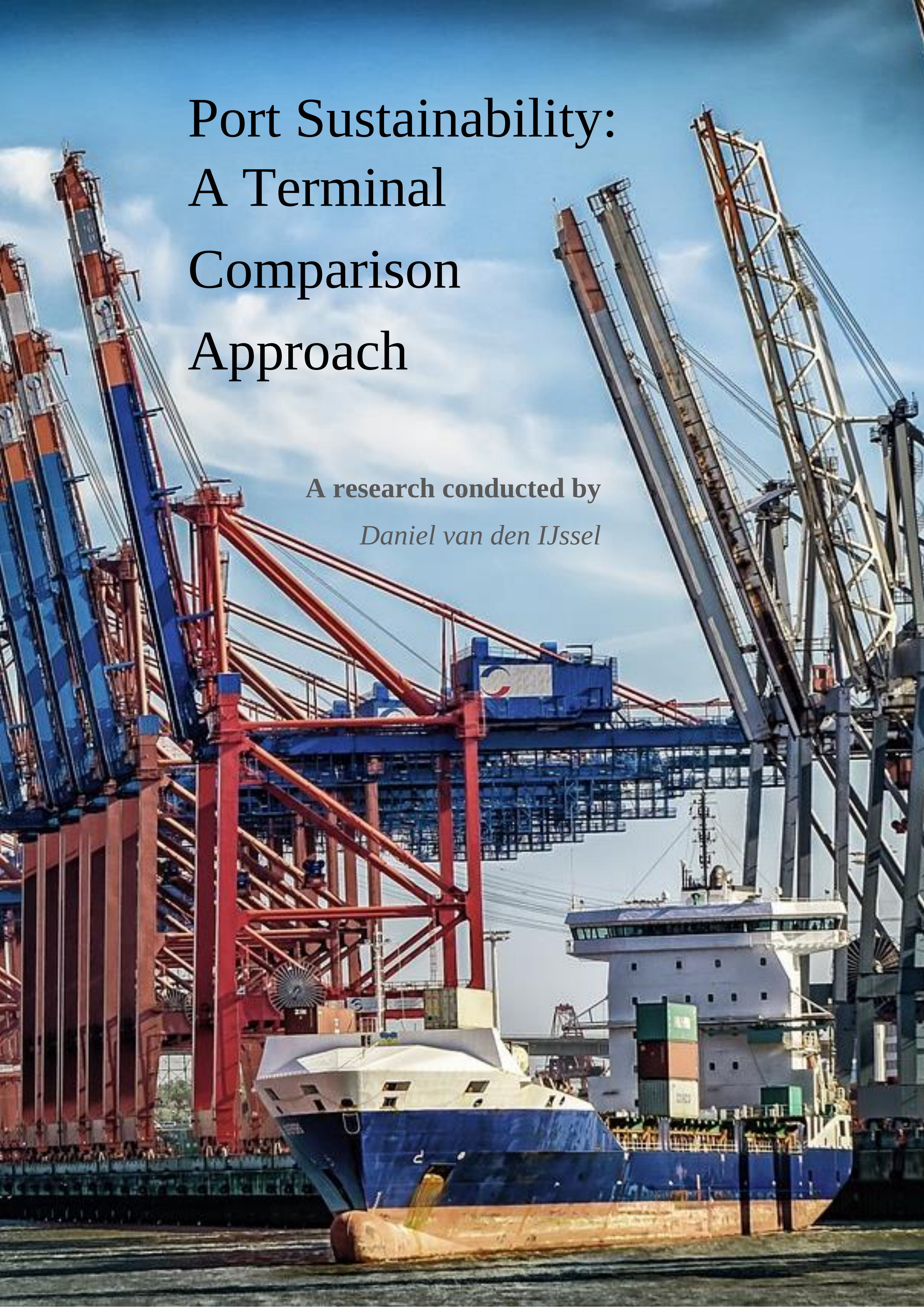
Port Sustainability: A Terminal Comparison Approach

A research conducted by

Daniel van den IJssel



Port Sustainability:
A Terminal Comparison Approach

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D. van den IJssel

Student number: 4626508

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Graduation committee

Chairperson:	*Prof. dr. J.H. Slinger, Section of Policy Analysis*
First Supervisor:	*Prof. dr. J.H. Slinger, Section of Policy Analysis*
Second Supervisor:	*Dr. M.L.C. de Bruijne, Section of Organisation and Governance*
External Supervisor:	*Dr. H.S.I., Vreugdenhil, Deltares*

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Foreword

This thesis manuscript documents the journey undertaken in the past several months for the partial fulfillment of the Engineering and Policy Analysis MSc program at Delft University of Technology, faculty Technology, Policy and Management. The dissertation is an example of a comparative study in the port sector.

This research effort was carried out on behalf of, and as a contribution to, the NWO project 'Integrated and Sustainable Port Development in Africa' (Vellinga, Slinger, Taneja, & Vreugdenhil, 2017); which aim it is to develop an common framework for sustainable port development, viewed from an interdisciplinary, stakeholder inclusive, perspective. This research enforces the understanding of Ports Sustainability, especially viewed from the perspective of one of the two paramount actors involved in port governance, the Terminal Operator. This dissertation could potentially be of interest to a diversity of stakeholders; in order to accommodate for a comprehensive list of potentially interested parties: *port researchers*, *port-based industries*, *harbor authorities*, *terminal operators*, *port-city governance councils*, *coastal managers*, and *sustainability academia* are identified as being problem owners of this research. Despite this vast list of stakeholders, the most prominent group of actors that could benefit from this dissertation are academia. This dissertation provides a framework for the benchmarking of sustainable performance in the context of terminal operators. The study is an initial attempt in this direction and leaves ample space for improvement.

Before one proceeds with reading the research dissertation, I would like to devote some words for the descriptions of some practical matters that will ultimately enhance comprehensibility and the understanding of the reader.

- In this document, the words *variable*, *indicator* and (to a lesser degree) *metric* are used interchangeably. Even though from a performance measurement perspective these words are not substitutable, they converge to a satisfactory degree for the purpose of this study, and hence are regarded as the same. In this manuscript these words refer to: "Instruments which evaluate the positive or negative state of the environment and the consequences of applied measures" (Peris-Mora, Diez Orejas, Subirats, Ibanez, & Alvarez, 2005, p. 1650).
- In this document the words *operator(s)* and *terminal operator(s)* are used interchangeably. They refer to the common entity which is responsible for the provision of logistic services in ports. In some instances, the abbreviation TO [Terminal Operator] is being used throughout the report, also referring to the exact same definition. Other wordings used in literature to indicate the same are *stevedores* or *logistic service providers*. Another term coined in this report is Large Terminal Operator (LTO) or local terminal operator, which indicates a subgroup of the larger group of operators.
- In terms of the economic dimension of sustainability, in the report it is often signified with the word *financial dimension*.
- Throughout the report the three dimensions of sustainability are indicated with a unique color. The red color indicates the financial dimension; the green color indicates the environmental dimensions; and the blue color indicates the social dimension. However, this color palette is not applied in every circumstance.

Acknowledgements

I would like to seize the opportunity to out some final words and to express my thankfulness to some of the people who have helped me through my graduation phase which proved to be a difficult and challenging endeavour.

The last several months of my life have consisted of working my way through materials and documents related to this research effort which I now proudly call my master's thesis. The process of getting to the stage I am right now proved to be a challenging one and can be considered by no means a straight-forward trajectory. I've learned many valuable things, form the content perspective but certainly also about the process of conducting research itself. It has taught me that taming a messy problem, or in EPA terms, a global challenge, isn't easy by any means. It is maybe the most intrinsic lesson that the Engineering and Policy Analysis curriculum has been trying to convey for the last two years. I am delighted to conclude my academic career with this thesis document and look forward to the next phase in life.

First and foremost, I would like to thank my committee members whom have kept fate in a positive outcome despite the difficulty I encountered with taming the problem. Subsequently, my parents continued to support me throughout my entire academic career. Without their love and open-mindedness I certainly wouldn't be in the position I am in right now. Of course, I owe a lot of gratitude to my close friends and relatives, who have cheered me up in times of motivational crisis's and sometimes provided for a critical reflection throughout the process. Lastly, I wouldn't want to finish this document without mentioning some of my fellow Engineering and Policy Analysis graduates, who made academic life in the buildings of the Wijnhaven faculty and Technology Policy and Management faculty much more bearable. Their laughter, support, critique and motivation have certainly made up for a Master's program experience I will remember.

Executive Summary

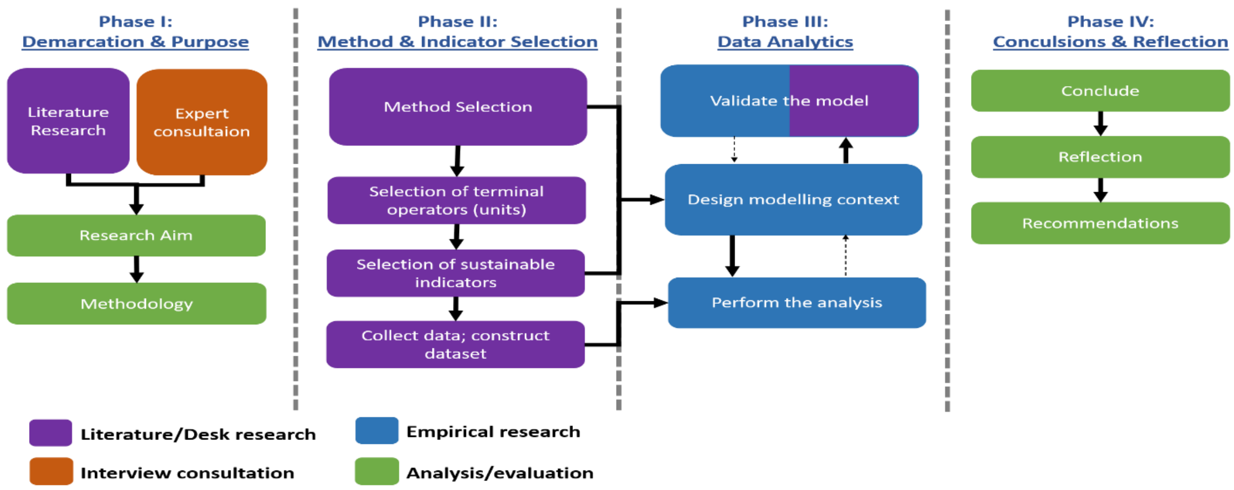
Ports are critical infrastructure for a regions' economy. Due to the rapid expansion of global trade in recent decades and the era of containerized transport, tremendous demands are placed on ports services and infrastructure, intensifying the competitive nature of the port sector. This external change triggered port governance reforms in order to foster efficiency and ports' competitiveness. However, no consensus on the implication of this shift seem to exist in scholarly publications. Furthermore, as ports are increasingly expected to transform their working routines to align with the sustainability paradigm, few researches have scrutinized the implications of port devolutions schemes on a ports' sustainability.

Phase I

This research intends to gain understanding of the notion of port governance and determining how sustainable aspirations of ports could be materialized. This search highlights the significance of terminals in the port governance framework, and its impact on port sustainability. Terminals are regarded as complex logistical cargo nodes within a port territory where cargo is transferred from one mode of transport to another. Whereas the notion of port sustainability is amply debated in academics, little research addresses the sustainability practices of individual actors in the port governance framework. Being the most prominent group of port actors, little is known with regards to how terminals and terminal operators perform when it comes to the sustainability realm. This research presents an effort to address this knowledge vacuum by means of an analysis of sustainable practices of autonomous terminal operators. Comparison and benchmarking have proved to be a valuable tool for decision making, and a quantitate set-up fits the purpose of this study as performance metrics are duly existent. Therefore, this research aims to contribute to the understanding of terminal operators' relative sustainable performance, articulated as follows:

"What insights can be garnered when comparing sustainable practices and performances of terminal operators?"

To provide an answer to the latter question, the research is structured into four phases. These phases are depicted in the diagram presented below. The first phase serves the purpose of creating a problem understanding and definition based on the notion of Ports' sustainability. The second phase serves as the indicator selection phase. Prior to the indicator selection, the comparative analysis methodology utilized in the study is explained alongside the terminal operator units which will be the focus of the research. In the third phase, the comparative analysis is executed, and the results are communicated. The fourth phase articulates the conclusions and findings of this study. Furthermore, in the final phase, a reflection and several implications are stressed.



Phase II
The criterium that is imposed in selecting of terminal operators for analysis was the terminals operator's availability of a sustainability report or the like. Out of the considerable number of terminal operators, only 10 were found eligible on the basis of this criteria. The starting point for the selection of terminal operators is the list issued by the Global Reporting institute which comprises of companies that published a sustainability report.

The indicator selection process is separated into two iteration waves. The first iteration wave encompasses the metrics that are communicated by the various terminal operators via one of the following means: **(1)** Sustainability report/Corporate Social Responsibility reports (all are incorporated); **(2)** Annual reports (only specific financial statistical data); and, **(3)** public statements (mainly throughput figures). The second iteration wave subsequently proceeds with determining the commonality of the various indicators inferred from the first iteration wave. Out of this iteration phase, the following metrics per dimension (financial, environmental and social) are selected for further analysis.

- **Financial dimension:** *Consolidated Throughput*, *Revenue*, and the *FTE*.
- **Environmental dimension:** *Total Electricity Consumption*, *Total GHG Emission* and *Water Consumption*.
- **Social dimension:** *Reported Incidents*, *Gender Diversey* and the *Lost Time Injury Frequency Rate*.

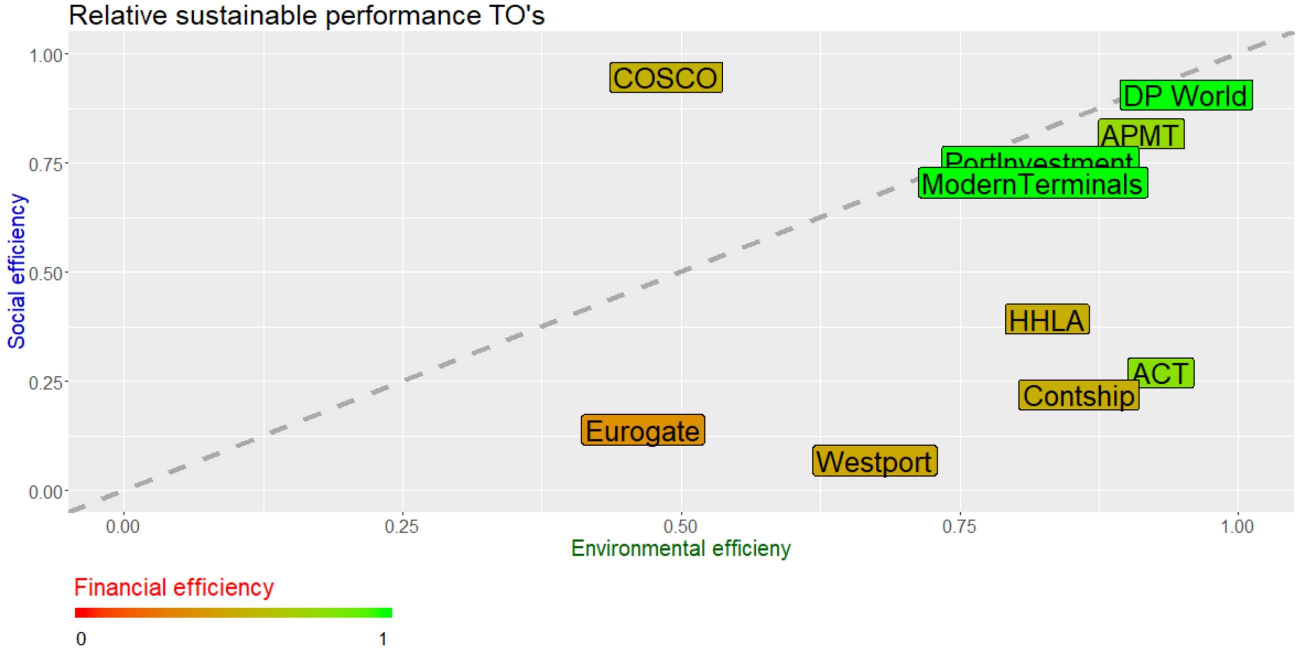
Not all the selected indicators are deemed relevant for the evaluation of their corresponding dimension. Furthermore, the indicators are all categorized as operational performance indicators, representing only operational consequences. This implies that all actions taken in the domain of sustainability not directly impacting the operation, such as management initiatives to support local communities, are disregarded.

Phase III
The data from the publicized reports contains missing data points due to data inconsistency and scarce reporting. Because a complete datasheet is necessary for analysis, the missing data points are interpreted as the means of the indicators relative to their *Consolidated Throughput* share.

The technique that is utilized in this research probe to compare various terminal operators is the Data Envelopment Analysis (DEA) technique. This is a linear programming technique that determines the efficiency of a Decision-Making Unit (DMU) relative to other, homogeneous DMU's. In this study, the DMU's are terminal operating businesses. The DEA algorithm uses input variables and output variables to characterize each of the DMU's. Input variables are typically inputs of a (production) process and outputs are typically what comes out of it. The underlying assumption of DEA, therefore, is that the inputs ought to be minimized and the outputs ought to be maximized. DEAs efficiency scores are normalized values on a fuzzy scale index ranging between 0, indicating inefficient performance, and 1, indicating efficient performance.

The underlying premise of the model is that all the indicators of a particular dimension have an equal weight in determining the overall score of a terminal operator on that sustainable dimension. For this study, an input-oriented DEA model application is chosen based upon the assumption that the negative externalities, perceived as inputs, ought to be minimized. For the environmental and social dimensions, the inputs are composed of the negative factors persisting in these dimensions and the outputs were composed of the (positive) financial indicators and a single positive indicator persistent with the social dimension itself. For the financial dimension the only input factor was *Full-Time Equivalents* and the outputs are comprised of positive financial outputs like *Revenue* and *Consolidated Throughput*. Various model scenarios are identified by means of combining possible input and output combinations amongst all dimensions. The model is built and implemented using the R programming language inside the RStudio environment.

The following figure illustrates the results of the DEA model in one aggregated overview. On the horizontal axis the environmental efficiency is presented; the vertical axis presents the scorings on the social dimension and the color index presents the efficiency on the financial dimension (the more green the label of the operator, the more sustainable it is deemed by the model in financial terms).



