wait to collect containers held on the waiting vessels. This, similar to high winds and fog, results in delays to the schedules of container trucks.

Large ocean swells, on the other hand, generally result in vessel ranging (Davids, 2015), which makes vessel berthing unsafe as the vessel can collide with the quay or the overhead gantry cranes situated on the edge of the quay. This results in delays to loading and unloading of containers to and from the vessel and the container stacks, and subsequently delays vehicle schedules.

In addition to the weather-related challenges discussed, the landside of the Port of Cape Town must contend with system and/or equipment related challenges. The current TOS system in use in the CTCT, is the NAVIS SPARCS N4 system. This system is not without its faults and occasionally experiences “down-time”, which has a negative impact on both the maritime and landside congestion levels in the CTCT. The most prominent impact involves increased turnaround time of vehicles within the terminal as vehicles wait to be allowed access to the stacks for loading and unloading of containers.

Freight vehicle movements on public roads are one of the largest contributors to landside or traffic congestion, with freight trucks making-up 36% of vehicles on South African roads (Londoño-Kent, 2009). The closely placed infrastructure of metropolitan areas, often surrounding ports, further exacerbates road congestion levels. In South Africa the transport minister, Elizabeth Dipuo Peters, introduced the idea of a proposed truck ban in recent news (Freight and Trading Weekly, 2015:1&12). The proposal would result in a ban of all heavy road trucks over nine-tonne gross vehicle mass (GVM) for approximately six hours a day.

This truck ban, according to Kevin Martin (MD of Freightliner Transport and former chairman of the Durban Harbour Carriers’ Association – DHCA), if implemented, would not only negatively influence the road transport industry, but also the maritime ports as it effectively reduces the 24-hour business day by approximately 25%.

The proposed embargo is set to ban trucks from public access roads for the 06:00-09:00 and 17:00-20:00 periods on weekdays. This will effectively result in all port terminal gates – container, bulk, break bulk and multi-purpose – congesting as trucks struggle to make deliveries and collections in such strict time periods.

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A number of issues are likely to arise in the Port of Cape Town due to the ban. Firstly, the container terminal would have to increase stacking space by a minimum of 25% in order to offset the trend of ever larger vessels and thus increased volumes of containers. Secondly, container terminal operators would have to extend stack times by a minimum of one day to account for the decrease in business hours (as the stacks are not open afterhours) whilst increasing the landside handling equipment by 25% (Freight and Trading Weekly, 2015:12).

Lastly, the resultant impact of the proposed ban would result in extended working hours and 25% larger storage capacity for shipping lines' empty container depots (Freight and Trading Weekly, 2015:12).

The previously mentioned maritime-side and landside congestion can potentially be reduced through an expansion of the CTCT and further upgrades to the Duncan Dock of the port. The most recent suggested expansion plans are discussed briefly in the following section.

5.5. Future Plans for the Port of Cape Town

According to Transnet National Ports Authority (Port of Cape Town, 2015) the only major project currently underway in the Port of Cape Town is the reconfiguration of the CTCT. This project involves the deepening of the Ben Schoeman dock and the reconfiguration of the landside container terminal. The deepening of the outer basin will allow the container terminal to accommodate larger container vessels, while the reconfiguration of the terminal itself will allow for faster and more accurate handling of containers.

Additional plans are currently underway to initiate a seaward expansion of the CTCT. However, these expansion plans may result in a number of environmental impacts, which influence beach and dune ecosystems, coastal communities and pollution emissions. Figure 5-31 illustrates the current layout of the Port of Cape Town.

The current Duncan Dock is visible with the MPT, bulk terminals, ship repair docks and fishing facilities (labelled 1 on the figure). The Ben Schoeman Basin with the container terminal is also visible (labelled 2).

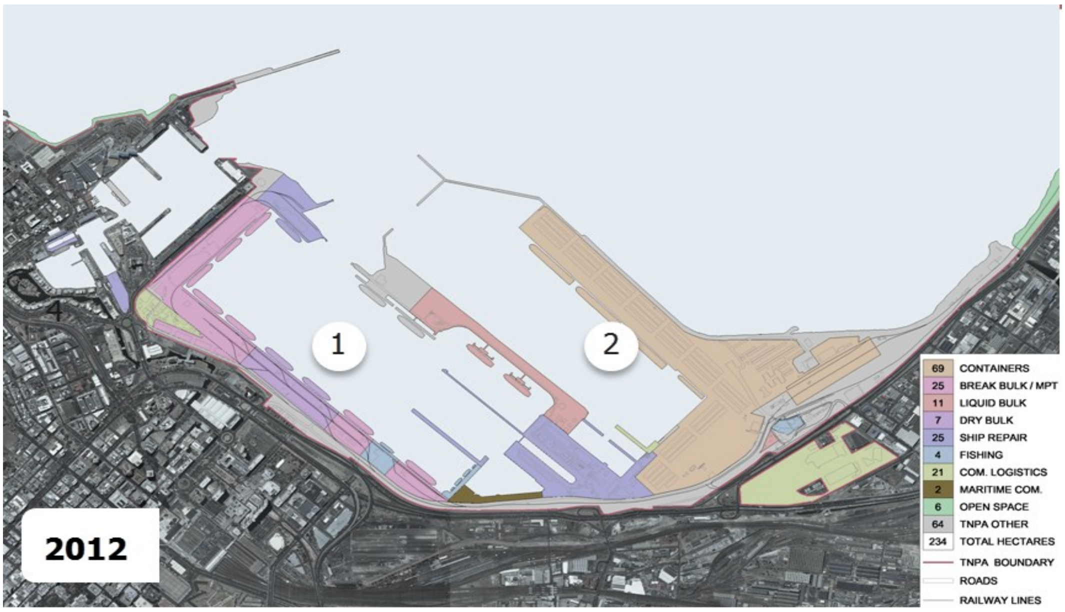

Figure 5-31: Current layout of the Port of Cape Town, 2012-2015

Source: Adapted from Transnet National Ports Authority, 2015

Figure 5-32 illustrates the long-term expansion plans for the CTCT, which are set to begin in the year 2042 and continue for a number of years thereafter.

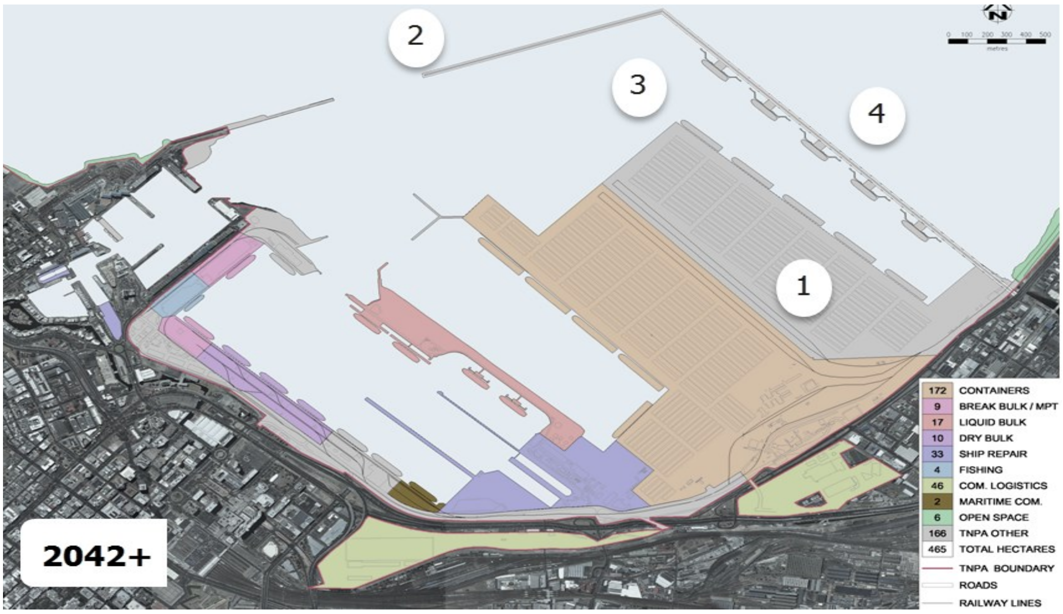

Figure 5-32: Long-term Expansion Plans for the CTCT, 2042+

Source: Adapted from Transnet National Ports Authority, 2015

According to TNPA (Port of Cape Town, 2015), the expansion plans would begin with a seaward reclamation to increase the landside container handling area (labelled 1 on Figure 32), which will include reefer-point expansion.

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At this point a new breakwater would be constructed (labelled 2) along with the construction of a new outer basin with deep water berths (labelled 3) to accommodate larger container vessels. Furthermore, the new container terminal would potentially house liquid bulk terminals and berths at label 4 on Figure 32.

These suggested expansion plans did, however, come with a number of critisisms from the 2006 Environment and Tourism Minister, Marthinus van Schalkwyk. According to a news article in Engineering News (CTCT Expansion, 2006), the Minister suggested that the environmetal-impact report for the proposed expansion was “flawed” and “irresponsible” in accurately assessing the project’s environmetal impact. The 2006 Minister went on to highlight environmetal issues which may result from the implementation of the expansion plans in their current state. These issues include the possibility of beach and dune erosion, air pollution from increased vessel engine emissions, negative impacts on sensitive ecosystems and beach nourishment.

These critisisms resulted in the delay of the expansion plans as further research is conducted to mitigate the enviromental impacts. In addition to the expansion of the CTCT, TNPA plans on constructing a Cruise Liner Terminal at Berth E and reclaim the dock where the Royal Yatch Club currently resides. Figure 5-33 is an artists impression of what the future Port of Cape Town will likely look like.

Figure 5-33: Artist’s impression of future Port of Cape Town

Source: Transnet National Ports Authority, 2015

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Expansion and improvement plans for the Port of Cape Town and the CTCT strive towards the mitigation of the port congestion mentioned in section 5.4. The expansion of port facilities should allow for an increase in cargo and container capacity, while the increase in space should reduce congestion.

Even though TNPA claims that the future expansion plans to the Port of Cape Town are expected to increase efficiency, other improvements to the management and operation of the port are considered more important according to Rob McEwan, Direction of Operations at MSC (2015). McEwan suggests that the most prominent areas for improvement which should be focused on, rather than an expansion of the port, revolve around equipment, manpower and technology. Equipment, such as appropriate container cranes and tug boats of sufficient power, are not currently available in the CTCT, while the appropriately trained manpower for such equipment is also lacking. Furthermore, important technology, such as the current TOS, is not operating efficiently and effectively in the terminal (McEwan, 2015). These areas of improvement, according to McEwan, can be easily addressed with improved management and communication within and between TNPA and TPT.

Overall, current operations within the CTCT are not satisfactory to those shipping lines operating through the terminal (McEwan, 2015). Inefficiencies within the terminal increase ship turnaround time (STAT) which subsequently result in a snowball effect, which negatively impacts vessel scheduling and fuel consumption, and costs shippers millions of Rands per day.

5.6. Closing Remarks

In closing, this chapter briefly discussed the past history of the Port of Cape Town from its origins in 1652 to its final current layout of facilities and operations. The importance of the port to international trade and the Western Cape economy was also discussed throughout the discussion of the current port facilities and operations.

The chapter went further to discuss the CTCT, its current facilities and operations, as well as the types of cargo and containers which move through the terminal on an annual basis. It was noted that the current facilities of the terminal limit the capacity of the terminal and this subsequently suggests that an expansion of the terminal is required. The current equipment available at the terminal was also discussed, indicating what cranes and trailers are currently in use for the handling of containers. In addition to the various physical equipment mentioned, the Port of Cape Town makes use of a TOS, known as NAVIS SPARCS N4, which assists in the smooth movement of container, vessels and vehicles through the CTCT.

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The discussion of the current port and container terminal facilities and operations led to a discussion on port congestion within the CTCT. It was noted that weather- and system-related challenges are the largest factors contributing to congestion within the terminal. The impact of weather and system challenges on both the maritime-side and the landside of the terminal was also discussed in sections 5.4.1 and 5.4.2.

The last section of this chapter introduced the future plans for expansion and upgrading of the port. An expansion seaward of the CTCT being the most extensive improvement planned, with smaller less significant plans also under consideration. The expansion of the container terminal is intended to alleviate capacity constraints. However, there is criticism regarding the environmental impact of the project, which has subsequently caused the current delay in the execution of the project. In addition to environment-related criticism, certain shippers suggest that improvements to TNPA and TPT management and communication could be the answer to equipment, manpower and technology challenges which are of greater importance than expansion plans.

This chapter concludes the literature for this study. Chapter 6, which follows, outlines the descriptive statistics of the study. The chapter discusses the graphical and numerical analysis of the data collected and presents the findings regarding current weather- and system-related port congestion within the CTCT.

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Chapter 6: Descriptive Data Analysis

One of the simplest statistical analysis techniques used in research is descriptive analysis (Zikmund & Babin, 2010:516). This form of data analysis focuses on the transformation of data in a way which describes the basic characteristics of the data within the context of the study. Descriptive statistics can be either graphical or numerical. Graphical descriptive statistics refer to graphs, tables and figures; while numerical descriptive statistics refer to statistical measures which describe the central tendency, distribution and variability of the data.

Chapter 6 initiates the data analysis portion of this study with descriptive statistics of port congestion in the container terminal of the Port of Cape Town. The chapter includes a section detailing the descriptive analysis of the data collected, which is followed by a second section discussing the results in terms of the frequency/incidences of congestion and the scheduling impact of congestion.

6.1. Descriptive Statistics Results

The descriptive analysis of port congestion is based on primary data collected during the course of this study from numerous study participants. The frequency and scheduling impact of port congestion, as mentioned in Chapter 2, is analysed using time series data, namely, vessel anchorage time (VAT), vessel berthing time (VBT), vessel working time (VWT), truck turnaround time (TTAT), weather delays data and system delays data.

Each data set is analysed separately using both graphical and numerical descriptive statistics. Graphical statistics are used to determine the shape and spread of the data, whilst numerical statistics are used to determine the central tendency and variation of the data. Both the numerical and graphical descriptive statistics are computed using Microsoft Excel.

The subsections to follow present the results of the different analyses. The VAT, VBT, VWT, TTAT, weather delays and system delays data sets are analysed as follows:

1. Observations of the different data sets are plotted on time series line charts.
2. Numerical descriptive statistics are required to compute the central tendency and variation of the data, and develop further graphical statistics.
3. Further graphical statistics are developed, such as frequency tables and histograms.

6.1.1. Ship Turnaround Time Data

Ship turnaround time, according to TNPA (Birkenstock, 2015), refers to the time a vessel takes to enter the port, offload/load containers, and finally exit the port. This includes time spent waiting outside the port (vessel anchorage), time spent preparing vessels for berthing and for setting sail (vessel berthing), and time spent offloading/loading containers (vessel working). This section of the study analyses VAT, VBT and VWT. It is important to note that the data sets analysed do not account for weather and system delays, which impact inbound and outbound ocean carriers.

- *Vessel Anchorage Time*

VAT, as mentioned earlier, is defined as the time ocean carriers spend anchored outside the port prior to berthing. Figure 6-1 illustrates the VAT observations and shows, using a trend line, that the observations of VAT between January 2011 and October 2015 have a downward trend. This suggests that the time ocean carriers spend anchored outside the container terminal is decreasing over time. This may be due to improved collaboration, coordination and communication between TNPA, TPT and shipping companies. This includes the availability of tug boats from the TNPA side to assist in the berthing process. The graph suggests that the planning of vessel entry/berthing by TNPA may be improving (as indicated by the downward trend).

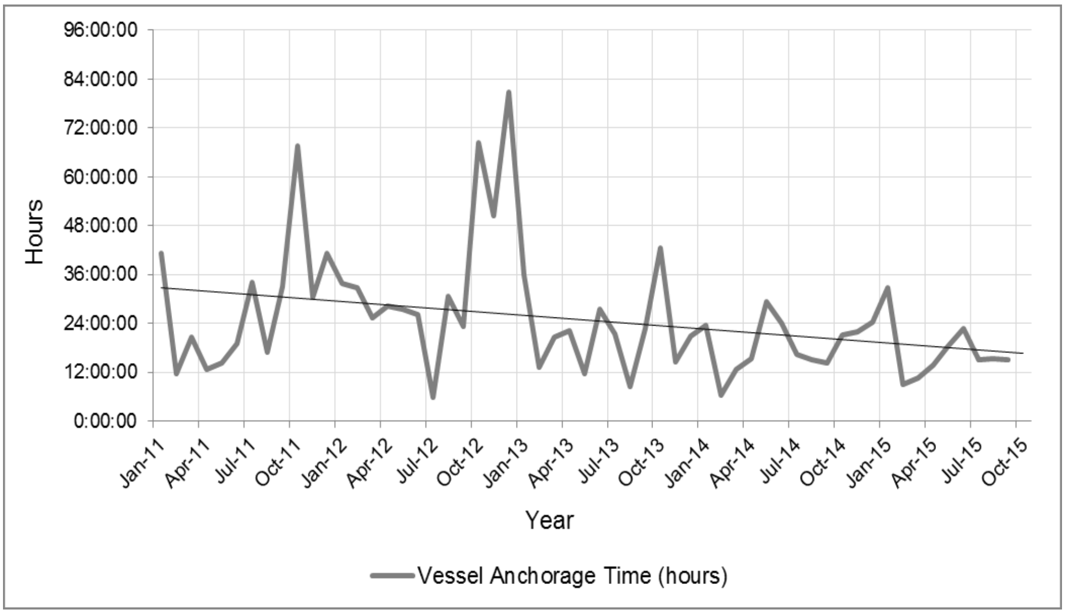

Figure 6-1: VAT outside the CTCT (2011 – 2015)

In addition, the graph indicates that anchorage time peaks during October months suggesting that ocean carriers experience longer anchorage times during these months. This, according to Marais (2015), is likely due to peaks in transhipment container volumes in either Durban or Namibia, which results in increased port congestion.

This subsequently results in transhipment containers being discharged in Cape Town to be trucked up to Durban or Namibia to arrive on time and avoid the congestion at the ports. This, however, exacerbates congestion within the Port of Cape Town.

In addition to peaks in transhipment containers, Julius (2015) suggests that the peaks in October may be due to the absence of stevedores[19] when the first berthing rope is tied onto vessels and the chains on containers are removed for discharging. The regularity of the peaks in anchorage time implies that the stevedores are regularly delayed on arriving at vessels during the month of October, and vessels cannot berth until a stevedore is available (Julius, 2015). The delays to stevedores may be related to the peak in transhipments discharged in Cape Town, as mentioned previously.

At this point numerical descriptive statistics were required to compute a number of measures. These measures, as mentioned earlier, pertain to central tendency and variation of the data set. Table 6-1 presents the descriptive statistics of VAT.

According to Table 6-1, the average anchorage time of ocean carriers outside the CTCT is approximately 24 hours and 47 minutes. This is slightly longer than the median of 21 hours and 59 minutes, which suggests that the data is slightly skewed and may include outliers.

Table 6-1: Descriptive statistics of VAT outside the CTCT (2011-2015)

Mean	24 hours, 47 minutes	**Range**	75 hours, 2 minutes
Median	21 hours, 59 minutes	**Minimum**	5 hours, 47 minutes
Standard Deviation	14 hours, 53 minutes	**Maximum**	80 hours, 49 minutes
Coefficient of variation	60.09%	**Number of Observations**	57

VAT has a standard deviation of 14 hours and 53 minutes, which according to Chebysheff's Theorem, suggests that at least 95% of ocean carriers anchor outside the CTCT for between 9 hours, 53 minutes and 39 hours, 40 minutes.

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[19] Individuals employed at the Port of Cape Town to load and unload containers and shipments from ocean carriers (Simple Definition of Stevedore, 2015).

This is a large range, which is supported by the coefficient of variation which suggests that there is a variance of 60.09% around the mean. This implies that vessel anchorage time varies widely around the average of 24 hours, 47 minutes.

From the mean and median computed, an indication of the shape of the data set was determined. In the case of VAT, the mean (24 hours, 47 minutes) is larger than the median (21 hours, 59 minutes), which indicates that the data set is positively skewed, possibly due to extremely high values.

To confirm this, a frequency table and histogram were developed to further illustrate the shape of the data set and the spread of the recorded observations. The frequency table for the VAT data set collected is presented in Table 6-2.

Table 6-2: Frequency table for VAT outside the CTCT (2011-2015)

Vessel Anchorage Time (VAT) in hours	
Hour Intervals	**Frequency**
Zero to 5 hours	0
5 hours, 1 minutes to 15 hours	17
15 hours, 1 minute to 25 hours	19
25 hours, 1 minute to 35 hours	13
35 hours, 1 minute to 45 hours	4
45 hours, 1 minute to 55 hours	1
55 hours, 1 minute to 65 hours	0
65 hours, 1 minute to 75 hours	2
75 hours, 1 minute to 85 hours	1
Total	**57**

The frequency histogram corresponding to the frequency table is illustrated in Figure 6-2. The histogram for the VAT data set supports the numerical statistics in suggesting that vessel anchorage time is positively skewed. The mean of VAT falls into the 15 hours, 1 minute to 25-hours interval. Overall, the histogram shows that the majority of VAT observations fall either within this interval, or fall below this interval.

In addition, the graph illustrates that significant outliers exist in the 75 hour to 85 hour intervals. This suggests that the median (21 hours, 59 minutes) is a more accurate indication of average vessel anchorage time.

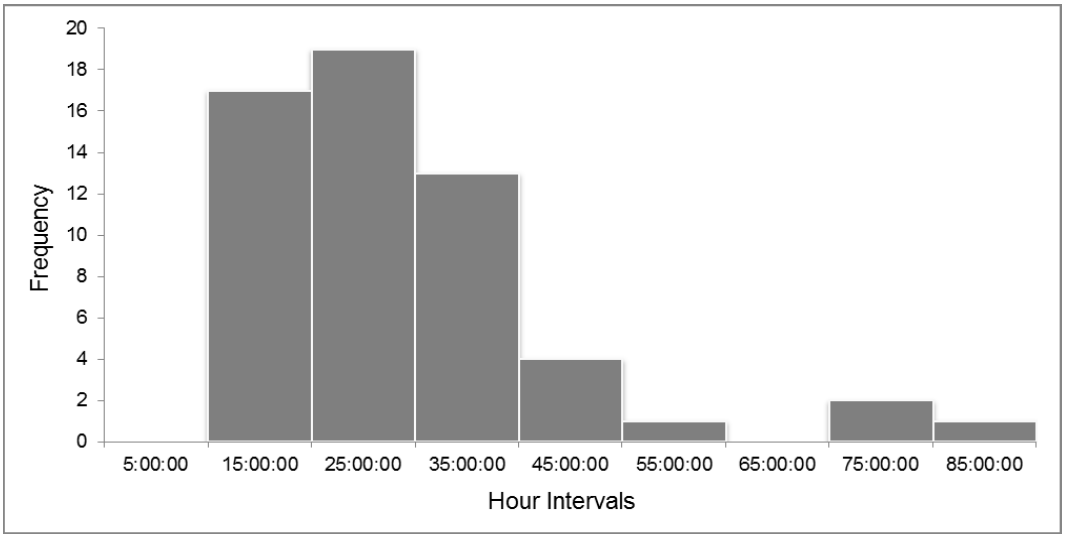

Figure 6-2: Histogram for VAT outside the CTCT (2011-2014)

The significance of the VAT results is discussed in sections 6.2.1 and 6.2.2 in terms of the frequency and the scheduling impact of port congestion. The second ship turnaround data set analysed is vessel berthing time (VBT) within the CTCT.

- *Vessel Berthing Time*

Vessel berthing time (VBT), as mentioned in the introduction of section 6.1.1, is defined as the time vessels spend preparing to offload/load containers within the CTCT. This time includes the act of offloading/loading as well as the movement of the vessel within the port (from breakwater point entry to breakwater point exit[20]).

Figure 6-3 illustrates the VBT observations and shows, using a trend line, that the observations of VBT between January 2011 and October 2015 have a slight upward trend. This suggests that the time ocean carriers spend berthing within the container terminal is increasing slightly. This slight increasing trend could be due to a lack of coordination within the terminal itself, between stevedores and crane operators, resulting in delays to vessel berthing (Julius, 2015).

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[20] This refers to the vessel passing the port breakwater on entry into, and on exiting the port. See Addendum I for a diagram of the Port of Cape Town, including the eastern and western breakwaters.

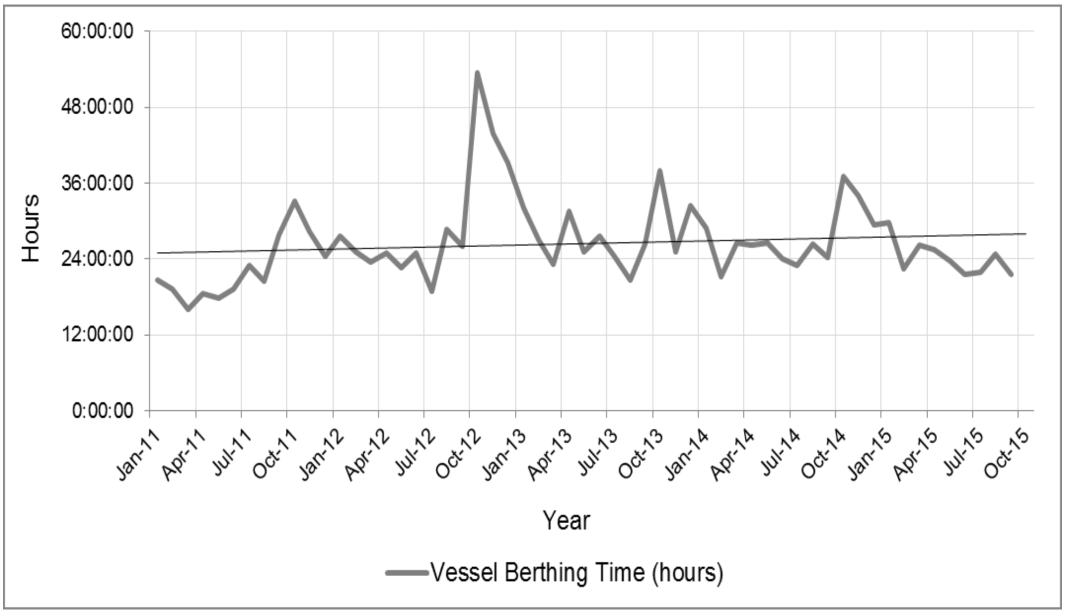

Figure 6-3: VBT within the CTCT (2011 – 2015)

In addition, the graph indicates that berthing time increases during October months suggesting that ocean carriers encounter longer berthing times during these months. This, similar to the VAT data and according to Marais (2015), is likely due to peaks in transhipment container volumes in either Durban or Namibia resulting in transhipment containers being discharged in Cape Town to be trucked up so as to arrive on time and avoid the congestion in Durban and Namibia. Furthermore, the delay of stevedore arrival, previously mentioned with regards to vessel anchorage, impacts the overall berthing time of vessels. The late arrival of experienced stevedores, according to Julius (2015), delays during berthing as only stevedores can perform the unlashing of containers on vessels before offloading/loading can be done.

The last factor which impacts berthing time, and could be the cause of the slight upward trend visible in Figure 6-3, stems from the TNPA and includes, namely, the availability of tug boats at the arrival of vessels to assist in the berthing process. The VAT graph suggests that this planning process may be improving, but the performance of the tug boats in completing the berthing process may be degrading, as suggested by the upward trend in vessel berthing times (Figure 6-3).

Table 6-3 presents the descriptive statistics of VBT. According to Table 6-3, the average berthing time of ocean carriers within the CTCT is approximately 26 hours and 26 minutes. This is relatively similar to the median of 25 hours and 7 minutes, which suggests that the data is relatively evenly spread and does not include any significant outliers.

Table 6-3: Descriptive statistics of VBT within the CTCT (2011-2015)

Mean	26 hours, 26 minutes	**Range**	37 hours, 22 minutes
Median	25 hours, 7 minutes	**Minimum**	16 hours, 7 minutes
Standard Deviation	6 hours, 32 minutes	**Maximum**	53 hours, 30 minutes
Coefficient of variation	24.72%	**Number of Observations**	57

VBT has a standard deviation of 6 hours and 32 minutes, which according to Chebysheff's Theorem, suggests that at least 97.5% of ocean carriers have a berthing time of between 19 hours, 54 minutes and 32 hours, 58 minutes. The coefficient of variation suggests that there is a variation of 24.72% around the mean.

From the mean and median computed, an indication of the shape of the data set is determined. In the case of VBT, the mean (26 hours, 26 minutes) is relatively similar to the median (25 hours, 7 minutes), which indicates that the data set is relatively evenly spread. To confirm this, a frequency table and histogram were developed to further illustrate the shape of the data set and the spread of the recorded observations. The frequency table for the VBT data set collected is presented in Table 6-4.

Table 6-4: Frequency table for VBT within the CTCT (2011-2015)

Vessel Berthing Time (VBT) in hours	
Hour Intervals	**Frequency**
Zero to 15 hours	0
15 hours, 1 minutes to 20 hours	6
20 hours, 1 minute to 25 hours	20
25 hours, 1 minute to 30 hours	21
30 hours, 1 minute to 35 hours	5
35 hours, 1 minute to 40 hours	3
40 hours, 1 minute to 45 hours	1
45 hours, 1 minute to 50 hours	0
50 hours, 1 minute to 55 hours	1
Total	**57**

The frequency histogram corresponding to the frequency table is illustrated in Figure 6-4. The histogram for the VBT data set supports the numerical statistics in suggesting that vessel berthing time is relatively evenly spread, however, the histogram does suggest that an outlier exists in the 55-hour interval. The mean of VBT (26 hours, 26 minutes) falls within the 25 hours, 1 minute to 30-hours interval. Overall, the histogram shows that the majority of VBT observations fall either within this interval, or fall below this interval.

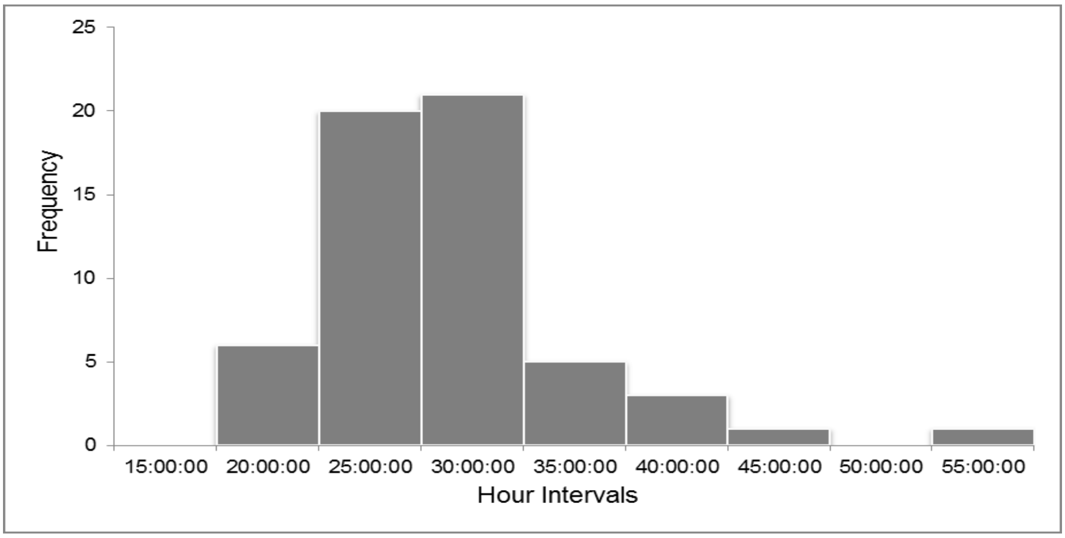

Figure 6-4: Histogram for VAT outside the CTCT (2011-2015)

The significance of the VBT results are discussed in sections 6.2.1 and 6.2.2 in terms of the frequency and the scheduling impact of port congestion. The last ship turnaround data set analysed is vessel working time (VWT) within the CTCT.

- ***Vessel Working Time***

Vessel working time (VWT), as mentioned in the introduction of section 6.1.1, is defined as the time vessels spend offloading and/or loading containers within the CTCT. This time forms part of the vessel berthing time (VBT) analysed previously and will likely indicate similar trends and patterns.

Figure 6.5 illustrates the VWT observations and shows, using a trend line, that the observations of VWT between January 2011 and October 2015 have a slight upward trend. This is similar to the vessel berthing time line chart seen previously. The trend similarly suggests that the time ocean carriers spend offloading and/or loading containers is increasing slightly. This is likely due to a lack of coordination within the terminal itself, as mentioned in the section on vessel berthing. A lack of coordination and communication between TPT, stevedores and crane operations would result in longer working times for vessels.

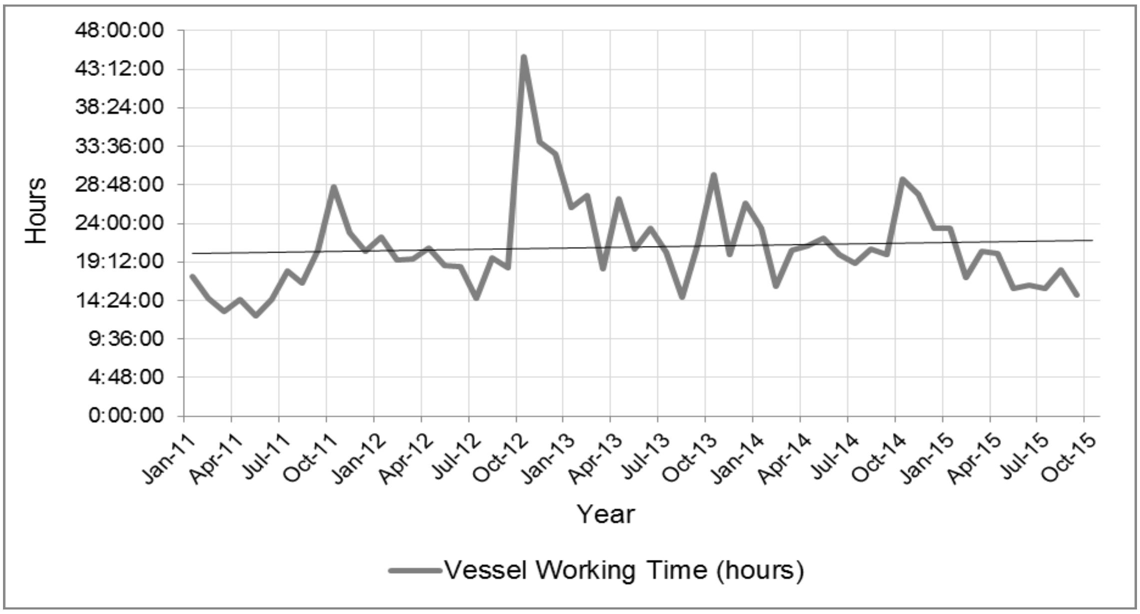

Figure 6-5: VWT within the CTCT (2011 – 2015)

In addition, and similar to the VBT data set, the VWT line chart illustrates significant peaks during the month of October, which may be due to maintenance and/or upgrades to terminal equipment (Davids, 2015). Similar to the VAT and VBT data, the peaks in October months may also be due to due to peaks in transhipment container volumes in either Durban or Namibia, which subsequently results in transhipment containers being discharged in Cape Town (Marais, 2015). This exacerbates congestion within the Port of Cape Town.

Furthermore, the delayed arrival of stevedores (as discussed in the VAT and VBT sections) would likely extend berthing periods as vessels are forced to wait as the terminal operations team cannot begin the discharge and loading process until the containers are unlashed on the vessel (Julius, 2015).

Table 6-5 presents the descriptive statistics of VWT. According to the table, the average working time of ocean carriers within the CTCT is approximately 21 hours and 4 minutes. This is relatively similar to the median of 20 hours and 16 minutes, which suggests that the data is relatively evenly spread and does not include any significant outliers.

Table 6-5: Descriptive statistics of VWT within the CTCT (2011-2015)

Mean	21 hours, 4 minutes	**Range**	32 hours, 15 minutes
Median	20 hours, 16 minutes	**Minimum**	12 hours, 31 minutes
Standard Deviation	5 hours, 46 minutes	**Maximum**	44 hours, 47 minutes
Coefficient of variation	27.39%	**Number of Observations**	57

VWT has a standard deviation of 5 hours and 46 minutes, which according to Chebysheff's Theorem, suggests that at least 96.7% of ocean carriers have a working time of between 15 hours, 18 minutes and 26 hours, 51 minutes. The coefficient of variation suggests that there is a variation of 27.39% around the mean. Overall this is similar to the VBT data set of which the VWT forms a part of.

In the case of VWT, the mean is relatively similar to the median, which indicates that the data set is relatively evenly spread. To confirm this, a frequency table and histogram were developed, the frequency table for the VWT data set is presented in Table 6-6.

Table 6-6: Frequency table for VWT within the CTCT (2011-2015)

Vessel Working Time (VWT) in hours	
Hour Intervals	**Frequency**
Zero to 12 hours	0
12 hours, 1 minutes to 16 hours	10
16 hours, 1 minute to 20 hours	15
20 hours, 1 minute to 24 hours	21
24 hours, 1 minute to 28 hours	5
28 hours, 1 minute to 32 hours	3
32 hours, 1 minute to 36 hours	2
36 hours, 1 minute to 40 hours	0
40 hours, 1 minute to 44 hours	0
More than 44 hours, 1 minute	1
Total	**57**

The frequency histogram corresponding to the frequency table is illustrated in Figure 6-6. The histogram for the VWT data set does not, however, support the numerical statistics in suggesting that vessel working time is relatively evenly spread. In contrast, the histogram suggests that the data set is positively skewed.

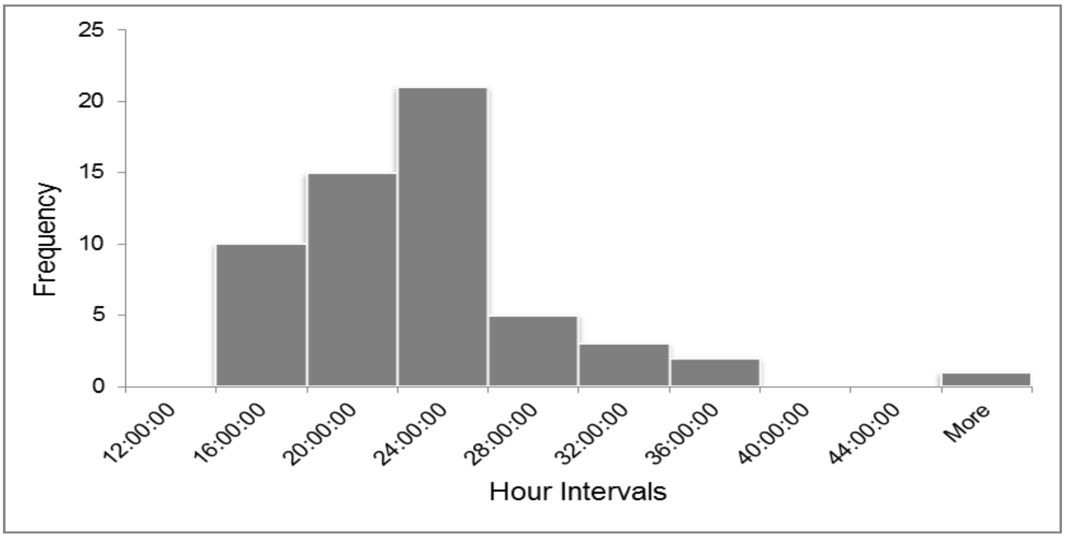

Figure 6-6: Histogram for VWT within the CTCT (2011-2015)

The mean of VWT falls into the 20 hours, 1 minute to 24-hours interval. The histogram shows that the majority of VWT observations fall either within this interval, or fall below the interval. In addition, the histogram indicates that an outlier may exist in the more than 44-hours interval. Overall the histogram reflects similar findings to the VBT histogram, of which vessel working time is a part of.

The significance of the VWT results is discussed in sections 6.2.1 and 6.2.2 in terms of the frequency and the scheduling impact of port congestion. The following section analyses the truck turnaround data set.

6.1.2. Truck Turnaround Time Data

Similar to the analysis of ship turnaround related data (VAT, VBT, VWT), truck turnaround time (TTAT) is analysed using a line chart, numerical statistics, a frequency table and a histogram.

Truck turnaround time, according to TNPA (Birkenstock, 2015), is defined as the average service time of container trucks within the CTCT. This is measured from the point of entry into the port (gate time in) to the point of departure from the port (gate time out). This data set excludes the impact of weather delays and system delays on container trucks, as well as the queuing time outside the terminal[21].

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[21] Queuing time outside the terminal was excluded as this is currently not recording for the Port of Cape Town (Birkenstock, 2015 and Yoyo, 2015).

Figure 6-7 illustrates the observations of the TTAT data set. The figure shows, using a trend line, that the observations of TTAT, between January 2011 and October 2015, have a steady downward trend. This suggests that the turnaround time of container trucks in the container terminal is decreasing over time. This is likely due to improved collaboration, coordination and communication within the terminal itself. The improvement of terminal equipment to withstand higher wind speeds, the improved coordination of containers into and out of container stacks, and a decrease in the number of vehicle breakdowns within the terminal may also be factors contributing to the decreasing truck turnaround time of container trucks (Julius, 2015).

It is, however, important to note that if the 2015 proposed truck ban is implemented truck turnaround time will likely increase both outside the port (queuing time) and inside the port. Therefore, it is recommended that Figure 6-7 be supplemented with additional research with regards to the impact of the truck ban and vehicle queuing time data.

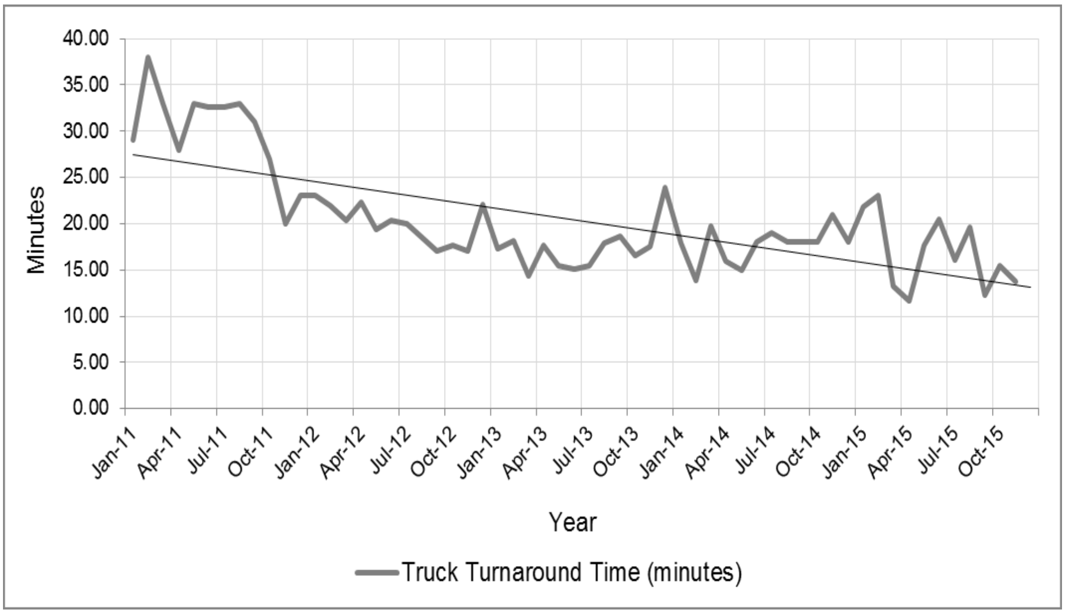

Figure 6-7: TTAT within the CTCT (2011-2015)

In addition, the line chart illustrates a significant decrease in truck turnaround time during October 2011. This decrease may be attributed to upgrades made to the NAVIS system (Davids, 2015) and may also have attributed to the downward trend exhibited in the data. The relatively short turnaround times may also be due to container trucks simply offloading the containers into a staging area (or loading containers from a staging area) and leaving the movement of the container to and from the container stacks to the container terminal staff (Lane, 2015; Yoyo, 2015).

The numerical descriptive statistics of TTAT are shown in Table 6-7. The standard deviation of TTAT is 5.92 minutes, which suggests that 97.15% of container trucks take between 14.51 minutes and 26.35 minutes to turnaround within the CTCT. This is a relatively large variation, and is supported by a coefficient of variation percentage of 28.98%.

Table 6-7: Descriptive statistics of TTAT within the CTCT

Mean	20.43 minutes	**Range**	26.29 minutes
Median	18.52 minutes	**Minimum**	11.71 minutes
Standard Deviation	5.92 minutes	**Maximum**	38 minutes
Coefficient of variation	28.98%	**Number of Observations**	59

According to Table 6-7 the average of 20.43 minutes for TTAT is larger than the median of 18.52 minutes. This indicates that the TTAT observations are positively skewed, possibly due to extremely high values in the data set. To support this, a frequency table for the data set is developed along with a corresponding histogram. The frequency table for the TTAT data set is presented in Table 6-8.

Table 6-8: Frequency table for TTAT within the CTCT (2011-2015)

Truck turnaround time (TTAT) in minutes	
Minute Intervals	**Frequency**
Zero to 11 minutes	0
11.1 to 14 minutes	5
14.1 to 17 minutes	9
17.1 to 20 minutes	23
20.1 to 23 minutes	11
23.1 to 26 minutes	1
26.1 to 29 minutes	3
29.1 to 32 minutes	1
32.1 to 35 minutes	5
35.1 to 38 minutes	1
Total	**59**

Figure 6-8 depicts a histogram which illustrates the spread of the TTAT observations and supports the suggestion that the data set is positively skewed. Furthermore, the mean of the data set falls within the 20.1 to 23-minutes interval. The histogram shows that the majority of the TTAT observations fall below this interval. A significant peak can be seen in Figure 6-8, in the 17.1 to 20-minute interval. This suggests that the median (18.52 minutes) is a more accurate indication of truck turnaround time.

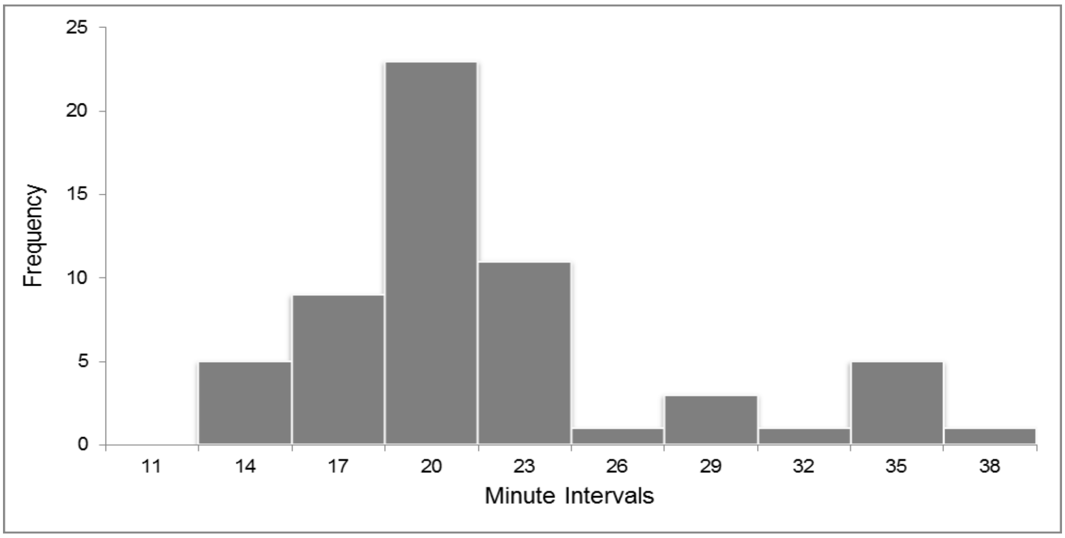

Figure 6-8: Histogram for TTAT within the CTCT (2011-2015)

The significance of the TTAT results is discussed in sections 6.2.1 and 6.2.2 in terms of the frequency and the scheduling impact of port congestion. The following subsection analyses the weather delays data recorded within the CTCT.

6.1.3. Weather Delays Data

The weather delays data collected is analysed similarly to VAT, VBT, VWT and TTAT. Weather delays, according to TNPA (Birkenstock, 2015), is defined as time delays (in hours) resulting due to high wind speeds, thick fog, vessel ranging, strong underwater currents and large ocean swells.

The recorded weather delays in the CTCT are plotted on a time series line chart, as seen in Figure 6-9. The linear trend line shown on the chart indicates that no upward or downward trend exists in the data set. This suggests that weather delays within the CTCT have not shown a steady increase or decrease over the past four years (2011-2014). This is an acceptable finding as weather patterns often don't exhibit trends in relatively short-term analysis (Nel, 2015).

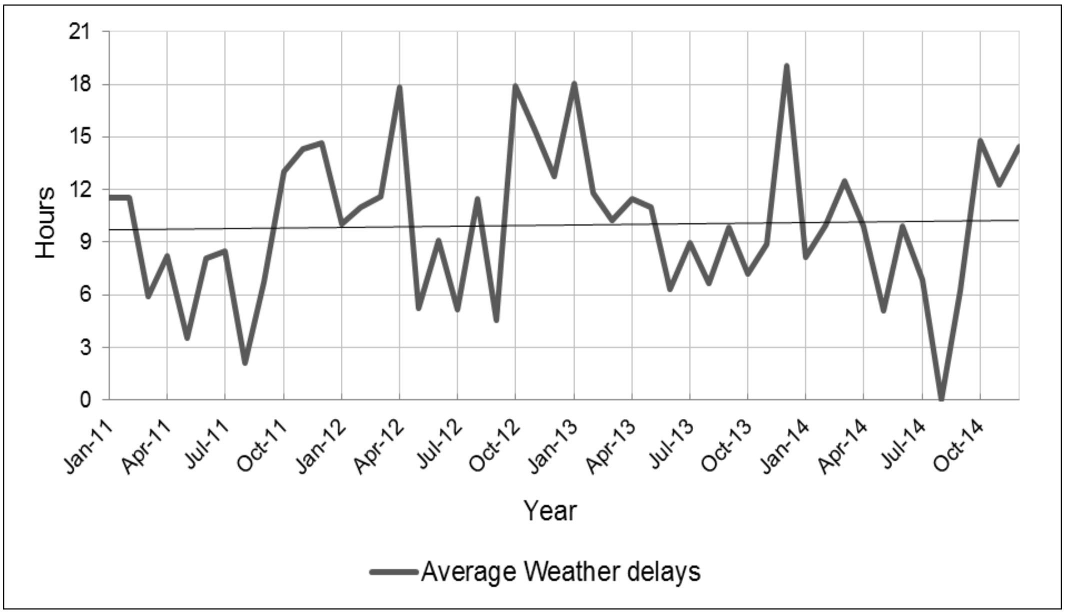

Figure 6-9: Weather delays recorded within the CTCT (2011-2014)

In addition, the line chart displays a number of peaks which are likely due to occurrences of exceptionally severe weather conditions. Similarly, the significant decreases could be attributed to times of mild weather. The October month trend visible in the VAT, VBT and VWT data sets is, based on Figure 6-9, not due to severe weather conditions as the graph indicates that October months experience relatively mild weather.

Weather delays recorded in the CTCT were analysed further to consider conditions experienced in the winter months versus the summer months. For the purpose of this study winter months are said to include June, July and August, while summer months range from early December to late February. Figure 6-10 illustrates the weather delays recorded during the winter and summer seasons of 2011 to 2014.

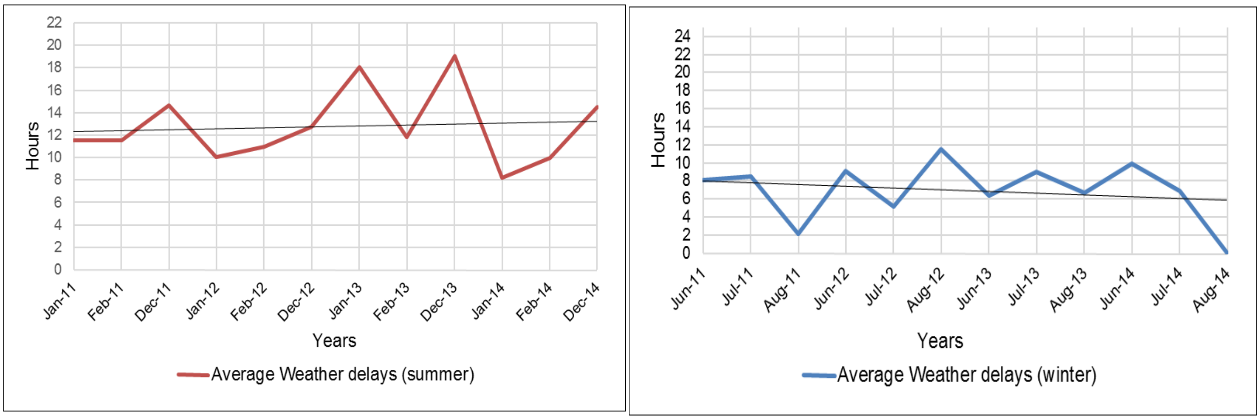

Figure 6-10: Weather delays recorded in summer and winter months (2011-2014)

Figure 6-10 illustrates that weather delays experienced during the summer months are significantly more than those experienced in the winter months. Summer delays were recorded to have an average of 12.76 hours, which is significantly higher than the average of 6.93 hours recorded for the winter season. This supports the literature discussed in section 5.4.1 in Chapter 5.

According to Table 6-9, weather delays recorded in the CTCT have a mean of 9.99 hours between 2011 and 2014. This is similar to the median of 9.94 hours, which implies that the data set is approximately symmetric and does not contain any outliers. This can, however, only be confirmed graphically with a histogram later in this section.

Table 6-9: Descriptive statistics of weather delays within the CTCT (2011-2014)

Mean	9.99 hours	**Range**	19.05 hours
Median	9.94 hours	**Minimum**	0 hours
Standard Deviation	4.2 hours	**Maximum**	19.05 hours
Coefficient of variation	42%	**Number of Observations**	48

The standard deviation for weather delays is 4.2 hours. This suggests, according to Chebsheff's Theorem, that 94.33% of weather delays in the CTCT range between 5.79 and 14.19 hours. This is a relatively large variation, and is supported by a coefficient of variation percentage of 42%. This high degree of variation is not uncommon in weather-related data sets (Nel, 2015).

With regards to the shape of the data set, a comparison of the mean (9.99 hours) and median (9.94 hours) suggest that weather delays within the CTCT are slightly positively skewed. To support this, a frequency table for the data set was developed (seen in Table 6-10) along with a corresponding histogram (seen in Figure 6-11).

Table 6-10: Frequency table for weather delays within the CTCT (2011-2014)

Weather delays in hours	
Hour Intervals	**Frequency**
0 to 2.9 hours	1
3 to 5.9 hours	1
6 to 8.9 hours	6
9 to 11.9 hours	12
12 to 14.9 hours	15
15 to 17.9 hours	8
18 to 20.9 hours	3
21 hours or more	2
Total	**48**

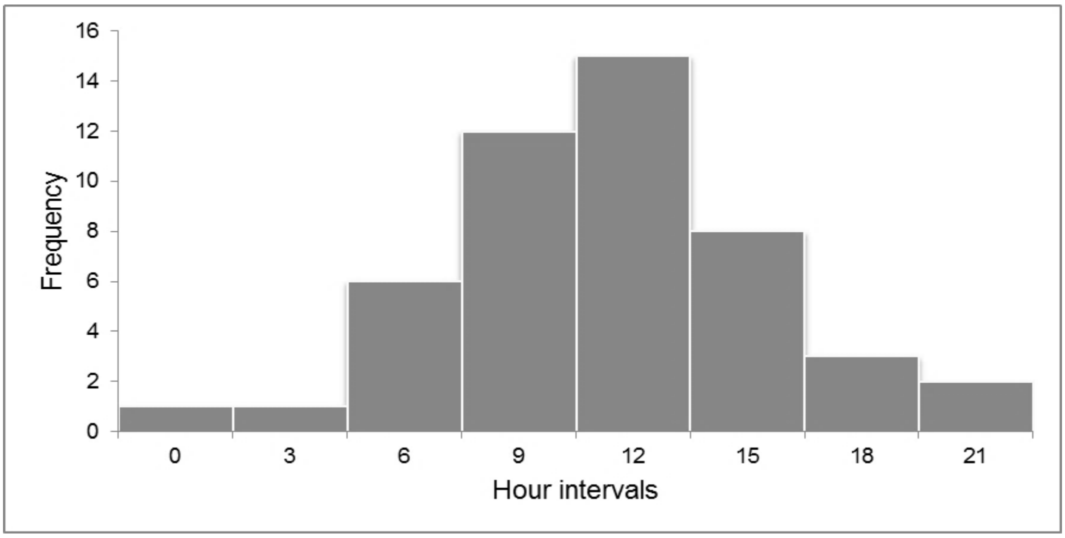

Figure 6-11: Histogram for weather delays recorded within the CTCT (2011-2014)

The data set, according to the histogram in Figure 6-11, appears to be relatively symmetrical; however, the observations are slightly skewed suggesting that the data set contains some extremely low values. This is illustrated in the histogram with observations falling in the zero to 3 hour intervals.

The significance of these results is discussed in sections 6.2.1 and 6.2.2 in terms of the frequency and the scheduling impact of port congestion. The following subsection analyses the system-related delays recorded within the CTCT between 2011 and 2014.

6.1.4. System Delays Data

The last data set to be analysed for the determination of frequency and scheduling impact of port congestion is system-related delays within the CTCT. System delays, according to TNPA (Birkenstock, 2015), refer to time delays resulting from NAVIS system-related issues such as shutdowns, maintenance and power failures.

The recorded system delays in the CTCT are plotted on a line chart, as seen in Figure 6-12, which included a linear trend line. The trend line indicates that, similar to weather delays, no significant upward or downward trend exists in system delays. This subsequently suggests that system delays have not shown an increase or decrease over the four year period. This fluctuation in delays may be due to the implementation of a NAVIS system upgrade (NAVIS SPARCS N4) in 2012, which required operations staff to obtain additional training (Davids, 2015).

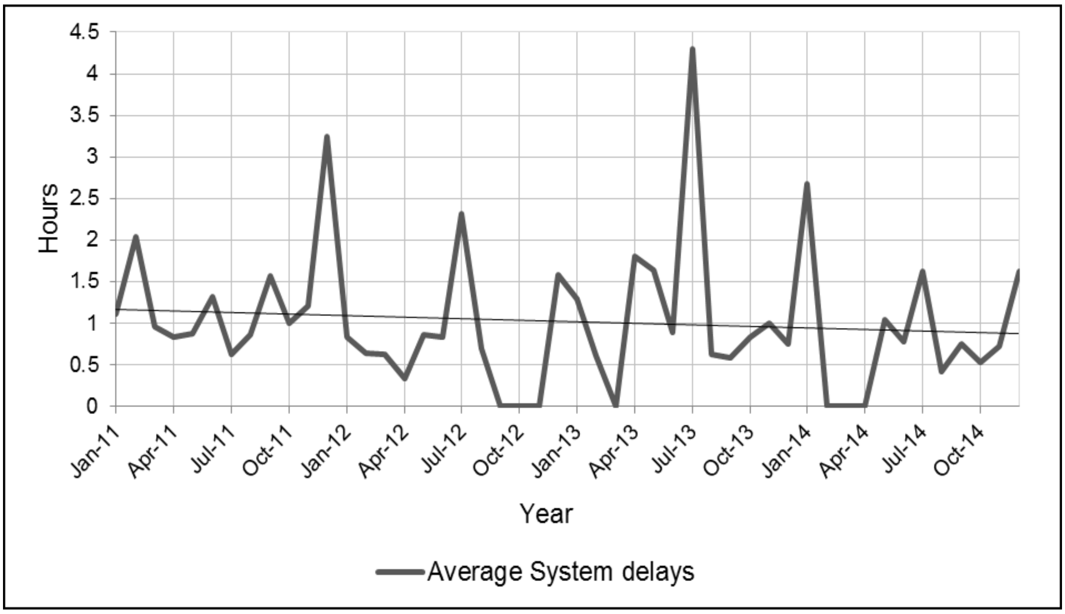

Figure 6-12: System delays recorded within the CTCT (2011-2014)

The graph similarly indicates that the October month peaks depicted in the VAT, VBT and VWT data sets is not due to system delays. In reality, Figure 6-12 illustrates that October months generally experience low occurrences of system delays.

The descriptive statistics of system delays (shown in Table 6-11) indicate that system delays have a mean of 1.02 hours. This is relatively larger than the median of 0.84 hours, suggesting that the data set is positively skewed.

Table 6-11: Descriptive statistics of system delays within the CTCT (2011-2014)

Mean	1.02 hours	**Range**	4.29 hours
Median	0.84 hours	**Minimum**	0 hours
Standard Deviation	0.85 hours	**Maximum**	4.29 hours
Coefficient of variation	83.3%	**Number of Observations**	48

The standard deviation for system delays within the CTCT amounted to 0.85 hours, therefore, the Chebysheff's Theorem could not be applied. This is a relatively large variation, and is supported by a coefficient of variation percentage of 83.3%. The high degree of variability found in the system delays data set is likely due to the implementation of the NAVIS upgrade (NAVIS SPARCS N4) in 2012 (Nel, 2015), as new systems generally require "debugging[22]" as operations staff adjust to the new system (Davids, 2015). The shape of the data, as mentioned previously, is positively skewed and this is supported through the calculation of a frequency table (Table 6-12) and a corresponding histogram (Figure 6-13).

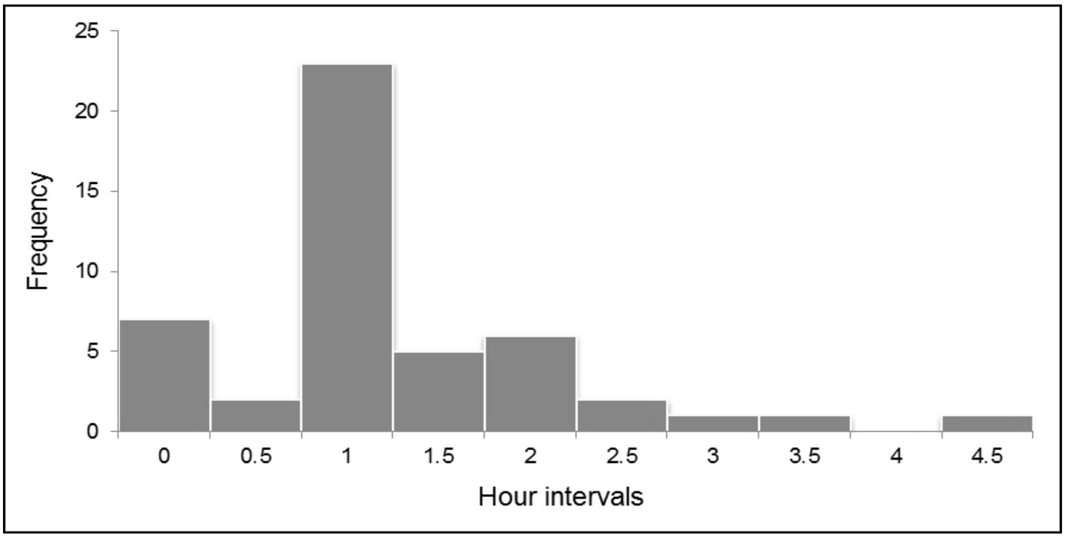

Figure 6-13: Histogram for system delays recorded within the CTCT (2011-2014)

The system delays recorded in the CTCT are illustrated in a histogram (Figure 6-13), which supports the suggestion that the data set is positively skewed. Furthermore, the histogram illustrates that the data set contains an outlier, situated in the 4.1 to 4.5-hours interval. This outlier may be due to an error in the data capturing process (Nel, 2015), or be a result of the implementation of the NAVIS upgrade in 2012 (Davids, 2015).

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[22] Process of finding and resolving system-related defects that prevent correct operation of computer software or a system (NAVIS, 2015).

Table 6-12: Frequency tables for system delays within the CTCT (2011-2014)

System delays in hours	
Hour Intervals	**Frequency**
0 to 0.4 hours	7
0.5 to 0.9 hours	2
1 to 1.4 hours	23
1.5 to 1.9 hours	5
2 to 2.4 hours	6
2.5 to 2.9 hours	2
3 to 3.4 hours	1
3.5 to 3.9 hours	1
4 to 4.4 hours	0
4.5 hours or more	1
Total	**48**

The following section includes the discussion of the results in terms of the frequency of port congestion, and the scheduling impact of port congestion.

6.2. Discussion of Results

The following two subsections discuss the significance of the descriptive analysis in terms of the two port congestion elements, namely the frequency of congestion and the scheduling impact of congestion. These sections are discussed in terms of ocean carriers, container trucks, weather delays and system delays. The methodology of these sections is discussed in Chapter 2.

6.2.1. Frequency of Port Congestion

The frequency of port congestion, as mentioned previously in section 2.2.3 of Chapter 2, can be measured in a number of ways. For the purpose of this study, and specific to this case study, the frequency of port congestion was taken to refer to the number of observations (in percentage form) exceeding the trend line of the data set. These percentages of occurrences per year were thus only an indication of the frequency of congestion incidences.

Prior to the analysis of frequency, the interpretation of frequency percentage (discussed previously in section 2.2.6 of Chapter 2) must be reiterated. For the purpose of this study, it is important to note that a frequency percentage of 100% suggests only that the majority of vessels/vehicles within the terminal experience at least one occurrence of delays of varying severity.

For the VAT line chart, the downward trend line suggests that port congestion experienced during vessel anchorage outside the port has a decreasing frequency. The frequency table and histogram support this suggested downward trend with the majority of observations appearing within or below the average of 24 hours, 47 minutes. The frequency of delays during vessel anchorage is analysed further using a bar chart (Figure 6-14).

Figure 6-14 shows that over the past five years (2011-2015) the number of congestion occurrences (observations exceeding the trend line) for ocean carriers anchored outside the CTCT has fluctuated, but does indicate a downward trend. The year 2012 saw the highest percentage of incidences with 83.33% of observations exceeding the trend line. This peak in anchorage related delays is likely due to terminal expansion done throughout that year, namely, the replacement of reach stackers, the instalment of CCTV, the delivery of new reach stackers, and the implementation of technology for reefer monitoring and reefer stacks (Port of Cape Town, 2015). Furthermore, the availability of tug boats from the TNPA side to assist in the berthing process can delay the entry of vessels into the port. The subsequent years (2013-2014), however, saw significant decreases to 41.67% and 8.33%.

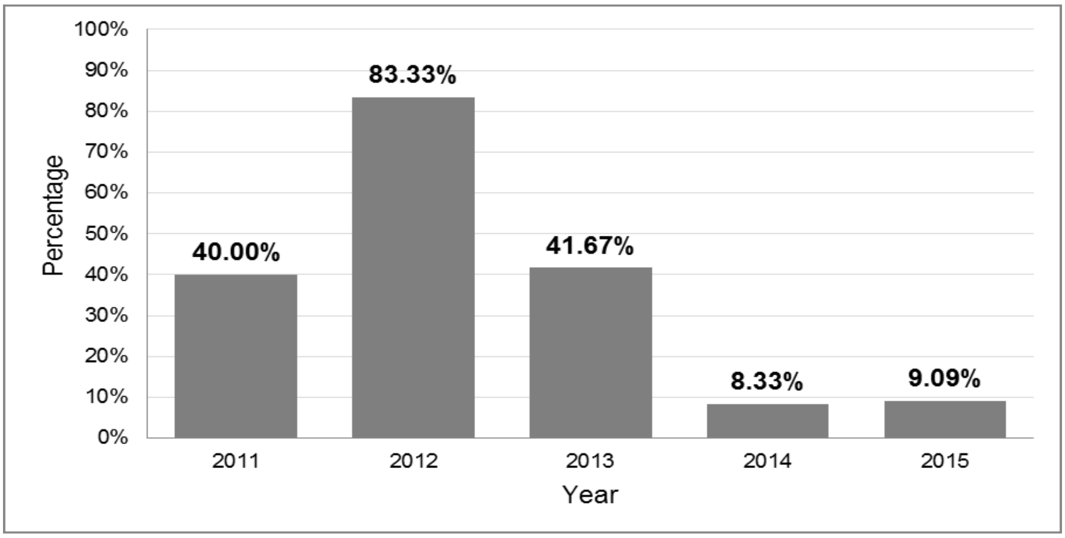

Figure 6-14: Vessel anchorage incident percentage (2011 to 2015)

The bar chart in Figure 6-14 suggests that the number of incidences experienced by ocean carriers during anchorage outside the CTCT may, indeed, be decreasing. However, this is discussed further after the analysis of the forecast results in Chapter 7.

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With regards to vessel berthing, the VBT line chart (with its slight upward trend) suggests that port congestion experienced during vessel berthing within the terminal has a slight increasing frequency. The frequency of delays during vessel berthing is analysed further using a bar chart (Figure 6-15).

Figure 6-15 shows that over the past five years (2011-2015) the number of incidences (observations above the trend line) for ocean carriers berthing within the CTCT has fluctuated, with no specific trend displayed.

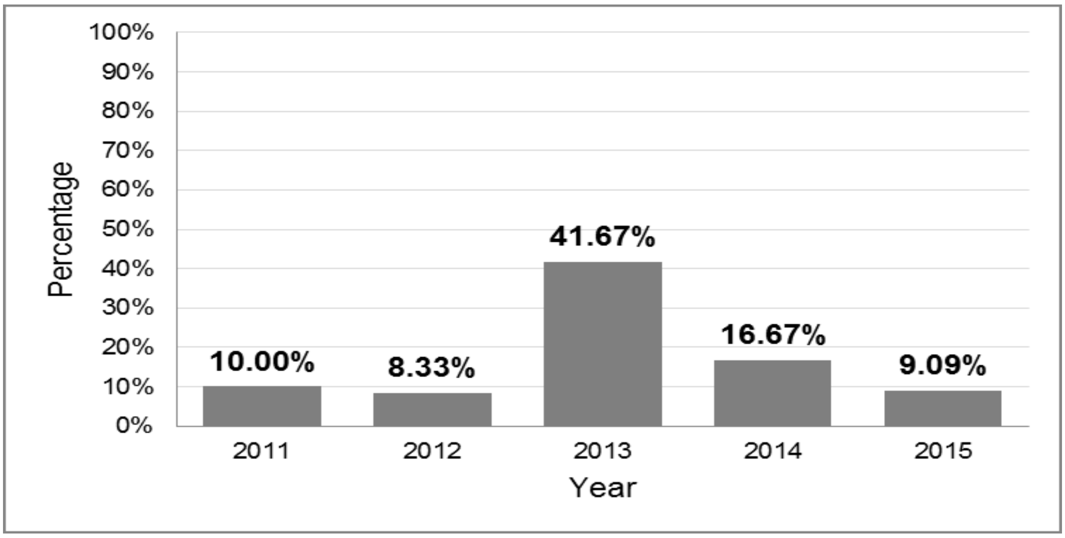

Figure 6-15: Vessel berthing incident percentage (2011 – 2015)

Berthing related incidences did, however, peak during 2013 at 41.67%, which is likely due to the final stages of the expansion of the terminal, namely, the completion of additional berths (Port of Cape Town, 2015). The initial opening of the additional berths likely resulted in miscommunication between TPT and shipping companies, which subsequently lengthened vessel berthing time.

Thus, the bar chart in Figure 6-15 indicates that incidences experienced by ocean carriers during berthing within the CTCT fluctuates over time. This is discussed further after the analysis of the forecast results in Chapter 7.

The VWT line chart, similar to the VBT chart, illustrates a slight upward trend, which suggests that congestion experienced during the offloading and/or loading of vessels has a slight increasing frequency. The frequency table and histogram did not, however, support this suggested upward trend with the majority of observations appearing below the average of 21 hours, 4 minutes. The frequency of delays during vessel offloading and/or loading is analysed further using a bar chart (Figure 6-16).

Figure 6-16 shows that over the past five years (2011-2015) the number of incidences (observations above the trend line) for ocean carriers offloading and/or loading containers has fluctuated. Incidences experienced during offloading and/or loading of containers is recorded at 10% and 8.33% in 2011 and 2012 respectively. This peaked in 2013 at 50%. This is likely due to the final stages of terminal expansion, which included the completion of additional berths (Port of Cape Town, 2015). It is likely that the initial opening of the additional berths resulted in a lack of coordination, which subsequently lengthened the working time of vessels.

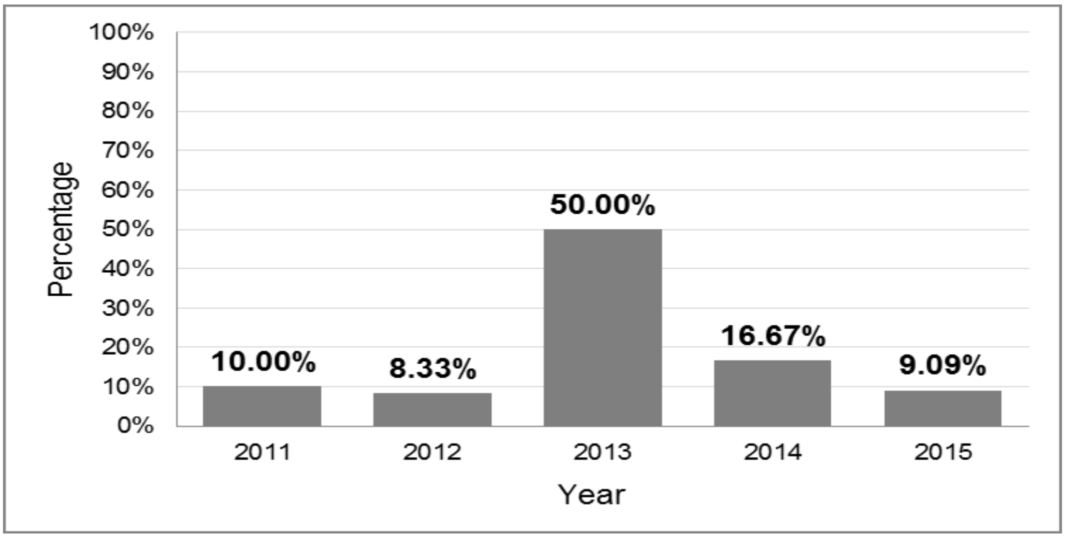

Figure 6-16: Vessel offloading and/or loading incident percentage (2011 – 2015)

Figure 6-16 indicates that the number of incidences experienced by ocean carriers during offloading and/or loading of containers within the CTCT fluctuates over time. This is discussed further after the analysis of the forecast results in Chapter 7.

For the TTAT within the CTCT, the line chart shows a downward trend line, which suggests that port congestion is decreasing in frequency for container trucks moving within the container terminal. The frequency table and histogram support this suggested downward trend with the majority of observations appearing below the average of 20.43 minutes. The frequency of delays in the turnaround of container trucks is analysed further using a bar chart.

Figure 6-17 shows that over the past four years (2011-2014) the number of incidences (observations exceeding the trend line) for container trucks has decreased substantially. The discussion of the line chart of TTAT did, however, highlight that this data should be supplemented with data regarding the proposed truck ban and truck queuing time outside the port.

The results indicate that 2011 experienced the highest incident percentage at 83.33%. This peak in vehicle related incidences is likely due to two factors. Firstly, 2011 saw the construction of a new truck staging area inside the CTCT (Port of Cape Town, 2015), which likely resulted in a decrease in coordination between TPT and trucking companies. The second factor, according to Marais (2015), involves a peak in the growth of fruit exports arriving via container truck and exiting South Africa via the CTCT (South African Fruit Trade Flow, 2014:4). This peak in the export of oranges, grapefruit, lemons and limes likely resulted in a peak in truck volumes, resulting in lengthened truck turnaround times inside the port.

The turnaround time of trucks within the CTCT saw a significant decrease in 2012 to 0%. This was followed by a slight increase in 2013 to 8.33%. However, incidences for container trucks decreased to 0% in 2014 and 2015. This is likely due to the construction of the previously mentioned truck staging area in 2011, as well as other factors such as equipment improvements, improved coordination of containers into and out of container stacks, and decreased vehicle breakdowns within the terminal (Julius, 2015).

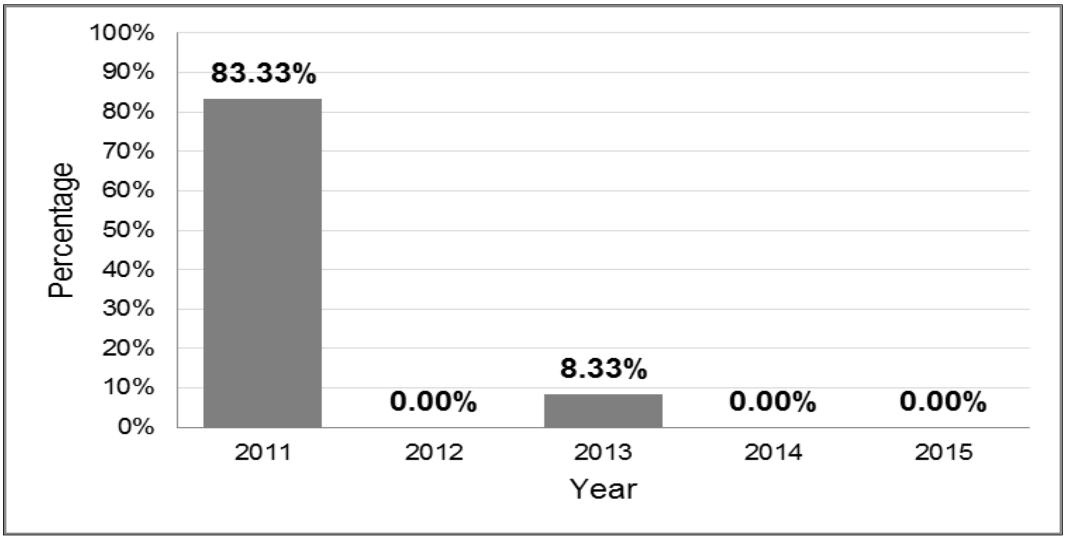

Figure 6-17: Incident percentage for container trucks (2011 – 2015)

The decreasing trend seen in the percentage of incidences experienced by container trucks suggests that the management of landside congestion may be improving. This is, however, analysed further after the forecast analysis in Chapter 7.

In addition to the frequency of congestion for ocean carriers and container trucks, the frequency of congestion resulting from weather delays and system delays is also analysed. According to the line chart, weather delays within the CTCT do not display any form of upward or downward trend between 2011 and 2014. Similarly, the summer and winter line chart illustrates that weather delays remained relatively stable over the past four years.

In addition, the frequency table and histogram suggest that the majority of weather delay observations are within the average of 9.99 hours. The frequency of weather delays within the CTCT is analysed further using a bar chart to determine the percentage of delays experienced by ocean carriers and container trucks from 2011 to 2014.

The bar chart in Figure 6-18 illustrates that weather delays have fluctuated over the past four years. In 2011 weather delays occurred 25% of the time. This increased to 33.33% in 2013, which was followed by a decrease to 16.67% in 2013, whilst 2014 saw another increase to 33.33%.

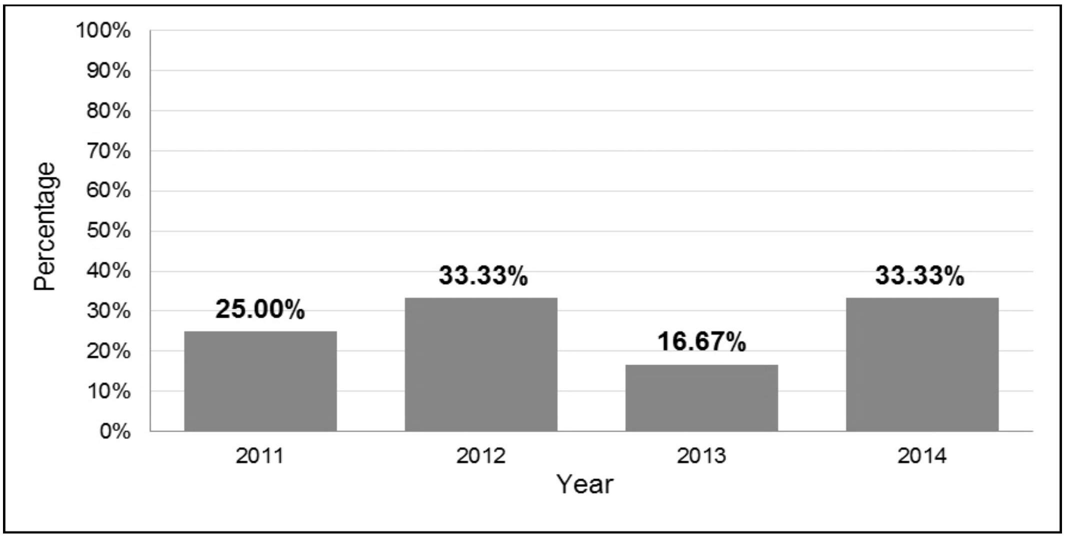

Figure 6-18: Percentage of weather-related incidences (2011 – 2014)

The fluctuation seen in Figure 6-18 is most likely due to the degree of variability found within the data set (coefficient of variation of 42%) and the unpredictable nature of weather conditions in the Port of Cape Town (Nel, 2015 & Davids, 2015). The fluctuations do, however, support the stable trend exhibited in the line chart of weather delays shown in section 6.1. This is discussed further in the forecast analysis in Chapter 7.

In addition to the general analysis of weather delays in the CTCT, the data set is analysed further to determine in which season, summer or winter, the majority of weather delays occur. A descriptive analysis of the two seasons determined that the average time of delays in summer amount to 12.76 hours, whilst the average time of delays in winter amount to only 6.93 hours.

Compared to the average weather delays experienced annually (9.99 hours), summer months experience longer delays than winter months. Furthermore, the bar chart in Figure 6-19 illustrates that in the summer months (December – February) ocean carriers and container trucks experience weather delays, which for the most part exceed the annual average.

Figure 6-19 suggests that in the summer months incidences of weather delays occur 66.67% of the time in 2011, and 100% of the time in 2012 and 2013. This percentage, however, saw a decrease in 2014 to 33.33%. This implies that incidences of weather delays are more prevalent in summer. The peaks in summer weather delays during 2012 and 2013 are likely due to the South-South Easterly wind known as the "Cape Doctor", which reduces equipment operating hours.

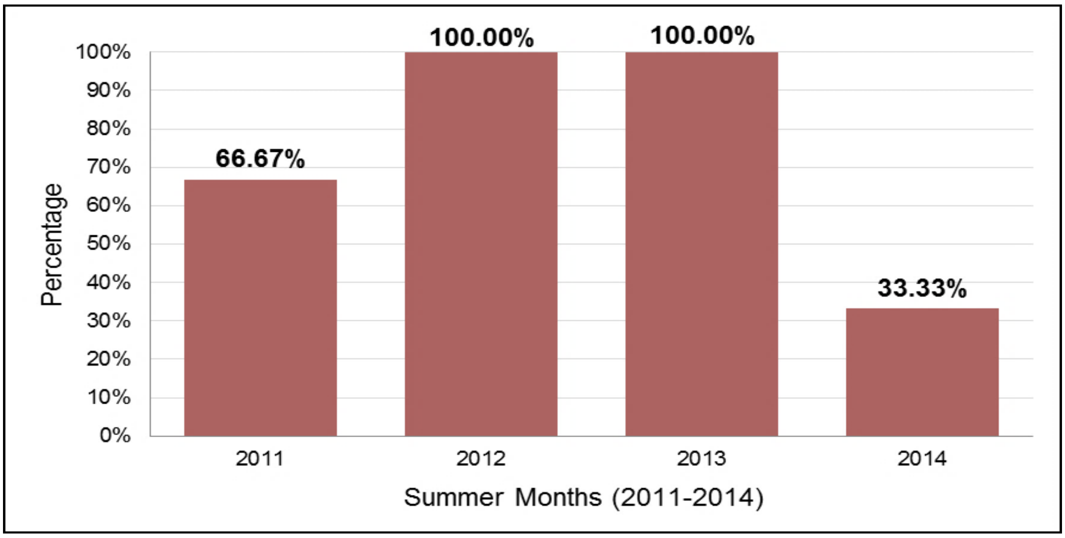

Figure 6-19: Percentage of weather delays in summer (2011-2014)

In contrast to the summer months, weather delays experienced in the winter months (shown in Figure 6-20) generally do not exceed the trend line. However, in 2012 incidences of weather delays amounted to 33.33%. This implies that, generally, ocean carriers and container trucks experience minimal incidences in winter months. The occurrence of weather-related congestion in 2012 is likely due to unusually high wind speeds of the South-South Westerly.

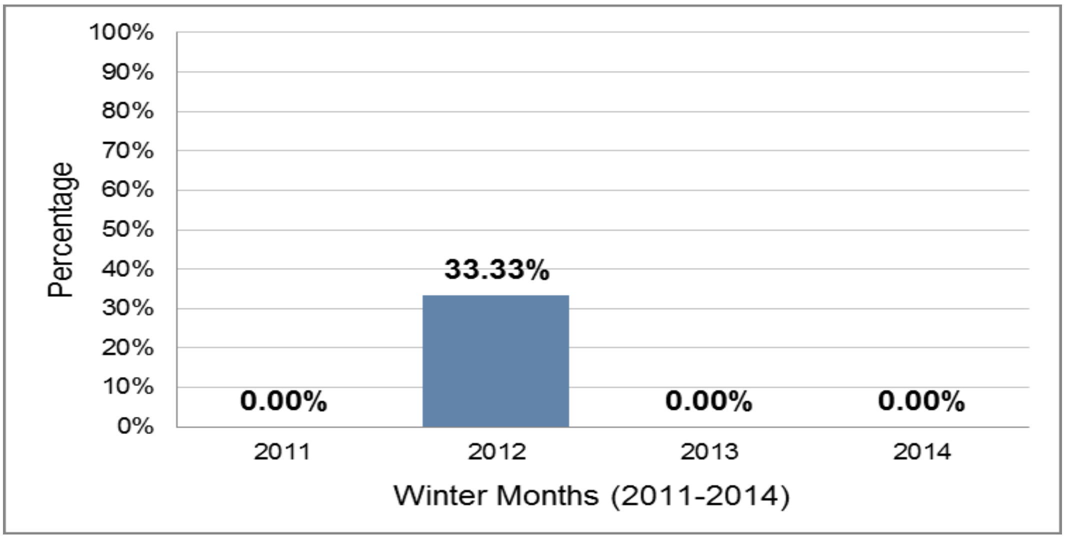

Figure 6-20: Percentage of weather delays winter (2011-2014)

Figure 6-19 and Figure 6-20 subsequently suggest that incidences of weather delays are more prevalent in the summer months of December to February. This is, however, discussed in further detail in the forecast analysis in Chapter 7.