Phase IV

The cross-comparisons led to an overall efficiency score for each terminal operator for each of the dimensions (view the image *Relative Sustainable Performance TO's*). It is shown that *DP Word*, *AMPT*, *PortInvesment* and *Modern Terminals* are superior in each of the dimensions of sustainability relative to the other operators. It can be inferred from the image that a linear correlation exists between the three dimensions of sustainability. Furthermore, the global terminal operators included in the sample (*APMT*, *COSCO*, and *DP World*) seem to perform relatively well on all dimension compared to their regional counterparts. This can be owed to the economics of scale benefits prevailing to them, and hence is not particularity surprising.

On a more aggregated level, this study provides for more insightful conclusions. All of the studies terminal operators addressed the notion of sustainability/CSR. The most profound channel they utilize is a section on their websites advocating their sustainability or CSR sympathy. Only 10 of the studied terminal operators have been found that reported on sustainability metrics that were adequate for incorporation in the analysis. However, no coherent set of indicators exists, making a cross-comparison on sustainable performance burdensome. Moreover, the interpretability of the data is often doubtful. (Large) Terminal operators often have such a diverse business portfolio that identifying the actual foundation of a statistic remains a difficult process.

The classified nature of the terminal industry makes it difficult to retrieve raw information anyway other than via their public issues. Efforts into standardization practices of sustainable performance in the industry need to be prioritized before quantitative analysis as a tool can actually be utilized to garner practical insights and implications for the industry.

Table of Contents

List of tables

List of figures

Introduction

Ports are often regarded as critical pieces of infrastructure for a countries' economy (Jung, 2011). Global trade is to a large degree attributable to the existence of maritime infrastructure (with a share of 75% of global trade in 2010 according to Jung, 2011) that allows for the transshipment of goods and passengers between coastal regions (Dwarakish & Salim, 2015). It has been reported that approximately 90% of global trade is carried out by the International shipping industry (United Nations Conference On Trade And Development (UNCTAD), 2017). The GDP of a country is significantly affected by the means businesses have to export their commodities on to the global market; ports are thus regarded as gateways for domestic and international markets (Dwarakish & Salim, 2015; Hou & Geerlings, 2016).

As sustainability has gained increased significance in global affairs, the port sector is also expected to adapt their ordinary working routines to this new paradigm (Laxe, Bermudez, Palmero, & Novo-Corti, 2016). Since their rapid expansions in past decades, ports have become more rigorously the focal interest for environmental regulatory compliance (Lam & Van de Voorde, 2012). Ports are therefore trapped in a continual effort to achieve a balance between economic, environmental and social factors that allows them to develop in a sustainable manner. Strategies are sought to achieve to this balance and literature is only gradually addressing this knowledge vacuum (Lam & Van de Voorde, 2012).

Scholarly discussions on sustainable port development address the matters from a multitude of angles, such as sustainable governance concepts (Ibrahimi, 2017), port-city integrated development (Schipper, Vreugdenhil, & de Jong, 2017), sustainable hinterland connectivity (Hou & Geerlings, 2016) and sustainability assessments (C. Chen & Lam, 2018). Another trend In port literature is the emphasis on supply chain sustainability, arguing that sustainability at a sub-system level, such as the port level, can contribute only if the sub-system is perceived as an integral part of the overall supply chain system (Denktas-Sakar & Karatas-Cetin, 2012; Lu, Lai, & Chiang, 2016; Lu, Shang, & Lin, 2016a). Despite the contributions of existing literature, much uncertainty persists regarding ports' sustainability, and how this is best accomplished (Brooks, Cullinane, & Pallis, 2017).

With the acknowledgement of the basic concept of sustainable ports, we are left with a problem frame which leaves ample space for refinement. Based on the decision tree on policy analysis (as abstracted from Enserink et al., 2010, p. 33), the concept of ports' sustainability identifies as a problem that involves multiple decision makers whose interest are not completely aligned, consensus on the technological information is achieved partially (but seen the scholarly ambiguity can be improved), poses an important matter in contemporary decision making but is not necessarily an immediate risk. This problem identification qualifies either for the interactive analysis approach, the good communication approach or the traditional science approach of the policy analyst. Albeit these various approached require a different set of actions, their ultimate interest is to enrich the understanding of the main concept at stake.

Before proceeding with selecting the correct policy analyst' strategy, a refinement of the ports' sustainability concept is necessary. This refinement process should safeguard the definition of a feasible and cohesive problem description, followed by a research aim addressing that problem. In order to structure the demarcation process of the main concept, a question is formulated underpinning the purpose of the refinement. Throughout this process, the role of the author will resemble that of the traditional scientist (Enserink et al., 2010), acquiring insights through researching and analyzing. This style may change however, based on the problem definition as a consequence of the demarcation process.

How to shift from the concept of ports' sustainability to a feasible and cohesive problem definition with a feasible solution scope?

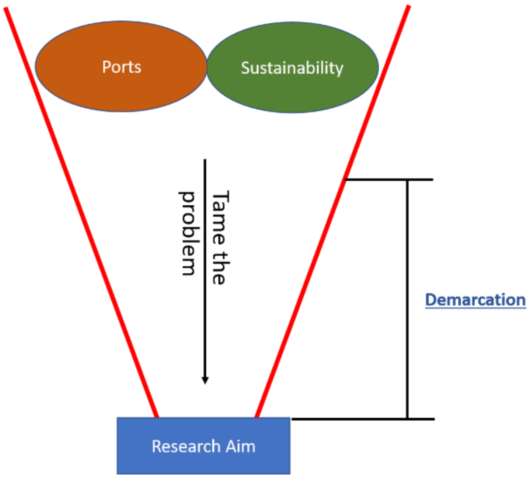
This question remains central in the first phase of this research manuscript. The first phase concludes by formulating the problem and the aim of the research, specifying sub-questions and selecting a methodology. Phases II and III provide constructive answers to the sub-research questions. In the last phase the overall conclusions are articulated, together with a reflection and implications of the study. A more extensive elaboration of the methodology is provided in paragraph 2.4.

# Phase I .	Demarcation & Aim

This phase serves the purpose of demarcating the problem as it is stressed in the general introduction. The question which stays central to this phase of the research is the following:

<u>How to move from the unstructured problem of port sustainability to a structured problem formulation with a feasible solution scope?</u>

The following figure schematically illustrates the purpose of this phase. The outcome of this phase is structured research questions which addressed a knowledge gap persistent academia.



In the hunt for a constructive answer to the central question of this phase, the matter is investigated more deeply leading to an approach angle which fits the specificity of the problem at hand. This process is guided by the steps as they are listed below:

- **Literature Research;**
  A literature study is conducted to gain insights in the realm of sustainability of ports.
- **Expert Consultation;**
  Expert Consultations are composed of a number of unstructured interviews with experts from both the field and academics to grasp a variety of perspectives on the problem at hand. The expert consultations were carried out as a process of demarcation steered the pathway of the problem demarcation. An overview of the experts consulted for this research see Appendix II.
- **Defining research aim;**
  With this step, structure is created in the unstructured problem formulation. This is expressed by means of a concise research question.
- **Choice of methods.**
  In the final step of this phase, a research methodology is proposed.

These four steps are divided into two chapters; Chapter 1: 'Exploratory Analysis' and Chapter 2: 'Research Outline'.

Chapter 1. Exploratory Analysis

In this chapter, the sustainable port concept is explored. The purpose of this chapter is finding structure in the chaos persisting the in the grand framework surrounding the concept of sustainable ports. Figure 1.1 illustrates the process of demarcation that persisted in this study. The dark blue rectangles present the pathway that has been followed, constituting the red line through the demarcation process. The light blue rectangles, on the other hand, represent explored research paradigms presumed fruitless for further discovery. As was brought to attention in the introduction, the departure of this process is ports' sustainability as the central theme in this dissertation. The following paragraphs elaborate on the concepts that constitute the stepping stones of the demarcation process to come to an appropriate angle for analysis.

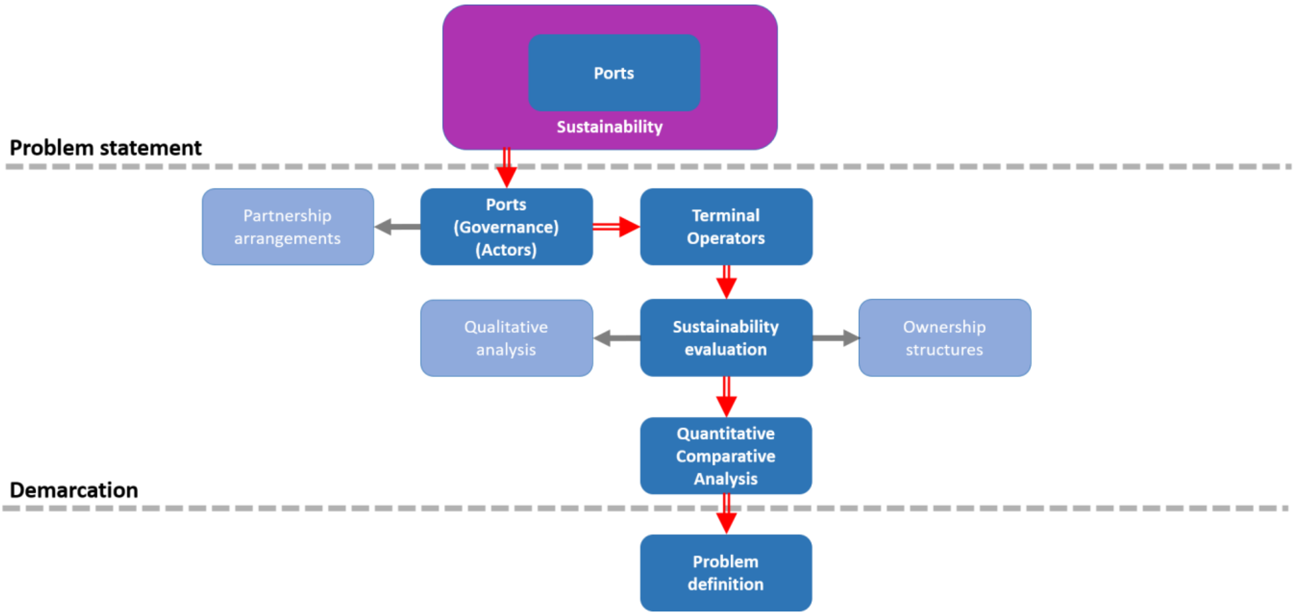


Figure 1.1: Demarcation process

The following pathway illustrates the line of reasoning of the demarcation process in an aggregated fashion and is further delineated in the succeeding section.

Ports' sustainability → Port (governance) → Terminals → Terminal operators → Performance evaluation → Quantitative comparative analysis

Port sustainability has been an amply debated concept in recent scientific publications. Nevertheless, no coherent definition of the concept seems to persist among scholars. To gain a thorough understanding of the concept, the concept is explored in vast detail. Ports are subject to a governance framework that impacts the way it behaves and performs. Operators are a prominent actor in this framework and thus have a significant impact on the ports' performance. Whereas the roll of the port authority and the port cluster is a well-researched paradigm, the impact of terminal operators on ports' performance is only vaguely understood. In order to enhance the understanding, performance evaluations of terminal operators can provide a means to address this vacuum and contribute to scientific elaborations on the role of operators in ports' sustainability.

1.1 Ports' Sustainability

Sustainability in the port sector has been widely debated in recent decades (e.g. Asgari, Hassani, Jones, & Nguye, 2015; Kim & Chiang, 2014; Martí Puig, Wooldridge, Michail, & Darbra, 2015). According to Barnes-Dabban, Van Koppen, and Mol (2017), environmental reform practices of ports is the results of the interplay between three interfering factors, namely **(1)** globalized economic and political dynamics, **(2)** national politico-administrative structures and **(3)** local conditions and port institutions. In relation to the second factor, Barnes-Dabban et al.'s main conclusion is that flexible politico-administrative structures are vital to effectively advance environmental reforms in ports. The relationship between a states' institutions and a port determines the rate of environmental reforms of the port on its term (Barnes-Dabban et al., 2017). This implies that a ports sustainability is subjected to the institutional framework it belongs to.

In light of the port cluster theory, contemplating a port as a cluster of actors interacting with each other (Haezendonck, Pison, Rousseeuw, Struyf, & Verbeke, 2001), it has been argued that a higher degree of cooperation among proximate ports may lead to a positive effect on their environmental performance, as resources, such as hinterland transport connections, are shared more efficiently (de Langen & Haezendonck, 2012). Port cluster literature often focusses on sustainable supply chains rather than sustainable ports. This is supported by the following quote: "Port corporations are major operators at ports; however, their major source of pollutants are their users or suppliers such as ocean-going vessels, harbor craft, cargo-handling equipment, and trailers. Therefore, effective implementations of sustainable practices in ports need to take into account sustainable management both within organizations and in partnerships with external members, including terminal operators, stevedoring companies, and trucking and warehouse operators" (Lu, Shang, et al., 2016a, p. 910). Lu, Shang, et al. (2016a) plea for extensive integration of external stakeholders in port governance to improve sustainable performance. This view is supported by Elkington and Rowlands (1999), who signified the importance of integrating stakeholder consultation in governance affairs for sustainable development as early as the 1990s.

The recent tendency of port governance structures to converge to a more neo-liberalized form of governance (as is further detailed in the succeeding paragraph) has not resulted in performance enhancements per se (Baltazar & Brooks, 2006). In addition to ambiguity persistent in operational outputs, the increased privatization trend of ports has also been amply fueling debates on environmental risks and mitigation strategies of ports (Barnes-Dabban et al., 2017).

1.2 Ports

In this paragraph the concept of ports is discussed in further detail. First, the concept of ports is explained from a literature perspective, followed by an elaboration on the shift of environment they have been subjected to in recent decades.

"A commercial port is a territorial, operational and institutional cluster of interrelated social-economic resources, activities and legitimate actors engaged in appropriate agreements (in)directly related to the transfer of goods and people between land and sea vehicles, serving as a node for the foreign trade and tourism for the industry, logistics and supply chains, and for the global transport system ever more intermodal in its hinterland and foreland" (Ibrahimi, 2017, p. 272). Ports are socio-technical systems, characterized by their sensitivity to institutions contextualizing the system (Ibrahimi, 2017). As a consequence of their importance for a regions' economy and the massive increase of international trade in the past decades, ports have seen a striking increase in competition (Dwarakish & Salim, 2015). In a push to establish ever-increasing traffic volumes and revenues, ports are expected to continuously enhance efficiency in the use of their resources (Jung, 2011). Resources are assets which are to some degree scarce and unique to a ports' cluster, approximating the competitiveness of that port cluster (Haezendonck et al., 2001). Furthermore, Haezendonck et al. (2001) argue that a combination of resources constitutes a ports' competence, complementing their argument by stating that the contribution of a resource in isolation is often impossible to measure.

Port governance in recent decades has been predominantly affected by the concept of port devolution. Port devolution, signifying the shift from centralized public port governance structures to a more privatized model of port governance, has been a global trend for the past three decades (Baltazar & Brooks, 2006; Ferrari, Parola, & Tei, 2015). This shift has emerged from the New Public Management (NPM) principle, and its intention was to accommodate for the developments in global trade and fierce competition. Port devolution is deemed to make ports more competitive, efficient and, like Brooks et al. (2017) emphasize, also as a means to leverage sustainability priorities.

The consequence of port devolution is that ports changed their form of governance from a predominantly state-led authoritarian body being responsible for the clear majority of port functions, to a governance form in which private actors were involved in various aspects of a ports' functions. Classification of various port governance models was proposed by the Port Reform Toolkit substantiated by the World Bank (World Bank, 2016). This classification ranges from service ports to fully privatized ports and distinguishes on the basis of public/private interference in port functions. Nowadays, ports identify as Landlord or fully privatized ports predominantly, but governance structures that are prevailing publicly controlled do still exist.

According to Zhang, Geerlings, El Makhloufi, and Chen (2018), the actors involved in port governance, although being very contextually sensitive (Debrie, Lavaud-Letilleul, & Parola, 2013), can generally be identified as an entity exercising authority over other actors in the port environment, commonly referred to as the Port Authority (PA), and the operator(s) who are charged with the operational/logistics service provision duties of the port. Many literature citations have concentrated on the notion of the Port Authority and studied its relation to sustainability (e.g. Asgari et al., 2015; Kim & Chiang, 2014; Martí Puig et al., 2015). However, the terminal operators have received little attention when it comes to scientific elaborations in relation to sustainability (Brooks et al., 2017).

To address the lack of attention devoted to operators in ports, in the next paragraph the notion of terminals, being the main assets of terminal operators, is explored.

1.3 Terminals

Just like the port sector, the terminal business is confronted with a highly competitive environment since the emergence of container trade (Hyuksoo & Sangkyun, 2015; Yeo, 2015). Terminals require a high throughput volume in order to justify their large infrastructural spending. Terminals provide for the processing of goods or people from one means of transportation to another (or in some specific cases to the same means of transportation); e.g. train, airplanes, trucks or barge. Flows of entities can range from passengers (passenger terminals), dry bulk (sand or construction materials) to fluids or gas (such as oil products). Container terminals are terminals specifically designed to process incoming and outgoing containers, measured in Twenty-foot Equivalent Unit (TEU) (Kemme, 2013). Terminals usually offer a combination of at least two alternative means of transportation. They compete heavily on their modal transportation matrix, which stresses the hinterland connectedness of the terminal (Cho, 2014; Hyuksoo & Sangkyun, 2015). (Deep-)Sea-terminals are terminals characterized by the vessel transportation inclusion in their modal transportation provisions. Inland-terminals, in contrast, often provide a modal transportation network including rail, truck and inland waterway transportation services. Terminals are often regarded as critical nodes in global supply chains due to their function as the connecting point between various means of transportation, connecting multiple local markets and multiple supply chains (Notteboom & Rodrigue, 2012).