According to the system delays line chart, delays due to system challenges do not display any form of upward or downward trend. Furthermore, the frequency table and histogram suggest that the majority of observations are within the average of 1.02 hours. The frequency of system delays is analysed further using a bar chart to determine the percentage of delays experienced by ocean carriers and container trucks from 2011 to 2014.

Figure 6-21 illustrates that incidences of system delays within the CTCT decreased from 50% in 2011 to 16.67% in 2012. This sudden decrease is likely due to the implementation of new technology on the reefer stacks, which subsequently decreased the number of system-related delays (Port of Cape Town, 2015), but likely resulted in coordination challenges for TPT (Marais, 2015).

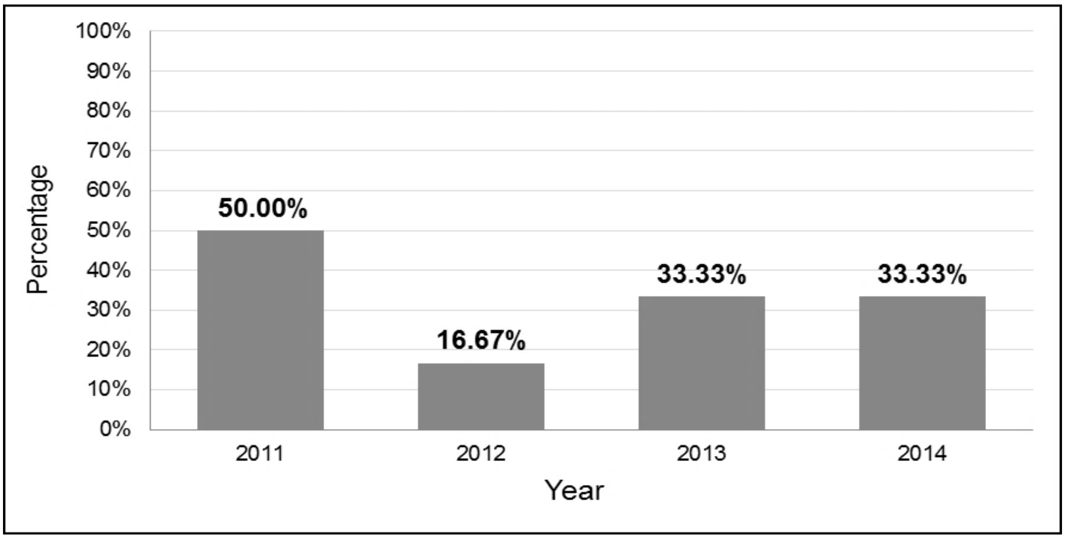

Figure 6-21: Percentage of system-related incidences (2011 – 2014)

It is important to note that the bar chart in Figure 6-21 does not suggest that a downward trend exists, due to the large degree of variability found within the data set (coefficient of variation of 83.3%) (Nel, 2015). However, any trends in system delays are analysed further in the forecast analysis in Chapter 7.

The following section discusses the scheduling impact of port congestion, based on the descriptive statistics conducted in section 6.1.

6.2.2. Scheduling Impact of Port Congestion

The scheduling impact of port congestion, as mentioned in Chapter 2, refers to additional time experienced due to weather delays or system delays. This is defined further to include the scheduling delays experienced by ocean carriers and container trucks. In addition, additional time due to weather-related congestion is defined to include a comparison of delays experienced by ships and trucks in summer versus delays experienced in winter.

For the purpose of this study, scheduling impact is defined as the additional time experienced due to weather- and system-related port congestion. The scheduling impact of congestion is, therefore, seen as the amount of time exceeding the trend line and thus in addition to the average time spent in port. The findings with regards to the scheduling impact of congestion for ocean carriers and container trucks are presented below, along with the scheduling impact of weather delays and system delays within the CTCT.

For VAT a bar chart, seen in Figure 6-22, is developed to illustrate the average additional time spent anchored outside the CTCT by ocean carriers per year.

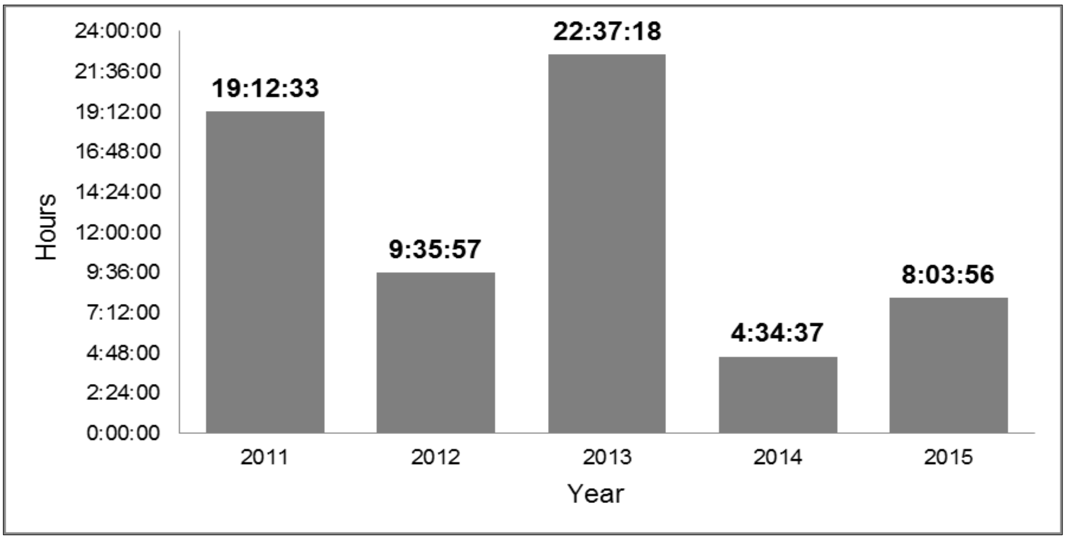

Figure 6-22: Average additional hours spent anchored outside the CTCT (2011-2015)

In 2011, average scheduling delays amounted to 19 hours, 12 minutes. This decreased significantly to 9 hours, 35 minutes in 2012. This decrease was, however, followed by a peak in average scheduling delays of 22 hours, 37 minutes in 2013, which was directly followed by a decrease in 2014 (4 hours, 34 minutes) and a slight increase in 2015 (8 hours, 3 minutes).

The major peak in additional anchorage time seen in 2013 is likely due to the final stage of terminal expansion, which involved the construction of additional berths. It is likely that the initial opening of the new berths resulted in decreased coordination between TPT and shipping companies. This subsequently led to delays of longer periods outside the terminal. This is analysed further in the forecast analysis in Chapter 7.

For VBT a bar chart is developed to illustrate the additional time spent berthing within the CTCT. Figure 6-23 shows the amount of additional time experienced by ocean carriers during berthing within the CTCT. These amounts are compared to the annual average berthing time of 26 hours, 26 minutes.

In 2011, average scheduling delays amounted to 4 hours, 5 minutes. This increased significantly to 8 hours, 6 minutes in 2012 and 7 hours, 45 minutes in 2013. This increase was followed by a trough in scheduling delays of 3 hours, 14 minutes in 2014, which was directly followed by another increase in 2015 to 4 hours, 34 minutes.

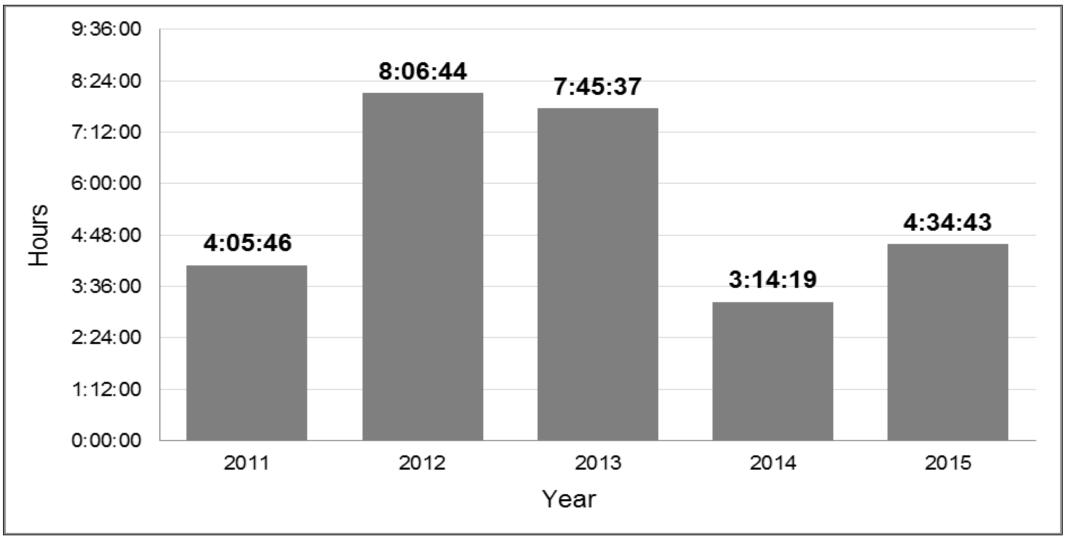

Figure 6-23: Average additional hours spent berthing within the CTCT (2011-2015)

The peaks seen in Figure 6-23 during 2012 and 2013 are likely additional time delays resulting from the previously mentioned terminal expansion, which occurred during this time. Elements of the expansion, which likely caused additional delays in vessel berthing include the replacement of reach stackers, the implementation of reefer monitoring and the opening of additional berths (Port of Cape Town, 2015).

The bar chart in Figure 6-23 suggests that, on average, ocean carriers spent an additional 5 hours, 33 minutes berthing than the annual average of 26 hours, 26 minutes. This is analysed further in the forecast analysis in Chapter 7.

For VWT a bar chart is developed to illustrate the additional time spent working within the CTCT. Figure 6-24 shows the average amount of additional time experienced by ocean carriers during the offloading/loading of containers within the CTCT. These amounts are compared to the annual average working time of 21 hours, 4 minutes.

Figure 6-24 illustrates that in 2011, average scheduling delays amounted to 7 hours, 30 minutes. This increased to 8 hours, 54 minutes in 2012, which was followed by a decrease to 6 hours, 42 minutes in 2013. Scheduling delays during offloading/loading decreased to approximately 3 hours in 2014 and 2015. The peak in 2012 of time delays is likely due to terminal expansion plans implemented during that year. As mentioned with regards to vessel berthing, reach stackers were replaced, reefer monitoring was implemented and, furthermore, technology was implemented on all reefer stacks (Port of Cape Town, 2015). This likely resulted in delays in the offloading and/or loading of containers.

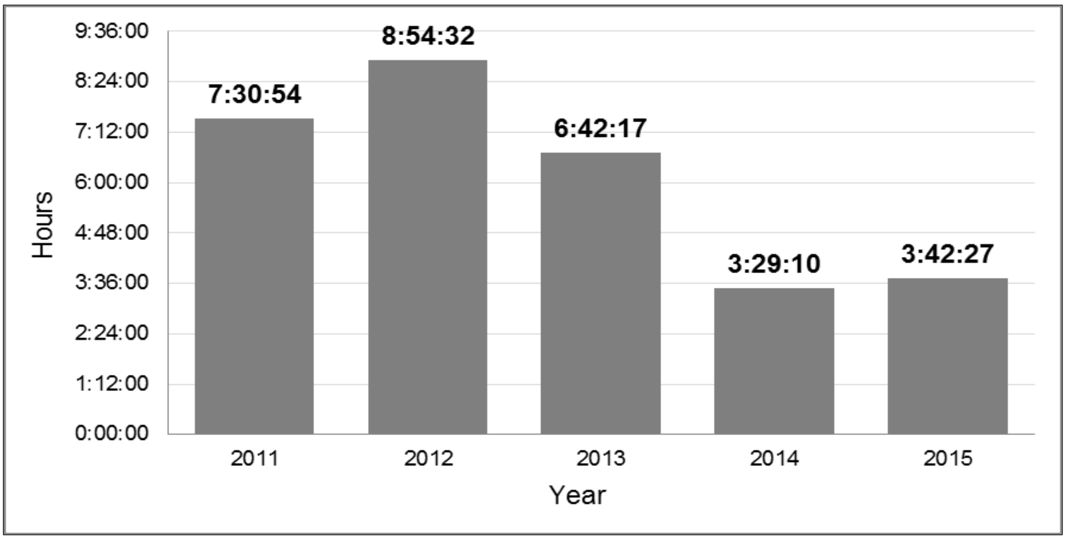

Figure 6-24: Average additional hours spent offloading/loading within the CTCT (2011-2015)

The bar chart in Figure 6-24 suggests that, on average, ocean carriers spent an additional 6 hours, 3 minutes offloading and/or loading containers than the annual average of 21 hours, 4 minutes. This is analysed further in the forecast analysis in Chapter 7.

For truck turnaround time within the CTCT, scheduling delays are illustrated on a bar chart, seen in Figure 6-25. The bar chart suggests that scheduling delays are decreasing over time, with additional time exceeding the average turnaround of container trucks becoming less each year. In 2011, container trucks spent an average of 10.49 additional minutes in the CTCT, likely due to the construction of a new truck staging area within the terminal. This new staging area is also likely the cause for the decrease in time delays seen from 2012 to 2015 (Port of Cape Town, 2015).

In addition, improvements to terminal equipment, improved coordination of containers into and out of container stacks, and decreasing occurrences of vehicle breakdowns are also likely contributors to the decreasing average time delays experienced by container trucks (Julius, 2015).

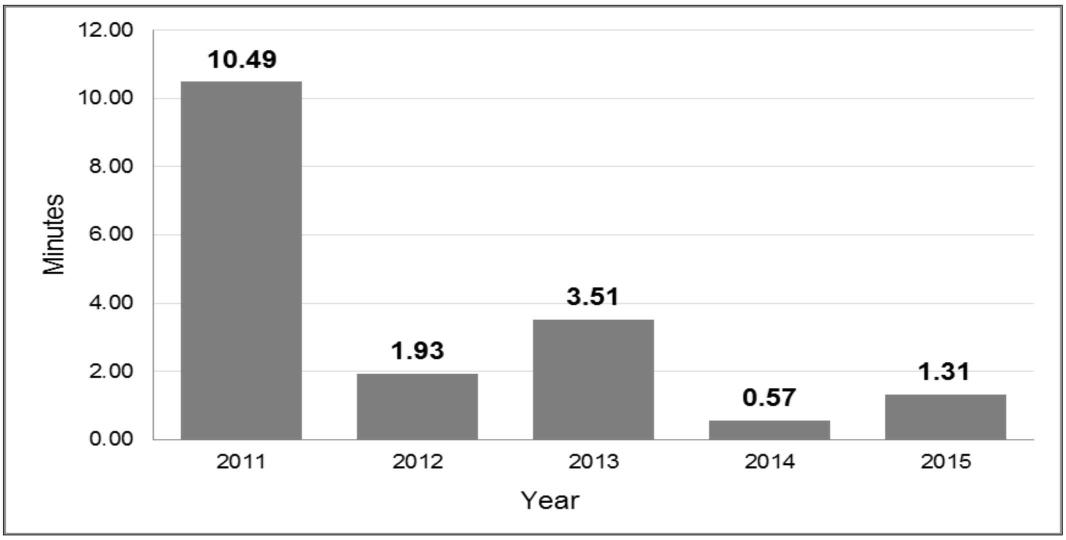

Figure 6-25: Average additional minutes spent in the CTCT by container trucks (2011-2015)

The downward trend in delays experienced by container trucks, as mentioned previously, should be supplemented with data pertaining to vehicle queuing outside the terminal as well as the 2015 proposed truck ban. The scheduling impact on container trucks is analysed further in the forecast analysis in Chapter 7.

In addition to the scheduling impact of congestion for ocean carriers and container trucks, the scheduling impact of congestion resulting from weather delays and system delays is also analysed. According to the line chart, weather delays within the CTCT do not display any form of upward or downward trend between 2011 and 2014.

The scheduling impact of weather delays within the CTCT is analysed further using a bar chart (Figure 6-26) to determine the total weather-related delays experienced by ocean carriers and container trucks from 2011 to 2014.

The bar chart in Figure 6-26 suggests that the average scheduling impact of weather delays has remained relatively constant over the past four years with delays amounting to approximately 3 hours. The graph indicates that in 2011, total weather delays amounted to 3.03 hours. This grew to 3.51 hours in 2012 and 3.62 hours in 2013. These surges were, however, followed by a decrease to 3.51 hours in 2014.

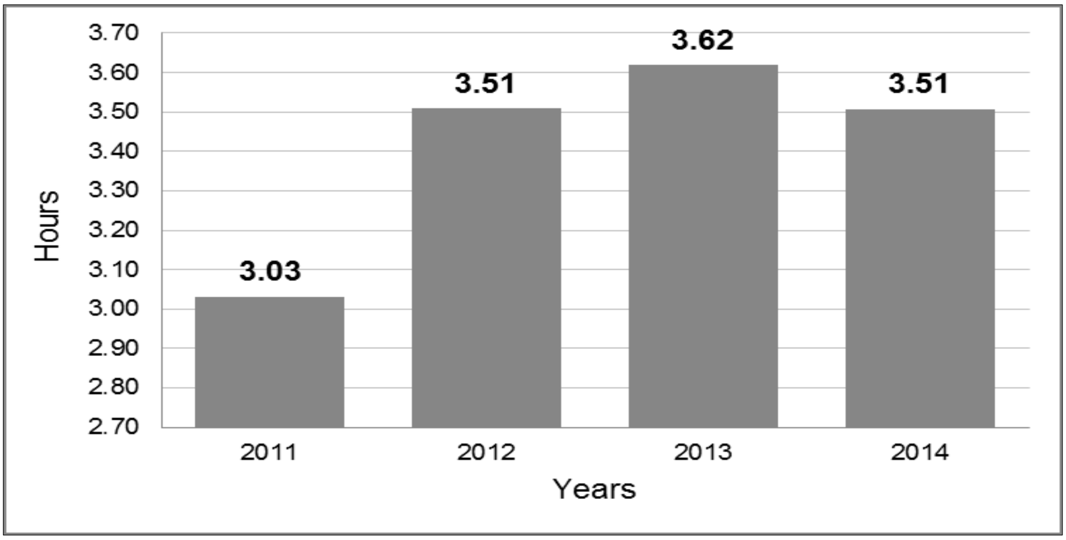

Figure 6-26: Weather delays experienced within the CTCT (2011-2014)

Figure 6-26 suggests that the impact of weather delays (in hours) is slowly increasing, however, this is analysed further in the forecast analysis in Chapter 7.

In addition to the general analysis of weather delays in the CTCT, the data set is analysed further using a bar chart (Figure 6-27) to determine in which season, summer or winter, the largest scheduling impact is experienced. The bar chart in Figure 6-27 illustrates that in the summer months (December – February) ocean carriers and container trucks experience weather delays exceeding the annual average of 9.99 hours by between one and six hours.

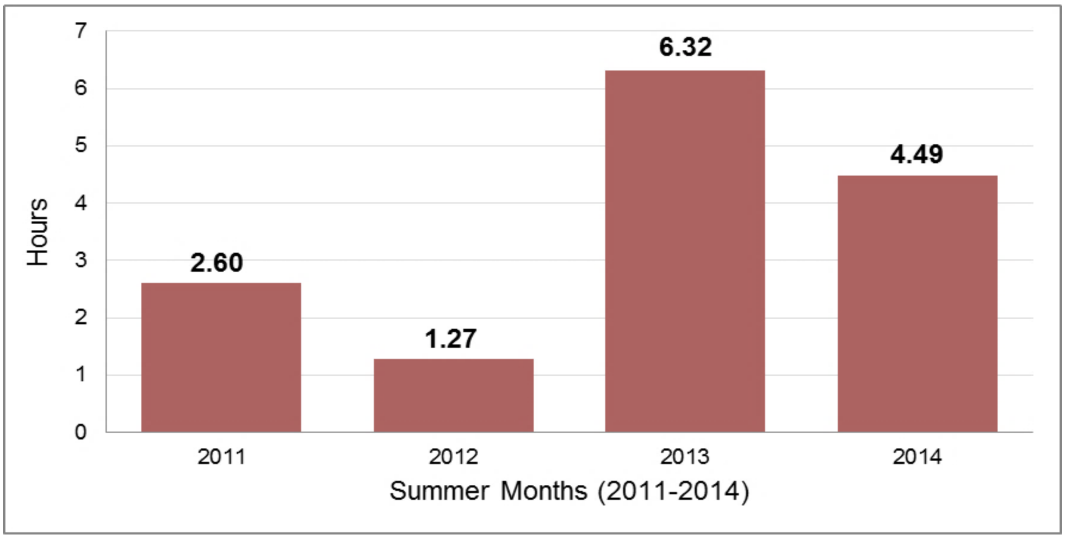

Figure 6-27: Weather delays experienced in summer (2011-2014)

In 2011, ocean carriers and container trucks experienced weather delays of 2.6 additional hours. This decreased to 1.27 hours in 2012. In 2013, weather delays in summer peaked at 6.32 additional hours. This amount, however, decreased again to 4.49 hours in 2014.

The peak in weather delays during 2013 (approximately 6 hours) coincides with a peak in congestion percentage (100%) shown in the previous section. This peak is likely due to higher than usual wind speeds of the South-South Easterly (Julius, 2015). Figure 6-27 suggests that ocean carriers and container trucks experience delays in summer, which exceed the annual average by at least one hour. This implies that, in addition to a higher frequency of congestion, the scheduling impact of congestion is more prevalent in summer.

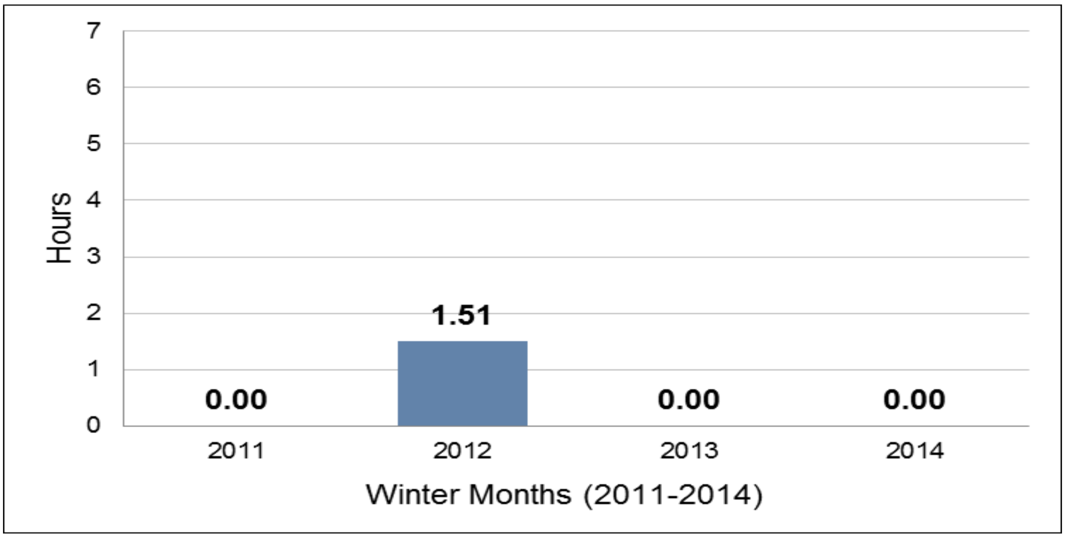

Figure 6-28: Weather delays experienced in winter months (2011-2014)

In contrast to summer, the winter months seen in Figure 6-28 generally exhibited weather delays, which do not exceed the annual average of 9.99 hours, with the exception of 2012 where delays exceeded the annual average by 1.51 hours. This peak in weather delays coincides with the congestion percentage shown in the previous section (33.33%), and is likely due to unusually high wind speeds of the South-South Westerly (Julius, 2015).

Figure 6-28, therefore, suggests that the scheduling impact of congestion, in addition to the frequency of congestion, is significantly less prevalent in winter. Despite the suggested implications of Figure 6-27 and Figure 6-28, the scheduling impact experienced in summer and winter are analysed further in Chapter 7.

With regards to system delays, the line chart does not display any form of upward or downward trend between 2011 and 2014, suggesting that system delays are relatively constant. The scheduling impact of system delays is analysed further using a bar chart (Figure 6-29) to determine the amount of additional time experienced by ocean carriers and container trucks due to system-related congestion.

In 2011, Figure 6-29 illustrates that vessels and trucks experienced system delays of 0.64 hours. This, however, increased in 2012 and 2013 to 0.95 hours and 1 hour respectively. In 2014, this decreased to a 0.74-hour delay. Figure 6-29 illustrates that, in contrast to the congestion percentage bar chart shown in the previous section, the year 2012 does not exhibit a significant decrease in congestion delays. This suggests that despite the decrease in the occurrences of congestion, the time impact of system-related congestion during 2012 remains a concern.

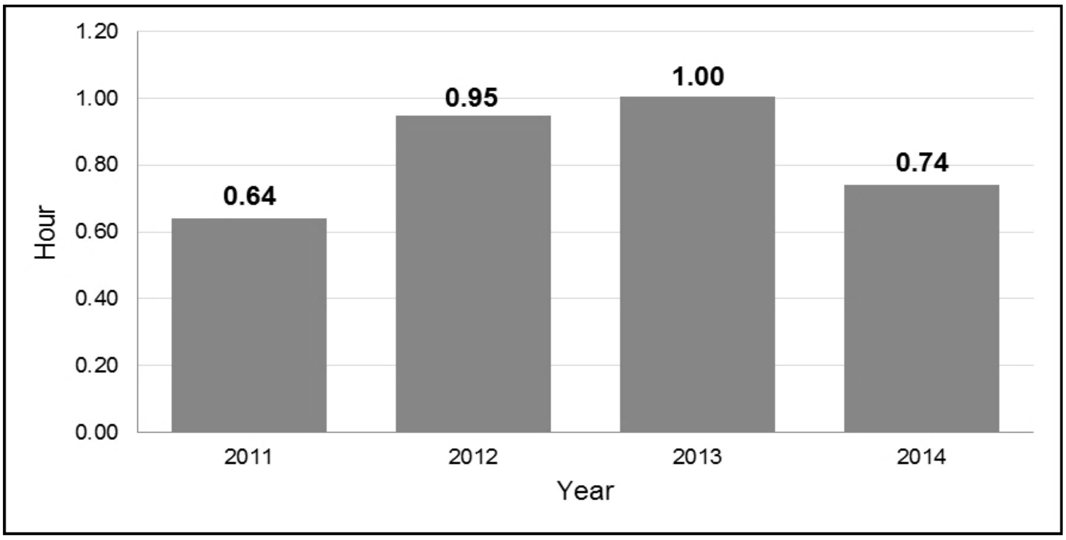

Figure 6-29: System delays experienced within the CTCT (2011-2014)

Figure 6-29 suggests that, on average, ocean carriers and container trucks experience system delays of 0.83 hours between 2011 and 2014. The scheduling impact of system delays is analysed further in the forecast analysis in Chapter 7.

The last section summarises the findings of this chapter and gives closing remarks with regards to the frequency of congestion and the scheduling impact of congestion within the CTCT.

6.3. Closing Remarks

The purpose of this chapter is to present the graphical and numerical descriptive analysis of the historical data sets collected. These different data sets are then analysed in terms of the current frequency and scheduling impact of port congestion within the CTCT, from 2011 to 2014.

The VAT data set suggests that the number of incidences for ocean carriers during anchorage outside the port has decreased over the past five years. This is possibly due to improved collaboration, coordination and communication between TNPA, TPT and shipping companies. Furthermore, the data exhibited peaks in anchorage time during October months, which is possibly due to the absence of stevedores and/or peaks in congestion in Durban or Namibia.

With regards to scheduling, the VAT data suggests that the additional time spent anchored outside the CTCT is, on average, 12 hours, 48 minutes more than the average anchorage time of 24 hours, 47 minutes. The amount of additional time spent at anchorage did, however, fluctuate over the five-year period, which is likely due to terminal expansion plans implemented between 2011 and 2013.

The analysis of the VBT data implies that a slight upward trend exists in the berthing time of vessels within the CTCT. Furthermore, and similar to the VAT data set, the VBT data exhibited peaks during October months, which is likely due to the absence of stevedores and/or peaks in congestion in Durban or Namibia. The frequency of berthing related incidences did, however, not exceed 50%, which suggests that incidences of delays occur less than 50%.

With regards to scheduling, the data indicated that the additional time spent berthing within the CTCT is, on average, 5 hours, 33 minutes more than the average berthing time of 26 hours, 26 minutes. This average delay is significantly less than those experienced during anchorage outside the port (12 hours, 48 minutes). Overall, the amount of additional time spent during vessel berthing fluctuated over the five-year period, which is likely due to the expansion plans implemented within the terminal between 2011 and 2013.

The VWT data illustrated that a slight upward trend exists in the offloading/loading time of vessels within the CTCT. This upward trend is likely due to a lack of coordination and communication between equipment operators and shipping companies. Furthermore, and similar to the VAT and VBT data sets, the VWT data displayed peaks during October months, possibly due to the absence of stevedores and/or peaks in congestion in Durban and Namibia. The frequency of vessel work-related incidences peaked at 50% in 2013, but for the remaining years fluctuated between eight and 17%. The average frequency of vessel work-related incidences suggests that approximately offloading/loading incidences result approximately 18.82% of the time. Fluctuations in incidences are likely due to terminal expansion plans implemented between 2011 and 2013.

With regards to scheduling, the data indicated that additional time spent offloading/loading containers is decreasing over time with delays amounting to, on average, 6 hours, 3 minutes more than the average working time of 21 hours, 4 minutes. This average delay is significantly less than those experienced during anchorage outside the port (12 hours, 48 minutes), but slightly more than experienced during vessel berthing (5 hours, 33 minutes). Overall, the amount of additional time spent during vessel berthing fluctuated over the five-year period, likely due to terminal expansion plans implemented between 2011 and 2013.

The TTAT data set suggests a downward trend in the turnaround time of container trucks within the CTCT. This is possibly due to improved coordination and communication between TPT and trucking companies, as well as improvements to equipment, improved coordination of container stacks and decreased occurrences of vehicle breakdowns. It is, however, important to note that the TTAT data should be supplemented with additional data pertaining to vehicle queuing and the 2015 proposed truck ban. The frequency of incidences of delays experienced by container trucks similarly displayed a downward trend, with a large percentage of observations falling below the trend line. This implies that incidences experienced by container trucks is decreasing over time. The analysis of the TTAT suggests that, on average, the incident percentage experienced by container trucks is approximately 18.33%. The rapid decrease in vehicle congestion is likely due to the opening of a new five lane truck staging area in 2011, which alleviated a significant amount of congestion within the terminal.

The TTAT scheduling data analysed suggests that the amount of additional time spent in port by container trucks is, similar to frequency, decreasing over time. The analysis suggests that container trucks experience an average delay of approximately 3.56 minutes. The decreasing trend in time delays is likely similarly due to the opening of a new truck staging area featuring five lanes for loading/unloading.

Weather delays were analysed both annually and seasonally. When analysed annually, neither the frequency nor the scheduling impact of congestion showed any upward or downward trends. This is due to the relatively short-term analysis done, as weather patterns are not identifiable over a five-year period. Furthermore, it was determined that weather delays in October months were not the cause of the peaks displayed in vessel anchorage, berthing and working time data. Weather delays was subsequently analysed to determine in which season, summer or winter, ocean carriers and container trucks experienced the most congestion.

The average weather delays in winter (6.93 hours) fell below the annual average of 9.99 hours, suggesting that the frequency of port congestion in winter is, on average, only 8.33%. The impact of port congestion is shown to average only 0.36 additional hours. Weather delays in summer, however, averaged at 12.76 hours, which exceeds the annual average of 9.99 hours. This suggests that the frequency of delays is more prevalent in the summer months than the winter months, with delays occurring an average of 75% of the time in summer. The impact of delays is also shown to be significantly more in the summer months, with additional time spent in port by ocean carriers and container trucks averaging 3.67 additional hours.

The system delays data suggests that neither the frequency nor the scheduling impact of delays has increased or decreased over the past four years. This relatively stable trend is likely due to the implementation of a NAVIS system upgrade in 2012, which required operations staff to obtain additional training. Furthermore, and similar to weather delays, the system delays data indicated that the October peaks displayed in vessel anchorage, berthing and working time was not due to system delays. The frequency of incidences of system delays was recorded at 50% in 2011, which fluctuated before settling at 33.33% in 2014. This was possibly due to the implementation of new technology on all reefer stacks in 2012, which caused a significant decrease in the percentage of system-related incidences. Similarly, additional time experienced by ocean carriers and container trucks due to system delays was recorded at 0.64 hours in 2011. However, the year 2012 did not display a similar decrease in congestion percentage, suggesting that system delays remain a concern.

The findings of this chapter indicate that ocean carriers are currently experiencing decreasing incidences of delays during anchorage, but increasing incidences of delays during berthing and offloading/loading of containers. Container trucks, however, are currently experiencing decreasing incidences of delays inside the terminal. This suggests that maritime-side congestion is of greater concern currently, than landside congestion. With regards to weather delays and system delays, the results suggest that ocean carriers and container trucks currently experience neither increasing nor decreasing incidences. The weather delays results did, however, indicate that ocean carriers and container trucks experience more occurrences of delays, and more additional time in port, in summer months than in winter months.

The overall findings of this chapter illustrate the frequency and scheduling impact of current congestion over the past four to five years. To accurately determine whether future congestion will increase or decrease, an analysis of five year forecasts is done. The forecasts and analysis findings are discussed in following chapter.

Chapter 7: Forecasting Results and Discussion

Following on from the descriptive analysis of current port congestion in Chapter 6, this chapter introduces a five year forecast of the individual data sets analysed previously and details the descriptive analysis of the forecasted results. Furthermore, the chapter discusses the analysis of the forecasts with regards to the future frequency and the scheduling impact of port congestion in the CTCT from 2015 to 2019/ 2016 to 2020.

7.1. Forecasts and Analysis

The forecasts presented in this section of the thesis were predicted with the help of statistical expert Prof Daan Nel. The outcome of the forecasting process identified the best forecast model for the data sets collected. The forecast model selected was Holt-Winters forecasting using twelve-month periodicity. The formula for this model is shown and discussed in section 2.2.4 of Chapter 2 where the notation of the formula is explained in a table. The basic forecast formula is, however, shown below:

$$\hat{Y}_{1+n} = (E_t + nT_t)S_{t+n-L}$$

This model included the use of the three best fitting parameters, which were automatically selected by the statistical program *ForecastX,* and can therefore not be featured in this study. These three parameters included, the overall smoothing parameter, the trend smoothing parameter and the seasonal index smoothing parameter (Wilson, *et al.*, 2009:120). The formulae for the calculation of these parameters are shown below:

Overall smoothing parameter is: $E_t = \alpha\left(\frac{Y_t}{S_{t-L}}\right) + (1 - \alpha)(E_{t-1} + T_{t-L})$

Trend smoothing parameter is: $T_t = \beta(E_t - E_{t-1}) + (1 - \beta)T_{t-1}$

Seasonal index smoothing parameter is: $S_t = \gamma\left(\frac{Y_t}{E_t}\right) + (1 - \gamma)S_{t-L}$

Smoothing constants being: $0 \leq \alpha, \beta, \gamma \leq 1$

The following subsections present the forecasts of the individual data sets collected (VAT, VBT, VWT, TTAT, weather delays and system delays) and the descriptive analysis conducted on the forecast data. It is important to note that the forecasts predicted are under the assumption that conditions[23] within the CTCT will remain constant in the future.

7.1.1. Forecasted Ship Turnaround Time

This section of the chapter analyses the forecast results of three ship turnaround time related data sets, namely, vessel anchorage time (VAT), vessel berthing time (VBT) and vessel working time (VWT). It is important to note that the data sets analysed do not account for weather and system delays, which impact inbound and outbound ocean carriers.

❖ *Forecasted Vessel Anchorage Time*

VAT is forecasted for the period January 2016 to December 2020. The forecast in Figure 7-1 illustrates that the slight downward trend seen in the analysis of current VAT (2011 to 2015) in Chapter 6 is likely to become an upward trend. This is due to the nature of the forecast programme used. The *ForecastX* programme identifies all previous trends within the historical data set and represents the most dominant trend in the forecast predicted (Nel, 2015). The forecast therefore indicates that in the future ocean carriers may experience longer anchorage times outside the container terminal. This, however, may not be true.

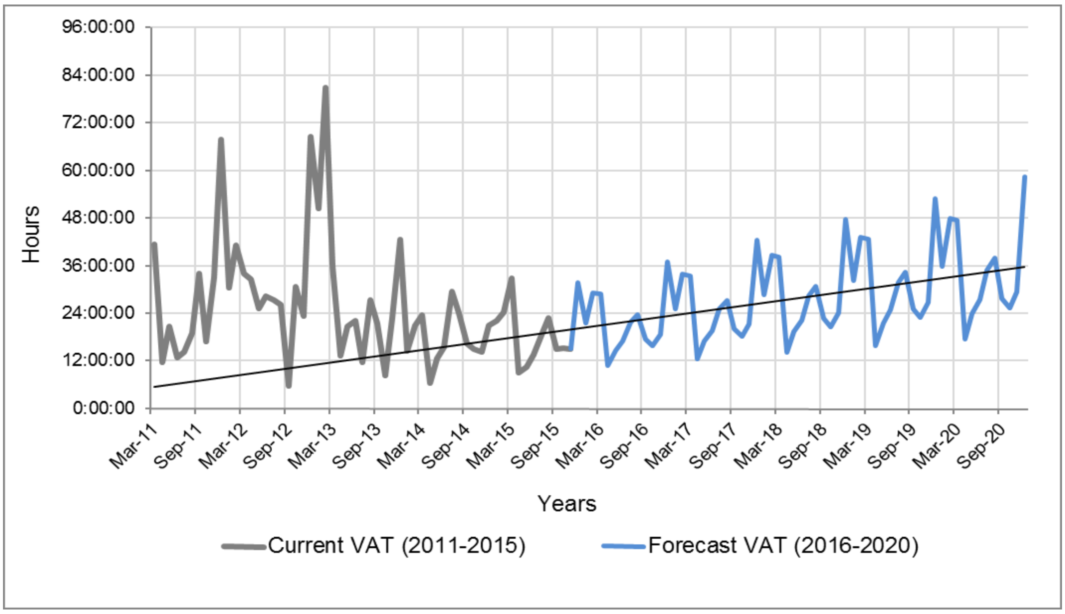

Figure 7-1: Forecast of VAT outside the CTCT (2016-2020)

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[23] Conditions such as weather conditions, system performance, level of coordination, collaboration and communication between TPT, TNPA, shipping companies and trucking companies.

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The upward trend shown in the forecast may also be an indication of increasing delays within the terminal itself. This can, however, only be determined through further analysis of vessel berthing time (VBT) and vessel working time (VWT) in the following subsections.

In addition to the upward trend, the line charts exhibit slight peaks during December months. These peaks may be a result of the forecast program (*ForecastX*) mirroring a large peak in the historical data, or it may be due to a peak in delays due to weather conditions as December falls into the summer season (Nel, 2015; Davids, 2015). This, however, would require analysis of forecast weather delays, which is discussed in section 7.1.3. To further examine the forecasted VAT, Table 7-1 presents the descriptive statistics of the forecast of VAT.

Table 7-1: Descriptive statistics of forecasted VAT outside the CTCT (2016-2020)

Mean	27 hours, 53 minutes	**Range**	47 hours, 33 minutes
Median	25 hours, 10 minutes	**Minimum**	10 hours, 43 minutes
Standard Deviation	10 hours, 28 minutes	**Maximum**	58 hours, 17 minutes
Coefficient of variation	37.57%	**Number of Observations**	60

According to Table 7-1, the average forecasted anchorage time of ocean carriers outside the CTCT is approximately 27 hours, 53 minutes, which is significantly higher than the current anchorage time of 24 hours, 47 minutes. The forecasted VAT has a standard deviation of 10 hours, 28 minutes, which is significantly lower than the standard deviation of current turnaround time (14 hours, 53 minutes). This suggests that the forecasted observations are less wide spread around the mean than the historical data.

According to Chebysheff's Theorem (mentioned in Chapter 2 and Chapter 6), the standard deviation of the forecasted VAT indicates that at least 99.05% of ocean carriers anchored outside the CTCT are delayed by between approximately 17 hours, 24 minutes to 38 hours, 21 minutes. This is a significantly shorter period than currently experienced by ocean carriers in the CTCT, possibly implying that anchorage time is less variable in the future.

A frequency table and histogram are developed to illustrate the shape of the forecast data set and the spread of the recorded observations. The frequency table for the forecasted VAT data is presented in Table 7-2.

Table 7-2: Frequency table for forecasted VAT outside the CTCT (2016-2020)

Forecasted vessel anchorage time (VAT) in hours	
Hour Intervals	**Frequency**
Zero to 10 hours	0
10:01 to 16 hours	6
16:01 to 22 hours	14
22:01 to 28 hours	15
28:01 to 34 hours	10
34:01 to 40 hours	7
40:01 to 46 hours	3
46:01 to 52 hours	3
52:01 to 58 hours	1
58:01 or more hours	1
Total	**60**

The frequency histogram corresponding to the frequency table (Table 7-2) is illustrated in Figure 7-2. The mean of the forecast falls within the 28:01 to 34-hours interval. The histogram for the forecasted VAT data suggests that future vessel anchorage time is positively skewed, with the majority of observations falling to the left of the graph. Overall, the histogram shows that the majority of forecasted VAT observations are within, or exceed the interval wherein the mean falls.

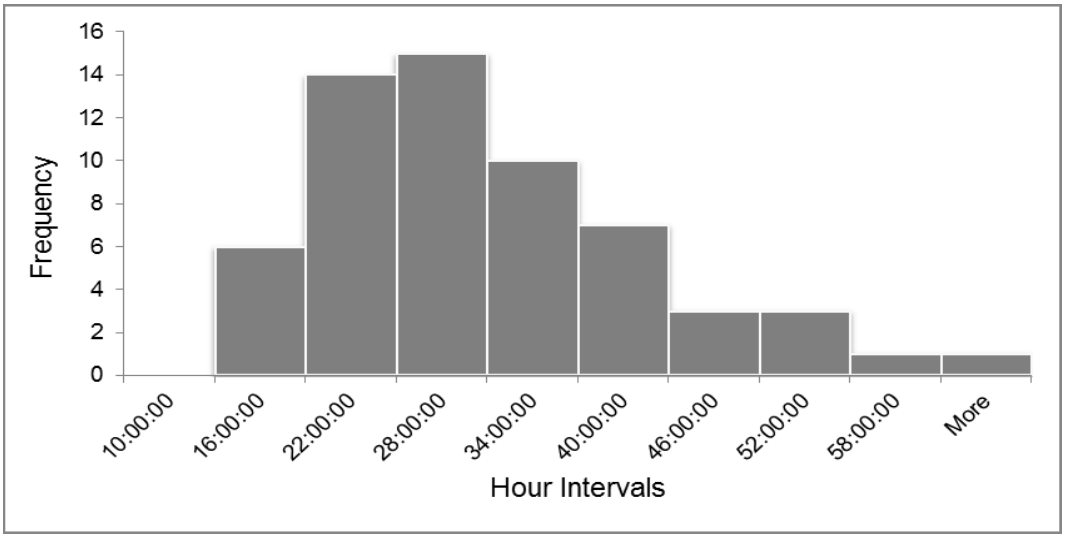

Figure 7-2: Histogram of Forecasted VAT outside the CTCT (2016-2020)

The significance of the forecasted VAT results is discussed in sections 7.2.1 and 7.2.2 in terms of the future frequency and scheduling impact of port congestion. The second vessel related forecast analysed is vessel berthing time (VBT) within the CTCT.

- ***Forecasted Vessel Berthing Time***

VBT is forecasted for the period January 2016 to December 2020. In contrast to the line chart of current vessel berthing time, seen in section 6.1.1 of Chapter 6, forecasted vessel berthing time illustrates no significant trend (seen in Figure 7-3). This suggests that vessel berthing time within the CTCT will likely remain constant in the future due to fluctuations in container volumes through the terminal (Chapter 4: Port Development Plan, 2014:126).

In addition, the forecast line chart seen in Figure 7-3 illustrates numerous peaks during December months. This suggests that vessel berthing time may be lengthened during this time. According to Davids (2015), this is likely due to severe weather conditions generally experienced in summer months.

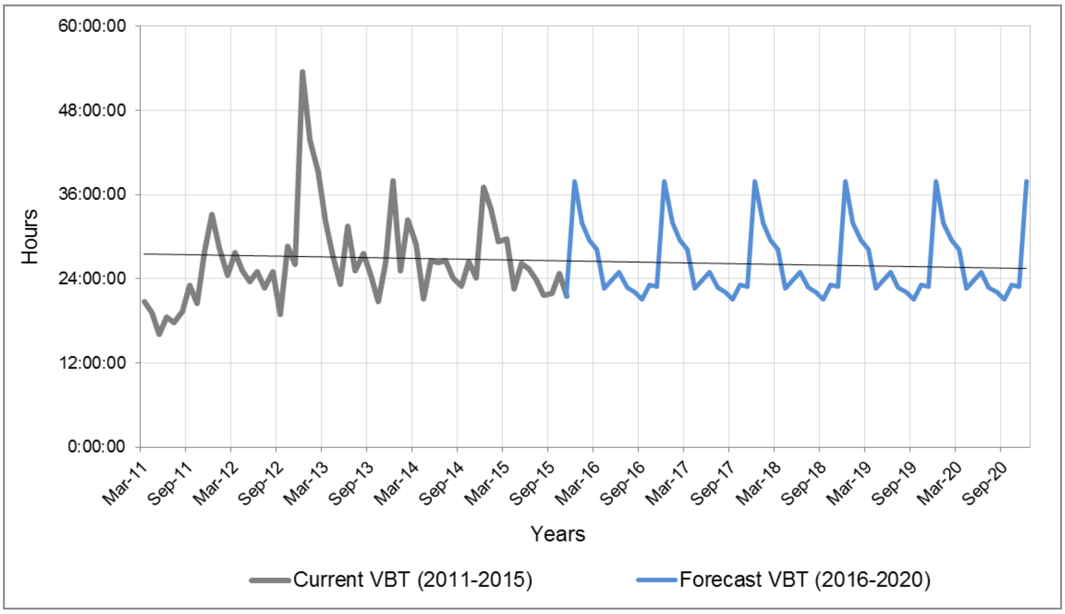

Figure 7-3: Forecast of VBT within the CTCT (2016-2020)

In consideration along with the VAT forecast previously analysed, the VBT forecast indicates that less efficient berthing is likely not the cause of the upward trend of anchorage time. To further analyse VBT, descriptive statistics of the forecast are presented in Table 7-3.

Table 7-3: Descriptive statistics of forecasted VBT within the CTCT (2016-2020)

Mean	25 hours, 54 minutes	**Range**	16 hours, 48 minutes
Median	23 hours, 28 minutes	**Minimum**	21 hours, 7 minutes
Standard Deviation	4 hours, 52 minutes	**Maximum**	37 hours, 56 minutes
Coefficient of variation	18.81%	**Number of Observations**	60

According to Table 7-3, the average forecasted berthing time of ocean carriers inside the CTCT is 25 hours, 54 minutes, which is slightly less than the current berthing time of 26 hours, 26 minutes. This suggests that a slight downward trend does exist in the forecast for the next five years. The forecasted VBT has a standard deviation of 4 hours, 52 minutes, which is significantly lower than the standard deviation of current turnaround time (6 hours, 32 minutes). This indicates that the forecasted observations are less wide spread around the mean.

Chebysheff's Theorem (mentioned in Chapter 2 and Chapter 6) supports this as the standard deviation of the forecasted VBT indicates that at least 95.11% of ocean carriers berth between approximately 21 hours, 2 minutes to 30 hours, 47 minutes. This is a significantly shorter period than currently experienced possibly implying that berthing time is less variable in the future.

A frequency table and histogram are developed to illustrate the shape of the forecast data set as well as the spread of the recorded observations. The frequency table for the forecasted VBT data is presented in Table 7-4.

Table 7-4: Frequency table for forecasted VBT within the CTCT (2016-2020)

Forecasted vessel berthing time (VBT) in hours	
Hour Intervals	**Frequency**
Zero to 21 hours	0
21:01 to 23:30 hours	30
23:31 to 26 hours	10
26:01 to 28:30 hours	5
28:31 to 31 hours	5
31:01 to 33:30 hours	5
33:31 to 36 hours	0
36:01 to 38:30 hours	5
Total	**60**

The frequency histogram corresponding to the frequency table is illustrated in Figure 7-4. The histogram for the forecasted VBT data suggests that future vessel berthing time is positively skewed, with the majority of forecasted observations falling below the interval wherein the mean falls (23.31 to 26-hours interval).

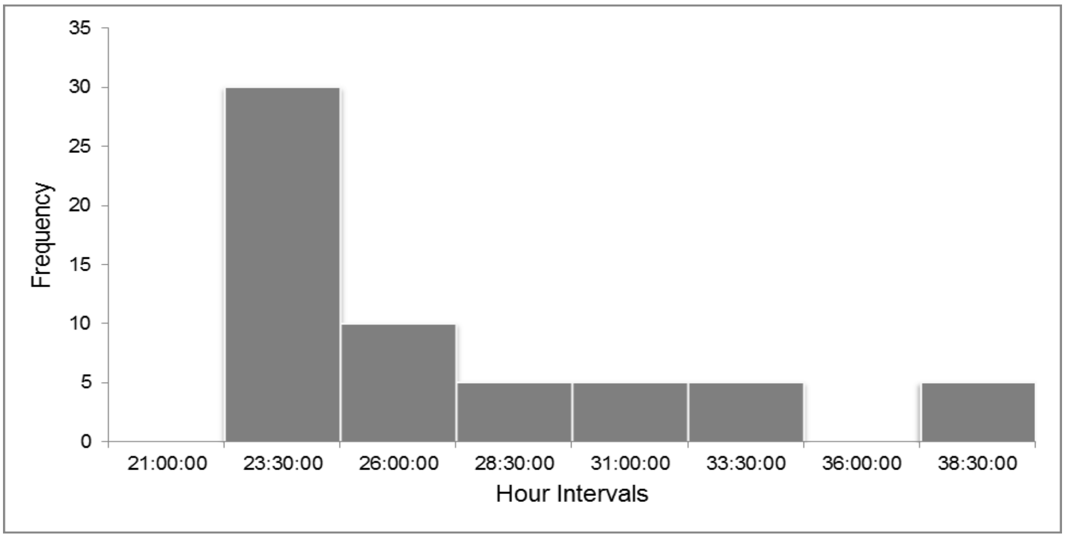

Figure 7-4: Histogram of Forecasted VBT within the CTCT (2016-2020)

The significance of the forecasted VBT results is discussed in sections 7.2.1 and 7.2.2 in terms of the future frequency and scheduling impact of port congestion. The third vessel related forecast analysed is VBT within the CTCT.

- ***Forecasted Vessel Working Time***

VWT is forecasted for the period January 2016 to December 2020. Despite the line chart of current vessel working time (seen in section 6.1.1 of Chapter 6) illustrating a slight downward trend, forecasted vessel working time illustrates no significant trend (seen in Figure 7-5).

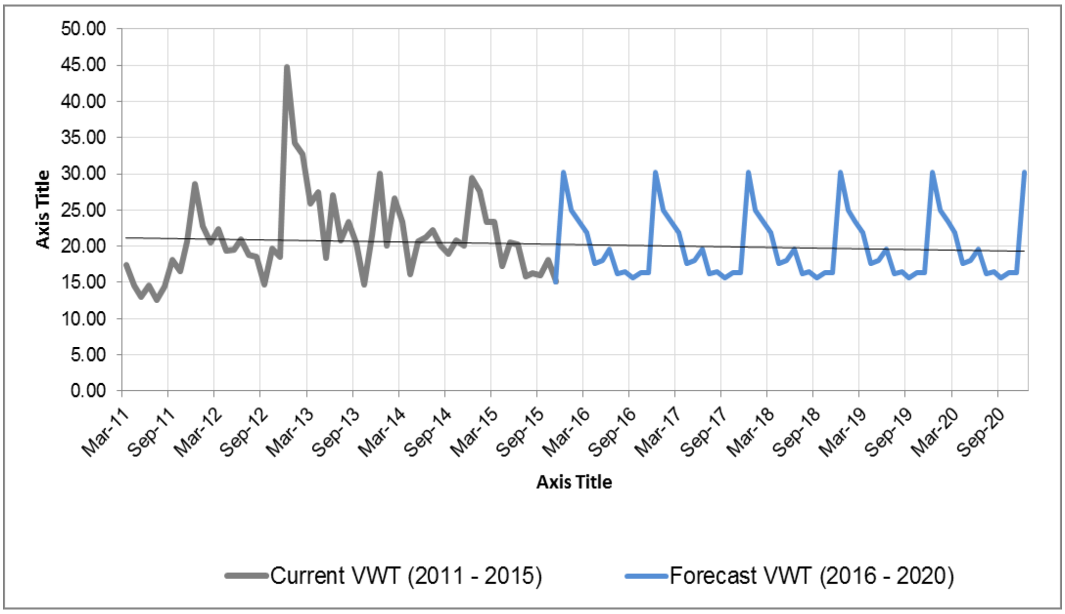

Figure 7-5: Forecast of VWT within the CTCT (2016-2020)

In addition to the constant trend, Figure 7-5 indicates that during December months vessels will likely experience lengthened working times within the CTCT. This, according to Davids (2015), is likely due to severe weather conditions experienced during summer months.

Table 7-5 presents the descriptive statistics of the forecast of VWT. According to Table 7-5, the average forecasted vessel working time inside the CTCT is approximately 19 hours, 42 minutes, which is significantly less than the current vessel working time of 21 hours, 4 minutes. This implies that despite the apparent constant trend seen in Figure 7-5, the forecasted vessel working time may decrease over the next five years by as much as 3 hours.

Table 7-5: Descriptive statistics of forecasted VWT within the CTCT (2016-2020)

Mean	19 hours, 42 minutes	**Range**	14 hours, 38 minutes
Median	17 hours, 51 minutes	**Minimum**	15 hours, 34 minutes
Standard Deviation	4 hours, 22 minutes	**Maximum**	30 hours, 12 minutes
Coefficient of variation	22.19%	**Number of Observations**	60

The forecasted VWT has a standard deviation of 4 hours, 22 minutes, which is lower than the standard deviation of current working time of 5 hours, 46 minutes. This suggests that the forecasted observations are less wide spread around the mean than the historical observations recorded.

According to Chebysheff's Theorem (mentioned in Chapter 2 and Chapter 6), the standard deviation of the forecasted VWT indicates that at least 94.39% of ocean carriers offload/load containers in approximately 15 hours, 20 minutes to 24 hours, 5 minutes. This is a significantly shorter period than currently experienced by ocean carriers in the CTCT, possibly implying that working time will be more variable in the future.

A frequency table and histogram are developed to illustrate the shape of the forecast data set and the spread of the recorded observations. The frequency table for the forecasted VWT data is presented in Table 7-6.

Table 7-6: Frequency table for forecasted VWT within the CTCT (2016-2020)

Forecasted vessel working time (VWT) in hours	
Hour Intervals	**Frequency**
Zero to 15 hours	0
15:01 to 17 hours	25
17:01 to 19 hours	10
19:01 to 21 hours	5
21:01 to 23 hours	5
23:01 to 25 hours	10
25:01 to 27 hours	0
27:01 to 29 hours	0
29:01 to 31 hours	5
Total	**60**

The frequency histogram corresponding to the frequency table (Table 7-6) is illustrated in Figure 7-6. The histogram for the forecasted VWT data suggests that future vessel working time is positively skewed. The mean of the forecast falls within the 19:01 to 21-hours interval. Overall, the histogram shows that the majority of forecasted VWT observations fall below this interval.

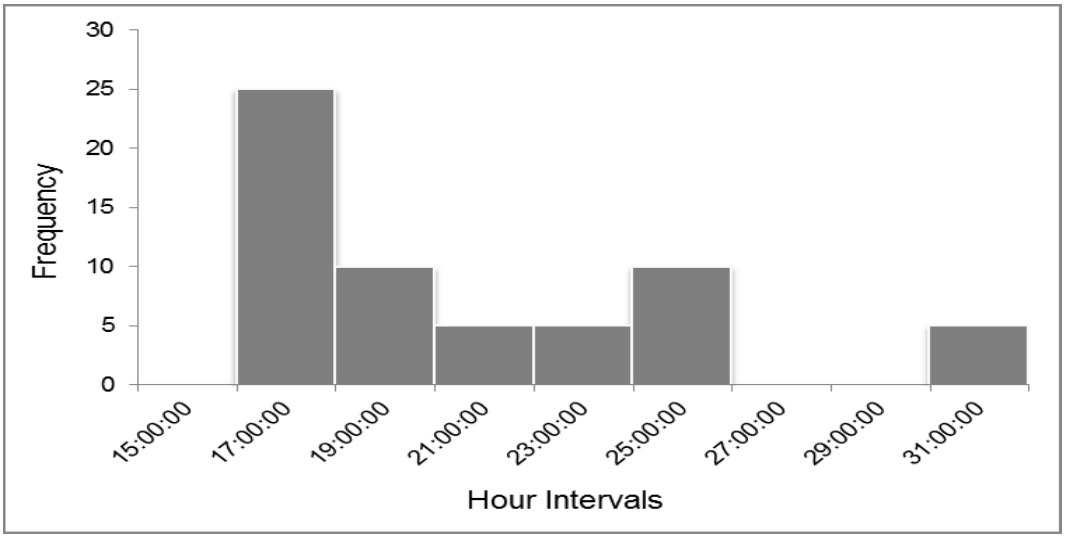

Figure 7-6: Histogram of Forecasted VWT within the CTCT (2016-2020)

In addition, the histogram illustrates that a significant outlier exists in the data and appears in the 29:01 to 31-hours interval. This suggests that the current median of the data set (17 hours, 51 minutes) may be a more accurate indication of the average working time of vessels within the CTCT. This is supported by the downward trend illustrated in Figure 7-5 and the large frequency of observations appearing in the 15:01 to 17-hours interval on the histogram in Figure 7-6.

The significance of the forecasted VWT results is discussed in sections 7.2.1 and 7.2.2 in terms of the future frequency and scheduling impact of port congestion. The forecast analysed of truck turnaround time (TTAT) within the CTCT in discussed in the following section.

7.1.2. Forecasted Truck Turnaround Time

The forecasted TTAT within the CTCT is analysed similar to the analysis of the ship turnaround time data sets (VAT, VBT and VWT). Figure 7-7 illustrates the five year forecast of truck turnaround time within the CTCT for the period, January 2016 to December 2020.

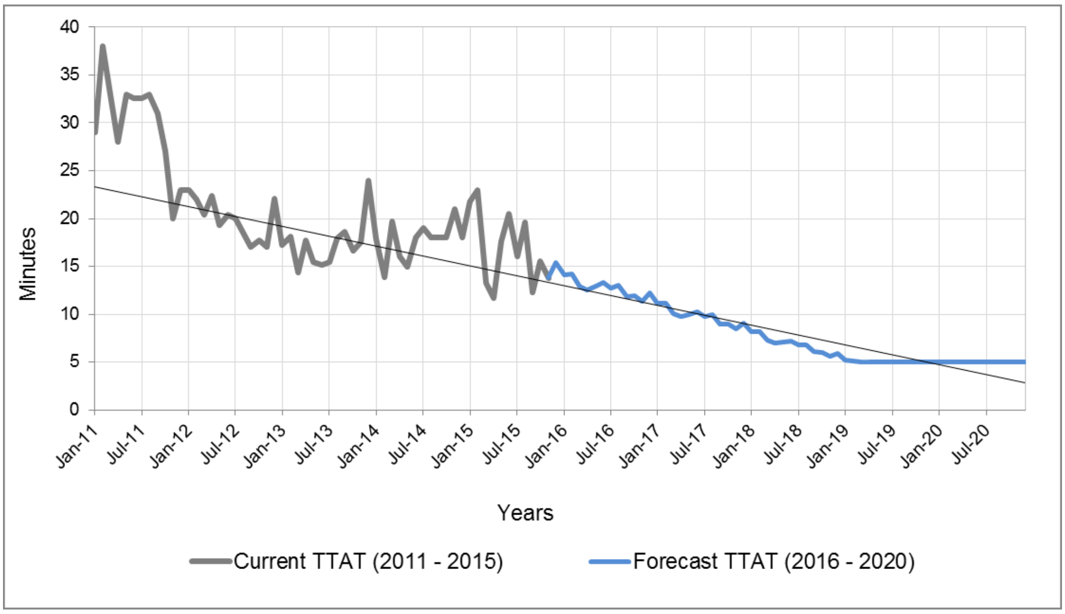

Figure 7-7: Forecasted TTAT within the CTCT (2016-2020)

The forecast in Figure 7-7 illustrates that the downward trend seen in the analysis of current TTAT (2011 to 2015) in Chapter 6 is indeed continuous. This suggests that in the future container trucks may experience shorter turnaround times in the container terminal.

However, theory and practice decree that turnaround time cannot physically decrease past a certain point. This minimum turnaround time [24] is, according to the CTCT Terminal Manager Pamela Yoyo, approximately 5 minutes from gate-in to gate-out. It is important to note that the likelihood of this minimum time being achieved is relatively minimal due to numerous factors inside and outside the terminal which contribute to varying truck turnaround times. This minimum time, according to Sanders (2014:51) and Julius (2015), is due to trucks simply dropping off/picking up containers from the staging area and leaving terminal staff to move the containers into/out of the container stacks.

The downward trend illustrated in the forecast data suggests, according to Davids (2015) and Lane (2015), that collaboration, coordination and communication between TPT, TNPA and trucking companies is improving. In addition, Lane (2015) observes that the decrease may also be attributed to improvements in terminal equipment in handling higher wind speeds, improvements in the coordination of containers into and out of container stacks, and a decrease in the occurrences of vehicle breakdowns within the terminal.

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[24] Which is subject to zero delays and thus ideal terminal conditions.

It is, however, important to note that the downward trend may not be an accurate prediction of future truck turnaround time within the terminal as it should be supplemented with data pertaining to vehicle queuing outside the port, and the potential impact of the 2015 proposed truck ban.

The numerical descriptive statistics of the forecasted TTAT are shown in Table 7-7. Forecasted truck turnaround time, according to Table 7-7, has a mean of 7.88 minutes, which is significantly lower than the current turnaround time of 20.43 minutes. This suggests that the turnaround time of container trucks may be decreasing over time.

Table 7-7: Descriptive statistics of forecasted TTAT within the CTCT

Mean	7.88 minutes	**Range**	9.21 minutes
Median	6.89 minutes	**Minimum**	5 minutes
Standard Deviation	3.09 minutes	**Maximum**	14.21 minutes
Coefficient of variation	39.21%	**Number of Observations**	60

The standard deviation of forecasted TTAT is 3.09 minutes, which is lower than the current turnaround time standard deviation of 5.92 minutes. This suggests that, according to Chebysheff's Theorem, 89.53% of future container trucks will turnaround in the CTCT in approximately 4.79 to 10.97 minutes. The lower limit should, however, be no less than 5 minutes as previously discussed.

This forecasted turnaround time is significantly shorter than the current turnaround time of between 14.51 and 26.36 minutes, which, as mentioned earlier, suggests that truck turnaround time may be decreasing. Table 7-8 illustrates the frequency table for the forecasted data.

Table 7-8: Frequency table for forecasted TTAT within the CTCT (2016-2020)

Forecasted truck turnaround time (TTAT) in minutes	
Minute Intervals	**Frequency**
5 minutes	22
5.1 to 6 minutes	5
6.1 to 7 minutes	4
7.1 to 8 minutes	3
8.1 to 9 minutes	5
9.1 to 10 minutes	5
10.1 to 11 minutes	2
11.1 to 12 minutes	5
12.1 to 13 minutes	5
13.1 to 14 minutes	2
14.1 to 15 minutes	2
Total	**60**

Figure 7-8 depicts a histogram, which illustrates the spread of the forecasted TTAT observations and suggests that TTAT observations are positively skewed, with the majority of observations falling in the five-minute interval. This is, however, not an indication of what the average turnaround time of trucks will be in the future as the data does not consider changes in conditions within the terminal, vehicle queuing outside the port, and the impact of the 2015 proposed truck ban.

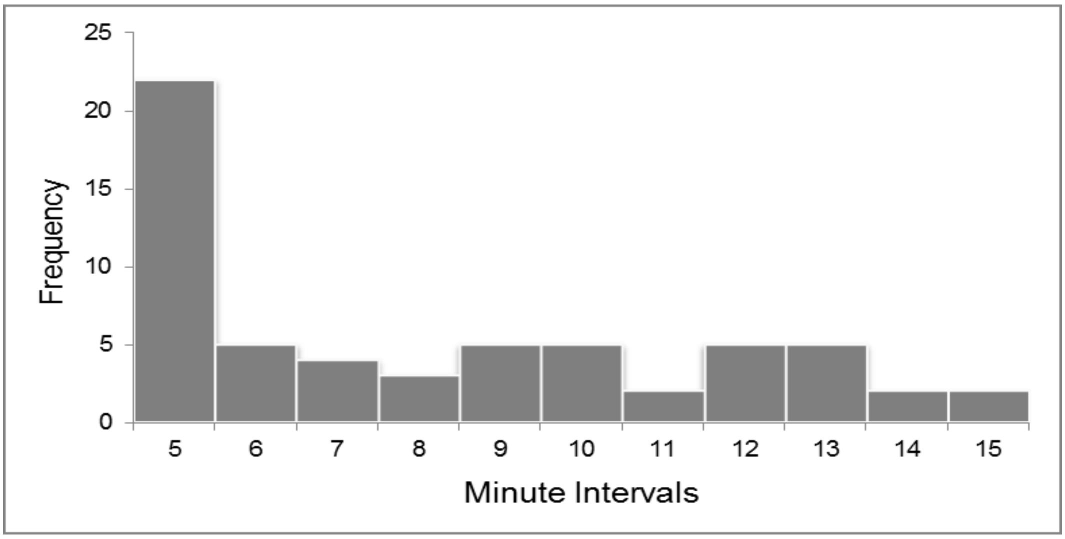

Figure 7-8: Histogram of forecasted TTAT within the CTCT (2016-2020)

The significance of the forecasted TTAT results is discussed in sections 7.2.1 and 7.2.2 in terms of the future frequency and scheduling impact of port congestion. The following section analyses the forecasted weather delays within the CTCT.

7.1.3. Forecasted Weather Delays

The forecasted weather delays data is analysed in a similar way to the forecasted VAT, VBT, VWT and TTAT data. Figure 7-9 illustrates the five year forecast of weather delays within the CTCT for the period, January 2015 to December 2019.

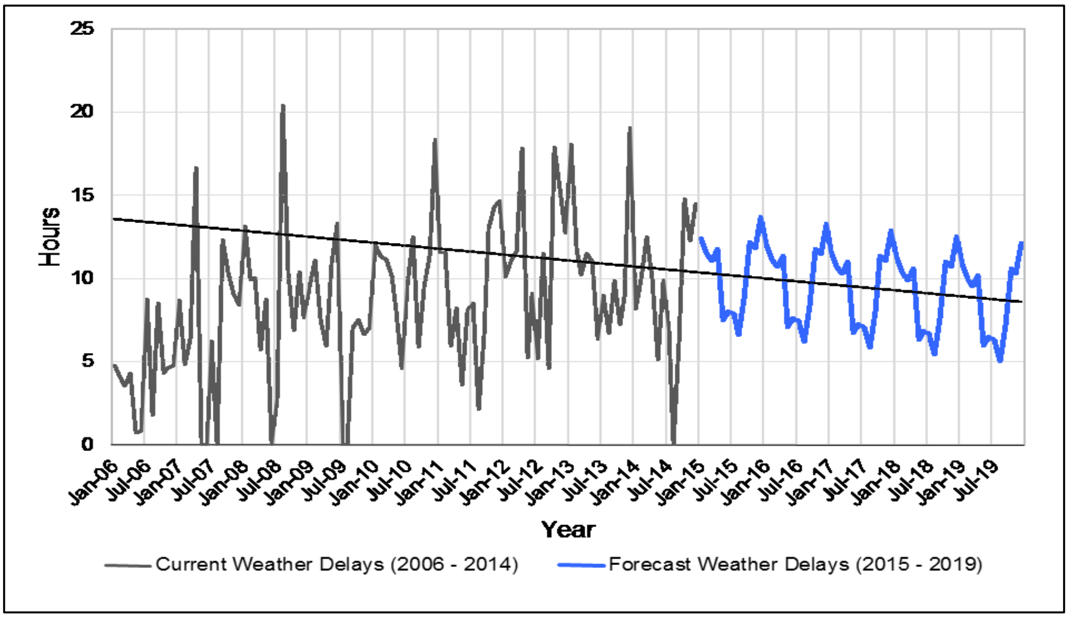

Figure 7-9: Forecasted average weather delays within the CTCT (2015-2019)

The forecast in Figure 7-9 shows a slight downward trend in the analysis of future weather delays (2015 to 2019) experienced by ocean carriers and container trucks in the CTCT. This is relatively normal for short-term weather-related forecasts. The forecast did, however, suggest that forecast weather delays will peak during December months. This is likely due to worsening wind speeds of the South-South Easterly ("Cape Doctor"), which is the predominant cause of weather delays during summer months (Davids, 2015). The peaks in weather delays during December months are also likely the cause of the December peaks found in the VAT, VBT and VWT forecasts shown in section 7.1.1.

Forecasted weather delays in the CTCT are analysed further to consider potential conditions experienced in the winter months versus the summer months. Figure 7-10 illustrates the forecasted weather delays recorded during the winter and summer seasons of 2015 to 2019.

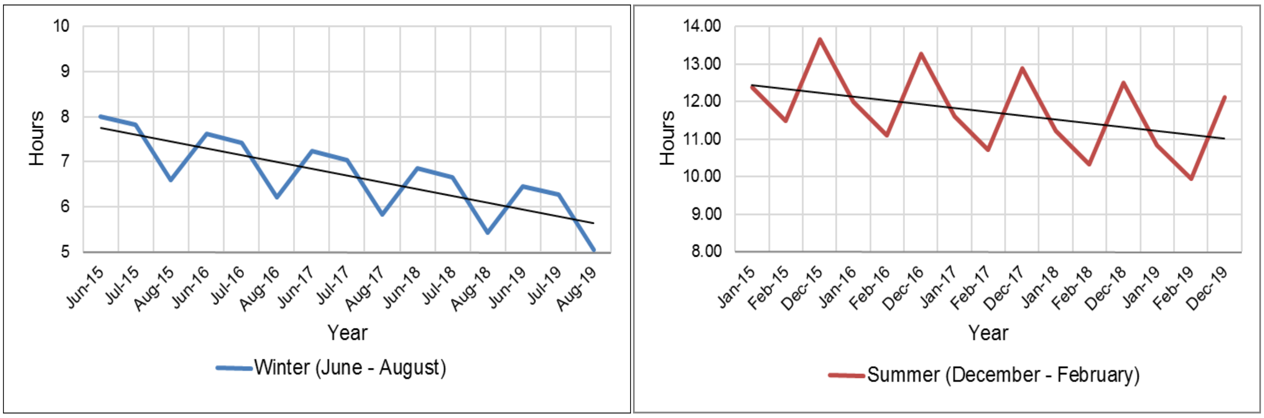

Figure 7-10: Forecasted weather delays in summer and winter months (2015-2019)

Figure 7-10 suggests that weather delays potentially experienced during the summer months of 2015 to 2019 are expected to be significantly more than those potentially experienced during the winter months.

The descriptive statistics of forecasted weather delays are shown in Table 7-9. According to the table, forecasted weather delays in the CTCT had a mean of 9.48 hours, which is slightly lower than the current average weather delays of 9.99 hours.

Table 7-9: Descriptive statistics of forecasted weather delays (2015-2019)

Mean	9.48 hours	**Range**	8.61 hours
Median	10.29 hours	**Minimum**	5.05 hours
Standard Deviation	2.34 hours	**Maximum**	13.67 hours
Coefficient of variation	24.68%	**Number of Observations**	60

The standard deviation of the forecasted weather delays amounted to 2.34 hours, which implies, according to Chebysheff's Theorem, that 81.74% of forecasted weather delays range between 7.14 and 11.82 hours. This forecasted variation is significantly smaller than the current standard deviation of 4.2 hours, suggesting that the forecasted observations are less wide spread around the mean than the historical observations. The frequency table for forecasted weather delays is presented in Table 7-10.

Table 7-10: Frequency table for forecasted weather delays within the CTCT (2015-2019)

Forecasted weather delays in hours	
Hour Intervals	**Frequency**
Zero to 5.0 hours	0
5.1 to 6.0 hours	4
6.1 to 7.0 hours	8
7.1 to 8.0 hours	9
8.1 to 9.0 hours	4
9.1 to 10.0 hours	3
10.1 to 11.0 hours	12
11.1 to 12.0 hours	13
12.1 to 13.0 hours	5
13.1 to 14.0 hours	2
Total	**60**

The supporting histogram is shown in Figure 7-11 and depicts the spread of forecasted weather delays in the CTCT, from 2015 to 2019. The mean of the forecast falls within the 9.1 to 10-hours interval and Figure 7-11 suggests that the majority of forecast observations of weather delays exceed this interval. This is supported by the significant variation between the mean of 9.48 hours and the median of 10.29 hours. The variance of forecast weather delays is likely due to the unpredictable nature of weather conditions.

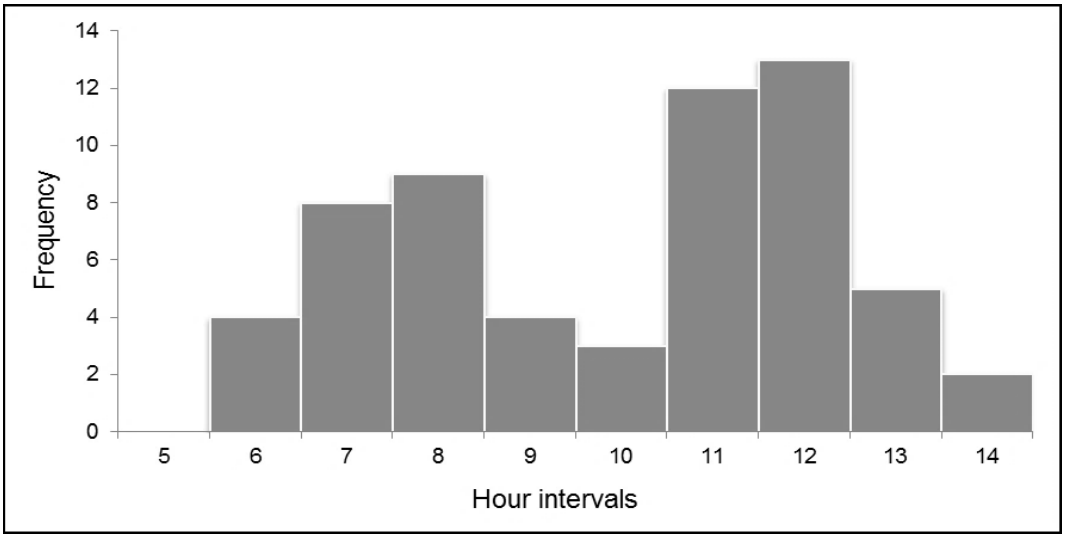

Figure 7-11: Histogram of forecasted weather delays within the CTCT (2015-2019)

The significance of these results is discussed in sections 7.2.1 and 7.2.2 in terms of the future frequency and scheduling impact of port congestion.

The following subsection analyses the forecasted system-related delays within the CTCT between 2015 and 2019.

7.1.4. Forecasted System Delays

The last forecast analysed is system delays within the CTCT. Figure 7-8 illustrates the five year forecast of system delays for the period, January 2015 to December 2019.

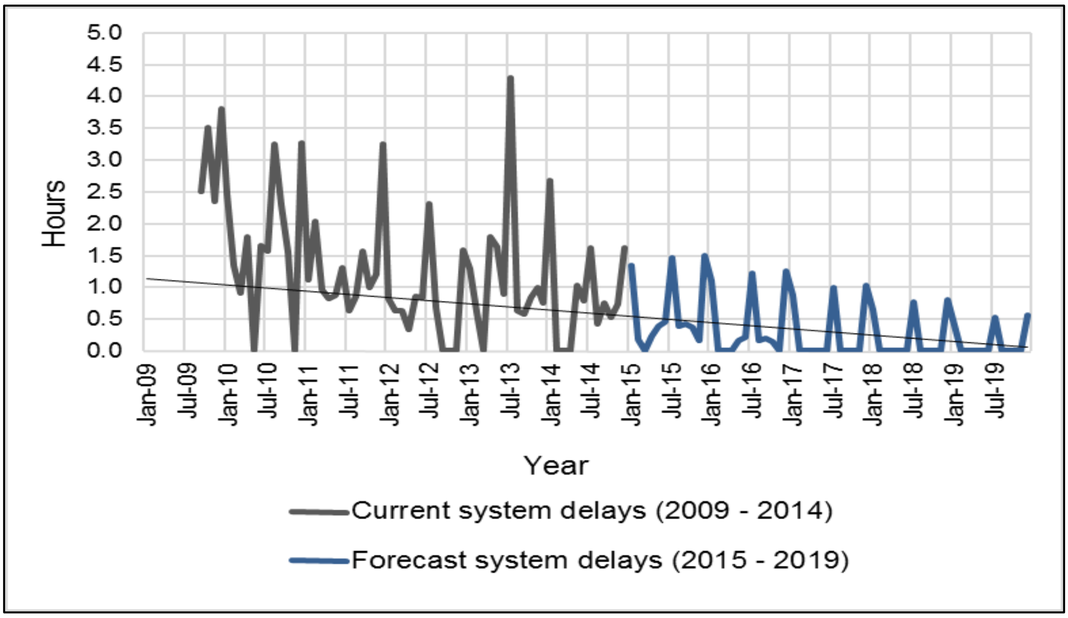

Figure 7-12: Forecasted system delays in the CTCT (2015-2019)

The forecast in Figure 7-12 illustrates that, similar to TTAT, a downward trend can be seen in the future system delays experienced by ocean carriers and container trucks in the CTCT. This downward trend suggests that system delays will reduce rapidly in the future, likely due to improvements in collaboration between TPT and TNPA, and improvements in communication of important system documents and information between shipping companies/trucking companies and TPT.

In addition, the forecast results indicate that from 2016 onwards, the dips of the graph decrease to zero more frequently and for longer periods. This suggests that system delays within the terminal may become more a seasonal challenge linked to weather conditions, as adequate maintenance is done and/or usage of the system is improved.

The downward trend and decreases to zero seen in future system delays are, however, predictions based on the assumption that the current TOS system in place will continue to be effective and will continuously reduce system-related challenges. This assumption does not consider the need for maintenance and upgrades to the system, and the high probability of the system being replaced in the future with a modern version (Davids, 2015; Julius, 2015).

Following on from the forecast, the descriptive statistics of forecasted system delays are shown in Table 7-11. Forecasted system delays, according to the table, has a mean of 0.3 hours, which is significantly less than the current system delays average of 1.02 hours.

Table 7-11: Descriptive statistics of forecasted system delays (2015-2019)

Mean	0.3 hours	**Range**	1.5 hours
Median	0 hours	**Minimum**	0 hours
Standard Deviation	0.44 hours	**Maximum**	1.5 hours
Coefficient of variation	146.67%	**Number of Observations**	60

The standard deviation for forecasted system delays in the CTCT amounted to 0.44 hours, therefore the Chebysheff's Theorem could not be applied. The standard deviation is slightly lower than the current system delays standard deviation of 0.85 hours. This suggests that the forecasted observations are less distributed around the mean. The frequency table for system delays is presented in Table 7-12.

Table 7-12: Frequency tables for forecasted system delays within the CTCT (2015-2019)

Forecasted system delays in hours	
Hour Intervals	**Frequency**
Zero hours	32
0.1 to 0.2 hours	6
0.2 to 0.4 hours	5
0.5 to 0.6 hours	5
0.7 to 0.8 hours	2
0.9 to 1.0 hours	3
1.1 to 1.2 hours	2
1.3 to 1.4 hours	3
1.6 hours or more	2
Total	**60**

The forecasted system delays in the CTCT are illustrated in a histogram (Figure 7-13), which suggests that the forecast is positively skewed. Furthermore, the mean of the forecast falls within the 0.2 to 04-hours interval. The histogram suggests that the majority of forecasted system delays fall below this interval.

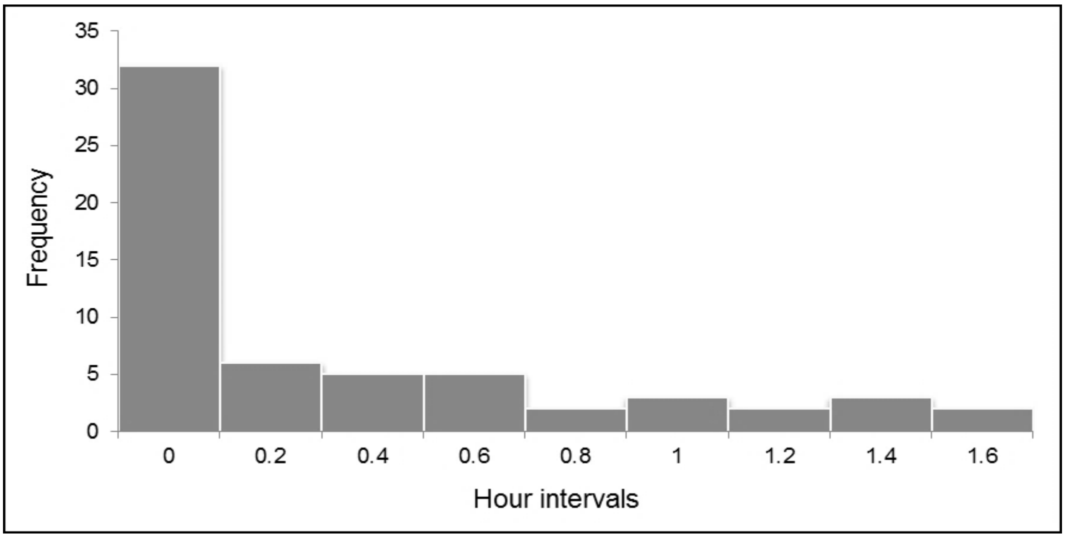

Figure 7-13: Histogram of forecasted system delays within the CTCT (2015-2019)

The significance of these results is discussed in sections 7.2.1 and 7.2.2 in terms of the future frequency and scheduling impact of port congestion. The following section includes the discussion of the forecast results presented in Section 7.1.

7.2. Discussion of Forecast Results

The subsections in the following section discuss the significance of the forecasts in terms of the two port congestion elements, namely the frequency of congestion and the scheduling impact of congestion. Furthermore, these sections discuss the forecasts in terms of future weather- and system-related port congestion potentially experienced by ocean carriers and container trucks. The methodology of these sections is similar to those of current congestion in section 6.2 of Chapter 6, and is discussed previously in section 2.2.3 of Chapter 2.

7.2.1. Forecasted Frequency of Port Congestion

The frequency of port congestion, as mentioned previously in section 2.2.3 of Chapter 2 and in Chapter 6, can be measured in a number of ways. For the purpose of this study, and specific to this case study, the frequency of port congestion was taken to refer to the number of observations (in percentage form) exceeding the trend line of the data set. These percentages of occurrences per year were thus only an indication of the frequency of port congestion incidences.

For the forecast of VAT, the line chart suggests that an upward trend is likely to occur between 2016 and 2020. This trend was supported by the accompanying frequency table and histogram. The frequency of forecasted anchorage delays outside the CTCT is, however, analysed further using a bar chart. Figure 7-14 shows the number of incidences likely to be experienced in the future by vessels during anchorage outside the CTCT.

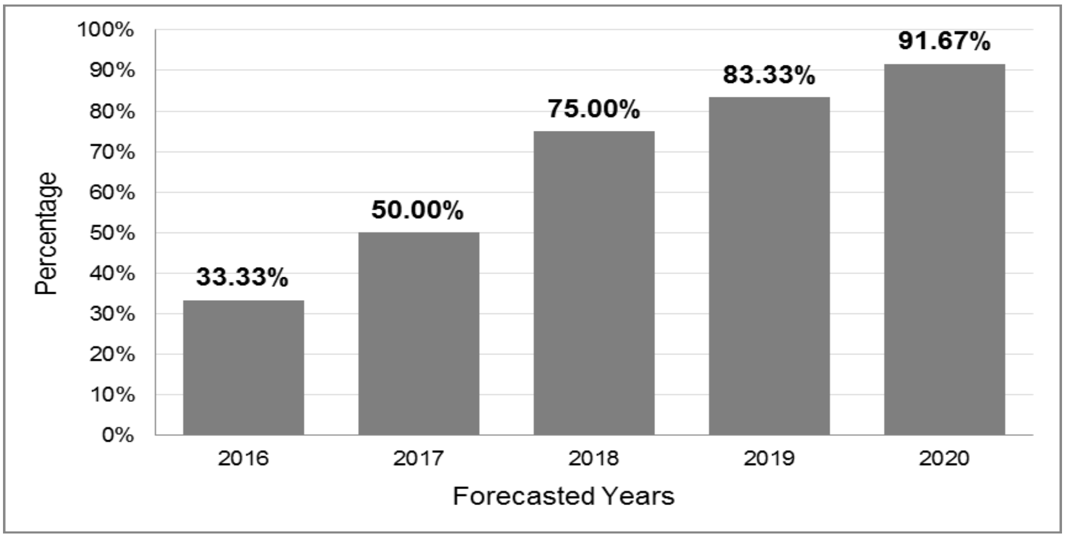

Figure 7-14: Forecasted incident percentage for vessel anchorage (2016 – 2020)

The bar chart supports the upward trend seen in the line chart (section 7.1.1), with incidences increasing steadily over time. The forecast suggests that ocean carriers will experience an incident percentage of 33.33% during anchorage in 2016, which could potentially increase to 50%, 75% and 83.33% in 2017, 2018 and 2019 respectively.