Terminals serve as a key node in a global supply chain network and private sector stakeholders in the transport industry have shown great interest in controlling terminals as part of their business (Notteboom, Parola, Satta, & Pallis, 2017). Some designated terminal operators have horizontally expanded their business through many mergers and acquisitions, strategic bidding and Joint-venture endeavors. Moreover, large shipping lines are vertically expanding their business, integrating terminal operations into their service portfolios (examples are Hutchison acquiring a stake in Rotterdam World Gateway on Maasvlake II or COSCO Shipping lines expanding its main business through the penetration in the stevedoring industry). The reason behind this tendency is strategic in nature, as it allows shipping lines to secure a highly efficient supply chain. Moreover, it is considered being a sustainable business model for operators (Wiegmans, Ubbels, Rietveld, & Nijkamp, 2002). These trends led to a container terminal market dominated by large shipping lines and large terminal operators, commonly referred to as Global Terminal Operators (GTO's) (Yeo, 2015). On their part, terminal operators are often part of a larger holding group whereas shipping lines, possibly a member of a holding company as well, do often operate under the flag of the alliance to which they belong (Araujo, Beresford, & Pettit, 2005). A hypothetical conceptual outline of the terminal market is provided in Figure 1.2, in which terminals in various countries are represented. In the example, the port authority from an imaginary port in Morocco owns shares in one of the terminal facilities. A shipping line possesses another (supposedly significant) share of the terminal and a minority share is owned by a terminal operator, responsible for the day-to-day operation of the terminal in question. Albeit the terminal operator will likely impose its own business practices (coming with its own environmental and social footprint), the terminal is largely dependent on the wishes of the shipping line. The shipping line can demand that its vessels be prioritized over other shipping lines' vessels (belonging to other alliances). An arrow in the figure indicates an ownership relation. As part of their vertical expansion trend, terminal operators are investing in transport services (such as a rail service in the example of Figure 1.2) in order to develop more reliable hinterland connectivity and therefore increase their competitiveness (Midoro, Musso, & Parola, 2005). (for an extensive description of the terminal market since the era of rapid global trade increases and the introduction of containerized traffic, reference is made to Appendix I).

The definition of a terminal needs also to be reviewed from the ownership perspective (Farrell, 2012). In literature, various types of terminals are distinguished based on their composition of ownership. Public or state-run terminals is a terminal owned and operated by the (public) PA in order to safeguard public interest; carriers – lease dedicated terminals and joint-ventures of the carriers and terminal operators are widely applied models (Marine Inshight, 2016). A terminal in a landlord port configuration gains its legitimacy due to a concession agreement provided by the PA[1]. One port may be composed of several terminals, each operating under their unique concession agreements. The tender procedure and concession agreement are the most notoriously known tools for a PA to exercise control over the terminal. However, as concession agreements may be subject to time-spans of up to 30 years, in practice PAs possess little capacity to alter the premises of the concessions under the public-private partnership arrangement (Notteboom, Pallis, & Farrell, 2012). Contracts for terminal concessions are subject to such lengthy time-spans to make them attractive to private investors, who desire a sufficient pay-back time to make up for their large investments.

Yeo (2015) studies the relationship between the emergence of GTO's, such as *PSA*, *DP world* and *Hutchison Ports*, the ownership structures of terminals, ranging from public to fully privatized, and the performance of container terminals. The study makes a clear distinction between GTO's and national or small service-provider terminal operators. Yeo argues that a positive relation is evident between the emergence of GTO's and performance of container terminals, but finds no support for this claim. The author calls for research on

[1] The most common way a container terminal operator receives its license to operate in a landlord port governance model is via a concession agreement with the respective PA. Other methods being imposed by PA's are negotiation practices and joint venture undertakings (Farrell, 2012).

the nexus between ownership structures and performance of terminal operators. The study by Hyuksoo and Sangkyun (2015) seeks for determinants of a terminal's competitiveness. The authors argue that the resources infrastructure quality, connectivity and operational efficiency, together with the institutional context, are important indicators for a terminal's competitiveness and performance.

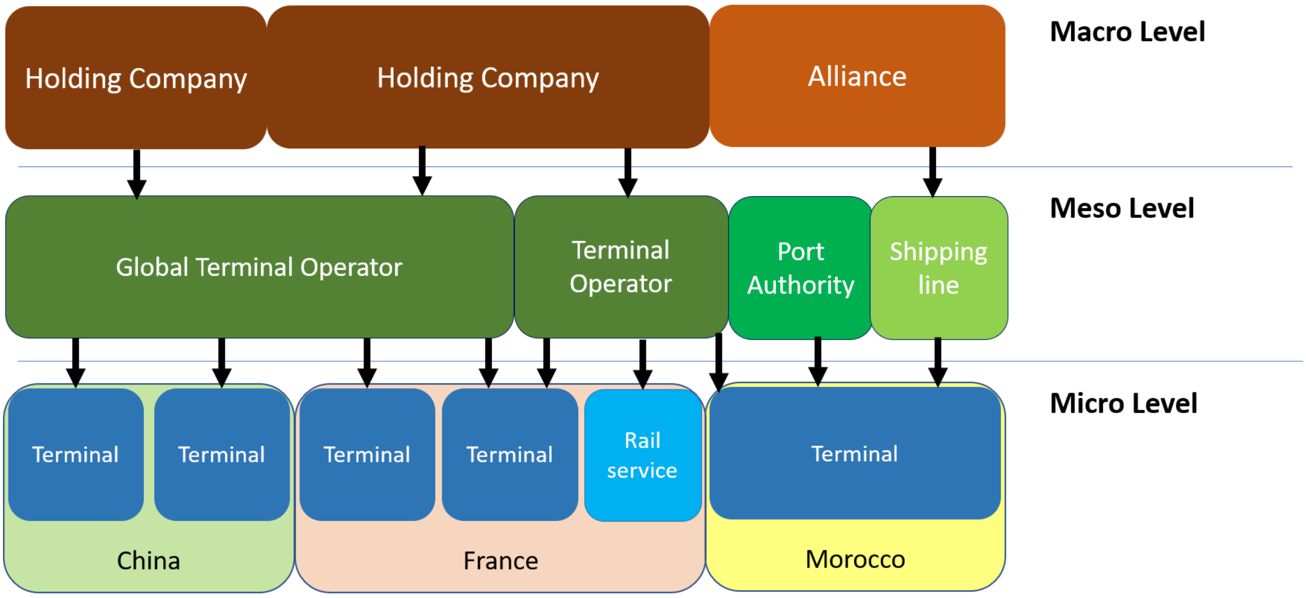


Figure 1.2: Terminal market conceptual representation

1.4 Comparative Analysis

How do the concepts of port sustainability and terminal operators intertwine? One answer to this question is sustainable performance evaluation of terminal operators. It is proclaimed that "Under the competitive environmental circumstances, port performance measurement is not only a powerful management tool for port operators, but also constitutes a most important input for informing regional and national port planning and operations" (Wang, Song, & Cullinane, 2003, p. 699). This view is supported by Quaresma Dias, Azevedo, Ferreira, and Palma (2012), who claim that performance evaluation is a common technique for a back-fed system, supplying decision-makers with valuable information about the system they are intending to manipulate. Conclusively, performance measurement seems to be a legit avenue to proceed. The next question to ask, however, is how sustainable performance of terminal operators can be evaluated.

"In order to compete in today's competitive environment, many organizations have recognized benchmarking as being of strategic importance in the drive for better performance and commitment to achieve a competitive advantage" (Sun, 2010, p. 7745). This quote underlines the thought that a comparative analysis is a meaningful approach to infer insight on performance statistics of terminal operators. Increasingly, companies are evaluating their performance according to the Triple-Bottom-Line (TBL) principle (Wiedmann, Lenzen, & Barrett, 2009), which encompasses three pillars of sustainability (economic, environment and social). This TBL principle was first introduced by Elkington (1998). In their paper, Wiedmann et al. assess the sustainable performance of a company based on the TBL principle combined with input – output analysis to rank the company relatively to industry standards.

Traditionally, the fields of quantitative research and qualitative research have always been two distinct paradigms (Rihoux, 2003; Yilmaz, 2013). Numerous calls are being made from the academic field to integrate the strengths of quantitative and qualitative techniques to do performance evaluations (Dixon-Woods, Agarwal, Jones, Young, & Sutton, 2005; Ragin, 2014). The Qualitative Comparative Analysis (QCA) approach has been invented for that aim, and has been around since the late 1980s (Rihoux, 2003). The approach is based Boolean algebra and reduces the complexity of a case to some indicators and KPI's. It is said to combine the strengths of the two traditional research paradigms (Rihoux, 2003), but given the limitations prevalent to this research (see paragraph 2.6) and the complexity and the rigorousness of the QCA approach, it is omitted in this study.

Whether to employ a quantitative or a qualitative research design for comparative sustainable performance evaluations of terminal operators is still open for debate. Yilmaz (2013) provides a comprehensive overview of the two distinct methods and addresses a multitude of definitions of the two concepts. The author stresses that "quantitative approach endorses the view that psychological and social phenomena have an objective reality that is independent of the subjects being studied" (p. 312). As this description seems to fit the purpose of this research, to subjectively analyze the sustainable performance of terminal operators, a quantitative research design is the preferred method of choice for this research.

An example of quantitative analysis is Multiple Criteria Decision Making (MCDM) research, which has been numerously used to evaluate the performance of businesses (Sun, 2010). The underlying logic of MCDM is that various alternatives are evaluated relative to each other based on a number of indicators. An example of the use of MCDM in performance evaluation is the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) approach. Wiedmann et al. (2009) highlight two pending issues with the use of quantitative accounting techniques in measuring sustainability. First, they mention the fact that indicators must account for both the direct effects of the companies' business, and the indirect effects triggered by the vast web of suppliers. Second, they stress the need to assign the impact of these indirect to the appropriate member of the supply-chain to avoid the double counting of these impacts. Wiedmann et al. stress that these two prerequisites are paramount to a robust ranking of corporate sustainable performance.

Quantitative comparative analysis is chosen in this study in order to assess the (relative) sustainable performance of terminal operating business. This is called 'Branch comparison', as it was coined by Rolstadås (2013), which implies the comparison of homogeneous units within the same particular branch.

Chapter 2. Research Outline

This chapter draws on the insights from the previous chapter to frame the research in a comprehensible manner and delineates the outline of the research in a structured way. First, the knowledge gap is defined, followed by the research aim, capturing the identified knowledge deficiencies. Subsequently, the relevance of the study is considered from the perspective of the problem owners (see the Foreword for a reference to the problem owners). Lastly, a methodology and the data acquisition strategy are selected, and some of the limitations prevailing in this research are being addressed.

2.1 Knowledge Gap

As can be inferred from the sustainable port concept elaboration, ambiguity seems to persist with respect to the impact of port devolution on ports' performances, both economically and sustainably. Moreover, whereas the roll of the port authority and the port cluster is a well-researched paradigm, the impact of terminal operators on ports' performance is only vaguely understood. As was coined by Zhang et al. (2018), operators have since the port devolution trend become independent/autonomous entities in port governance, charged with port logistic service provision. However, little is known about terminals and terminal operators when it comes to sustainability conducts, and how this impacts the sustainability of the port (cluster) as a whole.

2.2 Research Aim

Based on the identified knowledge gap, the aim of this research can be further elaborated. This research aims to contribute to the debate on practices of ports and operators in light of their sustainable performance, particularly those of terminal operators. The study addresses the issue of sustainability of terminal operators by means of assessing their relative sustainable performance. The following research question is defined to capture the essence of this study and address the knowledge gap:

"What insights can be garnered when comparing sustainable practices and performances of terminal operators?"

When examining the latter research question, two factors are deemed relevant for the fulfillment of the research aim. The first factor that is critical to the success of this study is the definition of sustainability, and the way terminal operators interpret sustainability. Hence, it is relevant to examine which set of parameters are suitable to assess the sustainable performance of terminal operators, such that their performance can be benchmarked with respect to the performance of others. The other important factor impacting the research aim is the comparative analysis of terminal operators themselves. Benchmarking the sustainable performance of terminals operators sheds light on sustainable performance standards of the industry, and additionally may provide for information on variables impacting performance and good business practices.

These two factors result in the definition of two sub-questions, as stated hereunder.

SQ 1: What is a suitable way of comparison and how do terminal operators communicate their sustainability matters?

SQ 2: What can we infer from a comparative study of the sustainable performance statistics of terminal operators?

To provide a coherent answer to the main research question, the two sub-questions need to be addressed. The two sub-questions form the basic structure for the systematic approach devised in this research. This will be further elaborated in paragraph 2.4 which addresses the methodology.

2.3 Societal Relevance

In order to determine whether this study is relevant in the wider context, one has to consider the perspective of the problem owner as they have been identified in the preface of this report. Figure 2.1 briefly summarizes the implications that this research could have for their operations.

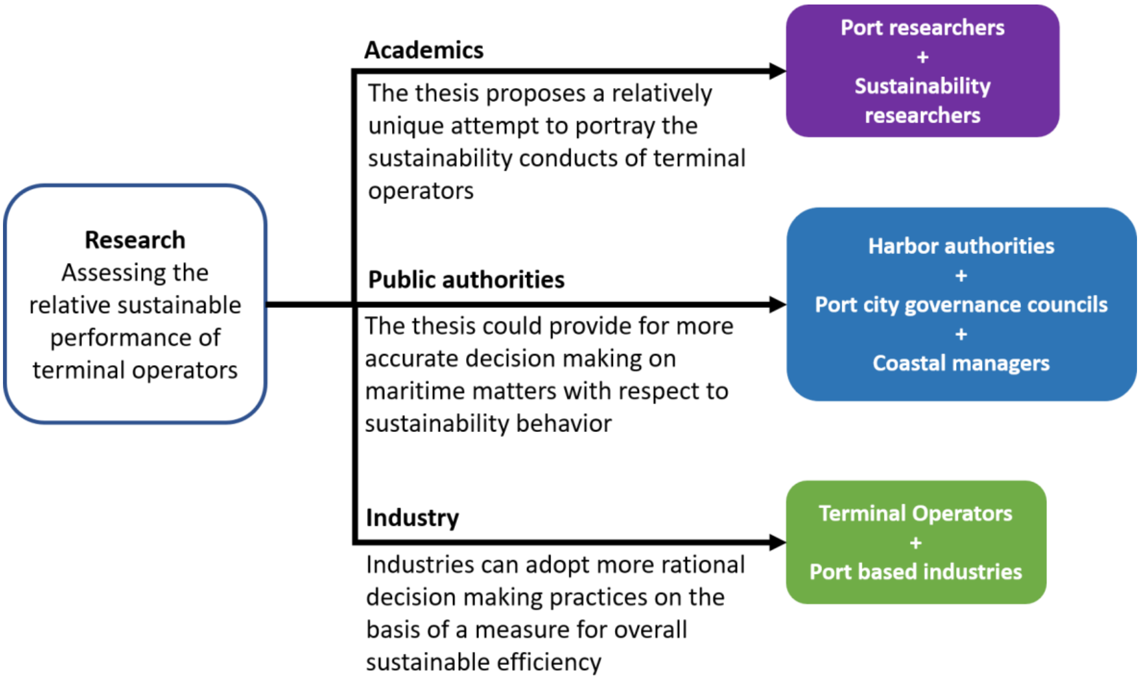


Figure 2.1: Relevance to problem owners

Despite the latter elaboration, science, as being the main problem owner of this study, would have the greatest benefits from this research. As this research provides for the (to the authors knowledge) first comparative analysis study of terminal operators' sustainable performance, academia could use this study as the basis for future attempts of comparing sustainable performance and tackle the potential deficiencies and shortcomings of this study. As was substantiated in the previous chapter, sustainability benchmarking studies have the capacity to become fruitful instruments to device future policies and strategies in the ports' sector and to facilitate enhanced sustainable performances of terminal operators.

2.4 Methodology

This paragraph discusses the methodology applied in this study. The paragraph is structured as follows: first, a generic overview of the research chronology is provided by introducing the four phases of the research. Subsequently, each of the four phases is described in more detail followed by the data collection strategy.

The study is divided into four phases. An overview of the framework depicting the methodology for this study including the different research phases is presented in Figure 2.2. The diagram illustrates the steps in the form of rectangles that are required to fulfill in order to carry out the research and provide for an answer the research question. The legend provides clarity on the type of research to be conducted for the various steps; a hybrid between multiple research methodologies might also be necessary. One can also infer from the framework that the sub-questions are the leading research provisions guiding phase II and III. In the final phase, the conclusions are drawn and a constructive answer to the main research question is provided. The subsequent sub-headings discuss the different phases in more detail.

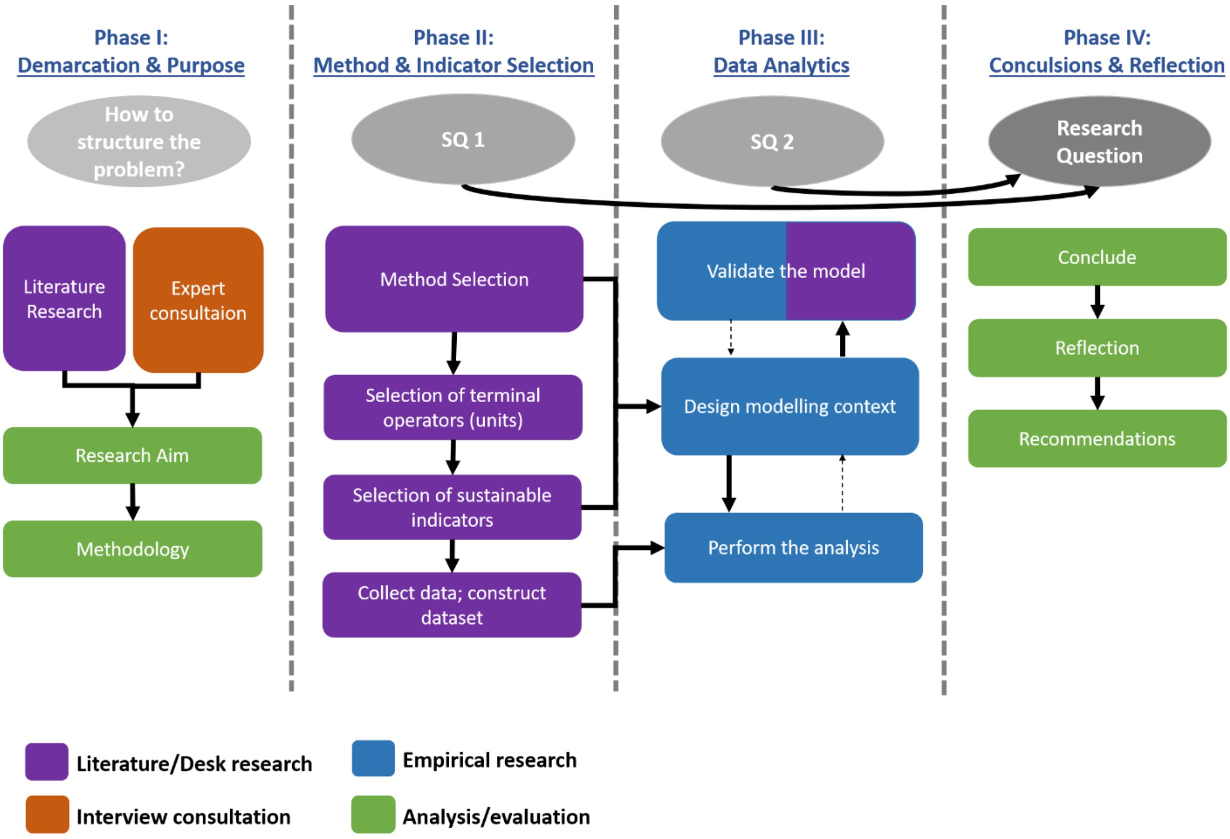


Figure 2.2: Schematic overview of the research

2.4.1 Phase I: Demarcation & Purpose

In the first phase, a demarcation process is executed to reduce the extensive problem of port sustainability to a comprehensible and understandable problem. This problem formulation follows from literature reviews and expert consultations and is partially fueled by the authors own interest. The problem statement is then substantiated into a knowledge gap and concise research question. The main research question is further delineated into sub-questions. The phase concludes with the choice of methodology to be utilized.

2.4.2 Phase II: Method & Indicator Selection

The intention of this phase is to gather all the necessary data for the comparative analysis stage. At first, a quantitative comparative analysis technique is selected in order to guide the process of unit and indicator selection. With a qualitative comparative method in mind, indicators can be selected on which basis the terminal operators will be selected. Prior to the selection of indicators for analysis, operating units are chosen based on the existence of sustainability publications. The sustainability publications are scrutinized to gather sustainable performance statistics of the operators. Once the indicators are selected, the data on the various indicators are collected. Subsequently, the relevance of the selected indicators for the representation of the corresponding dimension of sustainability is considered.

2.4.3 Phase III: Data Analytics

The third phase accommodates for the data analysis of the sustainable performance metrics. At first, the model layout of the comparative analysis needs to be established.

As inferred from the previous phase, a dataset of sustainable performance metrics is inserted in a quantitative comparative analysis model. As a first step, the dataset is processed and manipulated in order for it to meet the requirement of the data analysis model. Furthermore, scenarios are identified which will constitute various model iterations for each of the dimension of sustainability (economic, environmental and social). The quantitative comparative analysis model will be implemented in a coding environment in order to provide for a smooth and feasible application. Validity testing is applied to validate the proper functioning of the model, employing two validity-testing techniques. Lastly, once the model infrastructure is in place and successfully validated, the sample of terminal operators is evaluated for each of the sustainability dimensions to extract their relative sustainable performance.

2.4.4 Phase IV: Conclusions & Reflection

The fourth phase provides the conclusion of the research. The conclusion encompasses a synthesis of the findings and an extensive answer to the research questions. The policy implications of the outcomes are discussed together with the legitimacy and shortcomings of the research; this will immediately shed light on the extent to which the findings of this study are generalizable and whether the methodology can be applied in a broader context. In addition to the empirical findings, a reflection is provided. The research concludes with some remarks about the implications of the study for future research and the problem owners.

2.5 Data Acquisition Strategy

Based on the perception that research on terminal level (review Figure 1.2 for a representation of the terminal level, indicated as the micro-level in the figure) is more suitable for one-to-one comparisons (Wang et al., 2003), the initial idea of the research was to compare terminals at the micro level (see Figure 1.2). However, due to data deficiencies on the micro level (terminal level) of analysis, the decision was made to proceed at a more aggregated level of analysis, that of the terminal operator (meso-level, see Figure 1.2). Data for the terminal operators are available in their public reporting's of various kinds. According to Elkington and Rowlands (1999), sustainability reports are increasingly becoming a valuable tool for the assessment of a companies' sustainable performance and comparative analysis. Hence, for this research, the reported performance metrics on sustainable matters are of particular interest. Accordingly, the sustainable reports issued by some terminal operators have been used as the predominant source of data.

This data acquisition strategy is further elaborated in paragraph 4.3 of the report.

2.6 Bounding Factors

The concluding paragraph of this chapter sheds light on the limitations to which this study is subjected. These limitations are presented in the form of constrains and elaborated in a bullet-point way hereunder.

- **Time constraint;**

This research was subjected to a time constrained implying a maximum number of weeks the research was ought to consume. The regulations to which this research was subjected highlight that the research, including the reporting, was to be completed within a period of 19 weeks from the start of the research. The start-date of the research was 26 October 2018.

- **Resource constraint;**

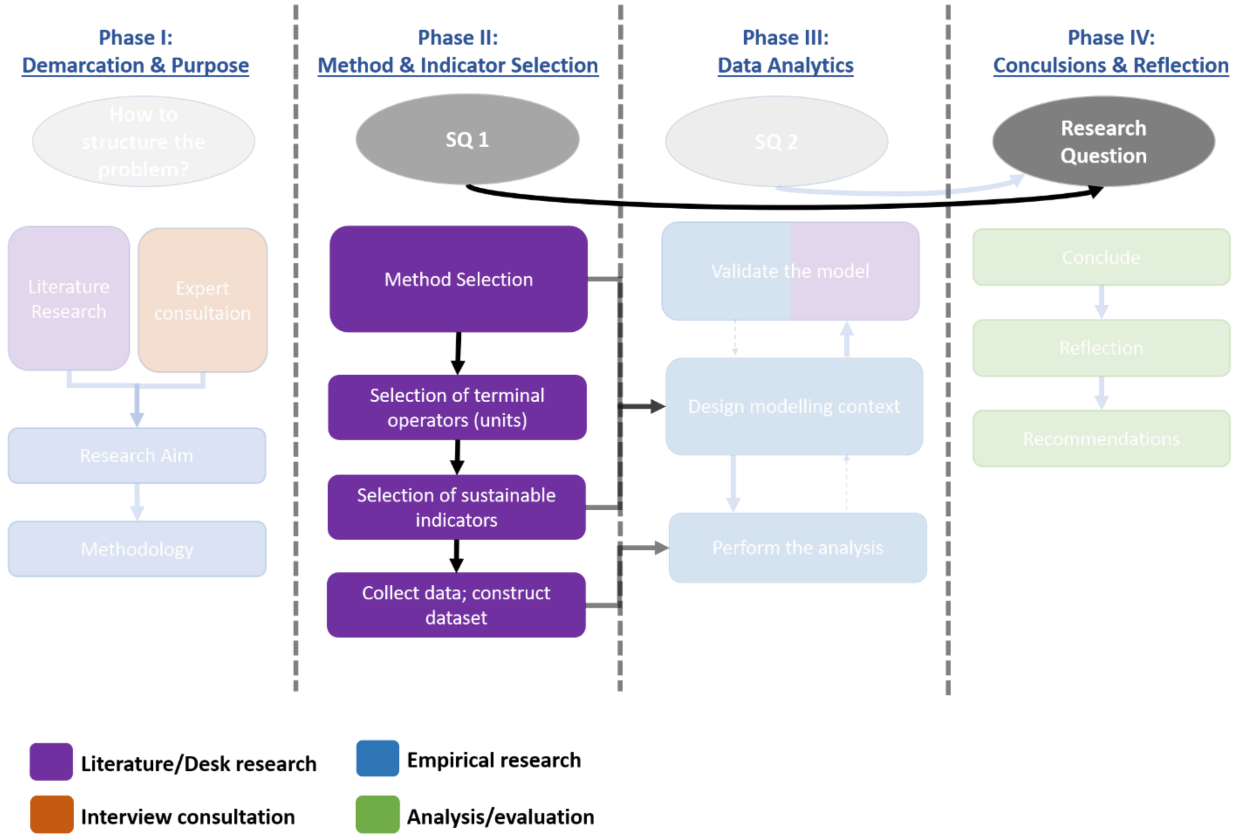
The research is an individually effort to enhance the understanding of sustainable performance of terminal operators. This necessitates choices to be made considerably. Furthermore, no pre-fabricated and processed data is available to me that can facilitate this research. And extensive network of academia and experts in the field is at my disposal. Additionally, for the implication of the data analysis methodology an abundance of expertise is available in the form of professors and materials.

- **Budget constraint.**

This research is carried out with no budget. The consequence of this is that paid resources are not attainable and mobility options are also limited.

Phase II . Method & Indicator Selection

An overview of the contribution of the second phase of the research to the study is provided in the following diagram. The steps are represented by the rectangular boxes.



This phase sheds light on the first of the two sub-questions. This sub-question, which was defined in paragraph 2.2 in Phase I, is repeated hereunder:

SQ 1: What is a suitable way of comparison and how do terminal operators communicate their sustainability matters?

Four steps provide a constructive answer to the question. These steps are the following:

- **Method selection;** At first, the selection for a quantitative comparative analysis technique is substantiated. The methodology is utilized for the comparative analysis of the various units, being terminal operators, under scrutiny.
- **Selection of terminal operators (units of analysis);** Based on the availability of sustainability performance metrics, terminal operators are selected for inclusion in the analysis. The main criteria for this selection are the availability of sufficient sustainable performance metrics of the terminal operator in question.
- **Select sustainable indicators;** The reporting practices of terminal operators are addressed. This step will shed light on the communication strategy opted by various terminal operators.
- **Collect data; construct dataset:** Lastly, the performance metrics of the selected terminal operators is gathered and structured in a dataset.

These four steps are divided into two chapters: Chapter 3 'Method Outline' and Chapter 4: 'Unit & Indicator Selection'.

Chapter 3. Method Outline

The comparative analysis of terminal operators based on their sustainable performance is conducted with a linear programming algorithm called Data Envelopment Analysis (DEA). A traditional approach for a DEA analysis is depicted in Figure 3.1. Because this research constitutes the application of a traditional DEA analysis, the methodology applied in this study follows a similar procedure (the structure of Phase II and Phase III of this manuscript mimic this scheme to a large extent).

Data Envelopment Analysis (DEA) is a linear programming application meant for the evaluation of the relative efficiencies of similar, homogeneous processes; e.g. production processes, decision-making processes, logistic processes and others (Lozano, 2015). The collective name for such processes is Decision-Making Units (DMU's). DMU's can be embodied by a large variety of entities; e.g. firms, factories, government, institutions, supply chains; but such DMU's can also be identified on a more micro-scale; e.g. mechanical components, technologies, households. DMU's are characterized by their inputs and outputs. If a DMU is located on the frontier, it is granted an efficiency score of 1; if the DMU is not positioned on the frontier, meaning its performance is not efficient, it gets an efficiency score <1. Hence DEA is regarded as a simple tool for evaluating the efficiency of DMU's relative to other (similar) DMU's (Charnes, Cooper, & Rhodes, 1978).

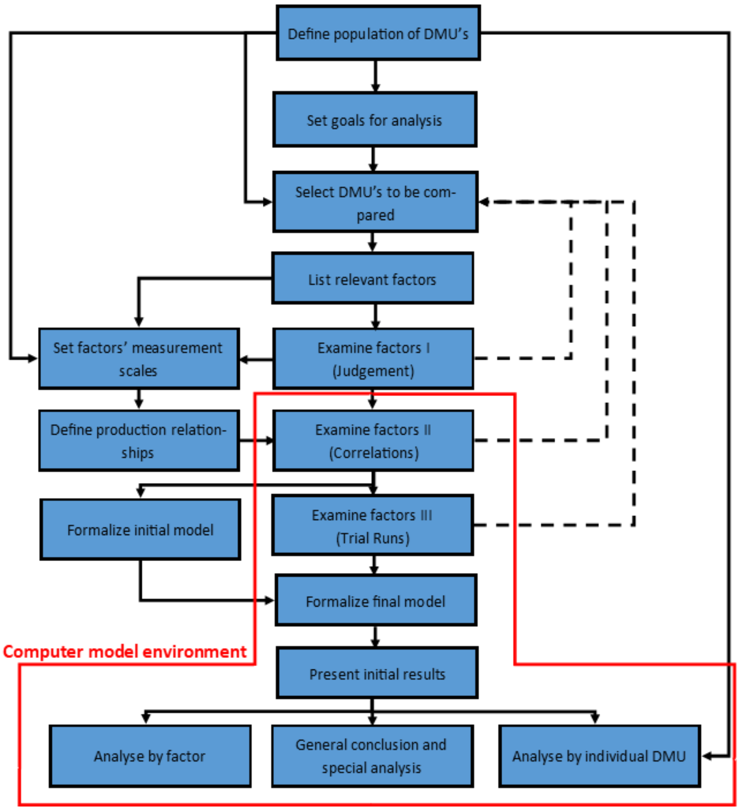


Figure 3.1: Conventional DEA analysis framework (source: Golany & Roll, 1989)

As can be inferred form Figure 3.1, a DEA methodology application commences with defining a population and proceed with a selection of indicators for evaluation. This is being discussed in the Chapter 4 of this phase. Prior to that, the theory and argumentation behind the DEA methodology is further delineated in this chapter. The chapter starts with a literature overview of DEA applications. Second, the reasoning behind the selection of the DEA methodology is outlined. Subsequently, the theory behind the technique is described based on some questions inferred from literature. Lastly, the method is demonstrated with the help of a hypothetical example.

3.1 Literature Review

Application of the DEA model has been widespread across academic fields (C. Chen & Lam, 2018), and has seen ample examples of application for varying purposes. Wiegmans and Witte (2017) apply the DEA model to the case of inland waterway terminal systems as a Multiple Criteria Decision Making tool. In that case, the various DMU's are considered as alternatives to a common problem (Cook, Tone, & Zhu, 2014). Theunissen (2016) employs the framework for an assessment of the Health Insurance Companies in the Netherlands, and pioneers the integration of the Principal Component Analysis (PCA) in alignment with DEA. His dissertation provides an example of a DEA model incorporating both qualitative and quantitative parameters to evaluate the efficiencies of units. Another widely explored field is the financial sector, such as the study by Mercan, Reisman, Yolalan, and Emel (2003), which evaluates the relationship between public/private ownership of Turkish banks against their financial performance.

DEA is also applied widely in the port literature, although models and approaches do vary substantially (Panayides, Maxoulis, Wang, & Ng, 2009). Examples are the comparisons of container terminals by Wiegmans and Witte (2017), and Guimarães, Junior, and Garcia (2014); and comparisons of entire ports and port clusters by Valentine and Gray (2001), Gutiérrez, Lozano, Adenso-Díaz, and González-Torre (2015) and Kutin, Nguyen, and Vallée (2017), to name a few. Wang et al. (2003) compare DEA with another benchmarking technique called Free Disposal Hull (FDH). FDH, like DEA, is a benchmarking technique but has seen only limited implementation efforts. Their concluding remarks stress that DEA is more goal oriented, but these goals should be subjected to further study. Another DEA study subjected on terminals is the one by Quaresma Dias et al. (2012), who assess the performance of the main Iberian seaport container terminals. A comprehensive overview of DEA studies in the port context is provided by Panayides et al. (2009).

Most DEA literature views efficiency from the angle of operational efficiency or financial efficiency (e.g. Sevkli, Lenny Koh, Zaim, Demirbag, and Tatoglu (2007) and Nguyen, Nguyen, Chang, Chin, and Tongzon (2015)). This means that efficiency is studied to enable the enlargement of a units' business/economic output. Some, however, do take a more aggregated definition of efficiency; they incorporate environmental externalities in their analysis (e.g. L. Chen, Lai, Wang, Huang, and Wu (2018) and L. Chen, Wang, and Lai (2017)) as an example. However, most scholars do not explore the entire realm of sustainability (people, planet, profit) with DEA analysis. Some exceptions are the studies by Galán-Martín, Guillén-Gosálbez, Stamford, and Azapagic (2016), and Zhou, Yang, Chen, and Zhu (2018). Application of the DEA model to assess sustainability is much broader in other domains, however, as examplified by the papers of Wu, Yin, Sun, Chu, and Liang (2016), and Zhou et al. (2018).

3.2 Argumentation

Gutiérrez et al. (2015, p. 592) justify their use for DEA due to "DEA being a well-established, nonparametric frontier analysis technique, capable of evaluating the relative efficiency of a set of operating units (DMU's) with multiple inputs/outputs". Cook et al. (2014, p. 4) argue that "DEA examines performance in multiple criteria and helps organizations to test their assumptions about performance, productivity, and efficiency". DEA's strength lies in its capacity to identify the causes of inefficiency and is focused on efficient resource consumption and maximizing business outputs (Halog & Manik, 2011). Furthermore, it has the capacity to provide for specific guidelines and interventions to enhance the efficiency of the system under scrutiny (Galán-Martín et al., 2016). Additionally, DEA is often praised for its ability to make sense of the relation between inputs and outputs without any principle prior knowledge about this relationship (Wilson, 2008). The following arguments describe the drawbacks of conventional efficiency measuring in contrast to DEA:

- Conventional approaches predominantly focus on process measures rather than outcome measures (Galán-Martín et al., 2016);
- The difficulty to translate qualitative variables into weighted factors (Boussofiane, Dyson, & Thanassoulis, 1991; Galán-Martín et al., 2016);
- The complexity of assigning an explicit relationship between inputs and outputs (Galán-Martín et al., 2016);
- Averaging performances across many samples is falling short in describing individual units' performance (Galán-Martín et al., 2016).

Table 3.1 provides an overview of the individual arguments for the use of DEA. Furthermore, arguments for the use of DEA in this dissertation are provided in the table.