Furthermore, the forecast and Figure 7-14 suggest that anchorage related incidences could increase to as much as 91.67% by 2020, if the upward trend continues. This implies that the majority of ocean carriers to make port at the CTCT in 2020 are likely to experience incidences of delays of varying severity. Fluctuations in vessel volumes will likely force vessels to endure more variable anchorage times unless improvements are made in the coordination and communication between TNPA, TPT and shipping companies with regards to vessel scheduling into and out of the port (Marias, 2015).

With regards to vessel berthing, the forecast of VBT suggests that vessel berthing time is likely to remain constant over time. This is supported by Figure 7-15, which shows that the number of incidences forecast to be experienced by ocean carriers during berthing is likely to remain constant at 33.33% over the next five years (2016-2020). This constant percentage of berthing related incidences suggests that the 2015/16 cruise season will not impact the berthing of container vessels inside the container terminal.

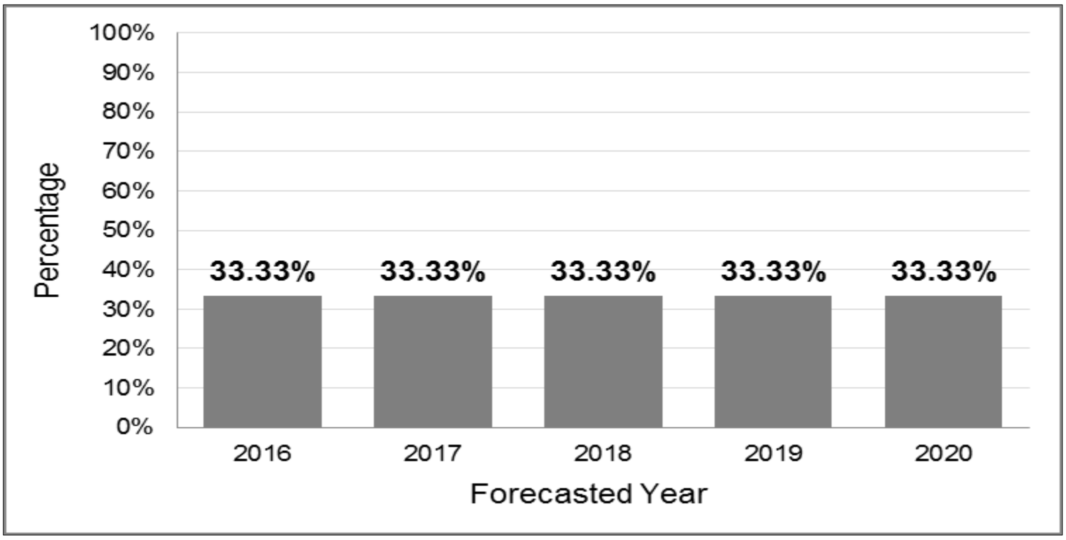

Figure 7-15: Forecasted incident percentage for vessel berthing (2016 – 2020)

Furthermore, fluctuations in container demand in the future will likely contribute to the berthing time of vessels. Figure 7-15, therefore, implies that between 2016 and 2020, the percentage of berthing incidences will be 33.33%.

For the forecast of VWT, the forecasted line chart suggests that vessel working time will remain relatively constant over time. Congestion experienced during offloading/loading was, however, analysed further using a bar chart. The bar chart of congestion frequency shown in Figure 7-16 suggests that vessels are likely to experience a constant frequency of congestion during the offloading and/or loading of containers within the CTCT. This is supported by the forecast line chart (Figure 7-5) seen in section 7.1.1, which illustrates no upward or downward trend in vessel working time.

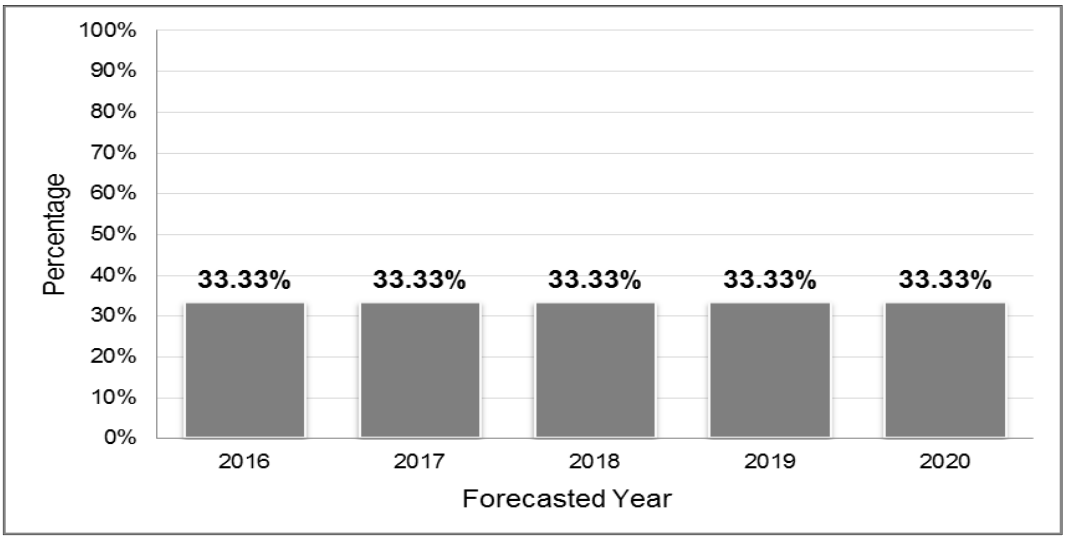

Figure 7-16: Forecasted incident percentage for vessel working time (2016 – 2020)

Figure 7-16 shows that, similar to vessel berthing time, the number of incidences forecast to be experienced by ocean carriers during offloading/loading is likely to remain constant at 33.33% over the next five years (2016-2020).

For forecasted TTAT, the forecast illustrates a downward trend which levels off at 5 minutes. This implies that future port congestion may potentially decrease in frequency for container trucks offloading/loading containers in the terminal. However, it is important to note that this forecast is predicted based on limited data and should be supplemented with data pertaining to vehicle queuing outside the terminal, as well as the potential impact of the 2015 proposed truck ban.

The frequency of forecasted delays in the turnaround of container trucks is analysed further using a bar chart. Figure 7-17 illustrates that the number of incidences forecast to be experienced by container trucks could decrease substantially over the next five years (2016-2020). The bar chart suggests that the majority of container trucks moving through the terminal are likely to experience incidences of varying delays between 2016 and 2017.

It is, however, acceptable according to trucking companies for trucks to turnaround in approximately 30 to 35 minutes (Lane, 2015). Therefore, the large peaks in congestion exhibited in 2016 and 2017 are less severe than the bar chart suggests.

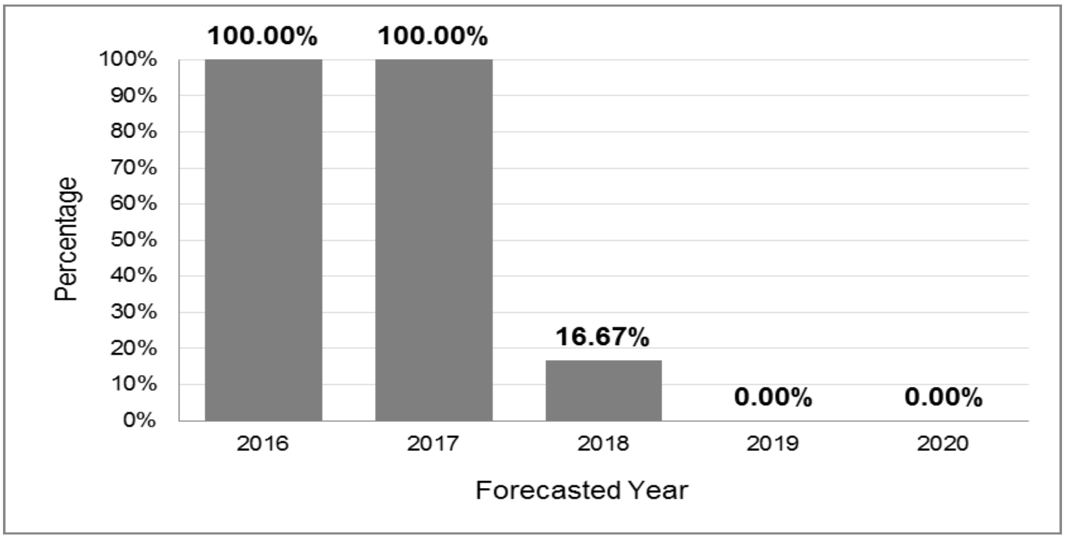

Figure 7-17: Forecasted incident percentage for container trucks (2016 – 2020)

The percentage of incidences is, however, forecasted to decline to 16.67% in 2018 and to zero per cent in 2019 and 2020. These drastic decreases suggest that container truck related incidences will likely decrease in the future. The reason behind the decrease may be due to improved traffic flow between the gate facilities, the container staging area and the container stacks (Julius, 2015).

Furthermore, improvements to terminal equipment, improved coordination of containers into and out of container stacks, and a decrease in vehicle breakdowns may also be contributors to the decrease in congestion occurrences. In addition to the forecasted frequency of congestion for ocean carriers and container trucks, the future frequency of congestion resulting from weather delays and system delays is also analysed.

According to the forecast, future weather delays within the CTCT do not display any form of upward or downward trend between 2015 and 2019. In addition, the frequency table and histogram suggest that the majority of forecasted weather delay observations exceed the average of 9.48 hours. The frequency of forecasted weather delays within the CTCT is analysed further using a bar chart (see Figure 7-18) to determine the percentage of delays likely to be experienced by ocean carriers and container trucks from 2015 to 2019.

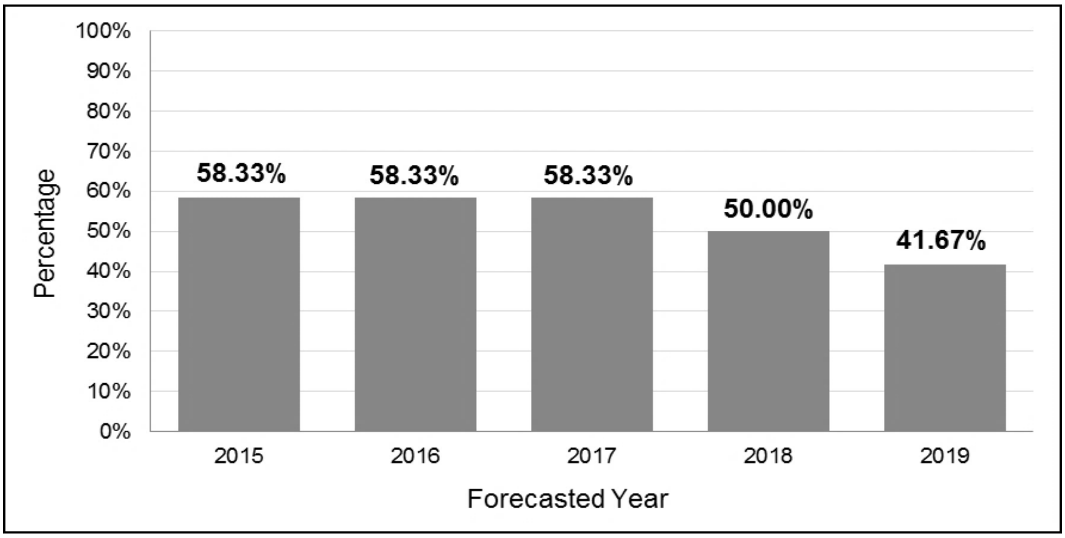

Figure 7-18: Forecasted percentage of weather delays (2015 – 2019)

The bar chart in Figure 7-18 illustrates that forecasted weather delays are likely to maintain a stable trend over the next five years, with incidences of delays likely to remain at 58.33% between 2015 and 2017. Forecasted incidences of weather delays are, however, expected to decrease to 50% and 41.67% in 2018 and 2019 respectively. This consistent percentage of weather-related incidences is likely due to the unpredictability of weather conditions and thus the unpredictability of congestion occurrences.

Similar to the TTAT forecast, system delays, according to the forecast, displayed a downward trend between 2015 and 2019. This downward trend is supported by the frequency table and histogram, which suggest that the frequency of system delays is likely to decrease over time. The forecasted frequency of system delays is analysed further using a bar chart to determine the percentage of incidences likely to be experienced by ocean carriers and container trucks from 2015 to 2019.

Figure 7-19 illustrates that future incidences of system delays peak in 2015 at 41.67%; however, system-related incidences are forecasted to decrease to 25% in 2016 and remain constant through to 2019. This suggests that future incidences of system delays are likely to decrease before stabilising over time. This is likely due to constant maintenance and upgrades to stabilise the system and thus minimise system-related time delays (Marais, 2015). This is under the assumption that the current TOS will not require replacement; however, the system will likely require several upgrades in the future to adequately handle the expected increases in container and vessel volumes (Davids, 2015).

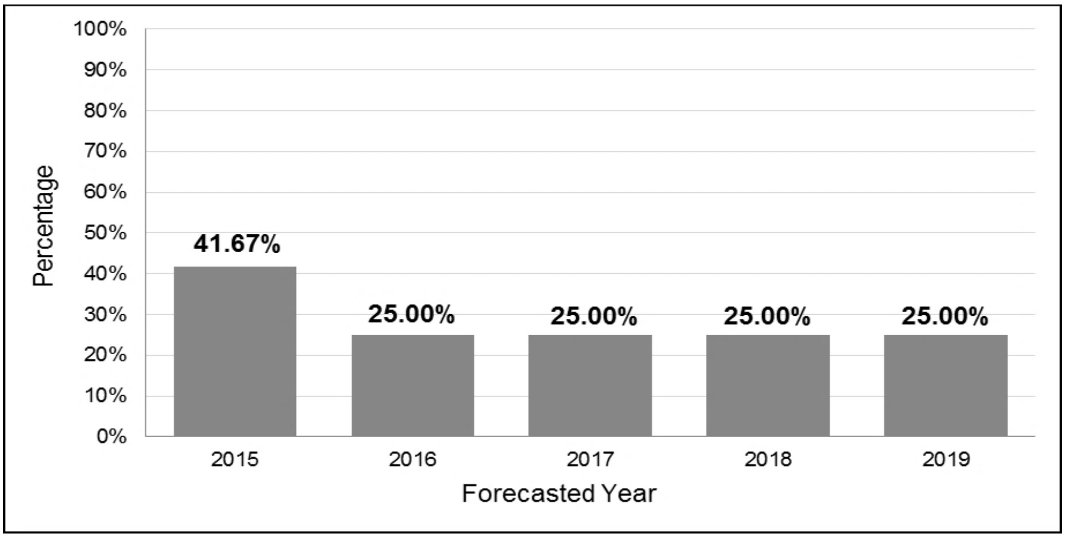

Figure 7-19: Forecasted percentage of system delays (2015 – 2019)

The following section discusses the forecasted scheduling impact of port congestion, based on the descriptive statistics conducted in section 7.1.

7.2.2. Forecasted Scheduling Impact of Port Congestion

The forecasted scheduling impact of port congestion is analysed in a similar way to the current scheduling impact of port congestion, discussed in section 6.2.2 of Chapter 6. The findings of forecasted scheduling impact for ocean carriers and container trucks are presented, along with those of forecasted weather delays and system delays within the CTCT.

The forecast of vessel anchorage time illustrates that ocean carriers are likely to experience longer anchorage times over the next five years. Forecasted VAT was analysed further using a bar chart to illustrate the amount of additional time likely to be experienced during anchorage. Figure 7-20 illustrates an upward trend in forecasted VAT.

This suggests that ocean carriers are likely to experience increasing delays during anchorage between 2016 and 2020. The upward trend in anchorage delays is likely due to fluctuations in container volumes predicted for the next 30 years (Chapter 4: Port Development Plan, 2014:152).

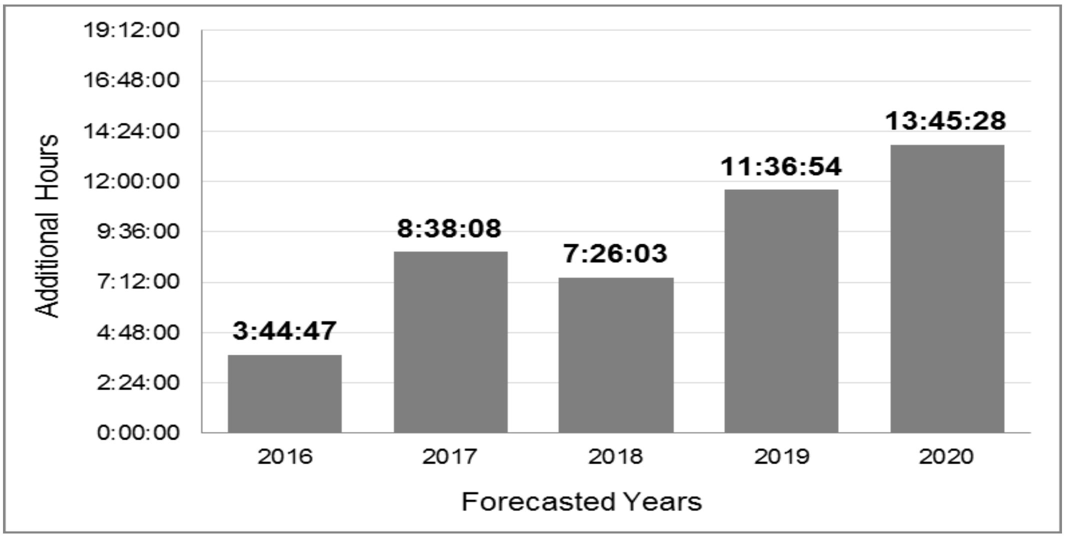

Figure 7-20: Forecasted additional hours spent at anchorage (2016-2020)

Overall, the bar chart in Figure 7-20 indicates that on average, ocean carriers are likely to spend an additional 9 hours anchored outside the port, in addition to the forecasted average of 27 hours, 53 minutes. However, it is important to note that this is significantly less than the current average additional time of 12 hours, 48 minutes. This is likely due to the downward trend exhibited in the current anchorage time data, but may also suggest that anchorage related congestion is likely to increase in frequency, rather than severity. This may be due to adequate management of vessel scheduling into and out of the port, which could reduce the severity of delays, but not necessarily the frequency of delays (Marais, 2015).

With regards to vessel berthing, a forecasted VBT bar chart is developed to illustrate the additional time likely to be experienced by ocean carriers during future berthing within the CTCT. The bar chart seen in Figure 7-21 does not display any form of upward or downward trend. Instead the graph indicates, similar to frequency, that congestion delays relating to vessel berthing will likely remain constant at 5 hours 59 minutes.

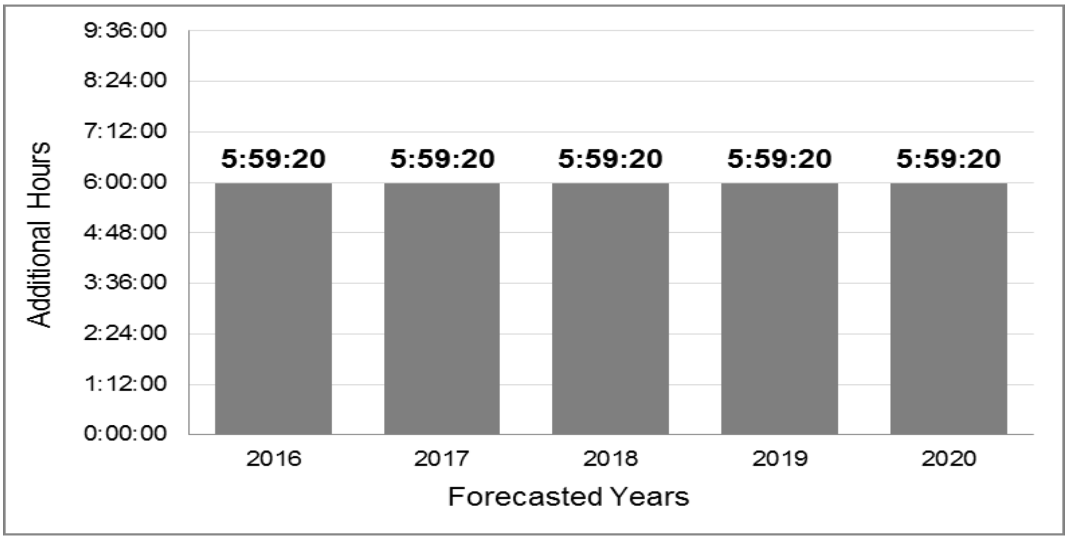

Figure 7-21: Forecasted additional hours spent berthing within the CTCT (2016-2020)

This implies that from 2016 to 2020 ocean carriers are likely to spend approximately 6 additional hours berthing in the terminal, in addition to the forecasted average berthing time of 25 hours, 54 minutes. This, according to Davids (2015), Marais (2015) and Julius (2015), is likely due to the decrease in container demand and the slow growth rate of container volumes predicted for the next 30 years.

For forecasted VWT a bar chart (seen in Figure 22) is developed to illustrate the additional time likely to be experienced by ocean carriers during the future offloading and/or loading of containers. The bar chart supports the forecasted line chart and the congestion frequency bar chart in suggesting that additional time spent offloading/loading containers is likely to remain constant over the next five years. Figure 7-22 illustrates that ocean carriers are likely to experience a consistent delay of 5 hours, 23 minutes in the future during the offloading and/or loading of containers in the terminal.

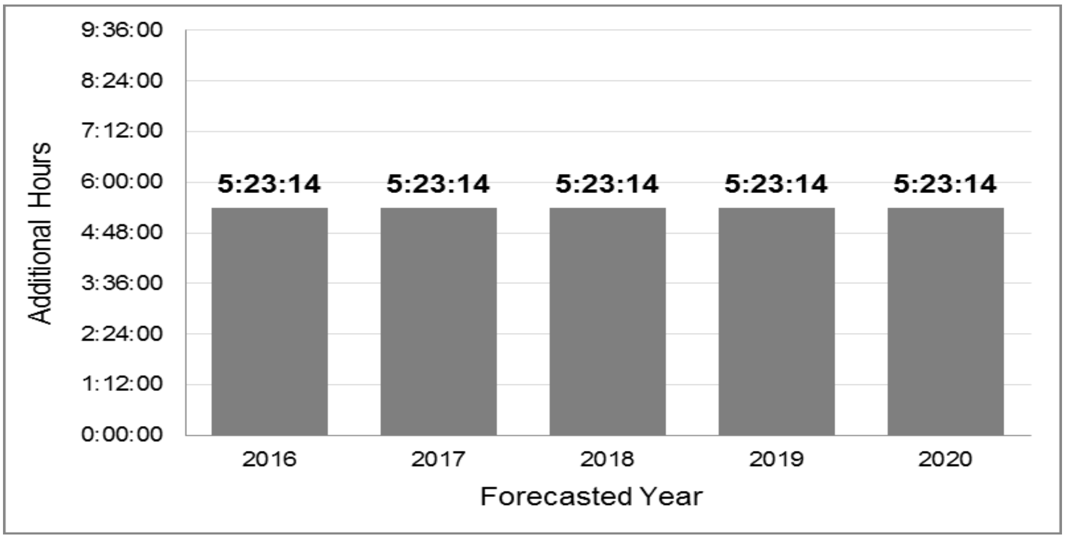

Figure 7-22: Forecasted additional hours spent working within the CTCT (2016-2020)

The constant trend in time delays during offloading/loading of containers, similar to VBT, is likely due to the predicted decrease in container demand and the slow growth rate of container volumes (Davids, 2015; Marais, 2015).

Overall, the bar chart in Figure 7-21 indicates that on average, ocean carriers are likely to spend a significantly less amount of additional time offloading/loading than the current average of between 6 hours, 3 minutes. This implies that the future scheduling impact experienced by ocean carriers during offloading and/or loading may decrease.

For forecasted TTAT within the CTCT, future scheduling delays are illustrated on a bar chart, seen in Figure 7-23.

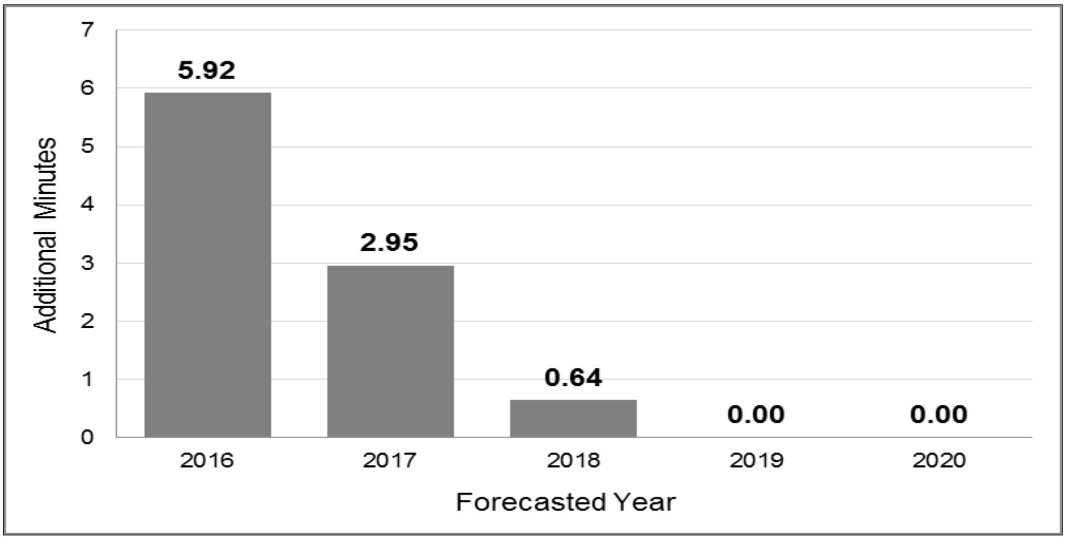

Figure 7-23: Forecasted additional minutes spent in the CTCT by container trucks (2016-2020)

The bar chart implies that forecasted scheduling delays are decreasing over time, with delays experienced by container trucks becoming less each year. In 2016, container trucks are forecast to spend an additional 5.92 minutes in the CTCT. This is forecast to decrease to zero minutes by 2019. The decrease in the additional time spent in the terminal is likely due to the previously mentioned factors in section 7.2.1, namely, improvements to terminal equipment, improved coordination of container stacks, and decreased occurrences of vehicle breakdowns.

In addition to the forecasted scheduling impact of congestion for ocean carriers and container trucks, the forecasted scheduling impact of congestion resulting from weather delays and system delays is also analysed.

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According to the forecast, future weather delays within the CTCT do not display any form of upward or downward trend for 2015 to 2019. The forecasted scheduling impact of weather delays with in the CTCT is analysed further using a bar chart (see Figure 7-24) to determine the total delay in hours likely to be experienced by ocean carriers and container trucks from 2015 to 2019.

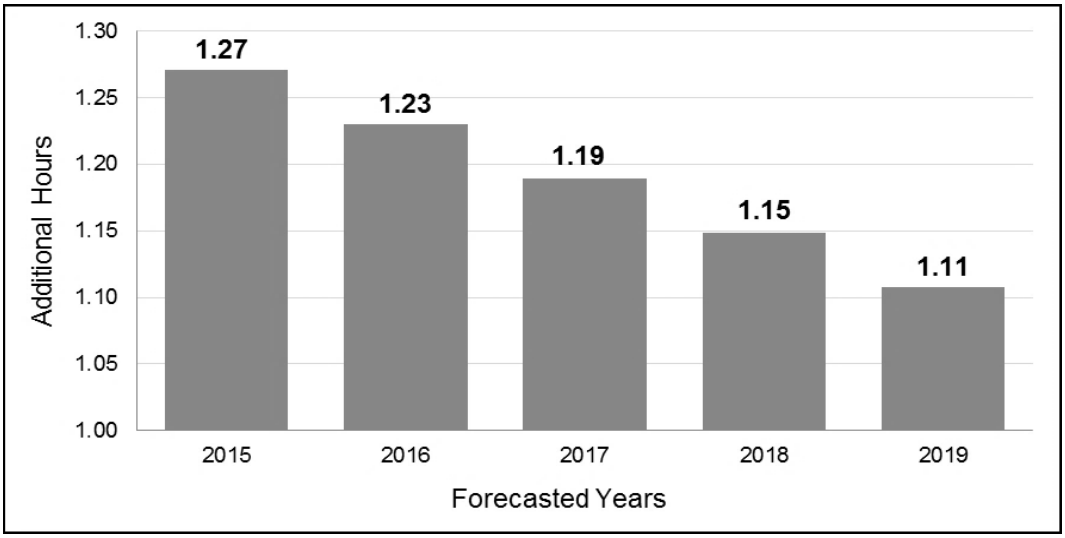

Figure 7-24: Forecasted weather delays experienced in the CTCT (2015-2019)

The bar chart in Figure 7-24 suggests that the future scheduling impact of weather delays is likely to decrease over the next five years. In 2015, forecasted weather delays in hours are likely to amount to 1.27 hours more than the forecasted average delay of 9.48 hours. This amount is forecasted to decrease to 1.11 hours by 2019. The bar chart, therefore, implies that the forecasted scheduling impact of weather delays (in hours) is likely to decrease over time. This is likely due to improvements in the management of weather-related challenges within the terminal with regards to equipment and planning of vessel and vehicle movements.

With regards to system delays, the forecast displayed a downward trend between 2015 and 2019. The forecasted scheduling impact of system delays is analysed further using a bar chart to determine the amount of additional time likely to be experienced by ocean carriers and container trucks due to system delays.

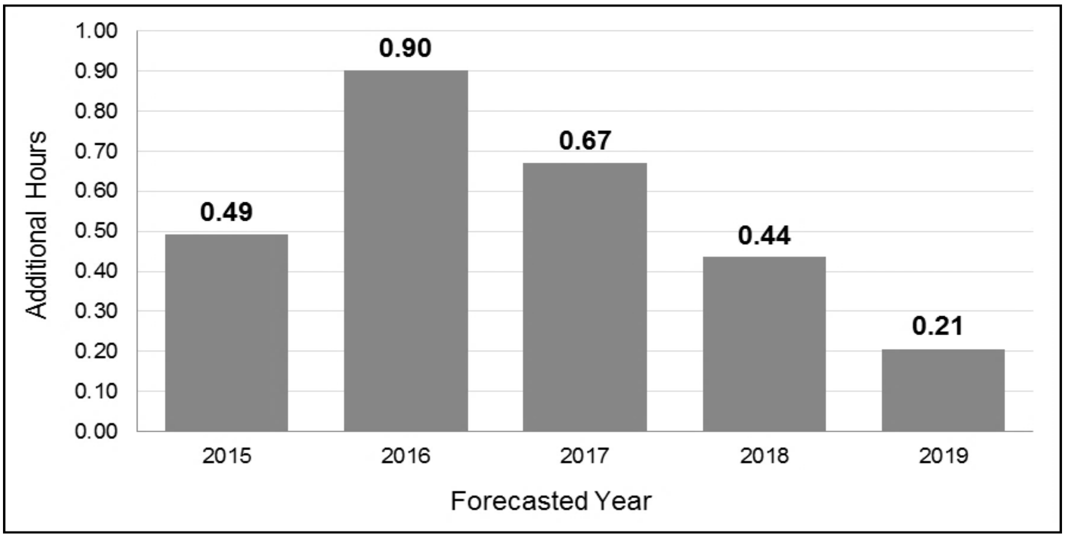

Figure 7-25: Forecasted system delays experienced by ocean carriers and container trucks in the CTCT (2015-2019)

The bar chart in Figure 7-25 illustrates the additional hours likely to be experienced by ocean carriers and container trucks due to forecasted system delays. Overall, the bar chart indicates that the average additional hours likely to be experienced by ocean carriers and container trucks due to system delays (between 2015 and 2019) will amount to 0.54 hours. This forecasted amount is substantially lower than the current average additional hours of 0.83 hours, therefore, implying that the scheduling impact of system delays is likely to decrease in the future. This decrease is, however, under the assumption that the current TOS will continue to perform adequately and reduce delays over time.

The final section of this chapter summarises the findings with regards to the forecasted frequency of congestion and the forecasted scheduling impact of congestion within the CTCT.

7.3. Closing Remarks

In conclusion, this chapter presented the graphical and numerical descriptive analysis of four forecasts, namely, ship turnaround time, truck turnaround time, weather delays and system delays. These five year forecasts were then analysed in terms of the frequency of congestion and the scheduling impact of congestion.

The forecasted VAT data suggests that the frequency of port congestion for anchored ocean carriers is likely to increase over the next five years. This suggests that the frequency of congestion experienced by ocean carriers during anchorage is likely to increase in the future, if not managed effectively.

Research suggests that the increase in anchorage congestion frequency is likely due to large estimated growth of cargo volumes for the next 30 years, which would increase the volume of ocean carriers requiring entry into the Port of Cape Town.

With regards to scheduling, findings suggest that vessels are likely to be anchored outside the CTCT approximately 9 hours longer than the average anchorage time of approximately 28 hours. This is significantly less than current delays of approximately 12 hours. This, therefore, implies that the scheduling impact of congestion may not be a great concern in the future, likely due to adequate management of vessel scheduling and thus less severe delays.

The analysis of the VBT forecast indicates that berthing time is likely to remain constant over the next five years with results showing that both the frequency and scheduling impact of berthing congestion are likely to remain constant in the future. This is likely due to the conflict between the expected decrease in container demand, and the expected slow growth rate of container volumes moving through the CTCT.

Overall, the forecast results indicate the between 2016 and 2020, ocean carriers are likely to experience berthing congestion a third (33.33%) of the time, with berthing taking approximately 6 hours longer than the average berthing time. This constant level of congestion is likely due to the decrease in container demand and slow grow rate of container volumes predicted for the next 30 years.

With regards to vessel working time (VWT), and similar to VBT, the forecast displayed no significant upward or downward trend. This constant trend, as mentioned with regards to VBT, is likely due to the conflict between the expected decrease in container demand and expected slow growth rate of container volumes through the CTCT. The findings indicate that the frequency of loading/offloading congestion is likely to remain constant at 33.33%, similar to berthing congestion. Similarly, congestion delays relating to vessel working is forecast to be consistent at approximately 5 hours, 23 minutes. This suggests that the frequency of congestion experienced during loading/offloading will not increase or decrease in severity.

The TTAT forecast indicates a downward trend in the future frequency of port congestion for container trucks over the next five years. This downward trend is, however, likely less drastic than indicated by the data. This is due to the data being limited to truck turnaround within the terminal, and excluding the impact of vehicle queuing outside the terminal and the 2015 proposed truck ban. Furthermore, it is important to note that the minimum turnaround time (5 minutes) suggested by TPT representatives is relatively unrealistic due to numerous internal and external factors contributing to truck turnaround time.

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Trucking companies indicate that an acceptable minimum truck turnaround time is closer to 30 to 35 minutes, taking into account all internal and external factors. This suggests that while congestion experienced by container trucks is likely to decrease over time, the decrease will likely be less significant than the data indicates.

The expected decrease in truck-related congestion, both in the frequency of occurrences and the amount of time delays, is likely due to factors such as improvements to terminal equipment, improvements in the coordination of container trucks, and decreases in vehicle breakdowns within the terminal.

The analysis of the weather delays forecast suggests that while the frequency of weather delays is likely to remain constant, the scheduling impact of congestion is likely to decrease in the future. The expected consistency of occurrences is likely due to the unpredictability of weather conditions and thus the unpredictability of congestion occurrences. The expected decrease in the scheduling impact, however, is likely due to improved coordination, collaboration and communication between TNPA, TPT, shipping companies and trucking companies in the management of weather-related challenges, thus minimising their impact over time.

The system delays forecast first illustrates a downward, then a stabilising trend from 2015 to 2019. This indicates that the frequency of system delays is likely to decrease in the future before levelling at a constant. With regards to scheduling impact, system delays are forecast to decrease over time by 2019. This suggests that ocean carriers and container trucks are likely to experience shorter delays due to system errors in the future likely due to constant maintenance and upgrades to stabilise the TOS system.

Overall, the results found in this chapter suggest that ocean carriers are likely to experience increases in anchorage congestion, while both berthing and offloading/loading congestion will likely remain constant in the future. Container trucks, similar to current data, will likely continue to experience decreasing congestion within the terminal. However, theory and practise shows that the turnaround time of trucks cannot reduce pass a certain point. This implies that while the forecast shows rapidly decreasing truck turnaround time, it is more probable that container trucks will experience fluctuating turnaround time due to numerous internal and external factors.

The forecasted weather delays results indicate that ocean carriers and container trucks are likely to experience a constant number of occurrences of congestion, while the scheduling impact of weather delays is forecast to decrease over time.

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This suggests that improvements in the management of weather-related challenges will likely occur in the future with improvements in collaboration, coordination and communication between TNPA, TPT, shipping companies and trucking companies. With regards to system delays, the forecast results suggest that ocean carriers and container trucks are likely to experience both decreasing occurrences of congestion and scheduling impact of system-related congestion. This is likely due to maintenance and upgrades to stabilise the TOS system.

The results and forecasts of this chapter are subsequently analysed to develop risk profiles of current and future port congestion within the CTCT. The results and discussion of the risk profiles are included in the following chapter.

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Chapter 8: Risk Profile and Discussion

This chapter focuses on the development of two risk profiles, namely, current and future port congestion within the CTCT. The current risk profile is based on descriptive analysis done on historical data, while the future risk profile is based on the five year forecasts discussed in Chapter 7. The main purpose of the chapter is to identify the level of risk which should be associated with current and future port congestion within the CTCT.

The first section of the chapter discusses the assessment of port congestion in terms of two important steps, namely, *risk quantification and prioritisation*, and *risk evaluation*. The second section of the chapter outlines the developed risk profiles of current and future port congestion.

8.1. Risk Assessment

The risk assessment process used to develop the risk profiles followed a number of steps. These steps commonly include *risk identification, risk analysis, risk evaluation* and *risk treatment*. For the purpose of this study however, certain of the steps were excluded, namely, *risk identification* and *risk treatment*. Therefore, the first step in the development of the port congestion risk profile is *risk quantification and prioritisation*.

8.1.1. Risk Quantification and Prioritisation

The first step in the risk assessment process of port congestion involves the analysis of congestion as a risk. This process generally includes the estimation of the frequency and impact of the risk occurring and prioritises the risk for treatment solutions.

This can be done through the use of various methods, the most common being the bow-tie method (Supply Chain Risk Leadership Council, 2011:15). The theory of the model is discussed in section 3.1.1 of Chapter 3. It was, however, noted in section 2.2.5 of Chapter 2 that for the purpose of this study certain elements of the model are excluded. These excluded elements are “preventative controls” and “recovery controls”, and are excluded due to the scope of the study. Therefore, for the purpose of this study, two separate bow-tie diagrams are constructed to analyse the triggers and consequences of both maritime-side port congestion and landside port congestion.

Figure 8-1 illustrates the bow-tie model of maritime-side congestion experienced within the CTCT. Typical triggers of maritime-side congestion are illustrated on the left of the bow-tie model, while typical consequences resulting from maritime-side congestion are illustrated on the right of the model. The triggers appear uncontrollable in terms of frequency, however, they are manageable with regards to the consequences. These elements are discussed in detail in section 5.4.1 of Chapter 5, and are represented in the data collected during the course of this study.

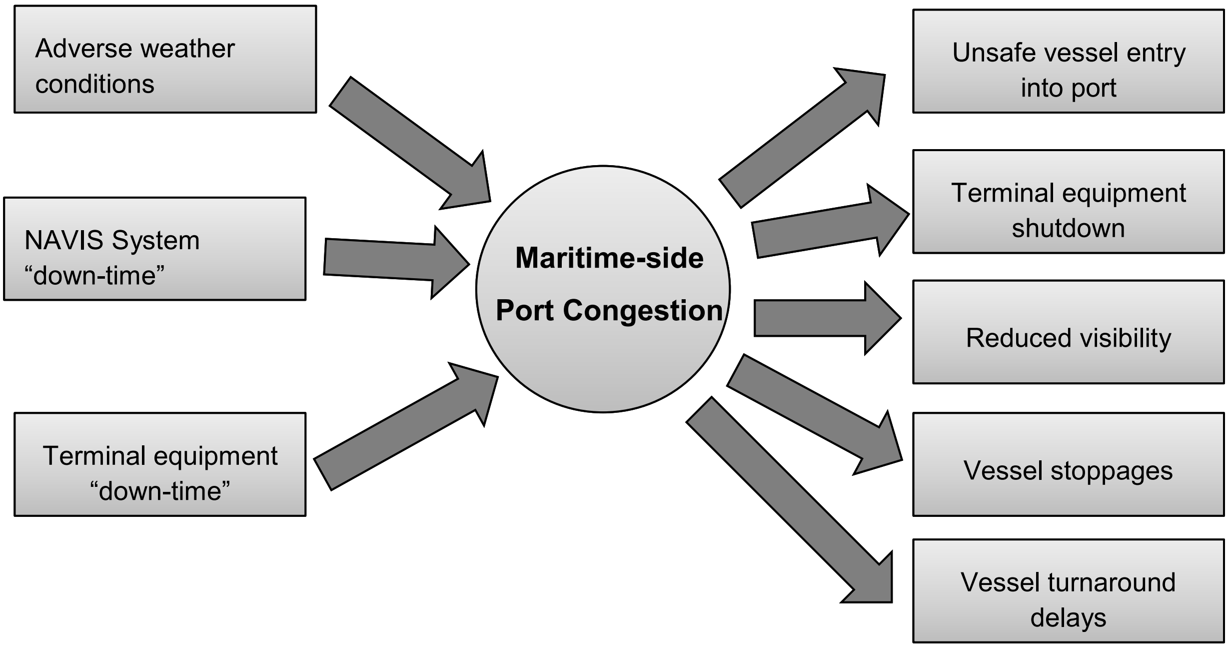

Figure 8-1: Bow-tie model of maritime-side port congestion within the CTCT

Similar to Figure 8-1, the bow-tie model illustrated in Figure 8-2 shows the triggers and consequences of landside congestion experienced within the CTCT. The typical triggers of landside congestion are illustrated on the left of the model. These congestion triggers often result in consequences which are illustrated on the right of the model. Similar to the maritime-side, the triggers of landside congestion are relatively uncontrollable, but can be managed to minimise consequences. These elements are discussed in section 5.4.2 of Chapter 5 and are represented in the data collected.