Arguments	Relevance for this study
Identification of the sources and amounts of relative inefficiencies in each of the compared units	The model allows for the exploration of impacts of individual indicators on a terminal operators' performance
Ranking the units by their efficiency outcomes	The model will provide a ranking of terminal operators based on their sustainable performance.
Evaluation of management heading the compared units	irrelevant
Evaluating the effectiveness of policies or programs	irrelevant
Creating a quantitative basis for reallocating resources among the units under evaluation	Although reallocating resources will not be of particular interest in this study (as we are dealing with negative externalities), negative externalities reduction potentials can be explored.
Identification of efficient units, or efficient input-output relations, for purposes not directly related to comparison among the units	The model facilitates indicator evaluation as well, as multiple combinations of inputs and outputs (constituted of various indicators) are used
Comparison and contrasting against results of previous studies	This would be potentially possible, however, due to the lack of any previous study addressing the sustainability of terminal operators it is not feasible.
Discrimination in the valuation of various factors	By combining and comparing the results of multiple input-output combinations the impact of certain variables can be identified.

Table 3.1: Arguments for the utilization of DEA

Conclusively, despite the existence of multiple quantitative comparison techniques, DEA is considered to be an adequate approach due to its capacity to evaluate efficiencies with little prior knowledge about the underlying process itself. As little knowledge exists with respect to the internal relationships causing sustainable outputs of terminal operators, DEA seems to be a good fit under the circumstances as outlined in this study.

3.3 DEA Theory

This paragraph is populated by a set of four constructive questions delineating the function of DEA. These questions are extracted from the paper by Cook et al. (2014) and are indicated in bold.

1. What is the purpose of the performance measurement and performance?

In many circumstances the common method of efficiency determination, as it is depicted in equation 1, is sufficient. However, this method is ineffective when multiple inputs and outputs are identified and one wants to understand the relations between them (Boussofiane et al., 1991).

$$Efficiency = \frac{Output}{Input} \tag{1}$$

One can overcome this hurdle by imposing a weight system. The input weights (v) and output weights (u) represent the value assigned to a certain indicator. The efficiency of a unit is now calculated based on weighted sums of the outputs divided by weighted sums of the inputs (equation 2) (Francisco, Pessanha, & Marinho, 2013).

$$Efficiency = \frac{\sum_1^n u_m y_m}{\sum_1^s v_s x_s} \tag{2}$$

Where

$$y = value\ output\ variables\ (y_1, y_2, \dots, y_m)$$
$$x = value\ input\ variables\ (x_1, x_2, \dots, x_s)$$

In the event of a comparative analysis, the definition of efficiency expressed in equation 2 is not always sufficient. The underlying premise of equation 2 is that the weight of the corresponding indicator is predetermined and stable, implying that a common set of weights for the various units under consideration needs to be imposed. This would undermine differentiation amongst units and provide a corrupted perception on efficiencies in the event of multiple input and output evaluations. Therefore, in DEA, the performance of a unit is conditionalized based on the performance of the other unit(s), by means of framing the efficiency problem as a linear programming problem.

2. What DEA model to be used?

Various models exist in DEA literature. The standard model of DEA is called the Charnes-Cooper-Rhodes (CCR) model, named after the founder of the DEA (Charnes et al., 1978). This standard model is a Constant Return to Scale (CRS) model (also called a CCR model), indicating that a constant relation between a system's inputs and outputs is assumed. As opposed to the CCR model, the Variable Return to Scale (VRS) model assumes that a dynamic relationship between a system's inputs and outputs exists. This model was introduced by Banker, Charnes, and Cooper (1984), and is also referred to as BCC DEA. As an addition to these two common DEA models, an extensive archive with ample variations to the default DEA application is to be found in literature (for further detail reference is made to the papers by Banker, Charnes, and Cooper (1984), Cook et al. (2014) and Seiford and Thrall (1990)).

Moreover, a DEA model can be utilized in two distinct ways. The model can be utilized to predict the excess inputs that the unit under scrutiny possesses, alternatively it can look into the shortfall in output of the unit in question. This distinction is referred to as input-oriented and output-oriented DEA respectively (Boussofiane et al., 1991).

3. What are these DMU's and their inputs and outputs which characterize them?

Golany and Roll (1989) give the following description of DMU's: **(1)** the units or processes of the DMU are tasked with the same objectives, and **(2)** the factors, implying the inputs and the outputs, are the same for all the units in the sample. This definition is in line with our statement regarding the homogeneous character of the scrutinized units.

The computational representation of a DMU is often stated as a DMU_j. The efficiency of a DMU_j containing multiple inputs and outputs is expressed in line with equation 3.

$$z_j = \frac{\sum_1^m u_m y_{mj}}{\sum_1^s v_s x_{sj}} = \frac{(u_1 y_{1j} + \cdots + u_m y_{mj})}{(v_1 x_{1j} + \cdots + v_s x_{sj})}$$

Where

$$z = efficiency\ DMU_j \tag{3}$$
$$y = value\ output\ variables\ (y_1, y_2, \dots, y_m)$$
$$x = value\ input\ variables\ (x_1, x_2, \dots, x_s)$$

The equation states that the efficiency of a particular DMU_j is determined by the sum of the weighted outputs values divided by the sum of the weighted input values. The weights expressed as u for the output variables and v for the input variables, are unknown values and are determined by the model (Golany & Roll, 1989). The underlying optimization algorithm seeks to maximize the efficiency score of the unit in question subject to a number of conditions and assigns weight to the variables accordingly. Computational representation of the standard CCR model is provided in equation 4, in which the algorithm maximized the efficiency of DMU_{j_0} (z_0) relative to the efficiency of other units (Ragsdale, 2006; Winston & Goldberg, 2004).

$$\max z_0 = \frac{\sum_1^m u_m y_{mj_0}}{\sum_1^s v_s x_{sj_0}}$$

Subject to

$$\frac{\sum_1^m u_m y_{mj}}{\sum_1^s v_s x_{sj}} \leq 1, \qquad j = 1, \dots, n$$
$$u_n, v_s \geq 0, \qquad \forall\ m\ and\ s$$

Where

$$y_{mj} = amount\ of\ output\ m\ from\ unit\ j \tag{4}$$
$$x_{sj} = amount\ of\ input\ s\ from\ unit\ j$$
$$u_m = the\ weight\ given\ to\ output\ m$$
$$v_s = the\ weight\ given\ to\ input\ s$$
$$n = the\ number\ of\ units$$
$$y = value\ output\ variables\ (y_1, y_2, \dots, y_m)$$
$$x = value\ input\ variables\ (x_1, x_2, \dots, x_s)$$

Inputs and outputs may correspond to the factors required for production and the outcomes from the production process. Some authors in the DEA literature refer to the inputs and outputs simply as factors (e.g. Guimarães et al., 2014). Another wording may be variables of the production process (under the simple assumption that every DMU always represents a production process). These variables or factors are mostly quantitative in nature, but might also be qualitative (Hwang, Lee, & Zhu, 2016). If the DEA model is used for efficiency analysis of a production process (e.g. the manufacturing of a commodity), identifying the input and the output factors is straight forward. Moreover, if the process involves a more general benchmarking process, then the general assumption of 'the less inputs the better' and 'the more outputs the better' is legitimized.

In literature, various computational methods are identified to guide indicator selection for DEA analysis[2] (Adler & Yazhemsky, 2010; Nataraja & Johnson, 2011). For small sample sizes, meaning the amount of observation, Nataraja and Johnson (2011) contend that the PCA-DEA method is the most applicable, given that other methods only show sensible results when evaluating large sample sets.

- [2] The most common on these methods are Efficiency Contribution Measure (ECM), Principle Component Analysis (PCA) applied to DEA, Variable reduction based on partial covariance (VR), Regression based test and Bootstrapping (Adler & Yazhemsky, 2010).

4. **What number of DMU's are required for a correct model outcome given the number of inputs and outputs characterizing them?**

The general rule of thumb is: "the number of DMU's has to be at least twice the number of inputs and outputs combined" (Cook et al., 2014, p. 2; Golany & Roll, 1989, p. 239). This rule of thumb is a guideline for the number of DMU's and input and output variables that are presumed to be necessary in order to retrieve sensible model outcomes. Some authors even state that the sample size requirements should be stricter, meaning a further reduction in the number of input and output indicators in comparison to DMU's (Adler & Yazhemsky, 2010). The reason for considering the thumb rule is because the discriminatory capacity of the DEA linear programming algorithm reduces with a greater number of variables accounted for (Kutin et al., 2017).

3.4 DEA Illustrative Example

In this paragraph, an example implementation of the DEA methodology is provided. The example provided is a trivial example of 5 DMU's being characterized by merely one input x and one output y. As this is just an example, it does not matter what sort of processes the DMU's fulfil, nor what the input or output variables of that process imply. According to Francisco et al. (2013), the procedure of applying the DEA framework basically consists of three segments. These are: **(1)** loading the input data, **(2)** the processing of the data and running of the model; and **(3)** the reporting of the outcomes. Hence, the first step is to present the actual data. The values of the input and output variable for the 6 DMU's are given in Table 3.2. From the table, one can infer that the DMU's are indexed from A to F.

	x	y
A	100	75
B	200	100
C	300	300
D	500	400
E	450	200
F	320	230

Table 3.2: Example DEA application DMU's inputs (x) and outputs (y)

Plotting the output against the input illustrates the stance of each of the units relative to each other. Common-sense in DEA is to draw an efficiency-frontier, which is essentially a production frontier. The frontier connects the points (DMU's) which are seemingly the highest performers and excludes the outliers which are underperforming (inefficient). As can be read in paragraph 3.2, there are various ways in which such an efficiency frontier can be drawn. The most common one in use is the VRS technique, which assumes that the relation between the outputs and inputs is not constant but rather dynamic. A scatter plot of the data presented in Table 3.2 together with the efficiency-frontier under the variable return to scale model is presented in Figure 3.2.

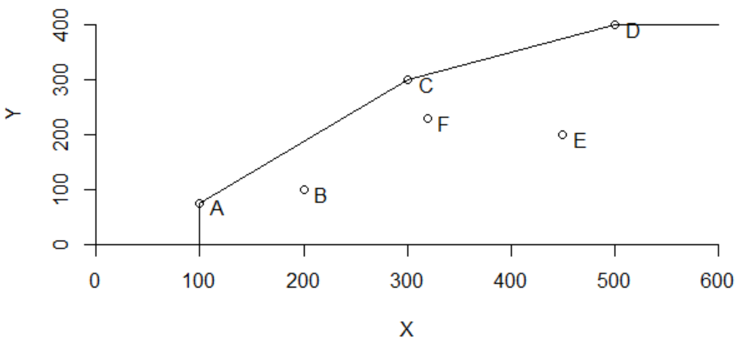


Figure 3.2: Plot of the DMU's and the efficiency-frontier

In analyzing Figure 3.2, one can infer that the efficiency-frontier connects the DMU's A, C, and D, implying that these units are efficient whereas DMU's B, F, and E are inefficient. The closest distance of the various units to the efficiency frontier determines the efficiency score of the units, meaning that the units on the frontier will be awarded an efficiency score of 1, and remaining units are awarded an efficiency score of 1 minus the distance to the frontier. DEA determines the distance to the frontier line by means of geometric calculations, using the efficient DMU's that are nearest to an inefficient unit, called peers. In the latter scenario for example, as illustrated in Figure 3.2, DMU B is located between the efficient units of A and C, its peers. Units which are positioned on the frontier will consider themselves as their peers. In the example, inefficient units will have mostly two peers (see Table 3.3), but they might identify as many peers as there are efficient units amongst the sample of units. One can alternatively calculate the implication of the inefficiency, by multiplying the inverse of the efficiency score (1 – efficiency score) of the DMU with its input value. An overview of the outcomes of the latter example is provided in Table 3.3.

	Efficiency score	Excess of input	Peer 1	Peer 2
A	1	0	1	N/A
B	0.611111111	77.77778	1	3
C	1	0	3	N/A
D	1	0	4	N/A
E	0.469135802	238.8889	1	3
F	0.743055556	82.22222	1	3

Table 3.3: Example DEA results plus peers

Chapter 4. Unit & Indicator Selection

The purpose of this chapter is to device a sample of units for analysis. These units are comprised of terminal operators with varying portfolios. Subsequently, a review of sustainability indicators being conducted, elaborating on literature findings. Publicly available data is collected based on quantitative sustainable indicators. In the conclusion section at the end of the chapter a brief overview of the indicator selection is provided.

4.1 Unit Selection

This paragraph intends to convey the methodology underpinning the unit selection and the conclusions of the unit selection process. Firstly, the criteria for unit selection are addressed, followed by the methodology that led to the identification of terminal operating units for analysis. Subsequently, an overview of the selected units is provided.

4.1.1 Selection Criteria & Method

Some remarks in relation to the selections of the appropriate units for analysis is that organizational, physical or regional boundaries should be considered, in addition to the time period being securitized. This implies that the extend of a unit's business should be accounted for. Additionally, one must bear in mind that outliers in the data can severely obscure the outcomes. Hence, incorporating particular DMU's which prove to be incoherent with respect to the other DMU's may not benefit the analysis (Golany & Roll, 1989).

Businesses, including terminal operators, find themselves in an environment which increasingly expects them to morally justify their business practices. The units that are selected for analysis are all terminal operators that do issue on performance and sustainable metrics. They are operators of operation sizes and portfolios. They are included due to their issuance of a sustainability report which provides for at least some statistics on their sustainable performance, or other reports issued which contain similar performance metrics. The process that led to the identification of terminal operating units consisted of two elements. (1) Some of the more well-known terminal operators in the international market were scrutinized from the front-end side to determine if any sustainable performance data was available. (2) Most of the terminal operators, however, were abstracted from the database of the Global Reporting Initiative (GRI) (Global Reporting Initiative, 2019). Some of the terminal operators have committed themselves to adhere to the G4 guidelines (Global Reporting Initiative, 2019) on sustainability reporting which is a framework set up by the GRI institute. The institute also maintains a record of all the businesses that publicize a sustainability report of some sort globally, which is the database used for terminal operator identification. Not all the operators which have been identified throughout the database have been included in this research. The primary reason for exclusion was that some terminal operators have chosen to publish their reports solely in their native tongue (mostly involving Spanish, Chinees and Korean langue), making it impossible to interpret sustainable performance. Other reasons were lack of enough performance metrics to get a solid glance at their status and incoherent indicators.

4.1.2 Selected Units

Table 4.1 provides an overview of the 10 Terminal Operators (TO's) that met this criterion. The table contemplates a rather limited number of terminal operators. This is owed to the fact that sustainability reporting is not yet common practice within the terminal sector. Two large players in the terminal market, PSA World and Hutchison Ports, albeit having expressed their commitment to sustainability on their public websites, do not issue any number of sustainable performance indicators and are therefore left out of the analysis.

Even though 10 units of analysis is rather small in terms of a DEA study, it is not uncommon according to the literature elaboration of DEA applications by Panayides et al. (2009).

Terminal Operator	Type	# of terminals
APM Terminals	International Terminal Operator	74
Aqaba container terminal	Single Terminal Operator	1
Contship Italia Group	Regional Terminal operator	6
Cosco Shipping Ports limited	International Terminal Operator	45
DP World	International Terminal Operator	54
Eurogate	Regional Terminal operator	9
GlobalPorts Investments	Regional Terminal operator	7
Hamburg Hafen und Logistik (HHLA)	Regional Terminal operator	7
Modern Terminals Limited	Regional Terminal operator	6
Westports Malaysia Sdn	Single Terminal Operator	1

Table 4.1: Selected Terminal Operators

Some of these TO's are among the world's largest terminal operators, owning a market share of up to 12% based on TEU throughput[3] (COSCO Shipping Ports) (Statista, 2018). Some others are rather small players and possess just a brief number of terminals, like Contship Italia and Modern Terminals. Aqaba Container Terminal and Westports Malaysia are companies in charge of a single terminal. Bellow, a description of all the selected terminal operating companies is provided. In the brackets, the name of the terminal operator as it is used in Phase III and throughout the remainder of this report is provided.

- **APM Terminals (APMT)**
  APM Terminals is likely the most well-known company in the list. This is partly due to their vast representation in North-West Europe and also because they are a member of the biggest logistics service provider on the globe, A.P. Møller - Mærsk A/S, or in brief: Maersk. Maersk operates a number of subsidiaries which together form a densely vertical integrated logistics supply-chain. Their largest business segment is container shipping with their subsidiary Maersk Line, which operates an ample amount of the biggest container ships in the world. Maersk Line contributed 68% of Maersk its total revenues in 2017. AMP Terminals is, in terms of revenue, their second largest business segment, with a contribution of approximately 15% to their 2017 revenue (A.P. Møller - Mærsk A/S, 2017).

- **Aqaba Container Terminal (ACT)**
  This comprises a container terminal in Aqaba, Jordan, which is a joint venture between APM Terminals and Aqaba Development Corporation (ADC). Both these companies hold a 50% shareholding in ACT. The daily operation and management of the terminal is in the hands of APM Terminals (Aqaba Container Terminal, 2018).

- **Contship Italia S.p.A. (Contship)**
  Contship Italia S.p.A. is an Italian operator for 66% in the hands of its German Holding company Eurokai GmbH & Co. KGaA and for 33% in the hands of Eurogate (also among the selected units). Contship Italia values environmental as being of secondary importance, as can be seen in their materiality matrix of their sustainability report (Contship Italia Group, 2017, p. 7).

[3] Largest five terminal operating companies (measured in TEU throughput) are: APMT, DP World, Hutchison, COSCO Shipping PSA World

- **COSCO Shipping Port Limited (COSCO)**
  This is the terminal subsidiary of its mother company China COSCO Shipping Corporation Limited, which, via its holding company COSCO Shipping Holdings CO., Ltd., currently holds 46.9% of its shares (COSCO SHIPPING Ports Limited, 2017, 2018).

- **DP World (DP World)**
  A remarkable observation is that DP World is the only company in the list which does not explicitly state information about their employees. Hence, the employment figures for DP World were retrieved from their annual reports that do state an approximation of their actual headcount (DP World, 2016a, 2016b).

- **Eurogate (Eurogate)**
  The Eurogate group is a network of fully owned subsidiaries and Joint-ventures operating under the same flag with one holding company named EUROGATE GmbH & Co. KGaA. Eurogate is in the hands of two companies which both hold a 50% share in Eurogate: BLG Logistics Group AG & Co. KG and EUROKAI GmbH & Co. KGaA. The company also has a 33% share in Contschip Italia S.p.A. as is also in this list (Eurogate, 2018).

- **Global Ports Investments PLC (GlobalPorts)**
  The business units of Global Ports Investments are split up in three segments: Russian ports segment, Oil products terminals segment and Finnish ports segment. For the analysis in this research, only the Russian port segment and the Finnish ports segment are incorporated due to the threat of inconsistency when also considering the Oil products and terminals segment which is merely a liquid product terminal facility. This is possible due to the adequate level of discrimination in the sustainability report of Global Ports Investments. APM Terminals holds a 30.75% share in Global Ports Investments (Global Ports Investments PLC, 2017).

- **Hamburg Hafen und Logistics (HHLA)**
  This company certainly has the best track record of sustainable related performances and presented them in a very nice fashion on their webpage (Hamburger Hafen und Logistik, 2017).

- **Modern Terminals Limited (ModernTerminals)**
  The most striking discovery when it comes to Modern Terminals Limited is that they have published with an interval of two years a Corporate Social Responsibility report, but have failed to issue a financial report of any kind (Modern Terminals Limited, 2015, 2017).

- **Westports Malaysia Sdn (Westport)**
  Westports Malaysia Sdn is a local terminal operator which exploits the terminal facilities of the Westport district of the Port Klang, located near the Malaysian capital Kuala Lumpur (Westports, 2016).

With the sample set used for the analysis is mind, a closer look is provided on the indicators used for sustainable performance analysis.

4.2 Discussion on Performance Indicators

This paragraph intends to provide an overview of existing sustainable indicator frameworks. To what extent is there a methodology prevalent for the reporting on sustainability generally, and more specifically within the ports and terminal industry? Cook et al. (2014), among others, stress the importance of selecting the appropriate variables for a DEA model. DEA itself does not provide for specific guidelines in terms of selecting input and output indicators for the analysis. However, there are several pitfalls when it comes to the selection of indicators: data may be unavailable, the production process is high dimensional or the inclusion of indicators which prove to be irrelevant (Nataraja & Johnson, 2011). The discriminatory capacity of DEA is an amply debated topic, and variable selection is of paramount importance to safeguard this intrinsic feature (Adler & Yazhemsky, 2010). In order to obviate the latter, this paragraph provides an overview of existing literature on sustainable performance metrics used in ports and criteria to evaluate their relevance.

4.2.1 Sustainable Indicators

A study conducted by Martí Puig, Pla, Seguí, and Darbra (2017) revealed that only 38% of the port operators publish a list of sustainability indicators. Even though it must be mentioned that only 13 operators were considered in their paper, this finding is in line with what has been discovered so far in this probe (with a list of only 10 terminal operators reported on sustainability performance matters in English out of a vast sample of studied terminal operators).

Three certification types are common in the port sector to monitor sustainable performance; **(1)** ISO 14001, **(2)** Green ports; and **(3)** Ecoports (Asgari et al., 2015). Martí Puig et al. (2017) complement this list with the **(4)** Eco-Management and Audit Scheme (EMAS) and the **(5)** Port Environmental Review System (PERS) methodologies; more commonly referred to as Environmental Management Systems (EMS). These EMS frameworks have been generally accepted and applied (seen through multiple applications in practice), and are designed by a number of scholars, public and semi-public institutions (see the paper by Peris-Mora et al. (2005) for a thorough overview of their establishments). Disagreement persists however as to the extent such schemes are able to grasp sustainable conduct. Various scholars have focused on developing an alternative framework/methodology for the assessment of sustainable performance, complementing these established schemes. In Table 4.2 an overview of literature citations is provided that address the topic of sustainability assessment. They alternatively propose a framework of indicators (selection) for ports and maritime supply chain stakeholders. The particular dimension of sustainability which is covered in the corresponding paper is also highlighted in Table 4.2. From the table, it can be inferred that the social aspect of sustainability is omitted the most in the analyzed literature and that environmental matters are addressed by the clear majority. It can be concluded that in the analyzed literature the notion of sustainability is not often studied holistically as the integral components of economy, environmentally and socially.

	(M. Puig, Wooldridge, & Darbra, 2014)	(Antão et al., 2016)	(Kemme, 2013)	(Roos & Kliemann Neto, 2017)	(Martí Puig et al., 2017)	(Laxe et al., 2016)	(Peris-Mora et al., 2005)	(Lu, Shang, & Lin, 2016b)	(Canbulat, 2014)	(Guimarães et al., 2014)	(Lu, Shang, et al., 2016b)	(Halog & Manik, 2011)	(Zhou et al., 2018)	(Galán-Martín et al., 2016)	(Schipper et al., 2017)	(Xiao & Lam, 2017)
Economic	✓		✓					✓				✓		✓	✓	✓
Environmental		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Social								✓				✓	✓	✓	✓	✓
Health		✓														

Table 4.2: Sustainability coverage of literature observations

The paper by M. Puig et al. (2014), which is a product of the PRISMS[4] project initiated by the European Commission provides a framework for the selection of Key Performance Indicators to evaluate the environmental performance of ports. Antão et al. (2016)[5] dissertation serves the same purpose but focusses both on environmental indicators and health-related indicators. The authors content that: "In case of the environment, EPIs [Environmental Performance Indicators] concern an organization's impact on living and non-living natural systems, including ecosystems, air, water, soil and sediment" (M. Puig et al., 2014, p. 125). Kemme (2013) identifies and categorizes indicators which are impacting the operational efficiency of terminals, such as design-related variables and economic related variables. To illustrate, the author stresses that the most popular equipment efficiency metrics for container terminals is the *Gross Crane Rate* (*GCR*), which represents the number of containers that are loaded and discharged by a single crane (QC) on the quay. *Equity-based throughput* is a measure to determine the throughput amount of a terminal that is attributable to a particular operator (Rodrigue, Comtois, & Slack, 2009). This metric became increasingly relevant in recent times where Joint-Venture structures and multiple-ownership of terminals became common practice. The probe by Roos and Kliemann Neto (2017) is unique in the sense that it identifies indicators that capture the economic effects of environmental measures management can call in order to mitigate negative environmental consequences. This would presumably constitute an interesting policy tool for management as it would allow them to immediately monitor the financial implications of their actions.

Peris-Mora et al. (2005) focus on the distinction between various types of variables. Their explicit focus targets environmental management indicators, aiming to contribute to the constructive decision making of at the PA level or operator management in matters concerning the environment. The proposed framework of M. Puig et al. (2014) categorize the environmental indicators used in the port sector into three classes: **(1)** Management performance indicators, information regarding the effort of management to advocate sustainable practices; **(2)** Operational Performance Indicators, information about the environmental consequences of the operation; and **(3)** Environmental Condition Indicators, which yield information regarding the status of the endogenous environment. The additional insights one can infer from this categorization is what factors of efficiency and performance are under the units' control and attributable to a certain cause .

4.2.2 Indicator validity

The following criteria, based on a literature review conducted by M. Puig et al. (2014), serves the need to evaluate the relevance and significance of selected indicators: *Policy relevant*, *Informative*, *Measurable*, *Representative* and *Practical*. The criteria can be assessed based on a question denoting the criteria in question. The questions, inferred from the study of M. Puig et al. (2014), are modified such that they fit the context of terminal operator, as is the purpose of this dissertation, and listed in Table 4.3.

Criteria	Question to be asked
Policy-relevant	Does the indicator monitor the key outcomes of the environmental legislation and measure progress toward policy goals?
Informative	Does the indicator provide information about the status and trends of the operators' environmental/social/financial performance over time?
Measurable	Does the indicator use readily available data or made available at a reasonable cost/benefit ratio?

[4] Port Performance Indicators: Selection and Measurement (PRISM), a European Commission initiative launched to establish a common framework to evaluate performances of ports.
[5] The paper by (Antão et al., 2016) is written in the context of the Ports Observatory for Performance Indicators Analysis (PORTOPIA) platform. The intention of the platform is for port authorities to communicate on their performances periodically to develop insights into the European port systems' performance.

Representative	Does the indicator provide a clear picture of environmental/social/financial conditions and pressures on the environment?
Practical	Is the indicator straightforward to monitor and easy to interpret?

Table 4.3: Criteria and questions for the evaluation of sustainable performance indicators

In conclusion in can be argued that no single sustainable indicator reporting mythology is prevalent generally and neither in the ports sector. Albeit initiatives exist (PIANC provides the greatest example in the ports domain (PIANC, 2014)), and the GRI G4 guidelines provides for some efforts in that direction, only gradual progression has been made. The consequence hereof is that no coherent strategy has been negotiated to report on sustainable matters, complicating the acquisition of homogeneous performance statistics.

4.3 Indicator Selection

Now that the literature regarding indicator selection has been reviewed and the units with a sustainability report publication have been selected, the indicators for sustainable performance evaluations' selection process can proceed.

M. Puig et al. (2014) stress two main methods for the selection of indicators; a top-down approach, implying consultation of literature and reports, and narrowing down the list of indicators to a descriptive set; and a bottom-up approach, referring to the compiling of a set of indicators based on suggestions from key stakeholders from the sector under scrutiny. As an illustrative model, Golany and Roll (1989) propose a factor identification technique of selecting a vast amount of indicators and refining the selection by a three wave process of judgmental screening, quantitative analysis, and DEA based analysis. This proposal is in line with the top-down approach suggested by M. Puig et al. and serves as an example of indicator selection for DEA analysis. A tailor-made moderation of Golany and Rolls' indicator refining model is utilized which fits the context of this study (Figure 4.1). In the figure the waves are referred to as iterations. The iterations consist of a first and a second refinement process for indictors that will be used for the comparative analysis in the next phase of this dissertation.

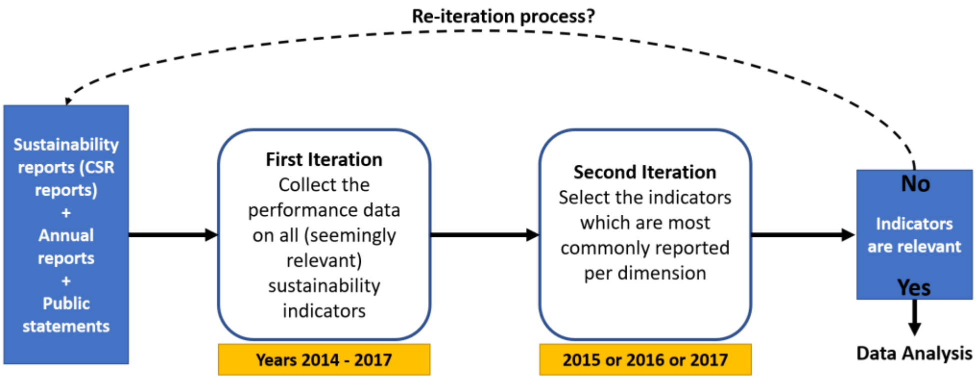


Figure 4.1: The Indicator selection process

Figure 4.1 illustrates the process of indicator selection applied in this research. All the indicators are inferred from, ranked in chronological order of importance, sustainability reports, annual reports, and public statements. The retrievable information was stored for the years 2014 until 2017. This is owed by the fact that the most recent statistics were not always available and thus a flexible time horizon was selected for the inclusion of the largest number of metrics.

Out of the first iteration of indicator selection a large data table is retrieved containing many missing entries. Therefore, a second wave is deemed necessary. The second wave of indicator selection determines the commonality of the identified indicators in the first wave and selects those indicators which are, to the highest attainable degree, universally shared by all terminal operators. This will result in a list of indicators. However, the relevance of these indictors in terms of sustainability is not certain and needs to be verified. The outcome of this process is a data table with the available data entries of the selected terminal operators on the selected indicators.

Despite efforts to validate the collected data on the sustainable performance metrics of terminal operators, action on this domain has proven to be rather fruitless. Some of the terminal operators have been contacted via email in order for them to reflect on the gathered performance statistics. From the five contacted operators, only one responded. This response provided little additional insights, as the main thread of the response was that more accurate data on performance statistics (including in the sustainable domain) was not open for public review. Hence, a validation step for the collected indicators has been left-out of this study.

4.3.1 First Iteration

This paragraph elaborates on the devised indicators initially selected in this manuscript. Since other sources of information are not widely available, this study exclusively depends on the figures which are available and communicated through **(1)** sustainability and/or Corporate Social Responsibility (CSR) reports issued by terminal operators, **(2)** annual reports that are issues on behalf of the terminal operator, and **(3)** public statements made by or on behalf of the terminal operator, often regarding its throughput figures. Out of these three data sources, some of the metrics were recorded. From the sustainability report issues all (or nearly all) of the reported indicators (that were interpretable) were stored. The annual files were only consulted when sufficient financial data was lacking from the sustainability reports. In some specific cases the throughput figures were missing in both the suitability reports and the annual reports. Therefore, in those circumstances other public statements were used to gather information regarding throughput and scope of the business.

The data of the operators were recorded for the years 2014 until 2017. A complicating factor was the fact that some operators would issue a sustainability report with a considerable delay (in some cases exceeding up to two years) or on a non-recurring basis. This resulted in a data frame with much missing data point. In the proceeding sections, the variables for each of the dimensions of sustainability are mentioned. Most of the indicators are belonging to a specific category. However, some are individually defined indictors.

A description for each of these variables can be found in Appendix III.

- **Economic/financial indicators**

In Table 4.4 the devised indicators for the financial dimension of sustainability are presented.

Indicator	Unit
Adjusted EBITDA	million Euro
Revenue	million Euro
Adjusted EBITA margin	% adjusted EBITDA of revenue
Profit	million Euro
Nett value added	million Euro
Revenue per TEU	EUR
Consolidated Capacity	mill TEU
	mill Tonnes
Consolidated Throughput	mill TEU
	mill Tonnes
Gross Capacity	mill TEU
	mill Tonnes
Gross Throughput	mill TEU

	mill Tonnes
Consolidated capacity utilization	% utilized consolidated capacity
Gross capacity Utilization	% utilized gross capacity
Full Time Equivalent	#

Table 4.4: Financial indicators

➢ **Environmental indicators**

In Table 4.5 the devised indicators for the environmental dimension of sustainability are presented.

Category	Indicator	Unit
CO 2	per TEU	kg
	Scope 1	Tonnes
	Scope 2	Tonnes
	Total	Tonnes
Energy	per TEU	Mega Joules
	Total	Giga Joules
	Water cons	m3/year
	Waste	Tonnes

Table 4.5: Environmental indicators

➢ **Social indicators**

The social indicators (Table 4.6) do not cover the full spectrum of social sustainability. The key categories which are commonly covered in sustainability or CSR reports are safety and wellbeing issues of the workforce. A main critique of the presented social indicators is that they do not provide any insight into an actor's attitude toward the surrounding community.

Category	Indicator	Unit
Health & well being	Reported Incidents	# of incidents
	Injury Rate	# of injuries/200,000 worked hours
	Lost Time Injuries	# of days
	Lost Time Injury Frequency Rate	# of days/200,000 worked hours
	Absentee days	# of days
	Absentee rate	% of absentee days
Training	Average training per employee	# Hours
	Gender diversity	% Female

Table 4.6: Social indicators

4.3.2 Second Iteration

The ample indicators mentioned in the first wave are not adequate for a comparative analysis study. The reason for this is twofold. First, due to the relatively brief amount of account units, incorporating an abundance of indicators will cause the model to produce inaccurate results (see paragraph 3.2 for the reasoning behind the inaccuracy). The second, more relevant argument is that there is a scarcity of data on all these indicators for all the units under scrutiny, resulting in a dataset with ample missing data points, undermining the validity of the analysis. The underlying argument behind the data deficiency is that in public communications (such as the three types used in this study) inconsistency in the 'what' and 'how' of the indicators often persists (consult the paper by Dainelli, Bini, and Giunta (2013) for a thorough discussion on inconsistencies in reported metrices by businesses).

The indicators which are used in the DEA model application are notified in this paragraph. The argument behind the selection of these indicators is the share of availability of sensible data points on these indicators. Table 4.7 gives an indication as for the number of available data points per variable selected in the first wave of variable selection. This availability is determined as follows: the percentage scores mentioned next to each of the indicators is the percentage of data points that contain a value relative to the desired amount of filled-in data points.

Financial	Availability	Environmental	Availability	Social	Availability
Adjusted EBITDA	37,5%	GHG emissions per TEU	25,0%	Reported Incidents	50,0%
Revenue	65,0%	GHG emissions Scope 1	25,0%	Injury Rate	20,0%
Adjusted EBITDA margin	37,5%	GHG emissions Scope 2	25,0%	Lost Time Injuries	20,0%
Profit	52,5%	GHG emissions total	70,0%	Lost Time Injury Frequency Rate	35,0%
Net value added	30,0%	Energy usage per TEU	22,5%	Absentee days	5,0%
Revenue per TEU	5,0%	Energy usage total	75,0%	Absentee rate	35,0%
Consolidated capacity (TEU)	12,5%	Water consumption	50,0%	Average training per employee	20,0%
(Dry Bulk & Others)	0,0%	Waste production	37,5%	Gender diversity	45,0%
Consolidated throughput (TEU)	69,2%				
(Dry Bulk & Others)	7,5%				
Gross capacity (TEU)	27,5%				
(Dry Bulk & Others)	0,0%				
Gross throughput (TEU)	20,0%				
(Dry Bulk & Others)	2,5%				
Consolidated capacity utilization	10,0%				
Gross capacity Utilization	15,0%				
Full-Time Equivalent	67,5%				

Table 4.7: Availability of data points per indicator

As it follows from Table 4.7 there are only several indicators which are suitable to be used in quantitative analysis. Though several methods exist to artificially fill in the empty fields of data, the credibility of the analysis is being jeopardized if variables are selected with too little data inputs.

- **Financial indicators:**
  The financial indicators which are incorporated in the model are *Consolidated Throughput*, *Revenue*, and *FTE*.
- **Environmental indicators:**
  The environmental indicators which are incorporated in the model are *Total Electricity Consumption*, *Total GHG Emission* and *Water Consumption*.

- **Social indicators:**
  The social indicators which are incorporated in the model are *Reported Incidents*, *Gender Diversey* and *Lost Time Injury Frequency Rate*.

In order to assess the relevance of these indicators, the criteria as they are addressed in paragraph 4.2.2 are used. The questions presented in Table 4.3, determining the soundness of an indicator with that criteria, are being asked for each of the selected indicators. The answers, being either a 'Yes' or a 'No', are presented in Table 4.8. The more 'Yes' answers an indicator yields, the more sensible it is as a predictor for the particular sustainable dimension. Because the *Policy relevant* criterium is subject to a particular act of legislation and this study does not involve any management indicator as such, the *Policy relevant* criterium is left out of the scope of this analysis.