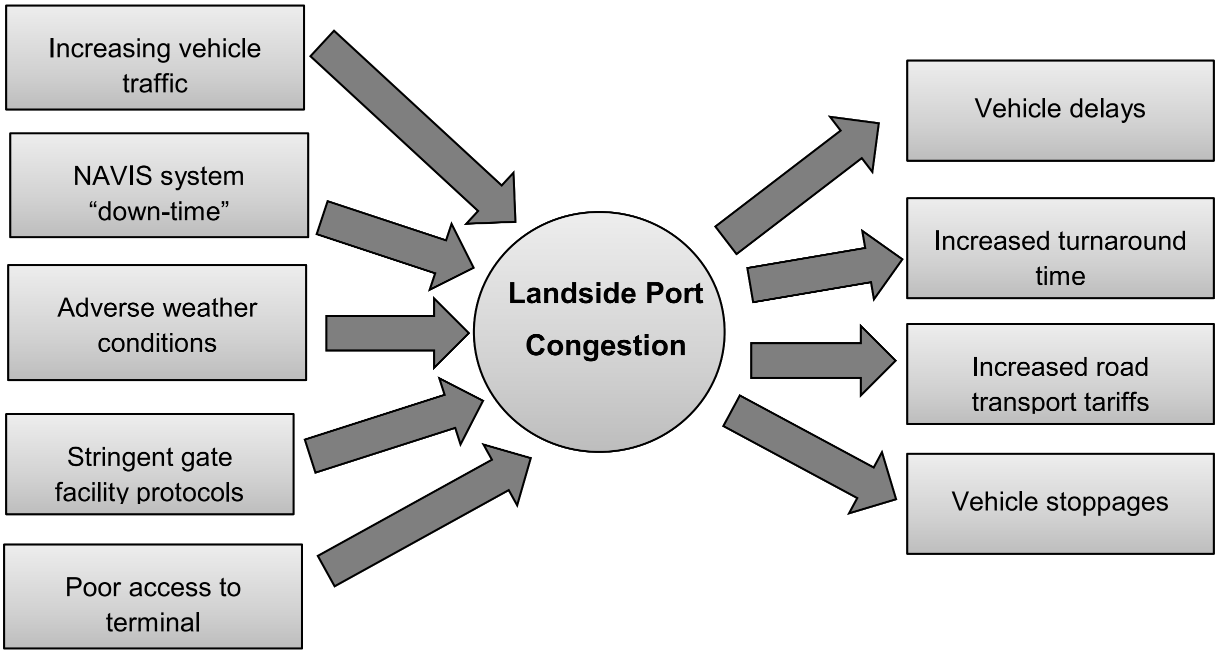

Figure 8-2: Bow-tie model of landside port congestion within the CTCT

The bow-tie models created for maritime-side and landside congestion visually illustrate the triggers and consequences of port congestion to both ocean carriers and container trucks which move through the container terminal. These visual representations assist in the interpretation of the data collected in terms of port congestion as a risk to efficiency. In the case of this study the VAT, VBT and VWT data sets pertain to maritime-side congestion and the TTAT data pertains to landside congestion. The weather delays and system delays data sets pertain to both maritime and landside congestion, as weather- and system-related challenges impact both ocean carriers and container trucks (as seen in Figure 8-1 and 8-2).

In addition to the visual representations, and data analysis done of current and forecasted port congestion, the risk assessment process involves the quantification of the risk. This, as mentioned in section 2.2.5 of Chapter 2, is done through the use of two measures, namely, risk probability or frequency (%), and risk impact (time). These measures are multiplied to calculate the risk severity of port congestion experienced by ocean carriers and container trucks within the CTCT. This calculation assists in determining whether the overall severity of the risk, in terms of frequency and impact, will increase or decrease in the future.

It is importtant to note, as mentioned in Chapter 2, that these calculations exhibit more detail on how the risk has changed over time, and are therefore more accurate indications of trends in the data than the line charts displayed in Chapters 6 and 7.

The following subsections present the current and forecasted risk severity calculations for the individual data sets/forecasts analysed for the purpose of this study.

- *Vessel Anchorage Time*

Table 8-1 illustrates the current and forecasted risk severity calculations for vessel anchorage outside the CTCT. The table suggests that current risk severity for vessel anchorage ranges from 22 minutes to 9 hours 25 minutes, while the forecasted risk severity is likely to range from as little as 1 hour 14 minutes to as much as 12 hours 36 minutes. This suggests that, similar to the forecast shown in section 7.1.1 of Chapter 7, future anchorage time will likely be a more severe risk than currently experienced.

Table 8-1: Risk severity calculations for vessel anchorage outside the CTCT

	Current					**Forecasted**				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Frequency %	40%	83%	42%	8%	9%	33%	50%	75%	83%	92%
Impact (hrs:mins)	19:12	9:35	22.37	4.34	8.03	3:44	8:38	7:26	11:36	13:45
Risk Severity (hrs:mins)	**7:41**	**7:59**	**9:25**	**0:22**	**0:43**	**1:14**	**4:19**	**5:34**	**9:40**	**12:36**
Average Risk Severity	**5 hours, 14 minutes**					**6 hours, 41 minutes**				

Overall, the average current risk severity is relatively lower than the forecasted risk severity implying that anchorage congestion will likely be a greater risk in the future than is currently experience. This, as mentioned previously in Chapter 7, is likely due to the large increase in cargo volumes predicted for the next 30 years.

- *Vessel Berthing Time*

Table 8-2 illustrates the current and forecasted risk severity calculations for vessel berthing within the CTCT. The table illustrates that the current risk severity for vessel berthing ranges from 24 minutes to 3 hours, 14 minutes. This relatively large time range of delays implies that vessel berthing is fairly fluctuant, which may be due to unpredictable weather conditions impacting the safety of vessel movement. In addition, expansions done to the CTCT between 2011 and 2013 likely impacted vessel berthing times.

Forecasted risk severity, however, remains relatively constant with a risk severity of 1 hour, 58 minutes, which is significantly less than the current average risk severity of 1 hour, 3 minutes.

The risk severity calculations suggest, in contrast to the forecast and congestion bar charts shown in Chapter 7, that berthing related congestion will likely be a more severe risk in the future than currently experienced. Despite the forecast not displaying an upward trend, the risk severity calculations indicate that the occurrences of berthing congestion will likely increase. The severity of time delays will similarly increase slightly.

Table 8-2: Risk severity calculations for vessel berthing within the CTCT

	Current					Forecasted				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Frequency %	10%	8%	42%	17%	9%	33%	33%	33%	33%	33%
Impact (hrs:mins)	4:05	8:06	7:45	3:14	4:34	5:59	5:59	5:59	5:59	5:59
Risk Severity (hrs:mins)	**0:24**	**0:40**	**3:14**	**0:32**	**0:24**	**1:58**	**1:58**	**1:58**	**1:58**	**1:58**
Average Risk Severity	**1 hour, 3 minutes**					**1 hour, 58 minutes**				

Overall, the average current risk severity is relatively lower than the forecasted risk severity. This implies that berthing congestion will likely be a greater risk in the future than is currently experienced.

- *Vessel Working Time*

Table 8-3 illustrates the current and forecasted risk severity calculations for vessel working time within the CTCT.

Table 8-3: Risk severity calculations for vessel offloading/loading within the CTCT

	Current					Forecasted				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Frequency %	10%	8%	50%	17%	9%	33%	33%	33%	33%	33%
Impact (hrs:mins)	7:30	8:54	6:42	3:29	3:42	5:23	5:23	5:23	5:23	5:23
Risk Severity (hrs:mins)	**0:45**	**0:44**	**3:21**	**0:34**	**0:20**	**1:47**	**1:47**	**1:47**	**1:47**	**1:47**
Average Risk Severity	**1 hour, 9 minutes**					**1 hour, 47 minutes**				

The table suggests that currently, vessel offloading/loading experiences a risk severity of between 20 minutes and 3 hours, 21 minutes. This, similar to vessel berthing, implies that vessel working time is relatively fluctuant, most likely due to system and/or weather delays. The forecasted risk severity, however, is likely to remain constant over the next five-year (2016-2020) with risk severity amounting to 1 hour, 47 minutes.

The risk severity calculations, in contrast with the forecast and congestion bar charts in Chapter 7, indicate that offloading/loading congestion will likely increase in the future. This is likely due to an increase in congestion occurrences, as well as slightly longer time delays (as shown in Table 8-3). Overall, the risk severity calculations suggest that offloading/loading related congestion will likely be a greater concern in the future than is currently experienced.

- ***Truck Turnaround time***

With regards to container trucks, Table 8-4 illustrates the current and forecasted risk severity calculations. The current risk severity of port congestion for container trucks, according to the table, ranges from as little as zero to 8.74 minutes. This amount appears to be relatively insignificant, but may have an impact on overall truck turnaround time during peak periods.

Table 8-4: Risk severity calculations for container trucks within the CTCT

	Current					**Forecasted**				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Frequency %	83%	0%	8%	0%	0%	100%	100%	17%	0%	0%
Impact (minutes)	10.49	1.93	3.51	0.57	1.31	5.92	2.95	0.64	0.00	0.00
Risk Severity (minutes)	**8.74**	**0.00**	**0.29**	**0.00**	**0.00**	**5.92**	**2.95**	**0.11**	**0.00**	**0.00**
Average Risk Severity	**1.81 minutes**					**1.80 minutes**				

The forecasted risk severity of port congestion, however, ranges from zero to 5.92 minutes, which is significantly less than the current risk severity. This suggests that, on average, vehicle related port congestion is likely to become a less severe concern in the future. It is, however, important to acknowledge that numerous factors contribute to vehicle related congestion, such as truck queuing outside the port and the 2015 proposed truck ban. These factors are not represented in the data set analysed in this study.

❖ *Weather Delays*

In addition to port congestion as a risk to the turnaround time of ocean carriers and container trucks, the risk severity of port congestion due to weather and system delays was also determined. Table 8-5 illustrates the risk severity calculations of current and forecasted weather delays experienced by ocean carriers and container trucks.

Table 8-5: Risk severity calculations of weather delays within the CTCT

	Current				**Forecasted**				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Frequency %	25%	33%	17%	33%	58%	58%	58%	50%	42%
Impact (hours)	3.03	3.51	3.62	3.51	1.27	1.23	1.19	1.15	1.11
Risk Severity (hours)	**0.76**	**1.17**	**0.60**	**1.17**	**0.74**	**0.72**	**0.69**	**0.58**	**0.46**
Average Risk Severity	**0.93 hours**				**0.64 hours**				

Overall, Table 8-5 suggests that currently weather congestion has a risk severity of 0.93 hours, while the forecasted risk severity is 0.64 hours. The table subsequently implies that, despite the forecast in Chapter 7 suggesting that weather delays will remain constant, weather-related congestion will likely decrease in the future. This slight decrease will likely be in terms of impact, rather than the frequency of occurrences, due to improved management within the terminal.

❖ *System Delays*

Similar to Table 8-5, Table 8-6 illustrates the risk severity calculations of current and forecasted system delays experienced by ocean carriers and container trucks. The table suggests that, currently, the risk severity of system-related port congestion ranges from 0.16 to 0.33 hours, while the forecasted risk severity ranges from 0.05 to 0.23 hours.

Therefore, Table 8-6 implies that system-related port congestion will likely decrease in severity in the future compared to delays currently experienced.

Table 8-6: Risk severity calculations of system delays within the CTCT

	Current				Forecasted				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Frequency %	50%	17%	33%	33%	42%	25%	25%	25%	25%
Impact (hours)	0.64	0.95	1.00	0.74	0.49	0.90	0.67	0.44	0.21
Risk Severity (hours)	**0.32**	**0.16**	**0.33**	**0.25**	**0.20**	**0.23**	**0.17**	**0.11**	**0.05**
Average Risk Severity	**0.27 hours**				**0.15 hours**				

The tables presented assist in the quantification of weather- and system-related port congestion as a risk to ocean carriers and container trucks. This quantification of port congestion must, however, be interpreted using a coding system or key before a risk profile of port congestion can be developed.

For the purpose of this study, specific coding systems were used for each data set analysed to produce an accurate risk profile of port congestion within the CTCT.

The process behind the development of the individual coding systems is discussed in section 2.2.5 of Chapter 2. The developed coding systems are used to interpret the above risk severity calculations and are subsequently used to create risk prioritisation tables. These risk prioritisation tables are visible in Table 8-7 and Table 8-8 and are linked to the individual data sets and forecasts analysed.

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Table 8-7: Risk prioritisation tables for VAT, VBT, VWT and TTAT

VAT	**Current**					**Forecasted**				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Frequency Ranking	2	5	3	1	1	2	3	4	5	5
Impact Ranking	4	2	5	1	2	1	2	2	3	3
VBT	**Current**					**Forecasted**				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Frequency Ranking	1	1	3	1	1	2	2	2	2	2
Impact Ranking	3	5	4	2	3	3	3	3	3	3
VWT	**Current**					**Forecasted**				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Frequency Ranking	1	1	3	1	1	2	2	2	2	2
Impact Ranking	4	5	4	2	2	3	3	3	3	3
TTAT	**Current**					**Forecasted**				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Frequency Ranking	5	1	1	1	1	5	5	1	1	1
Impact Ranking	5	1	2	1	1	3	1	1	1	1

Table 8-8: Risk prioritisation for weather and system delays

Weather Delays	**Current**				**Forecasted**				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Frequency Ranking	2	2	1	2	3	3	3	3	3
Impact Ranking	3	4	4	4	2	2	2	2	2
System Delays	**Current**				**Forecasted**				
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Frequency Ranking	3	1	2	2	3	2	2	2	2
Impact Ranking	4	5	5	4	3	5	4	3	2

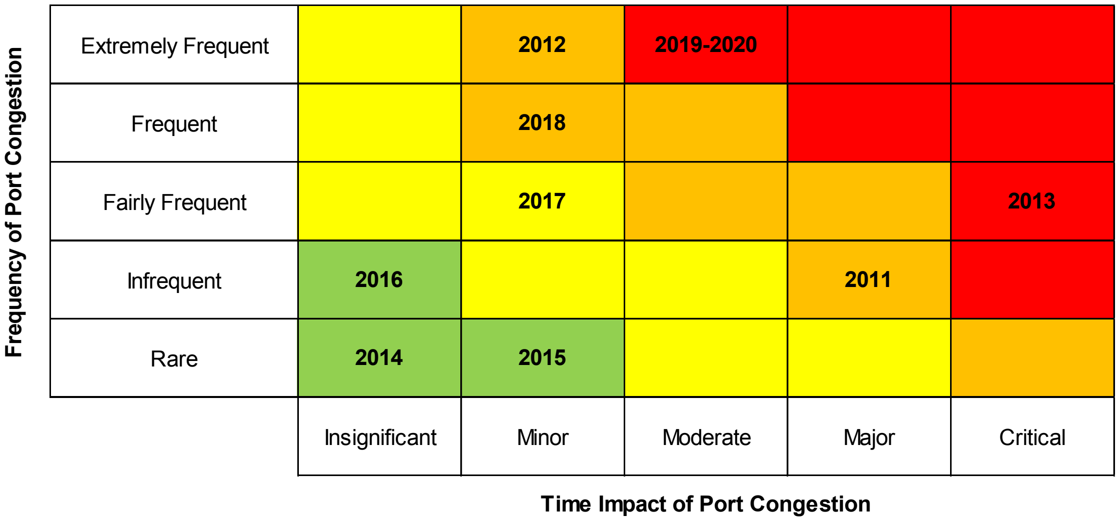
The significance of the prioritisation tables seen in Table 8-7 and Table 8-8 is discussed in the following section using a number of risk evaluation maps. The following section discusses the evaluation of weather- and system-related port congestion.

8.1.2. Risk Evaluation

The second and final step in the risk assessment process for this study involves the evaluation of port congestion as a risk to ocean carriers and container trucks. This evaluation is done through the use of the “heat-map” technique. The theory of the “heat-maps” is discussed in section 3.1.1 of Chapter 3, while the methodology behind the technique is discussed in section 2.2.5 of Chapter 2. The risk ranking of the “heat-maps” is as follows: minor risk = green; moderate risk = yellow; major risk – orange; and critical risk = red. The “heat-maps” for each individual data sets and subsequent forecasts are presented below.

For port congestion experienced by ocean carriers during anchorage, Figure 8-3 suggests that between 2011 and 2012 port congestion was deemed a major risk to the anchorage of ocean carriers. This increased to a critical risk in 2013 due to a high time impact rating, at which point it decreased drastically to a minor risk in 2014 and 2015.

The forecast results indicated that anchorage congestion would remain a minor risk in 2016, before increasing at a steady pace to a moderate risk in 2017, a major risk in 2018 and a critical risk in 2019 and 2020 due to high frequency ratings. This suggests that the frequency of anchorage congestion in the future is of greater concern than time impact.



Frequency of Port Congestion	Insignificant	Minor	Moderate	Major	Critical
Extremely Frequent		**2012**	**2019-2020**		
Frequent		**2018**			
Fairly Frequent		**2017**			**2013**
Infrequent	**2016**			**2011**	
Rare	**2014**	**2015**			

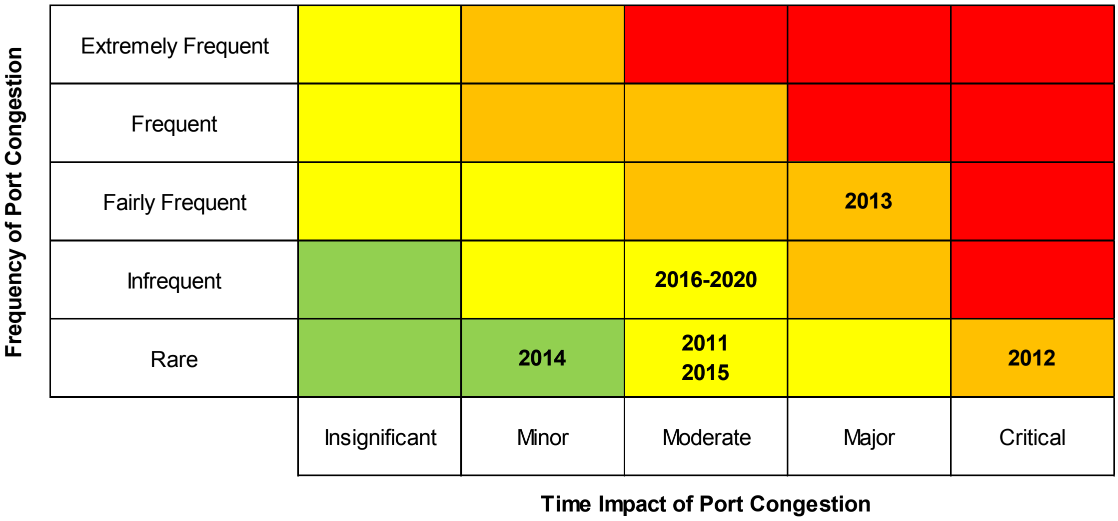
Time Impact of Port Congestion

Figure 8-3: Risk "heat-map" of congestion experienced during vessel anchorage

The rapid increase in the risk associated with vessel anchorage, as mentioned in Chapter 7, is likely due to the large growth of cargo volumes predicted for the next 30 years.

With regards to port congestion experienced by ocean carriers during berthing, Figure 8-4 suggests that in 2011 berthing congestion be deemed a moderate risk. This increased to a major risk from 2012 to 2013 due to high impact ratings, before decreasing to a minor risk in 2014. The latest current data indicated that berthing congestion be deemed a moderate risk again in 2015.

The forecast results support the 2015 suggestion with berthing risk being ranked a moderate risk between 2016 and 2020 with moderate impact and infrequent occurrences. This suggests that the impact of berthing congestion is of greater concern in the future than the frequency of delays.

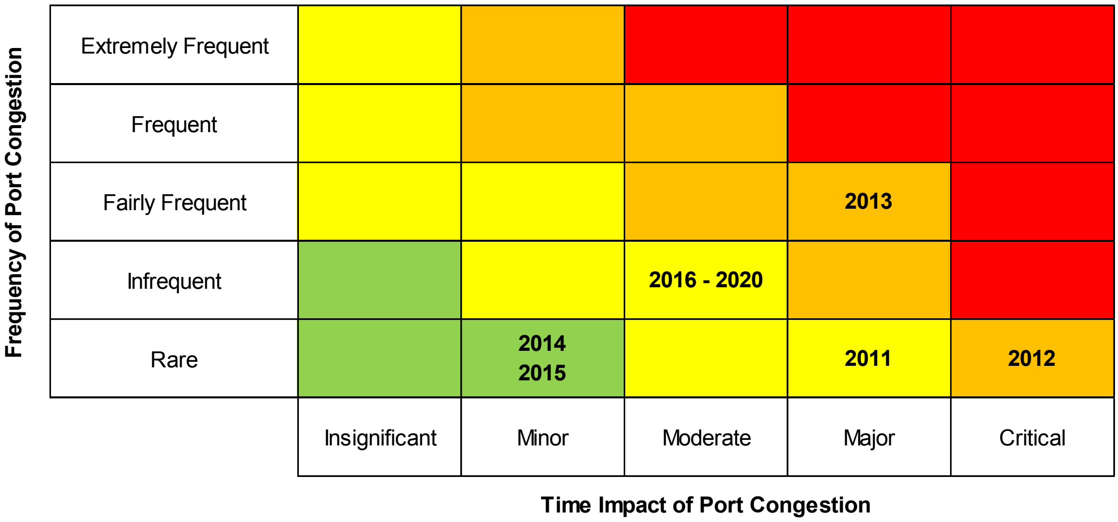


Frequency of Port Congestion	Insignificant	Minor	Moderate	Major	Critical
Extremely Frequent	🟨	🟧	🟥	🟥	🟥
Frequent	🟨	🟧	🟧	🟥	🟥
Fairly Frequent	🟨	🟨	🟧	🟧 2013	🟥
Infrequent	🟩	🟨	🟨 2016-2020	🟧	🟥
Rare	🟩	🟩 2014	🟨 2011 2015	🟨	🟧 2012

Time Impact of Port Congestion

Figure 8-4: Risk “heat-map” of congestion experienced during vessel berthing

For port congestion experienced by ocean carriers during the offloading and/or loading of containers, Figure 8-5 suggests that congestion be deemed a moderate risk in 2011 and a major risk in 2012 and 2013 with impact ratings exceeding frequency ratings. This decreased to a minor risk between 2014 and 2015, at which point it was forecast to increase to a moderate risk from 2016 to 2020 with moderate impact and infrequent occurrences.

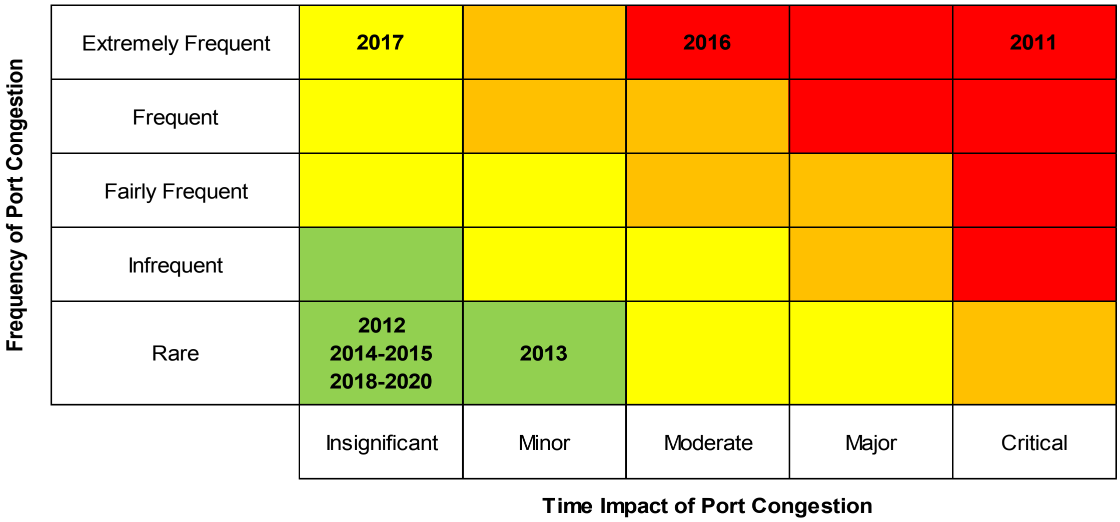


Frequency of Port Congestion	Insignificant	Minor	Moderate	Major	Critical
Extremely Frequent	🟨	🟧	🟥	🟥	🟥
Frequent	🟨	🟧	🟧	🟥	🟥
Fairly Frequent	🟨	🟨	🟧	🟧 2013	🟥
Infrequent	🟩	🟨	🟨 2016 - 2020	🟧	🟥
Rare	🟩	🟩 2014 2015	🟨	🟨 2011	🟧 2012

Time Impact of Port Congestion

Figure 8-5: Risk “heat-map” of congestion experienced during vessel offloading/loading

With regards to port congestion experienced by container trucks, Figure 8-6 suggests that in 2011 port congestion was deemed a critical risk with both extremely frequent occurrences and critical time impact. This decreased to a minor risk between 2012 and 2014, likely due to the implementation of the TOS NAVIS system and updates to the system (Julius, 2015).



Frequency of Port Congestion

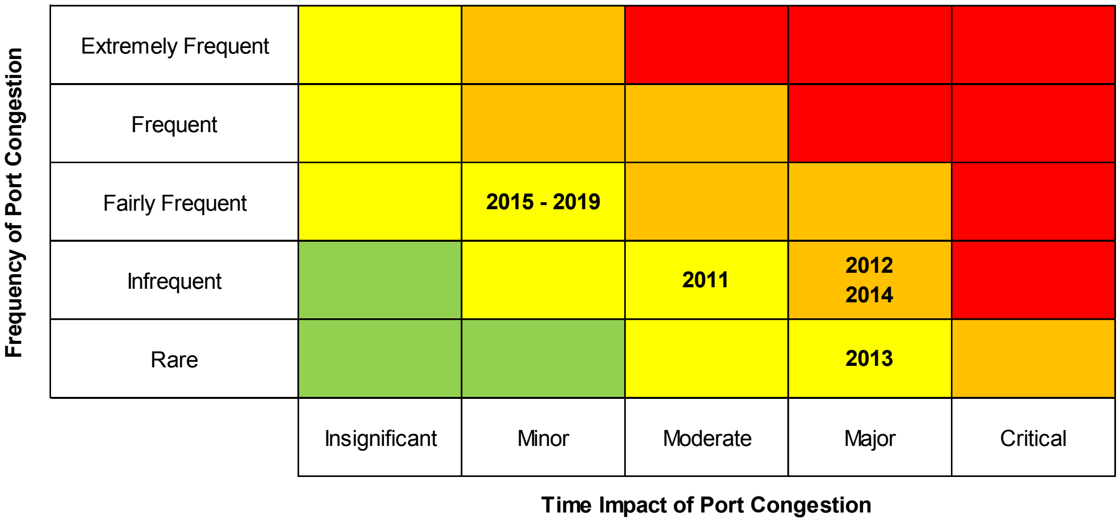
Extremely Frequent	🟨 **2017**	🟧	🟥 **2016**	🟥	🟥 **2011**
Frequent	🟨	🟧	🟧	🟥	🟥
Fairly Frequent	🟨	🟨	🟧	🟧	🟥
Infrequent	🟩	🟨	🟨	🟧	🟥
Rare	🟩 **2012** **2014-2015** **2018-2020**	🟩 **2013**	🟨	🟨	🟧
	Insignificant	Minor	Moderate	Major	Critical

Time Impact of Port Congestion

Figure 8-6: Risk “heat-map” of congestion experienced by container trucks

Port congestion experienced by container trucks is shown to remain a minor risk in 2015, however, it is likely to increase drastically to a critical risk in 2016 with moderate impact and extremely frequent occurrences. In 2017, container trucks are forecast to experience a moderate risk of congestion; however, this is forecasted to significantly decrease from 2018 to 2020 to a minor risk with insignificant impact and rare occurrences.

Weather-related port congestion, as seen in Figure 8-7, was deemed a moderate risk in 2011, which increased to a major risk in 2012 before decreasing to a moderate risk in 2013. The severity of the risk, however, increased again to a major risk in 2014. The forecast results suggest that weather-related port congestion, as a risk to ocean carriers and container trucks, is likely to reduce to a moderate risk over the next five years (2015-2019) with fairly frequent occurrences and minor time impacts.



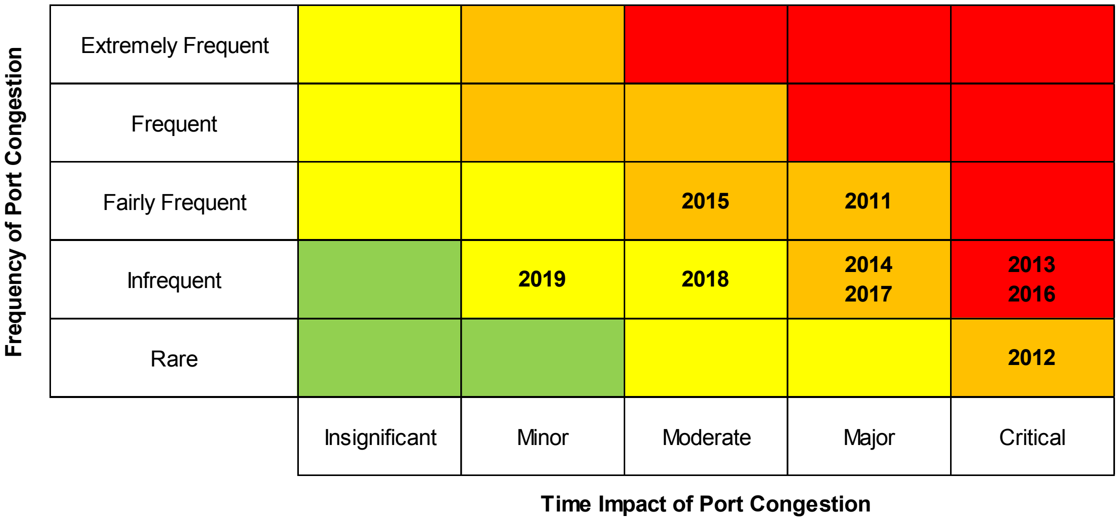
Frequency of Port Congestion

Extremely Frequent	🟨	🟧	🟥	🟥	🟥
Frequent	🟨	🟧	🟧	🟥	🟥
Fairly Frequent	🟨	🟨 **2015 - 2019**	🟧	🟧	🟥
Infrequent	🟩	🟨	🟨 **2011**	🟧 **2012** **2014**	🟥
Rare	🟩	🟩	🟨	🟨 **2013**	🟧
	Insignificant	Minor	Moderate	Major	Critical

Time Impact of Port Congestion

Figure 8-7: Risk “heat-map” of weather-related port congestion experienced by ocean carriers and container trucks

With regards to system-related port congestion, seen in Figure 8-8, the risk to ocean carriers and container trucks was deemed major from 2011 to 2012, and critical in 2013 with infrequent occurrences but critical time impacts.



Frequency of Port Congestion	Insignificant	Minor	Moderate	Major	Critical
Extremely Frequent	🟨	🟧	🟥	🟥	🟥
Frequent	🟨	🟧	🟧	🟥	🟥
Fairly Frequent	🟨	🟨	🟧 **2015**	🟧 **2011**	🟥
Infrequent	🟩	🟨 **2019**	🟨 **2018**	🟧 **2014** **2017**	🟥 **2013** **2016**
Rare	🟩	🟩	🟨	🟨	🟧 **2012**

Figure 8-8: Risk "heat-map" of system-related port congestion experienced by ocean carriers and container trucks

This decreased to major risk between 2014 and 2015. The forecast results suggest that system-related port congestion will likely still be deemed a critical risk in 2016, but will likely decrease to a major risk in 2017 and a moderate risk in 2018 and 2019 with infrequent occurrences and minor to moderate time impacts.

The "heat-maps" presented give a visual representation of the risk severity of weather- and system-related port congestion currently and likely to be experienced by ocean carriers and container trucks in the future. In the following section these "heat-maps", along with the risk severity calculations done in section 8.1.1, are used to develop risk profiles of current and forecasted port congestion within the CTCT.

8.2. Risk Profile and Discussion

The development of risk profiles is intended to assist in managing exposure to risks to prevent loss or minimise negative effects. This subsequently assists companies in business decisions and ventures. It is, however, important that risk profiles consider both the quantitative and the qualitative aspects of a risk; with *quantitative* being the frequency of occurrences and impact, and *qualitative* being the prioritisation of the risk in terms of frequency and impact.

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For the purpose of this study, the bow-tie models, risk severity calculation and “heat-maps” produced were analysed simultaneously to develop the best possible risk profiles of current and future port congestion within the CTCT.

The bow-tie models of maritime-side and landside port congestion offer a glimpse into what triggers port congestion within the CTCT, and what consequences subsequently result if port congestion is not managed. Overall it is noted that, on the maritime-side, ocean carriers often experience time delays or in the worst case, stoppages, due to adverse weather conditions and NAVIS system delays. In addition, container trucks on the landside of the CTCT are often seen to experience time delays and stoppages/queues, which could result in increases in road transport tariffs.

The risk severity calculations done on the different data sets and forecasts were analysed to reveal any specific trends. With regards to vessel anchorage, forecast congestion appeared likely to be more severe than currently experienced. Berthing congestion and offloading/loading congestion displayed a similar trend, with future congestion likely to exceed current congestion.

Truck turnaround time, weather delays and system delays however, displayed an opposite trend, with forecasted congestion exhibiting less severe congestion than currently experienced. Overall the risk severity calculations indicate that in the future ocean carriers are likely to experience more severe port congestion during anchorage, berthing and working than container trucks.

The “heat-maps” developed gave both a quantitative and prioritised view of port congestion experienced by ocean carriers and container trucks. The results of the “heat-map” ranking system for current port congestion are illustrated in Table 8-9, while those for forecasted/future port congestion are shown in Table 8-10. The tables assign individual rankings to each data set analysed/forecasted, as well as port congestion as a whole for each year analysed/forecasted.

Table 8-9 suggests that current port congestion ranged from a ranking of 3, a major risk, from 2011 to 2013, to a ranking of 2, a moderate risk, in 2014. Current available data, which excluded weather and system delays, suggests that for 2015 the risk ranking was 1, a minor risk. This can, however, only be confirmed after considering the forecast risk ranking of all the data sets used for this study.

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Table 8-9: "Heat-map" ranking for current port congestion (2011 – 2014/15)

	2011	**2012**	**2013**	**2014**	**2015**	**Average risk ranking**
VAT	3	3	4	1	1	**2**
VBT	2	3	3	1	2	**3**
VWT	2	3	3	1	1	**2**
TTAT	4	1	1	1	1	**2**
Weather delays	2	3	2	3		**3**
System delays	3	3	4	3		**3**
Average risk ranking	**3**	**3**	**3**	**2**		

Table 8-10, similar to Table 8-9, ranked port congestion as a whole per year, versus per forecast analysed. The table subsequently suggests that port congestion as a whole could be ranked a 2 in 2015 before increasing to a ranking of 3 between 2016 and 2017. In 2018 port congestion is likely to be ranked a 2, which will increase to a ranking of 3 between 2019 and 2020.

Table 8-10: "Heat-map" ranking of future port congestion (2015/16 – 2019/20)

	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**Average risk ranking**
VAT	*1*	1	2	3	4	4	**3**
VBT	*2*	2	2	2	2	2	**2**
VWT	*1*	2	2	2	2	2	**2**
TTAT	*1*	4	2	1	1	1	**2**
Weather delays	2	2	2	2	2		**2**
System delays	3	4	3	2	2		**3**
Average risk ranking	**2**	**3**	**3**	**2**	**3**	**3**	

Based on the "heat-map" ranking tables, two separate risk profiles were developed of current and future port congestion. These risk profiles are illustrated in Table 8-11. Due to the lack of current weather and system delays data for 2015, the year was classified as a forecast year and was computed using forecast and current data. It is, however, important to note that the 2020 prediction does not include weather and system delays, but focuses on the movement of ocean carriers and container trucks in and outside the terminal.

Table 8-11: Risk profiles of current and future port congestion

Current Port Congestion		Future/Forecasted Port Congestion	
Year	**Risk Rating**	**Year**	**Risk Rating**
2011	Major risk	2015	Moderate risk
2012	Major risk	2016	Major risk
2013	Major risk	2017	Major risk
2014	Moderate risk	2018	Moderate risk
		2019	Major risk
		2020	Major risk

The risk profiles illustrated suggest that port congestion should be considered a major risk between 2011 and 2013, before decreasing to a moderate risk in 2014 and 2015. This was forecast to increase again to a major risk in the future (2016 – 2017, and 2019 - 2020), with a lower rank of moderate risk in 2018.

According to the Risk Matrix User's Guide (Engert & Lansdowne, 1999:4), major risks (also known as serious risks) often cause major cost and scheduling increases and should not be ignored in the short-term. These risks results in the fulfilment of only minimum acceptable requirements, while additional customer satisfaction-related requirements are not.

With regards to moderate risks, these often cause moderate cost and scheduling increases and can, unlike major risks, be ignored in the short-term. These risks result in the fulfilment of minimum acceptable requirements and partial fulfilment of additional requirements which increase customer satisfaction (Engert & Lansdowne, 1999:4). Overall, both current (2011-2014) and future (2015-2020) port congestion should be assigned average ranking of major risk. It is, however, important to consider that risk rankings can change at any point, either for the worse or the better. Moderate risks can become major risks, and major risks can become critical risks if not addressed in the long-term. Therefore, it is suggested that port congestion be addressed in the short-term as it can become a more severe risk if mitigation strategies are not implemented in the near future.

8.3. Closing Remarks

The purpose of this chapter was to conduct a risk assessment of weather- and system-related port congestion, and develop risk profiles of current and forecasted congestion experienced by ocean carriers and container trucks within the CTCT. This was done through the use of a number of models and calculations.

The *risk quantification and prioritisation* stage of the risk assessment made use of bow-tie models and risk severity calculations to give both a qualitative and a quantitative overview of port congestion risk. The maritime-side bow-tie model suggested that ocean carriers experience port congestion due to adverse weather conditions, system “down-time” and equipment “down-time”. The landside bow-tie model, however, suggested that container trucks are more likely to experience port congestion due to increasing traffic, systems “down-time” and stringent protocols.

The risk severity calculations conducted suggested that forecasted port congestion (2016 to 2020) for ocean carriers is significantly more severe than currently recorded for 2011 to 2015. Container truck, weather- and system-related congestion displayed an opposite trend, with current congestion being more severe than forecasted for the future. However, to determine what risk rating to give port congestion, a risk severity key and risk prioritisation tables were required.

The risk prioritisation tables developed were subsequently used to develop risk “heat-maps” for each data set/forecast of port congestion. Overall, the “heat-maps” suggested that both current and future port congestion ranged between all the risk rankings, namely, minor, moderate, major and critical. To develop more accurate risk profiles of current and future port congestion, a “heat-map” coding system was developed.

The “heat-map” coding system allowed for overall port congestion to be assigned a risk ranking per year, and per data set/forecast. The results of the “heat-map” risk profiles suggested that both current and forecasted port congestion should be assigned a risk rating of between two and three, or moderate to major risk. This implies that, should conditions remain constant, both current and future port congestion result in moderate to major cost increases and time delays to ocean carriers and container trucks within the CTCT. This could have major impacts on the efficiency of both port management and shipping companies. It is, however, important to note that conditions within the port are likely to change over the next five years which suggests that the various elements of port congestion could change. The implications of the port congestion risk profiles, and recommendations for further research, are discussed in the final chapter of this thesis.

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Chapter 9: Conclusions, Implications and Recommendations

The final chapter of this thesis concludes this research study with the fulfilment of the research problem and the finding of implications and recommendations of the study. The primary purpose of this study was to assess the degree of risk experienced by ocean carriers and container trucks within the CTCT due to weather- and system-related port congestion. The findings of the research, briefly outlined and discussed in section 9.1 and 9.2, resulted in a number of implications of the study and areas where further research is possible. These implications are discussed in section 9.3.

In addition to the implications of the study, recommendations for both the Port of Cape Town, and shipping companies operating through the CTCT are revealed. These recommendations are similarly discussed in section 9.3. The secondary purpose of this chapter is to develop a risk profile template of port congestion, which can potentially be applied at other South African ports suffering from congestion related inefficiencies. This is addressed in sections 9.2 and 9.3. The chapter closes with final closing remarks regarding the purpose of the study and the final conclusions of the research.

9.1. Summary of Findings

The primary findings of this study centred on both the current port congestion situation within the CTCT, as well as the future congestion situation forecasted to occur. These results pertained to the frequency and scheduling impact of congestion, and are briefly outlined in the following subsections.

9.1.1. Current Port Congestion

Current port congestion was analysed using six data sets, which represented weather- and system-related port congestion experienced by ocean carriers inside and outside the port, and container trucks inside the terminal. The results suggest that ocean carriers currently experience decreasing congestion during anchorage outside the port with both the frequency of occurrences and the amount of scheduling delays decreasing over time.

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It was determined that, on average, 36.48% of vessels experience an average of 12 hours, 48 minutes delay during anchorage (2011-2015). The likely cause of these results stem from a number of factors, such as, delayed arrival of stevedores, discharge of transhipments meant for Durban or Namibia, as well as the availability of tug boats from TNPA.

Similarly, the results indicate that ocean carriers currently experience fluctuating congestion levels during berthing and offloading/loading within the CTCT. It was determined that, on average, 17.15% of vessel experience 5 hours, 33 minutes of delays during berthing (2011-2015). While the results show that, on average, 18.82% of vessels experience 6 hours, 3 minutes delays during the working phase of berthing (offloading/loading) between 2011 and 2015. Delays to berthing and offloading/loading of containers generally stem from the availability and productivity of tug boats from TNPA, the productivity of the operations teams of the terminal, as well as expansion plans implemented over the past five years.

Container trucks, according to the results, currently experience decreasing levels of port congestion, with the frequency of occurrences and severity of time delays decreasing over time. The results suggest that between 2011 and 2015, an average of 18.33% of trucks experienced 3.56 minutes of delays during offloading/loading of containers in the terminal. This decrease is, however, based on vehicle movement inside the terminal and does not consider vehicle queuing time outside the terminal. The decreasing trend is likely due to the construction of a larger truck staging area as well as improvements in the coordination of vehicles into, inside and out of the terminal.

In addition, the results suggest that neither weather nor system delays are currently increasing or decreasing. The lack of trend in the weather data is likely due to the unpredictability of weather conditions, while fluctuations in system delays is likely due to implementations of and maintenance of the current TOS system. Furthermore, weather delays are shown to be more severe in the summer months (December – February) with both a higher number of occurrences and a greater time impact.

This analysis of historical data pertaining to the current port congestion situation within the CTCT fulfilled the first and second secondary objectives (see section 1.3) of this study.

9.1.2. Forecasted Port Congestion

Similar to current port congestion, forecasted port congestion was analysed using the forecasted results of the six previously mentioned data sets. These results pertained to weather- and system-related port congestion likely to be experienced by ocean carriers and container trucks between 2015 and 2019.

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The forecasted results suggested that ocean carriers are likely to experience increasing port congestion occurrences, with increasing severity during anchorage between 2016 and 2020. Findings indicate that by 2020, vessels are likely to experience anchorage congestion 91.67% of the time with delays of approximately 13 hours. This increasing trend is likely due to increases in expected vessel movement through the port (both cargo and passenger) and increases in expected cargo volumes in the future. Future expansion plans will also likely impact anchorage congestion.

With regards to vessel berthing and working time, the forecast results suggest that both berthing and offloading/loading congestion will remain constant in both the number of occurrences and severity. The constant trends are likely due to fluctuations in container demand as well as the slow expected growth rate for container volumes. Furthermore, peaks in December months are likely due to severe weather conditions.

Container trucks, on the other hand, were forecasted to experience less severe port congestion between 2016 and 2020, with both decreasing frequency of occurrences and decreasing severity. The results suggest that by 2019, zero per cent of container trucks moving through the terminal will experience delays during the offloading/loading of containers. The predicted decrease in likely connected to decreases in vehicle breakdowns, improvements in container stack coordination and improvements in terminal equipment. It is, however, important to note that this prediction is based on limited data and does not consider data pertaining to the impact of vehicle queuing and the 2015 proposed truck ban.