Indicator	Informative	Measurable	Representative	Practical	Sensibility
Consolidated Throughput	No	Yes	No	Yes	2
FTE	Yes	Yes	No	Yes	3
Revenue	Yes	Yes	No	Yes	3
Profit	Yes	Yes	No	Yes	3
Total Energy consumption	Yes	Yes	Yes	No	3
Total GHG emission	Yes	Yes	Yes	No	3
Water consumption	Yes	Yes	Yes	No	3
Reported Incidents	Yes	Yes	No	Yes	3
Gender Diversity	No	Yes	No	Yes	2
Lost Time Injury Frequency Rate	Yes	Yes	No	Yes	3

Table 4.8: Criteria evaluation results

The column 'Sensibility' of Table 4.8 provides the sensibility score for each of the indicators. This is a number representing the number of criteria (out of 4 criteria) the indicator satisfies. It can be inferred that none of the indicators satisfies all the criteria, implying that neither of the indicators is perfect for describing their respective dimension. The indicators *Consolidated Throughput* and *Gender Diversity* are even particularly weak in describing their respective sustainable dimensions (with only 2 out of 4 criteria being satisfied). Due to significant data deficiencies persisting with other indicators (see Table 4.7), the condition of having weak predictors for to indicate sustainable performance cannot be overcome.

Moreover, the selected indicators can be classified as operational performance indicators, as it was coined by M. Puig et al. (2014). This implies that the indicators only reveal information regarding the sustainability of the operation, disregarding any actions imposed by management in the realm of sustainability or other dynamics at play which may not be reflected in the operational performance indicators.

4.4 Conclusion

The indicators which have been selected for analysis requires sustainability to be defined in a particular way fitting the context of this study. The dimensions of sustainability are only described by a brief number of indicators, causing the dimensions to be rather ill-defined. For the sake of this study, the three dimensions of sustainability are defined as follows:

- **Financial sustainability (red);**
  A function of the *Consolidated Throughput*, *Revenue*, and the *FTE*.

- **Environmental sustainability (green);**
  A function of the *Total Electricity Consumption*, *Total GHG Emission* and *Water Consumption*.
- **Social sustainability (blue).**
  A function of the *Reported Incidents*, *Gender Diversey* and the *Lost Time Injury Frequency Rate*.

The performance statistics of the terminal operator on the selected indicators are presented in Table 4.9.

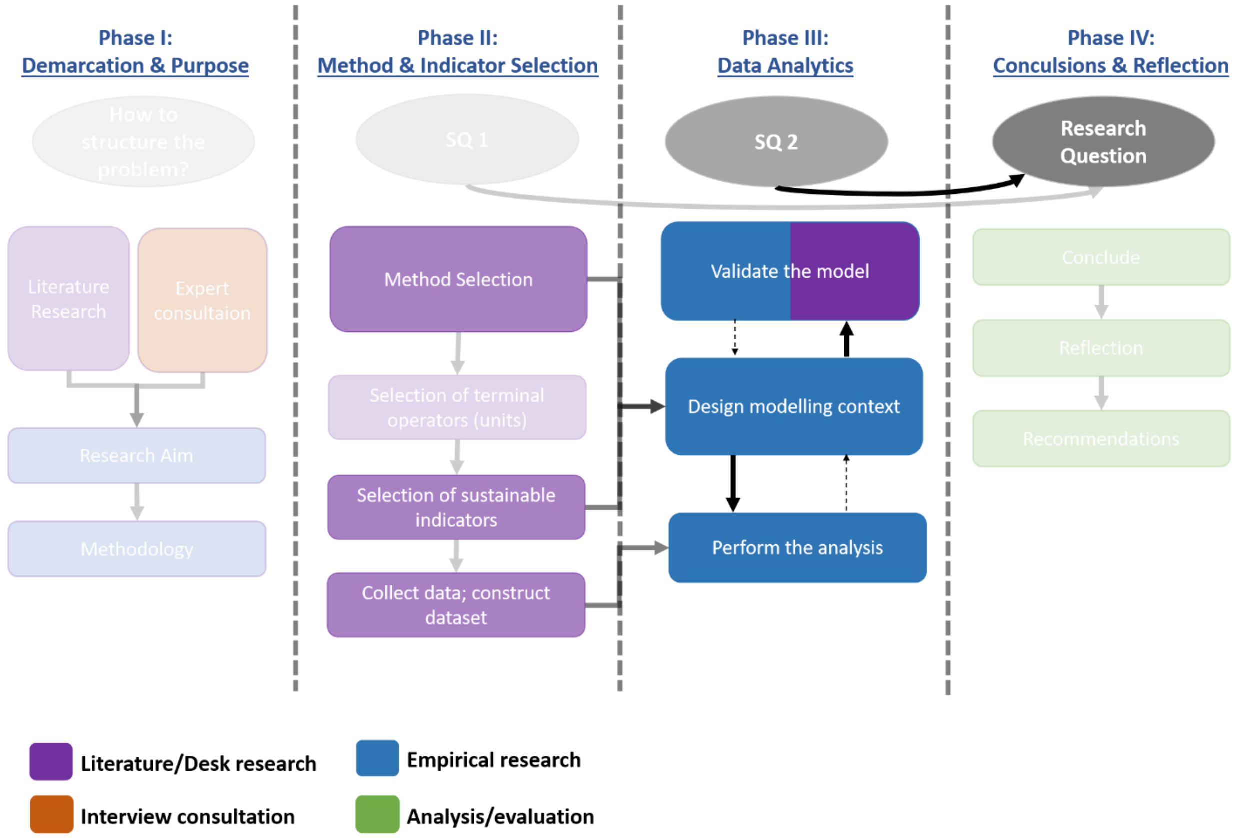
		Consolidated Throughput	FTE	Revenue	Profit	Total Energy Consumption	Total GHG emmission	Water consumption	Reported Incidents	Gender Diversity	Lost Time Injury Frequency Rate
TO/Units	Year	*Million TEU*	*#*	*Million EUR*	*Million EUR*	*Giga Joules*	*Tonnes*	*Cubic meters*	*#*	*% female*	*# days/200.000 worked hours*
APMT	2017	39.7	22,192	3,641	364	5,765,000	634,000	1,641,000	-	11.0%	0
ACT	2017	0.796	1,075	115	-	201,059	10,476	29,243	39	1.9%	0.358
Contship	2016	4.22	2,043	343	49	398,367	52,158	41,224	97	0.0%	0
COSCO	2017	17.7	9,683	-	-	4,364,000	416,474	2,615,609	84	13.0%	0.05
DP World	2016	36.5	-	4,148	1,063	10,091,078	1,067,447	-	-	0.0%	0
Eurogate	2017	3.3	3,420	608	85	1,504,800	109,700	-	296	11.1%	0
PortInvestment	2015	1.4886	-	327	(47)	67,214	-	-	-	36.0%	0.22
HHLA	2017	8.676	5,551	1,220	-	2,245,225	208,600	99,951	85	15.2%	0
ModernTerminals	2014	6.7	1,342	-	-	4,369,277	65,172	87,209	7	15.1%	0
Westport	2015	9.95	4,611	427	134	343,800	190,671	1,600,000	243	3.0%	2.26

Table 4.9: Data of the terminal operators on the selected indicators

As one can observe, some cells of Table 4.9 are empty. Therefore, prior to being analyzed, the data needs to be processed. The next phase, the collected is used for efficiency assessments of the terminal operators under scrutiny.

Phase III . Data Analytics

An overview of the third phases' purpose is provided in the following diagram:



This phase of the research provides an answer to the second sub-question of this research. This question, that was defined in paragraph 2.2 in Phase I, is repeated hereunder:

SQ 2: <u>What can we infer from the comparative study of the sustainable performance statistics of terminal operators?</u>

To answer this question, the steps as they are laid out in the diagram are performed. Hereunder the steps are briefly described.

- **Validate the analysis;** This step, as they are not in chronological order, is performed once the modeling context is in place. Its intention to verify whether the model is behaving as expected. The validating is conducted in alignment with the model construction step.
- **Design modeling context;** This step serves the purpose of model construction and the design of various iterations to assess the sustainable performance of the terminal operator units under scrutiny. Some important design choices, which are inferred from the methods' theory, are fundamental to the construction of the model alongside with the selected indicators, which are required for the model layout.
- **Perform the analysis;** This step encompasses the three phases of the DEA model iteration(s), as being identified by Francisco et al. (2013). These phases are: implementing the data, the processing of the DEA application and the appropriate recording of the output of the DEA process. Hence, this phase requires input from the data collection step of the previous phase.

The three steps are divided into two chapters; Chapter 5 'Data Processing' and Chapter 6 'Model Results'.

Chapter 5. Data Processing

In this chapter, a brief overview of the data which is inserted in the model is given. In paragraph 4.3 an overview of the selected indicators for analysis is provided together with the data extraction method and the raw data. This chapter proceeds with the extracted data and prepares the data to conduct the analysis. First, data preparation is required to get rid of the missing values in the dataset. Then, the discussion about the indicators must be supplemented with a DEA perspective. This refers to the process of labeling the indicators as either inputs or outputs, depending on the particular DEA model applied. Subsequently, various combinations of inputs and outputs can be identified. These combinations are referred to as scenarios in this manuscript and serve the aim of a thorough assessment of sustainable parameters. Lastly, a modeling methodology is selected.

5.1 Data Preparation

This phase is initiated by the data collected in the previous phase, as can be reviewed in Table X. This data, however, is not yet suitable for the analysis, since it contains quite an extensive amount of missing values. If the values are left empty, they will be interpreted as zero values for the analysis, which will trigger odd and flattered outcomes of the model. To avoid this, a value has to be assumed for the missing data. In order to do this, the nature of the variables is reviewed.

For the variable's *energy consumption*, *GHG emission*, *profit*, *revenue*, *water consumption*, *reported incidents* and *FTE*, some sort of positive correlation can be presumed between the scale of the corresponding units' business output and the value of the respective indicator. This assumption is supported by principal components of the dataset[6], which clearly distinguishes the (large) international operators form the local operators and the single terminal operators (Figure 5.1 illustrates the variables' significance in relation to the raw dataset and the modified dataset, represented by the length and direction of the arrow). For the sake of this research, the business output is simply defined as the *consolidated throughput* of a terminal operator. The advantage of using the *consolidated throughput* is that this figure is known for all terminal operators under scrutiny and that is serves as a proxy to indicate someone's scale of operation. The missing data points (i_m) for any of those variables are interpreted as the mean value of that variable, relative to the corresponding units' consolidated throughput, as is mathematically represented in equation 5.

$$i_m = \mu\ m * \frac{Consolidated\ Throughput_i}{\mu\ Consolidated\ Throughput}$$

Where

$$m = Indicator\begin{pmatrix} energy\ consumption, GHG\ emission, profit, \\ revenue, water\ consumption, reported\ incidents\ , \\ FTE \end{pmatrix} \qquad (5)$$

$$i = Terminal\ Operator\begin{pmatrix} APMT, ACT, Contship, COSCO, DP\ World, \\ Eurogates, Globalports, HHLA, \\ ModernTerminals, Westports \end{pmatrix}$$

For the remaining variables, *Lost time injury frequency rate* and *Gender diversity*, another rule applies. As these two variables are, presumably, not sensitive to the scale of the business, it is not necessary to multiply the means of the variables with the relative scale of the consolidated throughput of the units.

[6] Principle components is a term used in Principle Components Analysis (PCA) (Analytics Vidhya, 2016). It refers to the components, perpendicular to each other, which describe the largest degree of variation amongst the various dimensions of a dataset.

Applying the modifications described in the previous paragraph, an updated data frame is ready to be used for analysis (Table 5.1). As can be inferred from Figure 5.1, the data processing has consequences for the significance that some of the indicators have within the dataset. However, in the actual direction of significance not much has changed as most of the indicators still point towards the same direction, although with a more compelling urge (as can be inferred from Figure 5.1).

	Consolidated Throughput	FTE	Revenue	Profit	Total Energy Consumption	Total GHG emmission	Water consumption	Reported Incidents	Gender Diversity	Lost Time Injury Frequency Rate
TO/Units	*Million TEU*	*#*	*Million Eur*	*Million Eur*	*Giga Joules*	*Tonnes*	*Cubic meters*	*#*	*% female*	*# of days/200,000 worked hours*
APMT	39.7	22192	3641	364	5765000	634000	1641000	262	0.11	0.2888
ACT	0.796	1075	115	10	201059	10476	29243	39	0.018957346	0.358
Contship	4.22	2043	343	49	398367	52158	41224	97	0.106330074	0.2888
COSCO	17.7	9683	1486	228	4364000	416474	2615609	84	0.13	0.05
DP World	36.5	14120	4148	1063	10091078	1067447	1729587	315	0.106330074	0.2888
Eurogate	3.3	3420	608	85	1504800	109700	200608	296	0.111	0.2888
PortInvestment	1.4886	739	327	-47	67214	31780	92807	16	0.36	0.22
HHLA	8.676	5551	1220	127	2245225	208600	99951	85	0.152	0.2888
ModernTerminals	6.7	1342	639	105	4369277	65172	87209	7	0.150943396	0.2888
Westport	9.95	4611	427	134	343800	190671	1600000	243	0.0304	2.26

Table 5.1: Modified dataset for analysis

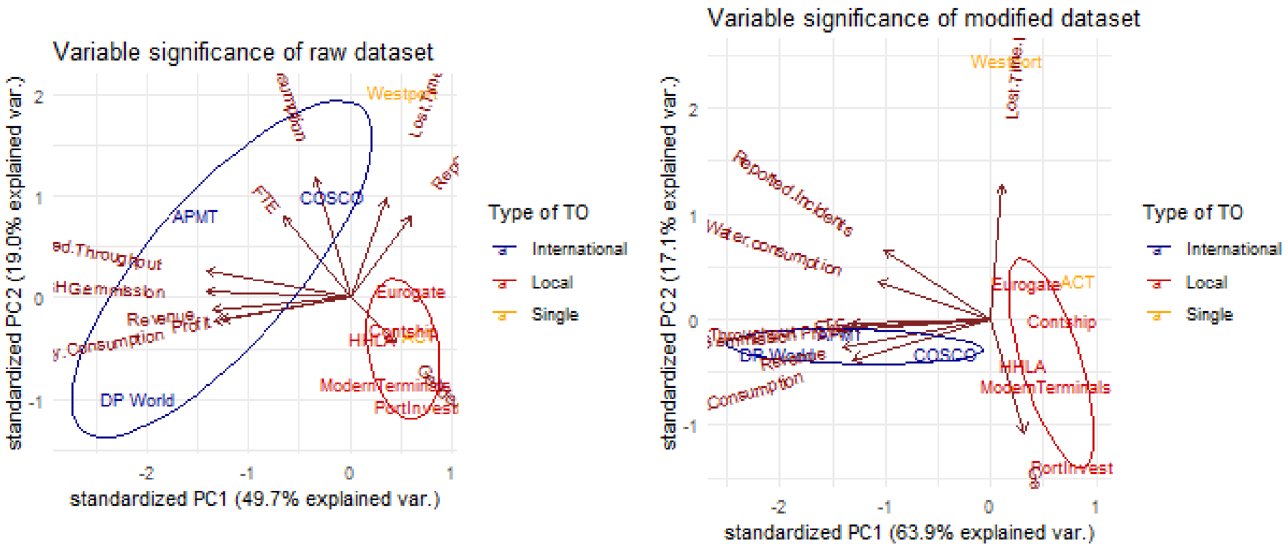


Figure 5.1: PCA graph illustrating the significance of the variables of the raw dataset (left) and the modified dataset (right)

5.2 Input/Output Selection

For this analysis, an input-oriented DEA model is used. An input-oriented DEA iteration determines if resources are rightly allocated and effectively used to produce a predetermined or fixed set of outcomes. The reason for using an input orientation is twofold:

- As the objective of this research is to contribute somehow to a more sustainable future, the intrinsic tendency is to focus on reduction rather than expansion (as is the assumption in output-oriented DEA).
- As the expansion and investment opportunities for terminal operators are highly volatile to external conditions such as (local) market fluctuations and the global economy, the assessment of expansions is not particularly useful for them. More realistic is to expect them to enhance their efficiency and improved allocation of resources consumed for their current business portfolio.

The assumption underlying the input-oriented DEA model is that inputs are to be reduced and thus undesirable. This makes sense for evaluating the operational efficiency of standard production and manufacturing processes, in which a (hypothetically) combination of raw materials x and y are processed and combined to produce output z. However, for evaluating the sustainable efficiency of a process, the standard definition of inputs and outputs (as used in the production contexts) must be altered. As an example, GHG emissions, a variable which is commonly seen as an output of a (production) process, is a negative externality of that process which one does not intend to increase. Therefore, GHG emission needs to be treated as in input variable for the DEA model. The question being asked for the consideration of a variable identifying as an input or an output variable is: *is the variable a positive or a negative externality or consequence of the terminal operators' business practices?* For example, *Consolidated Throughput* in the event of a terminal operator is used in this dissertation as a proxy for the magnitude of the operation. As terminal operators would likely see their business outputs grow (in respect to their investments), it is deemed as a positive externality and hence this indicator is considered as an output variable. The probe by van Dyck (2015) even uses it as the only output indicator to measure operational efficiency. Table 5.2 lists the variables and whether they are regarded as inputs or outputs.

For the comprehensibility of the analysis, the variables are assigned to letters which represent that variable, as can be seen in Table 5.2. The table also specifies whether the variable in questions concerns an input or an output variable, and for which dimension of sustainability the indicator is relevant.