The forecasted weather delays results suggested that while the frequency of port congestion is likely to remain stable in the future, the severity of the scheduling impact is likely to decrease over time. This is likely due to improvements in the management of weather-related challenges as the number of occurrences remains unpredictable in nature. The results pertaining to system delays suggested that system-related port congestion levels are likely to decrease in the future with both fewer occurrences and less severe time delays. This is likely due to improvements in maintenance and upgrades to the current TOS system over time.

This development of five year forecasts and the analysis of the forecasts relating to the future port congestion situation within the CTCT fulfilled the third and fourth secondary objectives (see section 1.3) of this study.

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9.1.3. Port Congestion Risk Profiles

The analysis of the current and forecasted port congestion situation within the CTCT resulted in two risk profiles. These profiles were developed based on bow-tie models, risk severity calculations, and risk “heat-maps”.

The results of these techniques suggested that both current and future port congestion should be ranked as moderate to major risks, with a score of between two and three on the “heat-map” risk profile. This indicates that port congestion experienced by ocean carriers and container trucks should be considered seriously in the short term to prevent increases in congestion occurrences and/or congestion severity in the long term.

This development of the current and future risk profiles of weather- and system-related port congestion within the CTCT fulfilled the fifth secondary objective (see section 1.3) of this study.

9.2. Conclusions

The findings briefly outlined in the previous subsections resulted in a number of conclusions. These conclusions are presented with regards to ocean carriers, container trucks, weather- and system delays, and the overall risk profile of port congestion.

9.2.1. Ship Turnaround Time Conclusions (VAT, VBT and VWT)

The analysis of current port congestion experienced by ocean carriers indicated that congestion is decreasing during anchorage, however, the forecasts predicted that anchorage congestion will likely increase in the future. This includes increasing occurrences of congestion and increasing severity of delays. The risk profile developed of anchorage congestion suggested that the risk will likely be of greater concern in the future than currently experienced, with the frequency of anchorage delays a greater risk than the time impact of the delays. The risk profile subsequently implies that anchorage congestion will increase from a moderate risk to a major risk over the next five years (2016-2020) and require risk mitigation strategies. This increase in risk severity is likely due to the expected growth in vessel volumes, both cargo and passenger, in the future.

With regards to berthing and offloading/loading congestion, ocean carriers currently experience slightly increasing congestion due to expansion made within the terminal over the past five years. The forecasts, however, suggest that in the future berthing and working congestion will likely be more consistent in nature due to fluctuations in the productivity of tug boats, terminal operations teams and due to unpredictable weather conditions. However, findings suggest that only slightly more time delays are likely to be experienced during berthing than during vessel working time, which may imply that berthing procedures may be the cause of congestion experienced by ocean carriers in the future. This is likely connected to the availability of stevedores and the productivity of TNPA tug boats.

In addition, the current and forecast data indicate that current peaks in October months of the vessel data are not linked to severe weather conditions, but rather due to the late arrival of stevedores and a peak in transhipment containers discharged in Cape Town, but destined for either Durban or Namibia. These October peaks are predicted to diminish in the future, with December peaks becoming more prevalent. These peaks were shown to be related to weather conditions as the weather delays data indicated similar peaks in weather-related congestion in the future.

The risk profiles developed for vessel berthing and vessel working time indicate that congestion will likely be of greater concern in the future than currently experienced. Both profiles suggest that the time impacts of berthing and working congestion will likely exceed the frequency of occurrences, implying that the management of impact should be the focus rather than the management of occurrences. The findings indicate that both risks should maintain risk ratings of moderate risk.

Overall, with regards to vessel related congestion, the findings of this study indicate that anchorage congestion will become a greater risk, as a major risk, than berthing and working congestion, as moderate risks. Furthermore, the findings suggest that the frequency of anchorage congestion is the main concern, while the main concern of berthing and working congestion is the time impact.

9.2.2. Truck Turnaround Time Conclusions

The analysis of the truck turnaround time data set indicates that container trucks are currently experiencing decreasing congestion, both in the number of occurrences and in congestion severity. This downward trend is likely due to the 2011 construction of a five lane staging area that likely resulted in less congestion within the terminal.

The forecast of vehicle related congestion supports the current downward trend, indicating that truck turnaround time will likely decrease to the minimum turnaround time of approximately five minutes. This forecast is, however, based on the assumption that conditions within the terminal will remain constant and is, furthermore, based on limited data not pertaining to vehicle queuing and the 2015 proposed truck ban.

The risk profile developed for vehicle related congestion similarly indicates that landside congestion will likely be of a lessor concern in the future than currently, with the frequency of occurrences likely to exceed impacts in severity. The risk is, however, predicted to remain a moderate risk to terminal efficiency. This risk profile based on the forecast should, however, be exclusively considered with regards to vehicle congestion inside the terminal. The risk rating associated with vehicle queuing congestion and the impact of the 2015 proposed truck ban should be determined to shed more light on landside congestion.

9.2.3. Weather Delays and System Delays Conclusions

The findings of this study indicate that, currently, neither weather nor system delays exhibit upward or downward trends. This suggests that delays experienced due to weather conditions, and/or system-related challenges, have been relatively consistent between 2011 and 2014. This consistent trend is likely due to the unpredictable nature of weather conditions, thus resulting in unpredictable occurrences and impact, as well as the constant maintenance and upgrading done to the current TOS system.

Furthermore, findings indicate that summer months experience higher occurrences of more severe port congestion than winter months both currently and in the future. This is likely due to high wind speeds produced by the South-South Easterly (“Cape Doctor”), which causes equipment shutdowns and prevents vessels from entering the port safely.

The forecast predicted for weather delays suggests that weather-related challenges will likely remain consistent for the next five years (2015-2019), with the impact of delays becoming less over time. This implies that while the frequency of weather delays will remain unpredictable and thus fluctuate over time, the time impact of the delays will lessen. This is likely due to improvements in the management of weather-related challenges with regards to vessel and vehicle movements and equipment operations. In addition, improvements in collaboration, coordination and communication between TNPA, TPT, shipping companies and trucking companies would likely minimise the impact of delays.

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In contrast to the weather delays forecast, the forecast predicted for system delays suggests that system-related challenges within the CTCT will likely decrease over the next five years. This decreasing trend is, however, related to the time impact of delays rather than the frequency of the system delays, which is forecast to remain relatively constant. This forecast is under the assumption that, provided the current TOS continues to perform adequately and does not require replacement in the future, the system will decrease time delays over time. It is, however, likely that an improved TOS will be implemented in the next five years, thus suggesting that the impact of system delays will likely fluctuate rather than decrease.

The subsequent risk profiles developed of weather delays and system delays indicate that, currently, weather- and system-related challenges are of greater concern than predicted over the next five years. Weather delays are predicted to decrease from a major risk to a moderate risk, while system delays are predicted to remain a major risk despite the forecast suggesting the risk be less severe than currently experienced. With regards to weather delays, the frequency of delays is predicted to be of greater risk than the impact. The unpredictable nature of weather conditions makes the management of occurrences impossible. The time impact of weather delays can, however, be adequately managed. The risk profile of weather delays therefore suggests that due to the predicted decreases in time impact, the risk can be considered a moderate rather than a major risk.

The system delays risk profile indicates that the impact of delays will likely be of greater concern than the frequency of occurrences. However, if the decreasing trend indicated in the findings persists, the impact of system delays will likely become a lessor concern than the frequency of occurrences. The likelihood of the current TOS system being replaced or upgraded is, however, relatively high suggesting that the risk rating of system-related challenges remain a major risk.

9.2.4. Port Congestion Risk Profile Conclusions

The risk profiles developed suggest that both current and future congestion be ranked as moderate to major risks. The years 2011 to 2013 were assigned major risk rankings, the years 2014 and 2015 were assigned moderate risk rankings, the years 2016 to 2017 will likely be assigned major risk rankings, 2018 will be assigned a moderate risk ranking, while 2019 to 2020 will likely be assigned rankings of major risk. It was concluded that both current and future port congestion be assigned an average risk ranking of major risk.

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The risk profiles imply that, should conditions within the terminal remain constant, both current and future port congestion should be considered major risks to operational efficiency as they result in major cost increases and time delays. It is, however, important to note that conditions within the terminal are likely to change over the next five years. The possible implementation of the 2015 proposed truck ban would likely cause significant increases in landside congestion as truck turnaround time inside the terminal and vehicle queuing outside the port will likely experience additional delays and challenges. In addition, the proposed construction of a passenger terminal inside the Duncan Dock of the port will likely impact vessel movement into, inside and out of the port as the number of cruise ships entering the port increase in the future. This will specifically impact vessel anchorage congestion unless improvements are made in the management of vessel scheduling. This suggests that port congestion may increase to a critical risk if not managed adequately in the future.

Further conclusions which can be drawn from this study pertain to maritime-side versus landside port congestion, and weather- and system-related port congestion. The risk "heat-map" ranking tables illustrate that currently, weather- and system-related port congestion are of greater concern, with major risk rankings, than congestion relating to vessel and vehicle movement (moderate risk rankings). However, the forecast risk rankings indicate that vessel anchorage congestion will likely increase to a major risk ranking between 2016 and 2020, while weather delays will likely decrease to a moderate risk ranking between 2015 and 2019. This suggests that in the future, ocean carriers are likely to experience more port congestion than container trucks, specifically during anchorage outside the port. This is likely due to the increases in cargo and vessel volumes expected to move through the Port of Cape Town in the future.

Finally, the secondary purpose of this chapter is to suggest a basic risk profile template for port congestion which could potentially be applied to other South African ports. The methodology used to develop the risk profiles for the CTCT was concluded to be sufficiently simple to be applied to other ports using data pertaining to the specific port.

The findings and conclusions of this study resulted in several implications of the research, which lead to suggestions for further research, and recommendations for the Port of Cape Town, TNPA and the shipping industry as a whole.

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9.3. Implications and Recommendations

This section discusses the implications, along with the corresponding recommendations, of this research study.

- ***Implication 1:***

The results of this study suggest that ocean carriers are likely to experience increasing congestion during anchorage in the future, despite the historical data illustrating a downward trend. This implies that with regards to maritime-side port congestion, vessel anchorage should be a larger concern than vessel berthing and the offloading/loading of containers. The forecast illustrated that both the percentage of anchorage congestion occurrences as well as the severity of time delays are likely to increase in the future.

The likely increase in anchorage congestion in the future will most likely be due to severe weather delays, inefficient port processes and procedures, and expected increases in cargo and vessel volumes through the port. It is, however, important to note that the forecast results indicate that weather delays will remain constant in the future, which implies that inefficiencies in the port, and increases in cargo and vessel volumes is more likely the cause of increasing anchorage congestion as vessels struggle to enter the port on time.

- ***Recommendation 1:***

With ocean carriers forecast to experience increasing anchorage related port congestion over the next five years, it is vital that TNPA, TPT and impacted shipping companies collaborate to develop viable management solutions. Viable management and risk mitigation solutions will assist in minimising time wasted anchored outside the port, and reduce the risk of anchorage congestion in the long-term. These solutions can relate to improved productivity and availability of TNPA tug boats, and improvements in the scheduling of vessels into and out of the port. It is recommended that TPT and shippers improve the coordination of vessel entry/exit to attempt to decrease the amount of time vessels are required to anchor outside the port. This should include the coordination of vessels from various different shipping companies and the consideration of weather conditions, which may impact safe entry/exit from the port. In addition, collaboration and communication between the different shipping companies is vital to ensure that time is not wasted and minimise the time that vessels are idle.

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- *Implication 2:*

In addition to the vessel anchorage implication, vessel berthing and working time should be considered when analysing port congestion within the CTCT. The overall vessel working time includes the offloading and/or loading of containers from the container stacks onto and off vessels. Vessel berthing time includes this working time, as well as the time taken from entering the port to being secured in a berth, to exiting a berth and finally exiting the port. The findings of this study indicate that berthing and working time of vessels will likely remain constant in the future with a slight increase in certain areas. The most prominent finding illustrated that vessels experience the majority of congestion inside the terminal during the offloading/loading of containers, opposed to the physical berthing of the vessel. This included more occurrences and more severe time delays during offloading/loading.

The risk profiles of the two variables indicated that the impact of the risks are of greater concern than the frequency of occurrences, suggesting that attention should be paid to reducing time delays during berthing and offloading/loading of containers. It was concluded that the main cause for time delays during berthing stemmed from the availability and productivity of tug boats, while time delays during offloading/loading are likely caused by the delayed arrival of stevedores and a lack of coordination of the terminal operations teams during discharging of containers.

- *Recommendation 2:*

The recommendations for this implication are similar to those for increasing vessel anchorage congestion discussed in the first implication. The simplest solution for inefficient offloading/loading of containers would include the collaboration of TNPA and TPT in facilitating the implementation of more stringent protocols with regards to the process of offloading and/or loading of containers. This should include ensuring equipment operators are both skilled and experienced in efficiently and effectively completing crane movements as well as the adequate maintenance of terminal equipment.

In addition, it can be recommended that shipping companies assist in the facilitation of efficient and effective offloading by ensuring vessels are correctly loaded at the port of origin. This will in turn assist terminal staff in the quick and accurate offloading of containers. Furthermore, shipping companies can assist in optimising loading by supplying correct documentation of loading plans to terminal staff.

- *Implication 3:*

In contrast with vessel-related congestion, the findings suggest that vehicle-related congestion (landside congestion) will likely decrease in the future, with both decreasing occurrences and decreasing severity of congestion. However, it is important to note that the data recorded and forecasted did not take into account the time taken for containers being offloaded from vehicles to being delivered to the container stacks and/or plugged into reefer points, as well as the time spent queuing outside the terminal. It is, therefore, possible for truck turnaround time to decrease over time, but not below the minimum time of five minutes as theory and practice decrees. In addition, the average turnaround time acceptable to trucking companies was suggested to be between 30 and 35 minutes, suggesting that the findings of this study in terms of the frequency and impact of delays is less severe than indicated.

However, if the proposed truck ban suggested by the Transport Minister (mentioned in Chapter 5) is implemented in the City of Cape Town, port congestion experienced by container trucks is likely to increase substantially as the number of trucks entering/exiting the port in a given time period increases. This, and the current restricted stack times, will cause bottlenecks at the entrance to the port and with the terminal itself as vehicles attempt to discharge and load containers on time. With the number of trucks inside the port in a given time period increasing, the number of vehicle breakdowns will likely increase due to increased strain on vehicle gearboxes[25].

A further contributing factor, which should be considered when investigating the implications of landside congestion, is the potential construction of the CCT Bellville Container Terminal (BELCON). The construction of this additional container terminal, with its staking capacity of approximately 500 000 TEU's (Richer, 2010:43) would likely impact the amount of vehicle congestion experienced inside and outside the CTCT. According to Richer (2010:44) the construction of the BELCON would remove approximately 400 trucks from Marine Drive and the N1, thus reducing the number of vehicles moving through the port. In addition, BELCON would allow for intermodal transport to and from the port and the Western Cape, which would decrease transport tariffs significantly. This implication addresses the final secondary objective of this study.

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[25] Vehicle gearboxes experience increased strain with the increased "stop-start" movements inside the terminal due to congestion.

- ***Recommendation 3:***

The downward trend illustrated in the truck turnaround time findings suggests that landside congestion is a less concerning risk than vessel related (maritime-side) congestion. However, the exclusion of the time from container-offloading to the container stacks/reefer plug-in, and vehicle queuing outside the terminal, suggests that further research should be conducted prior to making conclusions with regards to container truck congestion.

In addition, if the proposed truck ban is implemented resulting in increased landside congestion, it is important to consider the resulting implications requiring solutions to maintain the current level of productivity within the terminal.

The most important recommendation, should the ban be implemented, is for increased collaboration and coordination between TPT and the various trucking companies to ensure deadlines are met for loading and offloading of containers. This, however, can only be done if TPT implements a number of additional recommendations to offset the shorter operating hours of heavy road trucks.

These recommendations are discussed below and address the final secondary objective of this study in investigating the implications of the 2015 proposed truck ban:

- Increase stacking space to offset the increased volume of containers entering the terminal within the shorter operating hours.
- Extend stack times for container trucks to account for road congestion and queuing, which is likely to occur due to the reduced operating hours.
- Increase container handling equipment and staff to handle the increased volume of containers entering/exiting the terminal.
- Improve the NAVIS system substantially to mitigate system-related time delays, and give truck drivers a better indication of the ideal time to be spent in the terminal.

In addition to the recommendations for TPT, shipping lines are similarly advised to implement certain measures to reduce the impact of the truck ban, should it be implemented. These include increasing storage capacity and working hours of empty container depots.

With regards to the BELCON solution to landside congestion, it is important to consider the level of collaboration, coordination and communication required for success, specifically between TNPA and Transnet Freight Rail (TFR). Furthermore, the cooperation and collaboration of shipping companies and trucking companies would be required for the success of the BELCON as an additional container terminal for the Port of Cape Town.

Lastly, as outlined by Richer (2010:57), BELCON would also require substantial upgrades to equipment, improvements to facilities and the involvement of stakeholders to be successful.

- ***Implication 4:***

Similar to container truck congestion, the results indicated that port congestion resulting from weather conditions may decrease in the future. The risk profiles, mentioned in section 9.2.3, suggest that while system delays will likely remain constant as a major risk, weather delays are forecast to decrease from a major risk to a moderate risk. Due to the unpredictable nature of weather conditions the frequency of occurrences cannot be management, however, the impact can be managed through improvements in equipment and in terminal procedures and processes.

Despite this apparent downward trend in weather delays, it is important to consider that weather patterns are inherently difficult to predict over the short term. Therefore, it can be said that weather delays will likely remain a major risk between 2016 and 2020 to both ocean carriers and container trucks rather than decreasing.

In addition to the severity of weather conditions in the future, it is important to note that conditions within the port can change rapidly and unexpectedly, which subsequently impacts terminal operations. Factors which contribute to port conditions include the productivity and availability of equipment, operations teams, tug boats and stevedores; and adequate collaboration, coordination and communication between TNPA, TPT, shipping companies and trucking companies.

- ***Recommendation 4:***

The questionable reliability of the weather-related congestion risk profile suggests that further research should be conducted using a larger quantity of historical data as well as additional, more detailed, data pertaining to the impact of weather delays on ocean carriers and container trucks. This would require more extensive collaboration and cooperation from entities such as TNPA, TPT and various shipping companies.

With regards to the assumption that weather delays will likely remain a major risk due to the unpredictable nature of weather conditions, and the likelihood of port conditions changing over time, certain recommendations can be made.

The frequency of weather-related port congestion within the CTCT cannot be easily managed as weather conditions are relatively unpredictable. Therefore, recommendations for weather-related congestion pertain rather to the mitigation of the scheduling impact of port congestion.

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The first recommendation is increased collaboration and coordination between TPT and shipping lines, which could allow for improved scheduling of vessels entering/exiting the terminal. This can subsequently reduce waiting time of vessels outside, and inside the terminal. In addition, quicker/clearer communication and information exchange between the terminal and approaching vessels could potentially decrease miscommunications, which could delay vessel entry. This is a vital improvement as even a slight delay or error in communication can result in severe vessel delays due to rapidly changing weather conditions.

An additional recommendation for TPT includes improving coordination within terminal operations, which could decrease the impact of time delays. Improved operations could result in faster, more accurate movements of containers onto and off vessels, which could decrease the amount of time spent in port. Furthermore, expert training of terminal equipment operators could allow for longer productive periods, as operators would be skilled in knowing when to push for a deadline, and when to halt operations for safety reasons. This is specific to the operation of equipment under high wind speeds and thick fog.

Lastly, a possible solution to weather-related port congestion would entail either the upgrading of terminal equipment to handle higher wind speeds, or the reconfiguration of and/or expansion of the terminal stacks to allow for faster movement of containers between the stacks and the vessels. This would, however, require further research as it would require extensive financial investments.

In addition to the weather-related port congestion implication, the risk profile findings suggest that system delays will likely remain a major risk in the future. This suggests that terminal systems are currently not performing to standard and will either remain below standard, or worsen over time.

Another potential cause for the high risk ranking may be the coding system created and implemented to develop the risk profile of system delays. The coding system, which was developed using expert knowledge and perceptions of the severity of system delays, could be considered as stricter than the other coding systems created. The strictness of the coding system was created under the assumption that once a correct TOS system is implemented in a terminal; any errors should be minimal. Therefore, system delays were coded more strictly than weather delays, ocean carrier related delays and container trucks related delays.

Regardless of the strictness of the coding system, the high risk ranking of system delays required the consideration of TPT and NAVIS system staff to reduce current delays and subsequently reduce the overall risk ranking of system delays within the CTCT.

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- ***Implication 5:***

The port congestion risk profiles, discussed in the previous section, implied that both current and forecast port congestion within the CTCT be classified, on average, as a major risk. This was under the assumption that conditions within the port remain constant, which is unlikely.

Research and interviews conducted through the course of this study suggest conditions within the Port of Cape Town will likely change in the future. These conditions will likely change over the long term and include:

- Changes in weather conditions due to climate change with regards to rainfall, wind patterns and temperature changes;
- increase in the number of vessels moving through the port due to increases in import/exports and passenger cruises;
- potential outdating of the current TOS system requiring upgrades and maintenance;
- the potential implementation of the truck ban, resulting in a higher number of trucks entering/exiting the port in a given time period;
- the potential use of the BELCON terminal as an inland port;
- future expansion plans to the container terminal and the construction of a passenger terminal in the Duncan Dock; and
- changes to the infrastructure of the City of Cape Town, which further limit access to the port.

- ***Recommendation 5:***

With regards to the risk profiles of port congestion, it is recommended that action be taken now, before the risk escalates further. This can be done through further research into port congestion within the CTCT and the Port of Cape Town itself. These areas for further research are mentioned under “implication 6”.

In addition, improvements in collaboration and coordination between TNPA, TPT and shipping companies operating through the terminal could assist in minimising the probability of port congestion escalating in the future. However, with so many factors influencing port congestion it is likely that more than collaboration and coordination will be required.

- ***Implication 6:***

The scope of this research study was limited to focus on a number of particular elements. These focus areas are the following:

- Cape Town port, rather than Durban port, which is more widely known to experience port congestion.
- The Cape Town Container Terminal, rather than the Port of Cape Town as a whole or any other terminals.
- Weather- and system-related port congestion, rather than storage and equipment capacity and worker and equipment productivity related port congestion.
- Frequency and scheduling impact of port congestion, rather than the cost implications of port congestion.
- Maritime-side congestion and limited landside congestion, focusing on congestion inside the terminal.

In addition, the methodology of the risk profiles was deemed sufficient for the development of further risk profiles for other South African ports, provided the necessary data is accessible.

- ***Recommendation 6:***

The previously mentioned focus areas of this study lead to the following recommendations for further research:

- Conduct a risk profile of port congestion within the Durban Container Terminal.
- Conduct a risk profile of port congestion for the other Port of Cape Town terminals.
- Conduct a risk profile of capacity and productivity related port congestion, either in the CTCT or the Durban Port container terminal.
- Conduct a cost analysis of port congestion, in either the Port of Cape Town or Durban port, to determine the cost implications of congestion.
- Further research into landside congestion, including congestion inside the terminal (truck turnaround time), outside the terminal (vehicle queuing) and the impact of the 2015 proposed truck ban.

Lastly, the methodology of the risk profiles developed in this study suggests that further risk profiles can potentially be developed for other South African ports, such as Durban, which similarly suffers from port congestion relating to capacity and productivity challenges.

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9.4. Final Closing Remarks

The overall purpose and research problem of this study was to develop basic risk profiles of current and future port congestion within the CTCT. The risk profiles developed focused on weather- and system-related port congestion, and were based on the frequency and scheduling impact of port congestion.

The overall implications of this study suggest that ocean carriers are exposed to the majority of congestion, relating specifically to anchorage time outside the port and working time inside the CTCT. Furthermore, the findings indicated that the frequency of weather delays are likely to remain unpredictable in the future, however, the impact of weather conditions within the Port of Cape Town is likely to decrease in the future due to improvements in the management of weather-related challenges.

This study concludes that vessels will likely experience the majority of congestion and container trucks will likely experience less congestion. This is under the assumption that conditions remain constant within the port and is based on limited data pertaining to congestion within the terminal. It is, therefore, recommended that measures should be taken now to ensure that the frequency and impact of port congestion do not increase to a critical risk. Furthermore, it is important to note that container volumes are likely to fluctuate over time, which will place additional pressure on the operations of the CTCT. Thus, it is vital that time delays to ocean carrier and container truck turnaround times be minimised as much as possible to increase the overall productivity of the CTCT.

In conclusion, it is recommended that further research be conducted on the cost implications of port congestion with regards to the CTCT, to determine whether long-term financial investments should be made. Further research should also be conducted on landside congestion, to include vehicle queuing outside the port and the impact of the 2015 proposed truck ban.

Lastly, it is suggested that a similar study be conducted on capacity and productivity related port congestion within the Durban Port Container Terminal, as exploratory research suggests that this terminal often experiences port congestion issues.

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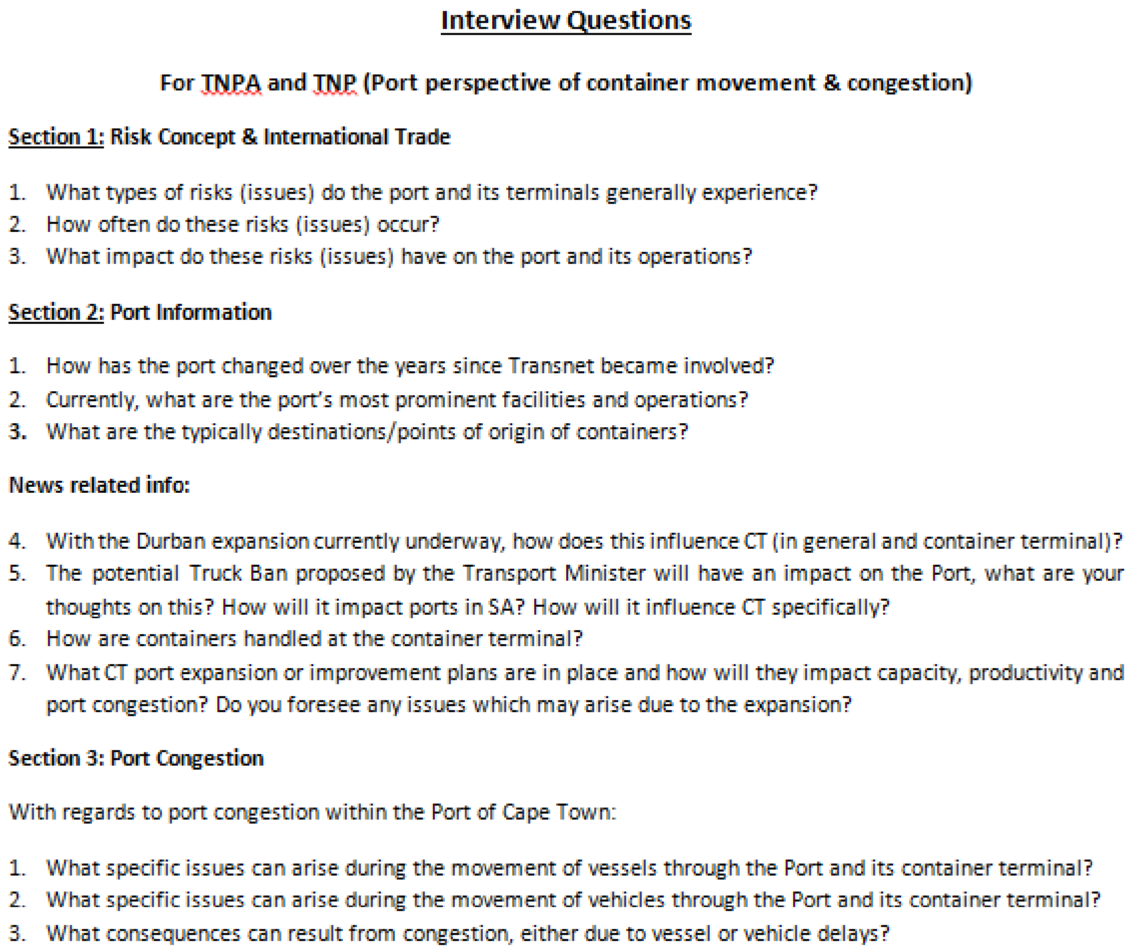
Chapter 11: Addendums

Addendum A: Interview template for port perspective of study



Interview Questions

For TNPA and TNP (Port perspective of container movement & congestion)

Section 1: Risk Concept & International Trade

1. What types of risks (issues) do the port and its terminals generally experience?
2. How often do these risks (issues) occur?
3. What impact do these risks (issues) have on the port and its operations?

Section 2: Port Information

1. How has the port changed over the years since Transnet became involved?
2. Currently, what are the port's most prominent facilities and operations?
3. What are the typically destinations/points of origin of containers?

News related info:

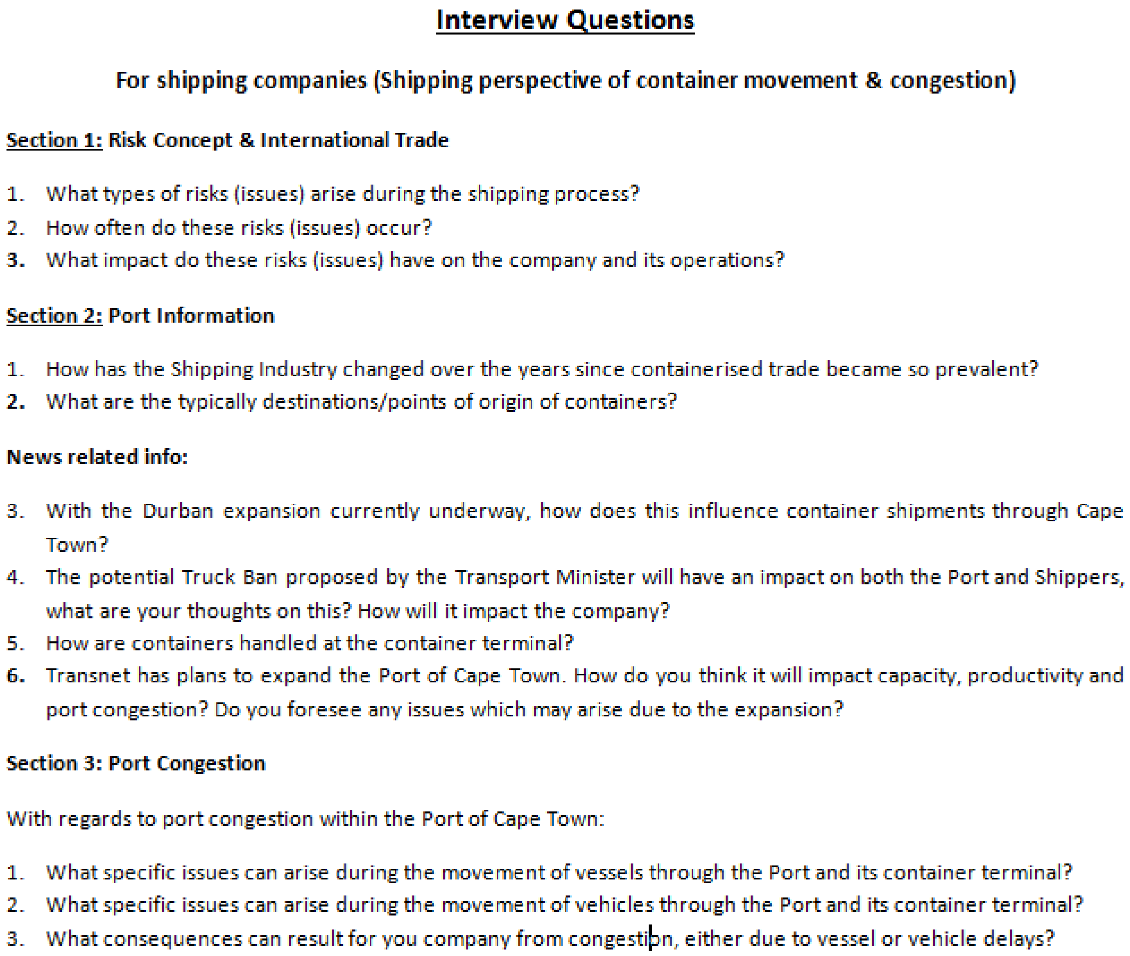
4. With the Durban expansion currently underway, how does this influence CT (in general and container terminal)?
5. The potential Truck Ban proposed by the Transport Minister will have an impact on the Port, what are your thoughts on this? How will it impact ports in SA? How will it influence CT specifically?
6. How are containers handled at the container terminal?
7. What CT port expansion or improvement plans are in place and how will they impact capacity, productivity and port congestion? Do you foresee any issues which may arise due to the expansion?

Section 3: Port Congestion

With regards to port congestion within the Port of Cape Town:

1. What specific issues can arise during the movement of vessels through the Port and its container terminal?
2. What specific issues can arise during the movement of vehicles through the Port and its container terminal?
3. What consequences can result from congestion, either due to vessel or vehicle delays?

Addendum B: Interview template for shipping perspective of study



Interview Questions

For shipping companies (Shipping perspective of container movement & congestion)

Section 1: Risk Concept & International Trade

1. What types of risks (issues) arise during the shipping process?
2. How often do these risks (issues) occur?
3. What impact do these risks (issues) have on the company and its operations?

Section 2: Port Information

1. How has the Shipping Industry changed over the years since containerised trade became so prevalent?
2. What are the typically destinations/points of origin of containers?

News related info:

3. With the Durban expansion currently underway, how does this influence container shipments through Cape Town?
4. The potential Truck Ban proposed by the Transport Minister will have an impact on both the Port and Shippers, what are your thoughts on this? How will it impact the company?
5. How are containers handled at the container terminal?
6. Transnet has plans to expand the Port of Cape Town. How do you think it will impact capacity, productivity and port congestion? Do you foresee any issues which may arise due to the expansion?

Section 3: Port Congestion

With regards to port congestion within the Port of Cape Town:

1. What specific issues can arise during the movement of vessels through the Port and its container terminal?
2. What specific issues can arise during the movement of vehicles through the Port and its container terminal?
3. What consequences can result for you company from congestion, either due to vessel or vehicle delays?

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Addendum C: Ship turnaround time statistics (2011 – 2015)

Time at Anchorage (in hours)

	January	Feburary	March	April	May	June	July	August	September	October	November	December
2011			41:16:00	11:33:01	20:36:56	12:42:05	14:19:25	19:01:17	34:03:40	16:45:57	32:58:00	67:40:45
2012	30:17:59	41:05:44	33:52:26	32:38:47	25:15:37	28:17:43	27:20:33	26:01:16	5:47:14	30:36:54	23:10:31	68:23:05
2013	50:26:19	80:49:39	35:51:45	13:19:01	20:38:01	22:10:19	11:38:36	27:25:01	21:20:04	8:21:32	22:49:24	42:29:01
2014	14:35:32	20:52:16	23:31:44	6:20:01	12:37:41	15:18:50	29:21:40	23:54:36	16:28:58	14:57:53	14:10:58	21:00:20
2015	21:59:03	24:12:53	32:50:59	8:54:55	10:32:00	13:37:31	18:29:40	22:42:31	14:56:52	15:11:48	14:59:25	

Vessel Berthing Time (in hours)

	January	Feburary	March	April	May	June	July	August	September	October	November	December
2011			20:46:00	19:11:24	16:07:51	18:35:22	17:44:27	19:17:09	23:00:53	20:25:58	27:53:40	33:11:10
2012	28:21:18	24:28:40	27:41:28	25:07:53	23:33:00	24:58:22	22:43:13	25:01:54	18:56:54	28:40:20	26:06:44	53:30:26
2013	43:47:14	39:15:00	32:06:00	27:10:06	23:11:52	31:30:01	25:09:29	27:36:29	24:28:26	20:43:20	26:18:28	38:01:00
2014	25:07:19	32:27:07	28:56:23	21:09:40	26:33:01	26:15:24	26:33:57	24:06:31	22:57:46	26:28:13	24:10:07	37:07:05
2015	34:00:37	29:20:18	29:43:11	22:30:24	26:09:43	25:26:58	23:47:33	21:37:59	21:52:46	24:41:59	21:33:29	

Total Working Time (in hours)

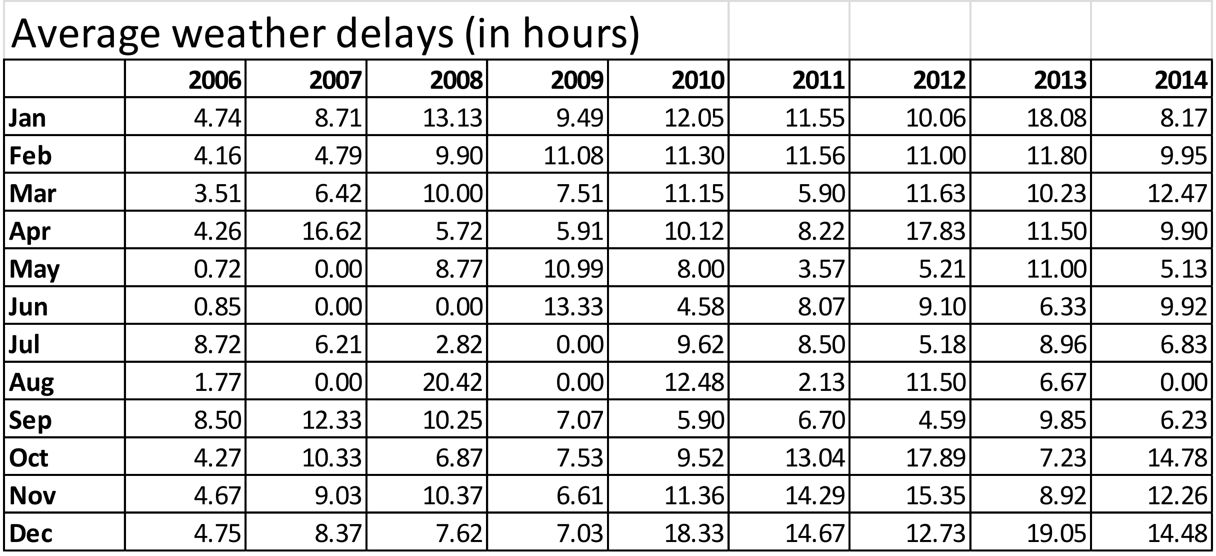
	January	Feburary	March	April	May	June	July	August	September	October	November	December
2011			17:21:54	14:36:42	13:02:49	14:34:31	12:31:53	14:29:40	18:06:43	16:33:05	20:41:17	28:35:33
2012	22:49:49	20:31:24	22:20:38	19:23:35	19:35:25	20:59:48	18:49:13	18:34:59	14:42:20	19:43:14	18:29:08	44:47:06
2013	34:11:47	32:42:01	25:57:25	27:27:03	18:20:31	27:02:08	20:46:10	23:24:18	20:20:39	14:45:51	21:28:39	30:02:05
2014	20:03:58	26:32:35	23:22:30	16:11:25	20:41:00	21:14:45	22:09:02	20:03:27	19:00:11	20:51:50	20:04:24	29:30:10
2015	27:35:41	23:23:22	23:22:16	17:18:22	20:35:11	20:16:25	15:50:15	16:17:02	15:56:07	18:09:22	15:06:13	

Addendum D: Truck turnaround time statistics (2011 – 2015)

Truck Turnaround Time (in minutes)

Year	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
2011	29.00	38.00	33.00	28.00	33.00	32.60	32.60	33.00	31.00	27.00	20.00	23.00
2012	23.00	22.00	20.36	22.36	19.33	20.39	19.99	18.52	17.05	17.70	17.05	22.09
2013	17.25	18.11	14.36	17.72	15.50	15.12	15.43	17.91	18.61	16.60	17.51	23.94
2014	17.89	13.87	19.72	16.00	15.00	18.00	19.00	18.00	18.00	18.00	21.00	18.00
2015	21.78	22.99	13.26	11.71	17.63	20.46	16.06	19.57	12.32	15.50	13.78	

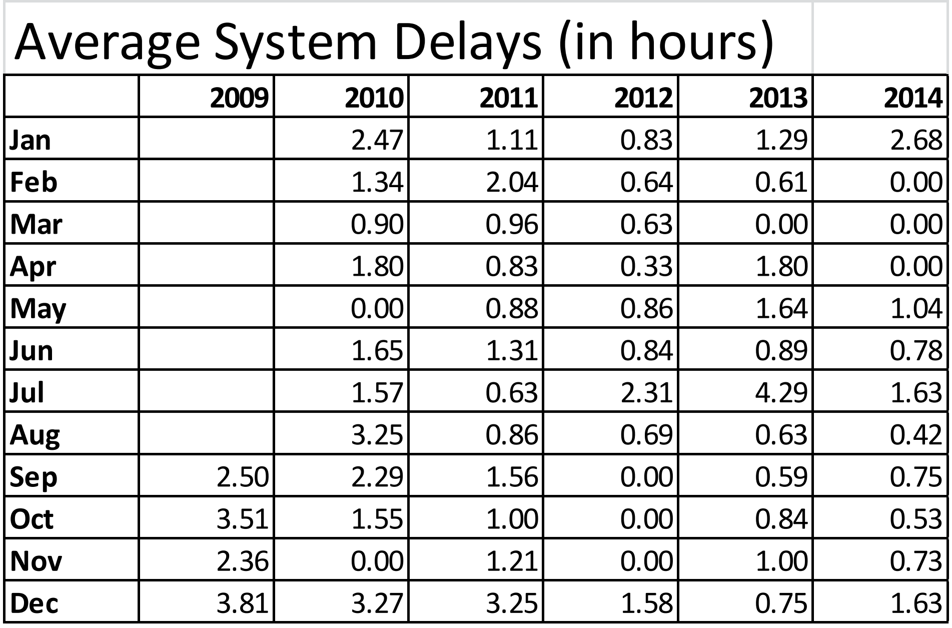
Addendum E: Weather delays statistics (2006 – 2014)



Average weather delays (in hours)

	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	4.74	8.71	13.13	9.49	12.05	11.55	10.06	18.08	8.17
Feb	4.16	4.79	9.90	11.08	11.30	11.56	11.00	11.80	9.95
Mar	3.51	6.42	10.00	7.51	11.15	5.90	11.63	10.23	12.47
Apr	4.26	16.62	5.72	5.91	10.12	8.22	17.83	11.50	9.90
May	0.72	0.00	8.77	10.99	8.00	3.57	5.21	11.00	5.13
Jun	0.85	0.00	0.00	13.33	4.58	8.07	9.10	6.33	9.92
Jul	8.72	6.21	2.82	0.00	9.62	8.50	5.18	8.96	6.83
Aug	1.77	0.00	20.42	0.00	12.48	2.13	11.50	6.67	0.00
Sep	8.50	12.33	10.25	7.07	5.90	6.70	4.59	9.85	6.23
Oct	4.27	10.33	6.87	7.53	9.52	13.04	17.89	7.23	14.78
Nov	4.67	9.03	10.37	6.61	11.36	14.29	15.35	8.92	12.26
Dec	4.75	8.37	7.62	7.03	18.33	14.67	12.73	19.05	14.48

Addendum F: System delays statistics (2009 – 2014)



Average System Delays (in hours)

	2009	2010	2011	2012	2013	2014
Jan		2.47	1.11	0.83	1.29	2.68
Feb		1.34	2.04	0.64	0.61	0.00
Mar		0.90	0.96	0.63	0.00	0.00
Apr		1.80	0.83	0.33	1.80	0.00
May		0.00	0.88	0.86	1.64	1.04
Jun		1.65	1.31	0.84	0.89	0.78
Jul		1.57	0.63	2.31	4.29	1.63
Aug		3.25	0.86	0.69	0.63	0.42
Sep	2.50	2.29	1.56	0.00	0.59	0.75
Oct	3.51	1.55	1.00	0.00	0.84	0.53
Nov	2.36	0.00	1.21	0.00	1.00	0.73
Dec	3.81	3.27	3.25	1.58	0.75	1.63

Addendum G: A comparison of the Holt-Winters Forecast to the observed time series with details about the goodness of the fit for VAT

Dates	Anchorage (hours) - Actual	Anchorage (hours) – Forecast (Holt-Winters)
Jun-11	41.27	*35.72*
Jul-11	11.55	*18.10*
Aug-11	20.62	*22.24*
Sep-11	12.70	*21.90*
Oct-11	14.32	*22.20*
Nov-11	19.02	*25.87*
Dec-11	34.06	*22.74*
Jan-12	16.77	*21.17*
Feb-12	32.97	*27.17*
Mar-12	67.68	*53.13*
Apr-12	30.30	*36.80*
May-12	41.10	*52.18*
Jun-12	33.87	*49.25*
Jul-12	32.65	*19.69*
Aug-12	25.26	*28.51*
Sep-12	28.30	*24.63*
Oct-12	27.34	*26.78*
Nov-12	26.02	*33.39*
Dec-12	5.79	*36.26*
Jan-13	30.62	*24.08*
Feb-13	23.18	*35.79*
Mar-13	68.38	*65.60*
Apr-13	50.44	*38.11*
May-13	80.83	*54.89*
Jun-13	35.86	*53.23*
Jul-13	13.32	*27.28*
Aug-13	20.63	*28.41*
Sep-13	22.17	*25.14*
Oct-13	11.64	*24.77*
Nov-13	27.42	*25.89*
Dec-13	21.33	*21.90*
Jan-14	8.36	*22.02*
Feb-14	22.82	*23.86*
Mar-14	42.48	*48.31*
Apr-14	14.59	*28.10*
May-14	20.87	*35.80*
Jun-14	23.53	*22.96*
Jul-14	6.33	*10.16*
Aug-14	12.63	*10.20*
Sep-14	15.31	*8.67*
Oct-14	29.36	*7.14*
Nov-14	23.91	*11.79*
Dec-14	16.48	*10.55*
Jan-15	14.96	*9.28*
Feb-15	14.18	*14.24*
Mar-15	21.01	*29.63*
Apr-15	21.98	*15.79*
May-15	24.21	*24.02*

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Jun-15	32.85	*20.20*
Jul-15	8.92	*9.40*
Aug-15	10.53	*13.44*
Sep-15	13.63	*14.35*
Oct-15	18.49	*17.66*
Nov-15	22.71	*18.27*
Dec-15	14.95	*14.52*
Jan-16	**15.20**	***12.69***
Feb-16	**14.99**	***16.46***
Mar-16		***31.73***
Apr-16		***21.50***
May-16		***29.05***
Jun-16		***28.80***
Jul-16		***10.72***
Aug-16		***14.69***
Sep-16		***16.93***
Oct-16		***21.69***
Nov-16		***23.67***
Dec-16		***17.41***
Jan-17		***15.87***
Feb-17		***18.61***
Mean Absolute Percentage Error (MAPE)	**41.93%**	
R-Square	**53.89%**	
Mean	**24.78**	
StandardDeviation	**14.89**	

Addendum H: A comparison of the Holt-Winters Forecast to the observed time series with details about the goodness of the fit for the VWT

Dates	**Working Time (hours) - Actual**	**Working Time (hours) – Forecast (Holt-Winters)**
Jun-11	17.36	*18.13*
Jul-11	14.61	*13.32*
Aug-11	13.05	*14.65*
Sep-11	14.58	*14.81*
Oct-11	12.53	*11.06*
Nov-11	14.49	*12.19*
Dec-11	18.11	*12.50*
Jan-12	16.55	*15.52*
Feb-12	20.69	*15.34*
Mar-12	28.59	*31.64*
Apr-12	22.83	*26.16*
May-12	20.52	*22.28*
Jun-12	22.34	*20.37*
Jul-12	19.39	*16.81*
Aug-12	19.59	*18.28*
Sep-12	21.00	*19.68*
Oct-12	18.82	*16.70*

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Nov-12	18.58	*18.17*
Dec-12	14.71	*18.16*
Jan-13	19.72	*17.30*
Feb-13	18.49	*18.14*
Mar-13	44.79	*31.61*
Apr-13	34.20	*32.08*
May-13	32.70	*30.39*
Jun-13	25.96	*30.42*
Jul-13	27.45	*24.56*
Aug-13	18.34	*25.99*
Sep-13	27.04	*24.09*
Oct-13	20.77	*21.80*
Nov-13	23.41	*21.91*
Dec-13	20.34	*21.85*
Jan-14	14.76	*22.40*
Feb-14	21.48	*19.28*
Mar-14	30.03	*34.94*
Apr-14	20.07	*27.45*
May-14	26.54	*22.28*
Jun-14	23.38	*22.24*
Jul-14	16.19	*19.30*
Aug-14	20.68	*17.28*
Sep-14	21.25	*20.70*
Oct-14	22.15	*17.06*
Nov-14	20.06	*19.72*
Dec-14	19.00	*18.88*
Jan-15	20.86	*19.31*
Feb-15	20.07	*20.74*
Mar-15	29.50	*34.51*
Apr-15	27.59	*26.69*
May-15	23.39	*25.94*
Jun-15	23.37	*23.02*
Jul-15	17.31	*19.30*
Aug-15	20.59	*18.45*
Sep-15	20.27	*21.06*
Oct-15	15.84	*17.47*
Nov-15	16.28	*17.09*
Dec-15	15.94	*15.81*
Jan-16	**18.16**	***16.41***
Feb-16	**15.10**	***17.65***
Mar-16		***30.22***
Apr-16		***24.93***
May-16		***23.45***
Jun-16		***21.80***
Jul-16		***17.68***
Aug-16		***18.05***
Sep-16		***19.54***
Oct-16		***16.13***
Nov-16		***16.45***
Dec-16		***15.58***
Jan-17		***16.32***
Feb-17		***16.41***

Mean Absolute Percentage Error (MAPE)	**12.12%**	
R-Square	**63.36%**	
Mean	**21.08**	
Standard Deviation	**5.77**	

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Addendum I: A comparison of the Holt-Winters Forecast to the observed time series with details about the goodness of the fit for the VBT

Dates	Berthing Time (hours) - Actual	Berthing Time (hours) – Forecast (Holt-Winters)
Jun-11	20.77	*22.44*
Jul-11	19.19	*15.97*
Aug-11	16.13	*18.72*
Sep-11	18.59	*18.15*
Oct-11	17.74	*16.14*
Nov-11	19.29	*15.84*
Dec-11	23.01	*16.71*
Jan-12	20.43	*21.18*
Feb-12	27.89	*20.08*
Mar-12	33.19	*38.57*
Apr-12	28.35	*31.55*
May-12	24.48	*26.85*
Jun-12	27.69	*24.94*
Jul-12	25.13	*20.70*
Aug-12	23.55	*23.33*
Sep-12	24.97	*24.16*
Oct-12	22.72	*22.41*
Nov-12	25.03	*21.80*
Dec-12	18.95	*22.88*
Jan-13	28.67	*22.64*
Feb-13	26.11	*25.05*
Mar-13	53.51	*39.57*
Apr-13	43.79	*40.30*
May-13	39.25	*38.28*
Jun-13	32.10	*38.20*
Jul-13	27.17	*30.68*
Aug-13	23.20	*29.78*
Sep-13	31.50	*28.03*
Oct-13	25.16	*27.26*
Nov-13	27.61	*26.01*
Dec-13	24.47	*25.72*
Jan-14	20.72	*27.55*
Feb-14	26.31	*24.44*
Mar-14	38.02	*40.58*
Apr-14	25.12	*33.82*
May-14	32.45	*26.80*
Jun-14	28.94	*27.82*
Jul-14	21.16	*23.38*
Aug-14	26.55	*22.67*
Sep-14	26.26	*26.02*
Oct-14	26.57	*23.42*
Nov-14	24.11	*24.59*
Dec-14	22.96	*23.20*
Jan-15	26.47	*24.85*
Feb-15	24.17	*25.92*
Mar-15	37.12	*40.20*
Apr-15	34.01	*32.61*

May-15	29.34	*30.99*
Jun-15	29.72	*28.70*
Jul-15	22.51	*23.88*
Aug-15	26.16	*24.12*
Sep-15	25.45	*26.38*
Oct-15	23.79	*23.63*
Nov-15	21.63	*23.26*
Dec-15	21.88	*21.45*
Jan-16	**24.70**	***23.55***
Feb-16	**21.56**	***24.10***
Mar-16		***37.94***
Apr-16		***32.00***
May-16		***29.52***
Jun-16		***28.15***
Jul-16		***22.69***
Aug-16		***23.82***
Sep-16		***24.98***
Oct-16		***22.70***
Nov-16		***22.09***
Dec-16		***21.12***
Jan-17		***23.13***
Feb-17		***22.85***
Mean Absolute Percentage Error (MAPE)	**10.66%**	
R-Square	**65.44%**	
Mean	**26.44**	
StandardDeviation	**6.54**	

Addendum J: A comparison of the Holt-Winters method to the observed time series with details about the goodness of the fit for TTAT

Dates	**TTAT (minutes) - Actual**	**TTAT (minutes) Forecast (Holt-Winters)**
Apr-11	29.00	*32.09*
May-11	38.00	*31.54*
Jun-11	33.00	*32.16*
Jul-11	28.00	*31.73*
Aug-11	33.00	*30.39*
Sep-11	32.60	*32.24*
Oct-11	32.60	*31.99*
Nov-11	33.00	*33.06*
Dec-11	31.00	*31.75*
Jan-12	27.00	*31.33*
Feb-12	20.00	*28.42*
Mar-12	23.00	*26.73*
Apr-12	23.00	*23.62*
May-12	22.00	*24.47*
Jun-12	20.36	*21.59*
Jul-12	22.36	*20.08*

Aug-12	19.33	*21.37*
Sep-12	20.39	*20.72*
Oct-12	19.99	*20.14*
Nov-12	18.52	*20.32*
Dec-12	17.05	*18.56*
Jan-13	17.70	*17.42*
Feb-13	17.05	*16.28*
Mar-13	22.09	*17.86*
Apr-13	17.25	*18.44*
May-13	18.11	*18.55*
Jun-13	14.36	*16.89*
Jul-13	17.72	*15.29*
Aug-13	15.50	*16.11*
Sep-13	15.12	*16.05*
Oct-13	15.43	*15.26*
Nov-13	17.91	*15.28*
Dec-13	18.61	*15.44*
Jan-14	16.60	*16.39*
Feb-14	17.51	*15.37*
Mar-14	23.94	*17.83*
Apr-14	17.89	*18.64*
May-14	13.87	*19.11*
Jun-14	19.72	*15.46*
Jul-14	16.00	*17.16*
Aug-14	15.00	*16.30*
Sep-14	18.00	*15.99*
Oct-14	19.00	*16.57*
Nov-14	18.00	*17.91*
Dec-14	18.00	*17.12*
Jan-15	18.00	*16.91*
Feb-15	21.00	*16.47*
Mar-15	18.00	*20.56*
Apr-15	21.78	*17.38*
May-15	22.99	*19.46*
Jun-15	13.26	*20.27*
Jul-15	11.71	*16.98*
Aug-15	17.63	*14.51*
Sep-15	20.46	*16.34*
Oct-15	16.06	*17.86*
Nov-15	19.57	*17.30*
Dec-15	12.32	*17.50*
Jan-16	**15.50**	***14.95***
Feb-16	**13.78**	***14.65***
Mar-16		***15.40***
Apr-16		***14.15***
May-16		***14.21***
Jun-16		***12.88***
Jul-16		***12.50***
Aug-16		***12.89***
Sep-16		***13.36***
Oct-16		***12.73***
Nov-16		***13.07***

Dec-16		***11.89***
Jan-17		***11.91***
Feb-17		***11.33***
Mean Absolute Percentage Error (MAPE)		**12.50%**
R-Square		**72.80%**
Mean		**20.43**
Standard Deviation		**5.92**

Addendum K: Stellenbosch University Ethical Approval Form

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DEPARTMENTAL ETHICS SCREENING COMMITTEE (DESC)

CHECKLIST

To be completed by applicant (researcher)

(Working paper draft of future E-form March 2014)

DEPARTMENTAL ETHICS SCREENING COMMITTEE (DESC) CHECKLIST (DATA COLLECTION)

To be prepared by the researcher (student researcher in consultation with supervisor/promotor) and attached to the actual research proposal, and submitted to your Departmental Chair

Name of researcher:	Ms Lilian Potgieter
Department of Researcher:	Department of Logistics Management
Title of research project:	Risk Profile of Port Congestion within the Cape Town Container Terminal
If a registered SU student, degree programme:	MComm (Logistics Management)
SU staff or student number:	16517997
Supervisor/promoter (if applicable):	Prof Jan Havenga and Dr Leila Goedhals-Gerber

1.	Does the research involve direct interaction with, or data gathering from (this includes completion of surveys) human participants as individuals, members of a group, organisation or institution?	**Yes** **X**	**No**
2.	Does the research involve access to institutional/organisational information that is not in the public domain?	**X**	
3.	Does the research involve accessing information from a database that contains information linked to personal identifiers (Names, ID numbers, student numbers etc.)? OR the database contains coded information but the researcher has access to the code that links the information to identifiers?	**X**	
4.	Does the research involve information that is in the public domain but that could be regarded as sensitive, or potentially sensitive?		**X**

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One or more YES answers? Complete the DESC form and submit it.

Only NO answers? The project probably does not require ethics approval (unless it involves animals, environmental or biosafety issues) and the DESC form does not need to be completed. **Confirm with your supervisor and DESC.**

NB! Please ensure that all required ‘permissions’ are obtained if applicable, before starting the study even if ethics approval is not required.

A. Familiarity with ethical codes of conduct

I have familiarised myself with the Policy for responsible research conduct at Stellenbosch University available at http://www0.sun.ac.za/research/assets/files/Policy_Documents/POLICY%20FOR%20RESPONSIBLE%20RESEARCH%20CONDUCT%20AT%20STELLENBOSCH%20UNIVERSITY.pdf

☒ Yes

☐ No *If no*, do so before proceeding

I have familiarised myself with the professional code(s) of ethics and/or guidelines for ethically responsible research relevant to my field of study

☒ Yes *If yes*, please specify the professional code(s) of ethics and/or guidelines which were consulted:

____

☐ No *If no*, do so before proceeding

Has data collection already commenced?

☐ Yes *If yes*, REC referral is required with an explanation as to why ethics approval is being sought after data collection has commenced.

☒ No

B. Nature of the proposed research

1. Is it linked to or part of a bio-medical research project?

☐ Yes *If yes*, REC referral is required

☒ No

2. A, multi-site international, externally-funded project?

☐ Yes *If yes*, REC referral is required. DESC to decide if other multi-site collaborative projects require review and approval by a full REC. Caution is advised.

☒ No

C. Does the proposed research intentionally involve the collection of data on people in the following categories?

1. Minors

☒ No

☐ Yes *If yes REC referral is required.*

2. People living with, or affected by HIV/AIDS

☒ No

☐ Yes *If yes:* REC referral may be required; DESC to decide, based on whether ethical risk is assessed as medium or high (*see Glossary and Addendum 3 in REC SOP*)

3. Prisoners

☒ No

☐ Yes *If yes:* REC referral is required

4. People living with disabilities

☒ No

☐ Yes *If yes:* REC referral may be required DESC to decide, based on whether ethical risk is assessed as medium or high (see Glossary and Addendum 3 in REC SOP)

5. Other category deemed vulnerable (*see Glossary in REC SOP*)

☒ No

☐ Yes *If yes:* Specify: ____________________

____

REC referral may be required; DESC to decide and motivate its decision based on whether ethical risk is assessed as medium or high (*see Glossary and Addendum 3 in REC SOP*)

6. Stellenbosch University staff, students, or alumni

☒ No

☐ Yes *If yes:* Permission will be required from the Division for Institutional Research and Planning; REC referral may be required: DESC to decide and motivate its decision

D. The proposed research involves processes regarding the selection of subjects/participants in the following categories: (*tick all that apply*)

☐ Subjects/ participants that are subordinate to the person doing the recruitment for the proposed research

☐ Third parties are indirectly involved because of the persons being studied

} REC referral may be required; DESC must assess and advise

(*Examples*: family members of HIV patients; parents or guardians of minors; friends)

F. **Steps to ensure established ethical standards are applied** (*answer regardless of risk assessment*)

1. Has appropriate provision been made for informed consent (either written or oral)?

☐ Yes *If yes*, document clear processes in the research proposal and clear with DESC
☐ No *If no*, attach justification and refer proposal to DESC for further assessment and advice

2. Will subject(s)/participant(s) be informed that they have the right to refuse to answer questions?

☐ Yes *If yes*, document clear processes in the research proposal and clear with DESC
☐ No *If no*, attach justification and refer proposal to DESC for further assessment and advice

3. Will subject(s)/participant(s) be informed that they have the right to withdraw from participation at any time?

☒ Yes *If yes*, document clear processes in the research proposal and clear with DESC
☐ No *If no*, attach justification and refer proposal to DESC for further assessment and advice

4. Will steps be taken to ensure personal data of informants will be secured from improper access?

☒ Yes *If yes*, document clear processes in the research proposal and clear with DESC
☐ No *If no*, attach justification and refer proposal to DESC for further assessment and advice

5. Will confidentiality of data be maintained?

☒ Yes *If yes*, document clear processes in the research proposal and clear with DESC
☐ No *If no*, attach justification or explicitly waiver of confidentiality by subject(s)/participant(s), and refer proposal to DESC for further assessment and advice

6. Will steps be taken to ensure personal data of participants will be secured from improper access?

☒ Yes *If yes*, document clear processes in the research proposal and clear with DESC
☐ No *If no*, attach justification and refer proposal to DESC for further assessment and advice

7. Will research assistants or fieldworkers be used to collect data?

☒ No
☐ Yes *If yes*, will ethics awareness be included in their training?
    ☐ Yes
    ☐ No *If no*, attach justification & refer proposal to DESC for further assessment and advice

8. What is the likelihood that mitigation of risk of harm to participants will be required?

☒ Low
☐ Medium / high *If medium/high*, will appropriate steps (e.g. referral for counselling) be taken?
    ☐ Yes *If yes*, develop and document clear processes in the research proposal and submit to DESC. Where necessary, identify suitable persons or organisations that are able to offer counselling or assistance to subject(s)/participant(s) during or after the research

☐ No *If no*, attach justification & refer proposal to DESC for further assessment and advice

9. Is institutional permission required to gain access to subjects/participants?

☒ No

☐ Yes *If yes*:

Has institutional permission been applied for?

☐ Yes *If yes*: Specify from whom: ____________________

____

Is/Are (a) permission letter(s) available?

☐ Yes *If yes*, submit to DESC

☐ No *If no*, indicate to DESC when it will be expected

☐ No *If no*, develop application for permission, clear with DESC and apply

Does institutional permission pose an obstacle to conduct the research?

☐ Yes *If yes*, refer proposal to DESC for assessment and advice

☒ No

10. Will (an) existing instrument(s) be used to gather data?

☐ No

☒ Yes

If yes, is/are it/they available in the public domain (i.e. without permission)?

☒ Yes

☐ No *If no*, obtain permission to use the instrument(s) and submit letters of permission with the proposal to DESC for assessment and advice

11. Is/are the instruments that will be used to gather data classified by law as psychological tests?

☒ No

☐ Yes

If yes, provide the following details of the person who will administer these tests:

Name: ____________________

Registration number: ____________________

Professional body: ____________________

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13. If unexpected, unsolicited data is revealed during the process of research, will data be kept confidential and only revealed if required by law?

☐ No *If no,* consult on this matter with DESC

☒ Yes

14. If an unexpected emergency situation is revealed during the research, whether it is caused by your research or not, will it immediately be reported to your supervisor/promoter and/or Departmental Chair for further advice?

☐ No *If no,* consult on this matter with DESC

☒ Yes

16. Are you aware of any actual or potential conflict of interest in proceeding with the proposed research?

☒ No

☐ Yes *If yes*: Identify concerns, attach details of steps to manage them, and refer to DESC for assessment and advice

E. Assessment of risk of potential harm as a result of the proposed research
(*see Glossary and Addendum 3 in REC SOP*; *tick only one*)**:**

☐ Minimal
☒ Low
} established ethical standards apply

☐ Medium
☐ High
} REC referral required

DECISION OF DESC

Referral to Research Ethics Committee: Yes / No **(PLEASE INDICATE!)**

[In the case of a referral to the RESEARCH ETHICS COMMITTEE, this checklist and its supporting documentation should be submitted, as well as the full application for ethics review, together with its supporting documentation, avoiding unnecessary duplication of documentation. Also list the ethical risks that are related to the research proposal that is submitted for review, together with the DESC's proposals to avoid or mitigate these ethical risks. Clearly indicate in a note exactly what ethical clearance is requested for.]]

If no referral is required, state any DESC conditions/stipulations subject to which the research may proceed (on separate page if space below is too limited): *[Or stretch table below if required]*

Any ethical issues that need to be highlighted?	**Why are these issues important?**	**What must/could be done to minimize the ethical risk?**

Print name of Departmental Chair	**Signature of Departmental Chair**
Date	

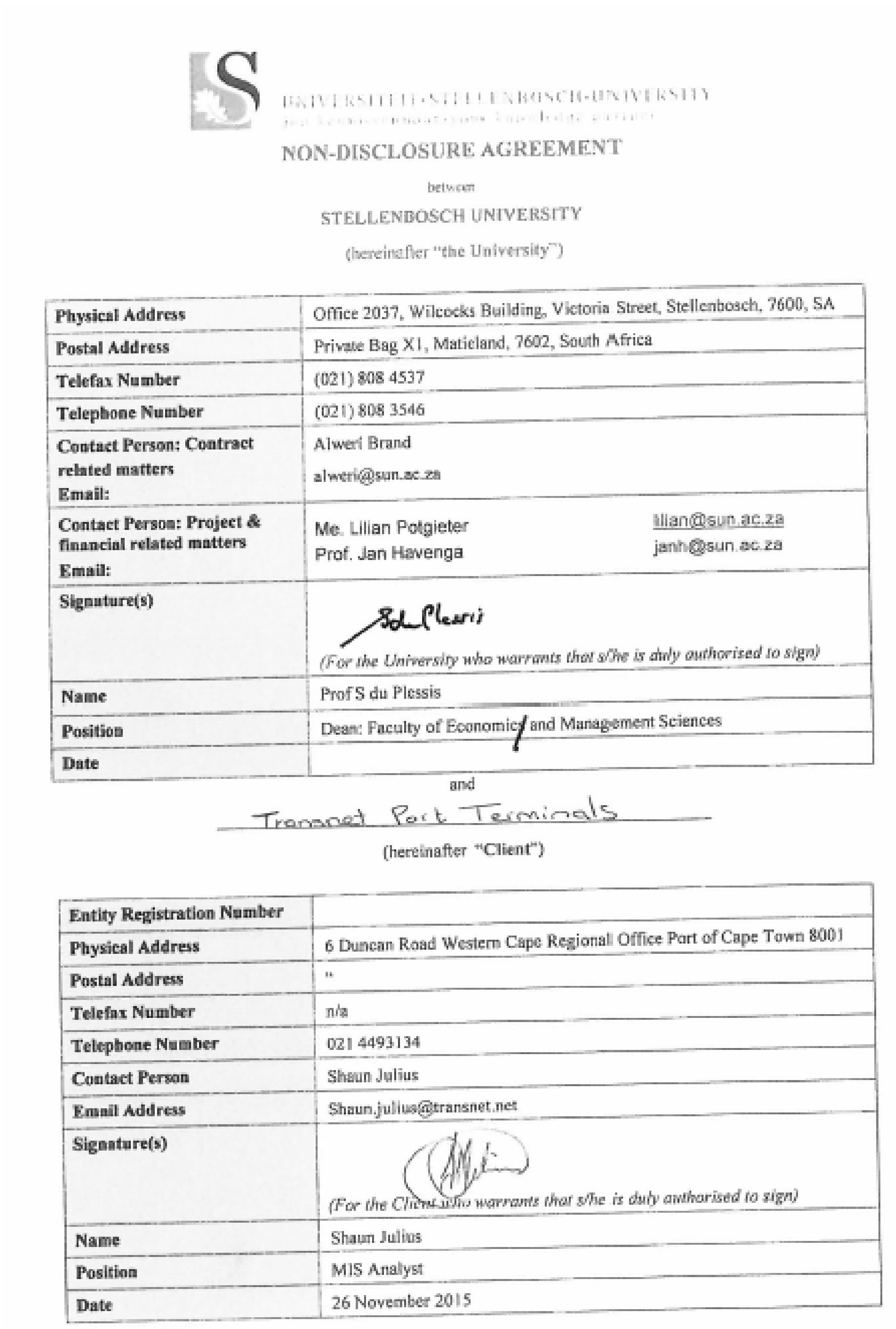
Print name of second member of DESC	**Signature of second member of DESC**
Date	

DOCUMENTS TO BE PROPERLY FILED IN THE DEPARTMENT AND (E-)COPIES OF DESC CHECKLIST SEND TO SU RESEARCH ETHICS COMMITTEE OFFICE. ON RECEIPT OF THIS COPY, THE RESEARCH ETHICS COMMITTEE SECRETARIAT WILL ISSUE A RESEARCH ETHICS COMMITTEE REGISTRATION NUMBER.

Note: Departments are requested to provide staff members and students with a list of professional Code(s) of ethics and guidelines for ethically responsible research relevant to their field of study on which they can indicate by signature that they have familiarised themselves with it. The last item in the list should be the ‘Framework policy for the assurance and promotion of ethically accountable research at Stellenbosch University’.

With thanks to the Department of Sociology and Social Anthropology, Stellenbosch University of the initial concept.

Addendum L: Non-disclosure Agreement between Stellenbosch University and Transnet Port Terminals



UNIVERSITEIT•STELLENBOSCH•UNIVERSITY

NON-DISCLOSURE AGREEMENT

between

STELLENBOSCH UNIVERSITY

(hereinafter "the University")

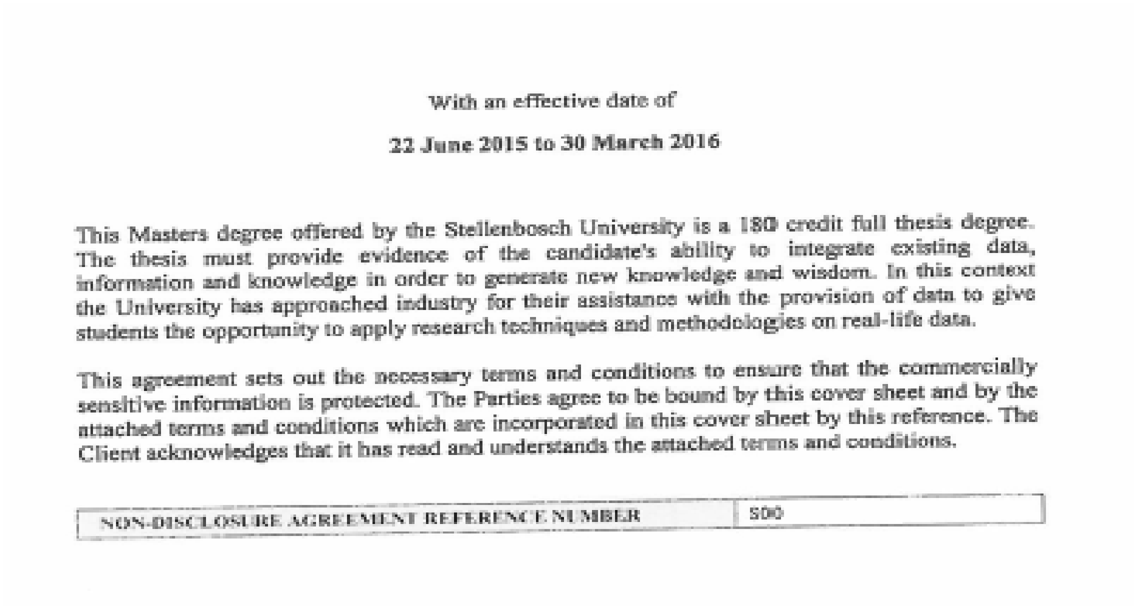
Physical Address	Office 2037, Wilcocks Building, Victoria Street, Stellenbosch, 7600, SA
Postal Address	Private Bag X1, Matieland, 7602, South Africa
Telefax Number	(021) 808 4537
Telephone Number	(021) 808 3546
Contact Person: Contract related matters **Email:**	Alweri Brand alweri@sun.ac.za
Contact Person: Project & financial related matters **Email:**	Me. Lilian Potgieter lilian@sun.ac.za Prof. Jan Havenga janh@sun.ac.za
Signature(s)	S du Plessis *(For the University who warrants that s/he is duly authorised to sign)*
Name	Prof S du Plessis
Position	Dean: Faculty of Economic/ and Management Sciences
Date	

and

Transnet Port Terminals

(hereinafter "Client")

Entity Registration Number	
Physical Address	6 Duncan Road Western Cape Regional Office Port of Cape Town 8001
Postal Address	"
Telefax Number	n/a
Telephone Number	021 4493134
Contact Person	Shaun Julius
Email Address	Shaun.julius@transnet.net
Signature(s)	*(For the Client who warrants that s/he is duly authorised to sign)*
Name	Shaun Julius
Position	MIS Analyst
Date	26 November 2015



With an effective date of

22 June 2015 to 30 March 2016

This Masters degree offered by the Stellenbosch University is a 180 credit full thesis degree. The thesis must provide evidence of the candidate's ability to integrate existing data, information and knowledge in order to generate new knowledge and wisdom. In this context the University has approached industry for their assistance with the provision of data to give students the opportunity to apply research techniques and methodologies on real-life data.

This agreement sets out the necessary terms and conditions to ensure that the commercially sensitive information is protected. The Parties agree to be bound by this cover sheet and by the attached terms and conditions which are incorporated in this cover sheet by this reference. The Client acknowledges that it has read and understands the attached terms and conditions.

NON-DISCLOSURE AGREEMENT REFERENCE NUMBER	500

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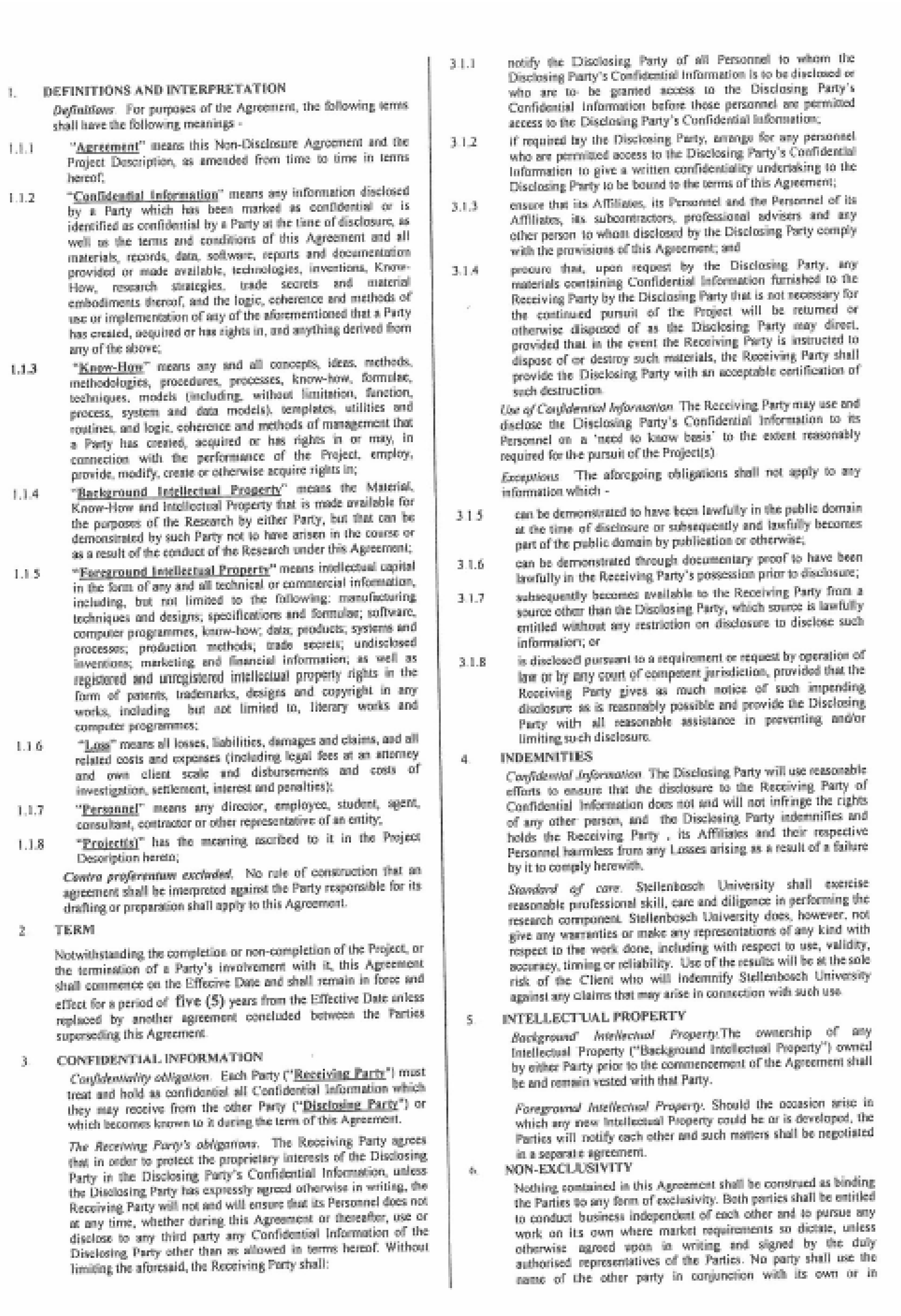

1. DEFINITIONS AND INTERPRETATION

Definitions. For purposes of the Agreement, the following terms shall have the following meanings -

1.1.1 "**Agreement**" means this Non-Disclosure Agreement and the Project Description, as amended from time to time in terms hereof;

1.1.2 "**Confidential Information**" means any information disclosed by a Party which has been marked as confidential or is identified as confidential by a Party at the time of disclosure, as well as the terms and conditions of this Agreement and all materials, records, data, software, reports and documentation provided or made available, technologies, inventions, Know-How, research strategies, trade secrets and material embodiments thereof, and the logic, coherence and methods of use or implementation of any of the aforementioned that a Party has created, acquired or has rights in, and anything derived from any of the above;

1.1.3 "**Know-How**" means any and all concepts, ideas, methods, methodologies, procedures, processes, know-how, formulae, techniques, models (including, without limitation, function, process, system and data models), templates, utilities and routines, and logic, coherence and methods of management that a Party has created, acquired or has rights in or may, in connection with the performance of the Project, employ, provide, modify, create or otherwise acquire rights in;

1.1.4 "**Background Intellectual Property**" means the Material, Know-How and Intellectual Property that is made available for the purposes of the Research by either Party, but that can be demonstrated by such Party not to have arisen in the course or as a result of the conduct of the Research under this Agreement;

1.1.5 "**Foreground Intellectual Property**" means intellectual capital in the form of any and all technical or commercial information, including, but not limited to the following: manufacturing techniques and designs; specifications and formulae; software, computer programmes, know-how; data; products; systems and processes; production methods; trade secrets; undisclosed inventions; marketing and financial information; as well as registered and unregistered intellectual property rights in the form of patents, trademarks, designs and copyright in any works, including but not limited to, literary works and computer programmes;

1.1.6 "**Loss**" means all losses, liabilities, damages and claims, and all related costs and expenses (including legal fees at an attorney and own client scale and disbursements and costs of investigation, settlement, interest and penalties);

1.1.7 "**Personnel**" means any director, employee, student, agent, consultant, contractor or other representative of an entity;

1.1.8 "**Project(s)**" has the meaning ascribed to it in the Project Description hereto;

Contra proferentum excluded. No rule of construction that an agreement shall be interpreted against the Party responsible for its drafting or preparation shall apply to this Agreement.

2 TERM

Notwithstanding the completion or non-completion of the Project, or the termination of a Party's involvement with it, this Agreement shall commence on the Effective Date and shall remain in force and effect for a period of five (5) years from the Effective Date unless replaced by another agreement concluded between the Parties superseding this Agreement.

3 CONFIDENTIAL INFORMATION

Confidentiality obligation. Each Party ("**Receiving Party**") must treat and hold as confidential all Confidential Information which they may receive from the other Party ("**Disclosing Party**") or which becomes known to it during the term of this Agreement.

The Receiving Party's obligations. The Receiving Party agrees that in order to protect the proprietary interests of the Disclosing Party in the Disclosing Party's Confidential Information, unless the Disclosing Party has expressly agreed otherwise in writing, the Receiving Party will not and will ensure that its Personnel does not at any time, whether during this Agreement or thereafter, use or disclose to any third party any Confidential Information of the Disclosing Party other than as allowed in terms hereof. Without limiting the aforesaid, the Receiving Party shall:

3.1.1 notify the Disclosing Party of all Personnel to whom the Disclosing Party's Confidential Information is to be disclosed or who are to be granted access to the Disclosing Party's Confidential Information before those personnel are permitted access to the Disclosing Party's Confidential Information;

3.1.2 if required by the Disclosing Party, arrange for any personnel who are permitted access to the Disclosing Party's Confidential Information to give a written confidentiality undertaking to the Disclosing Party to be bound to the terms of this Agreement;

3.1.3 ensure that its Affiliates, its Personnel and the Personnel of its Affiliates, its subcontractors, professional advisers and any other person to whom disclosed by the Disclosing Party comply with the provisions of this Agreement; and

3.1.4 procure that, upon request by the Disclosing Party, any materials containing Confidential Information furnished to the Receiving Party by the Disclosing Party that is not necessary for the continued pursuit of the Project will be returned or otherwise disposed of as the Disclosing Party may direct, provided that in the event the Receiving Party is instructed to dispose of or destroy such materials, the Receiving Party shall provide the Disclosing Party with an acceptable certification of such destruction.

Use of Confidential Information. The Receiving Party may use and disclose the Disclosing Party's Confidential Information to its Personnel on a 'need to know basis' to the extent reasonably required for the pursuit of the Project(s)

Exceptions. The aforegoing obligations shall not apply to any information which -

3.1.5 can be demonstrated to have been lawfully in the public domain at the time of disclosure or subsequently and lawfully becomes part of the public domain by publication or otherwise;

3.1.6 can be demonstrated through documentary proof to have been lawfully in the Receiving Party's possession prior to disclosure;

3.1.7 subsequently becomes available to the Receiving Party from a source other than the Disclosing Party, which source is lawfully entitled without any restriction on disclosure to disclose such information; or

3.1.8 is disclosed pursuant to a requirement or request by operation of law or by any court of competent jurisdiction, provided that the Receiving Party gives as much notice of such impending disclosure as is reasonably possible and provide the Disclosing Party with all reasonable assistance in preventing and/or limiting such disclosure.

4. INDEMNITIES

Confidential Information. The Disclosing Party will use reasonable efforts to ensure that the disclosure to the Receiving Party of Confidential Information does not and will not infringe the rights of any other person, and the Disclosing Party indemnifies and holds the Receiving Party , its Affiliates and their respective Personnel harmless from any Losses arising as a result of a failure by it to comply herewith.

Standard of care. Stellenbosch University shall exercise reasonable professional skill, care and diligence in performing the research component. Stellenbosch University does, however, not give any warranties or make any representations of any kind with respect to the work done, including with respect to use, validity, accuracy, timing or reliability. Use of the results will be at the sole risk of the Client who will indemnify Stellenbosch University against any claims that may arise in connection with such use.

5. INTELLECTUAL PROPERTY

Background Intellectual Property. The ownership of any Intellectual Property ("Background Intellectual Property") owned by either Party prior to the commencement of the Agreement shall be and remain vested with that Party.

Foreground Intellectual Property. Should the occasion arise in which any new Intellectual Property could be or is developed, the Parties will notify each other and such matters shall be negotiated in a separate agreement.

6. NON-EXCLUSIVITY

Nothing contained in this Agreement shall be construed as binding the Parties to any form of exclusivity. Both parties shall be entitled to conduct business independent of each other and to pursue any work on its own where market requirements so dictate, unless otherwise agreed upon in writing and signed by the duly authorised representatives of the Parties. No party shall use the name of the other party in conjunction with its own or in

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connection with any work otherwise than with the prior written consent of the other party

7. BREACH

If the Receiving Party, or any of its personnel, shall breach any provision of this agreement and fails to remedy such breach within a period of 10 (ten) days after receiving written notice from the Disclosing party,the Disclosing Party shall be entitled to cease negotiations, without prejudice to any other rights or remedies which it may have in law.

8. GENERAL

Entire Agreement. The Agreement constitutes the entire agreement between the Parties in respect of the subject matter thereof and no agreements, representations or warranties between the Parties other than those set out therein are binding on the Parties.

Variation. No amendment or modification to this Agreement shall be effective unless in writing and signed by authorised signatories of both the Parties.

Waiver. No latitude, granting of time or forbearance of a Party hereto regarding the performance of the other Party shall constitute a waiver of any term or condition of this Agreement and no waiver of any breach shall be a waiver of any continuing or subsequent breach. No waiver shall be effective unless it is expressly stated in writing and signed by the Party giving it.

Governing Law and jurisdiction. This Agreement shall be governed and construed according to the laws of the Republic of South Africa and the Parties agree to submit to the non-exclusive jurisdiction of the Cape of Good Hope Provincial Division of the High Court of South Africa.

9. PUBLICATIONS

The Client recognises that under the academic policies of SU, the results of research work must be publishable and agrees that the researchers or students engaged in the Research shall be permitted to present at symposia, national or regional professional meetings and to publish in journals, theses or dissertations, or other methods of reporting of their own choice, methods and results of the Research.

SU may publish or allow the publication of research results or data, on whatever medium, concerning the Research provided that this does not affect the protection of Intellectual Property Rights. The Client shall be given 30 (thirty) days prior written notice of any planned publication. If, before the end of this period, Client so request, a copy of the planned publication shall be provided to Client within 30 (thirty) days after receipt of such request. The Client may require the removal of any or all of its Confidential Information from a planned publication in order to protect its proprietary rights and interests and the Researchers will be required to comply with any such requirement prior to publication. The Client may object to the planned publication within 30 (thirty) days after receipt thereof. The planned publication shall be suspended until the end of this consultation period, not exceeding twelve (12) months. In the absence of any objection within the above-mentioned period, it is deemed that the Client agrees to the publication.

-end-

Addendum M: Current facilities at the Port of Cape Town