Variable	Represented by	Input/Output	Dimension
FTE	A	Input	Financial
Total energy consumption	B	Input	Environmental
Total GHG emission	C	Input	Environmental
Water consumption	D	Input	Environmental
Reported incidents	E	Input	Social
Lost Time Injury Frequency Rate	F	Input	Social
Consolidated Throughput	G	Output	Environmental, Financial, Social
Revenue	H	Output	Environmental, Financial, Social
Profit	I	Output	Environmental, Financial, Social
Gender Diversity	J	Output	Social

Table 5.2: Variable letters

5.3 Scenario Construction

Based on the dimensions to which the variables belong (see Table 5.2), combinations of input and outputs can be put together for various iterations of the DEA model. One constraint in creating these scenarios is the rule of thumb (See paragraph 3.2). The rule states that the sum of the input and output variables should not exceed the number of units divided by three. In this case, the number of units under scrutiny is 10, implying that the sum of input and output variables cannot exceed 3.33. In order to allow for a higher degree of variation in the output space this value is rounded up to 4 variables. Scenarios are determined by combining every input or collection of inputs associated with a particular dimension to an output or collection of outputs calling to that same dimension (as long as the number of variables does not exceed 4). An example of scenario construction for the environmental dimension is provided in Table 5.3. The table illustrates the combination of possible outputs for three combinations of inputs. Note that, due to the constraint with regards to the number of variables, not every potential combination of outputs is valid for each combination of inputs as in some cases the number of variables will exceed 4.

Inputs			Outputs			Scenario
B			G			BG
				H		BH
					I	BI
			G	H		BGH
			G		I	BGI
				H	I	BHI
			G	H	I	BGHI
	C		"	"	"	
		D	"	"	"	
B	C		G			BCG
				H		BCH
					I	BCI
			G	H		BCGH
			G		I	BCGI
				H	I	BCHI
B		D	"	"	"	
	C	D	"	"	"	
B	C	D	G			BCDG
				H		BCDH
					I	BCDI

Table 5.3: Example of scenario building of the environmental dimension

Albeit Table 5.3 illustrates a selection of scenarios, actually there are 42 scenarios for the environmental dimension, 38 for the social dimension and only 7 scenarios for the financial dimension. The difference is caused by the varying amount of inputs and outputs defined for each of the dimensions. For a full-scale overview of all the scenarios reference is made to Appendix IV.

An example of a scenario in the social dimension is EGHJ. This scenario refers to the situation where *Reported Incidents* is the only input, and *Consolidated Throughpu*t, *Revenue* and *Gender Diversity* are the outputs. The underlying question the DEA resolves in this circumstance for each DMU (terminal operator) is: '*to what extent can the number of reported incidents be reduced whilst the same magnitude of consolidated throughput, revenue and gender diversity are maintained?*'

5.4 Data Processing Techniques

This paragraph describes the tools used to perform the analysis and preparation for the analysis. The paragraph is split into three parts, encompassing the preparation, the modeling and the visualization elements of data analysis.

- **Data collecting and preparation;**

The data, as it was retrieved from the sustainability reports of the terminal operators, was gathered in Microsoft Excel. In Microsoft Excel data of the various indicators (and many more, as can be read in paragraph 4.3.1) was collected over various years and a final selection for the indicators was made.

- **Modeling;**

Subsequently, the model for the DEA implementation needs to be constructed. This model is constructed using the R programming language together with the R-studio programming environment. The reason behind this decision is the vastness of examples which exist in respect to DEA application in R, and the existing libraries which accommodate the execution of DEA modeling. In the R community, two packages are notorious for their capacity to solve DEA problems. These packages are '*rDEA*' and '*Benchmarking*'. Whilst both packages have been used for experimentation, the *Benchmarking* package is used after all for the analysis. This package is more user-friendly and offers a wider range of tailor-made modifications to the original model.

- **Visualization.**

As for the visualization of the model results, the R programming language was used as well. Various packages written for R, in alignment with its use in the R studio environment, are accommodating the creation of graphs and plots in order to make sense of the outcomes. For the visualization of the graphs used in the report, and in particular in Chapter 6, various packages were used. The most important ones are 'ggplot2', 'tidyverse' and 'ggbiplot' for the R library.

For the syntax used for the DEA application and visualization in this study, reference is made to Appendix V.

Chapter 6. Model Results

Recent developments in the DEA research field implied that two stages of DEA model processing can be identified. The first stage is the calculation of the radial efficiency scores of the various units. The second stage concentrates on calculating the slacks. As such, also a distinction between efficient and weakly-efficient units can be made, whereby efficient units respond to units which have no reduction potential for their input variables (in an input-oriented DEA application), and the weak-efficient unit refers to a unit which efficiency score is one, but nevertheless have a more desirable set of inputs and or outputs (Hwang et al., 2016; Morita, Hirokawa, & Zhu, 2005).

To address the first stage of DEA modeling, this chapter illustrates the appropriate interpretation of the modeling results. This process is guided by means of an example. This example is composed of scenario EGHJ, as it was also addressed in paragraph 5.3. The chapter proceeds with the rankings of the terminal operators for each of the dimensions of sustainability. Subsequently, an elaboration on three terminal operators' results sheds light on the implications of the results for each of the operators included in this study. The chapter concludes with a validity assessment of the DEA model application.

6.1 Ranking Based on a Single Scenario

In this paragraph, by means of illustration, one scenario is being described on the basis of its outcomes. The scenario being used in this example is the EGHJ scenario, where *Reported Incidents* is the input, and *Consolidated Throughput*, *Revenue*, and *Gender Diversity* are the outputs. This scenario is the same as was being mentioned before in paragraph 5.3. Figure 6.1 depicts the results of the EGHJ scenario in a graph. The graph projects in grey also the behaviour of the other scenarios in the social dimension to grasp an idea as to how this scenario behaves relative to others.

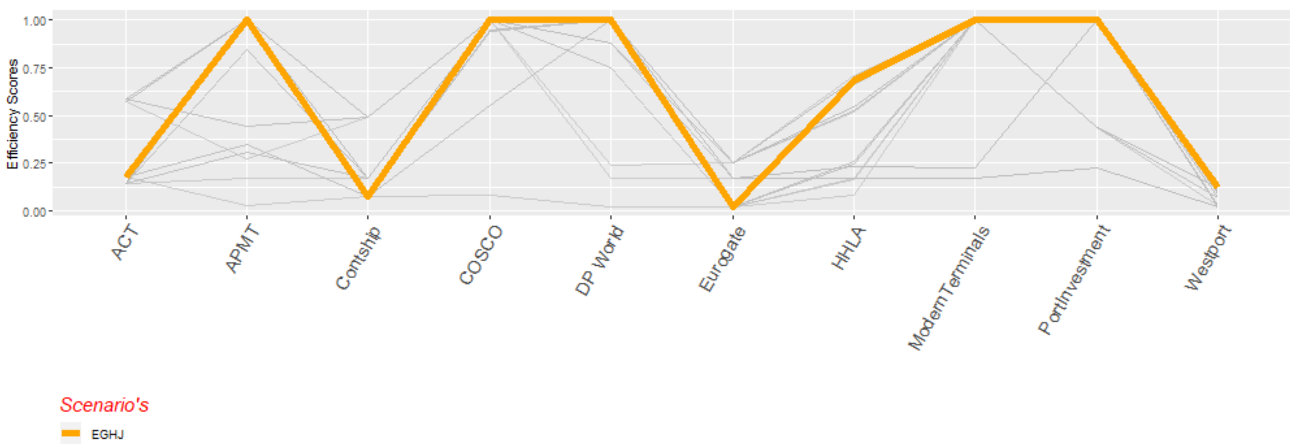


Figure 6.1: Results of the example scenario EGHJ

From the figure, it can be inferred that there is a high level of variation amongst the terminal operators' efficiency in the EGHJ scenario. *APMT*, *COSCO*, *DP World*, *Modern Terminals* and *PortInvestment* are determined to be efficient because their efficiency score is equal to 1; *ACT*, *Contship*, *Eurogate*, *HHLA*, and *Westport* are considered to be inefficient because their efficiency scores are less than 1. Inefficient in DEA terminology implies that the existing magnitude of the input/output variables are not optimal, and a reduction of the input variables (in case of in input-oriented DEA) is possible whilst still pertaining the same output. Table 6.1 provides an overview of the results of the EGHJ scenario. In addition to the DEA efficiency scores, the table also exemplifies the saving potential of the various terminal operators. The saving potential is determined by multiplying the inverse of the efficiency score of a unit with its value of the input indicator in question, as is displayed numerically in equation 6. With the outcomes, an answer can be formulated for the question raised in paragraph 5.3: T*o what extent can the number of reported incidents be reduced whilst the same magnitude of consolidated throughput, revenue and gender diversity are maintained?*

$$Savings\ Potential_i^m = (1 - efficiency(i)) * m^i$$

Where

$$m = (1,2,..,m)\ input\ variable \qquad (6)$$
$$i = (1,2,\ldots,i)\ Terminal\ Operator$$

	Reported Incidents	DEA efficiencies	Saving Potential	Attainable number of reported incidents
APMT	262	1	0	262
ACT	39	0.179487179	32	7
Contship	97	0.072164948	90	7
COSCO	84	1	0	84
DP World	315	1	0	315
Eurogate	296	0.023648649	289	7
PortInvestment	16	1	0	16
HHLA	85	0.681281206	27	58
ModernTerminals	7	1	0	7
Westport	243	0.122427984	213	30

Table 6.1: Outcomes of the EGHJ scenario

Because five of the terminal operators are deemed efficient in the latter example, it is not sensible to rank the operators based on the scorings of this single scenario. However, make a ranking based on the collective results on all the scenarios makes more sense, as it will show a higher degree of nuance in the outcomes. The next paragraph portrays the ranking of the terminal operators on each scenario for the different dimensions.

6.2 Ranking Terminal Operators

In Figure 6.2 to Figure 6.4 the analysis results are presented. In this clause, the results refer to the efficiency scores of the terminal operators under the various scenarios for each of the sustainability dimensions. The efficiency score is a normalized value between 0 and 1, which indicates a zero efficient and an efficient unit respectively. Table 6.2 indicates per terminal operator the means of their efficiency scorings per dimension. Under the assumption that all the variables included in this analysis are equally important for the description of their corresponding dimension (and sustainability as a whole), the rankings in Table 6.2 provide a means to judge which operator performs best and ~~which~~ worst in the sustainability realm. It can be inferred, for instance, that *DP world*, ranking first, second and second (for the environmental, social and financial dimension respectively), overall performs the best when it comes to the sustainable paradigm. *Eurogate*, on the contrary, can be perceived as a weak performer when it comes to sustainability due to its low ranging on each of the dimensions of sustainability.

TO	Environment	Rank	Social	Rank	Financial	Rank
APMT	0.912802482	3	0.8166421	3	0.7603262	5
ACT	0.930308501	2	0.26945122	7	0.8076412	4
Contship	0.856748312	4	0.21915234	8	0.514606	7
COSCO	0.486483841	9	0.94655126	1	0.532157	6
DP World	0.95301475	1	0.9067089	2	1	2
Eurogate	0.465607621	10	0.13900316	9	0.3593256	10
PortInvestment	0.821987771	6	0.75403708	4	1	2
HHLA	0.828099574	5	0.39229142	6	0.5107151	8
ModernTerminals	0.815826479	7	0.70523758	5	1	2
Westport	0.673704697	8	0.06823644	10	0.4750188	9

Table 6.2: Rankings of the terminal operators based on their mean efficiency scores per dimension

The first diagram in each of these figures is a boxplot diagram representing the dispersity of the efficiency scores per terminal operator measured over all the scenarios of the corresponding dimension. A boxplot representation is ordered as follows: a boxplot diagram represents the data as four zones which each contain 25% of the data points. The zones are characterized by two white boxes and in the middle a thick black line, representing the median, and two vertical black lines on either end of the white boxes. The white boxes represent the inner-quartile range, enclosing 50% of the data points, separated by the median. The vertical black lines represent the upper quartile and lower-quartile, each enclosing 25% of the data point. The blue dot in the boxplot diagrams represents the mean of the efficiency score. In the event that the surfaces of the percentiles are not noticeable in the diagram, it implies that the datapoint is not scattered sufficiently to be interpretable by the boxplot. One such example for the environmental dimension is ACT. Because only six scenarios prove to be inefficient (out of 42 scenarios in total, see paragraph 6.3.3), implying an efficiency score smaller than 1, most of the data points are located on top of each other, prohibiting a box to appear in sight.

The second diagram illustrates the scenarios, represented by the lines, and their scorings by the different terminal operators. The figures are valuable for observing trends and mean scores per terminal operator. For the environmental dimension, it can be derived from Figure 6.2 that *DP World* shows the best performance, as for almost every scenario it is considered to be efficient. This is also supported by the mean efficiency scores as presented in Table 6.2. Notice that for each of the dimensions, a different number of scenarios is defined prescribing the dimension in question (as explained in paragraph 5.3).

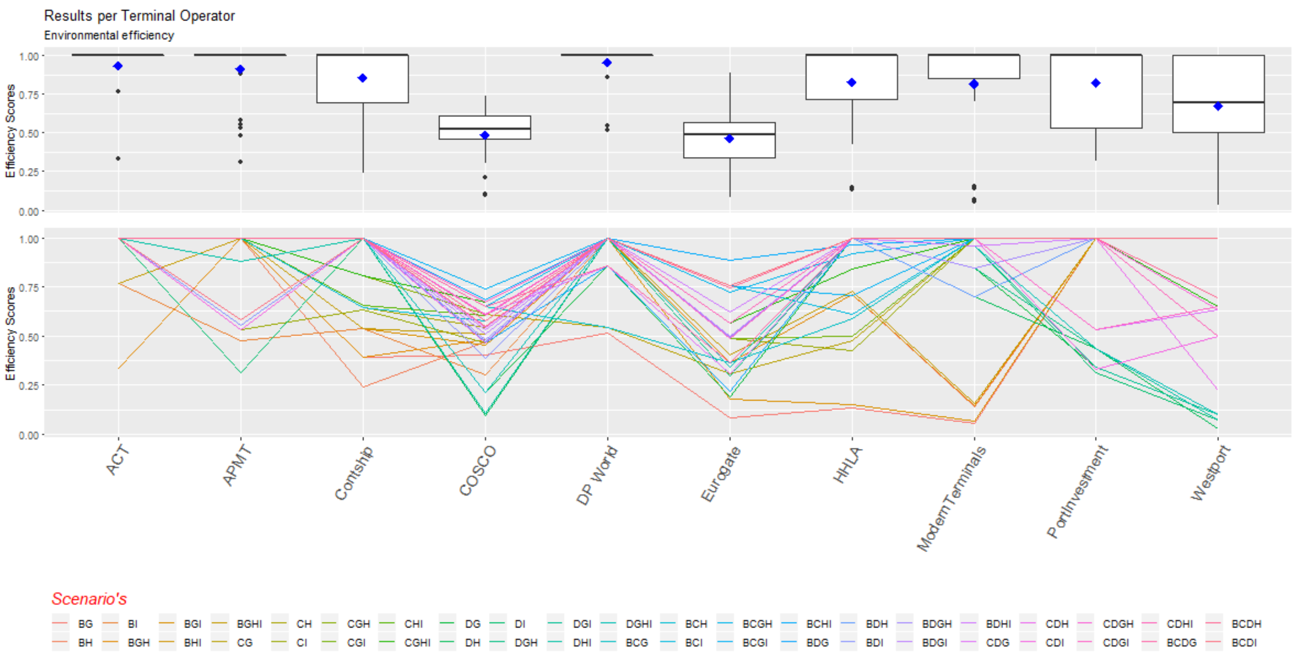


Figure 6.2: Environmental dimension results

For the social dimension (Figure 6.3), *ModernTerminals* and *PortInvestment* are represented by boxes which almost encompass the entire solution space of the DEA efficiency scores. This implies that for different scenarios, the operators have gotten very conflicting scores. This might indicate that the data is deceitful, as one does not expect such conflicting outcomes for scenarios of the same dimension (because the same indicators are used for many of the scenarios of the same dimension).

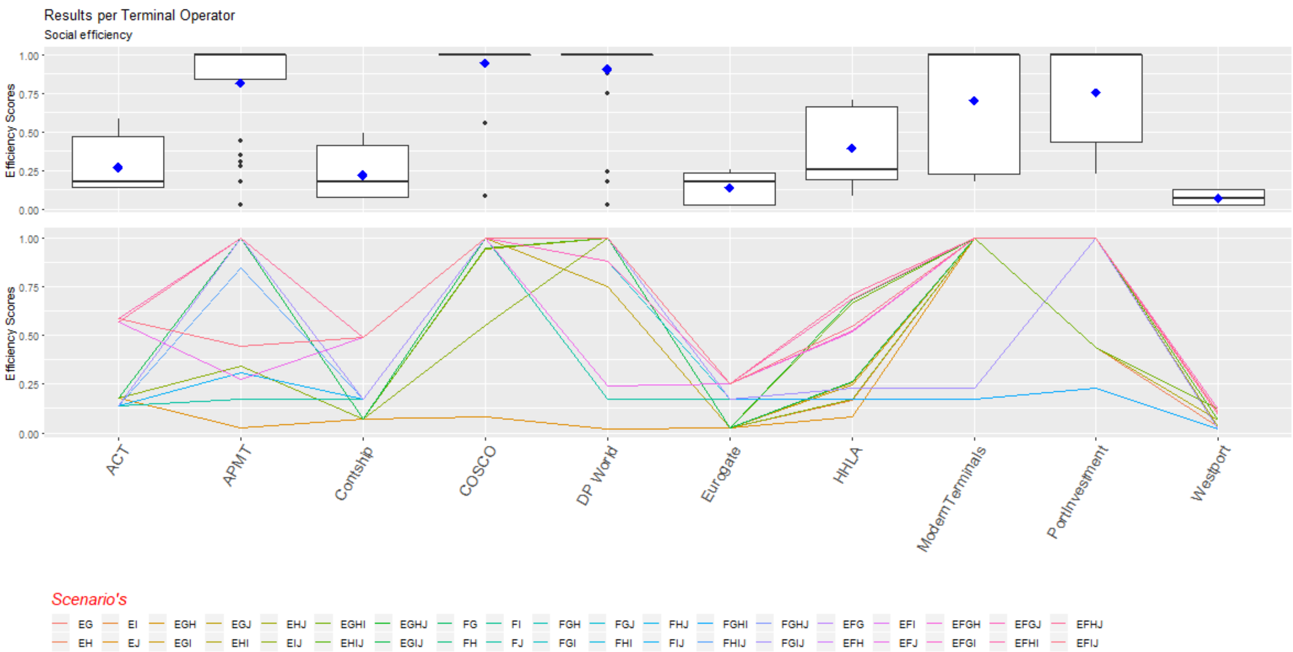


Figure 6.3: Social dimension results

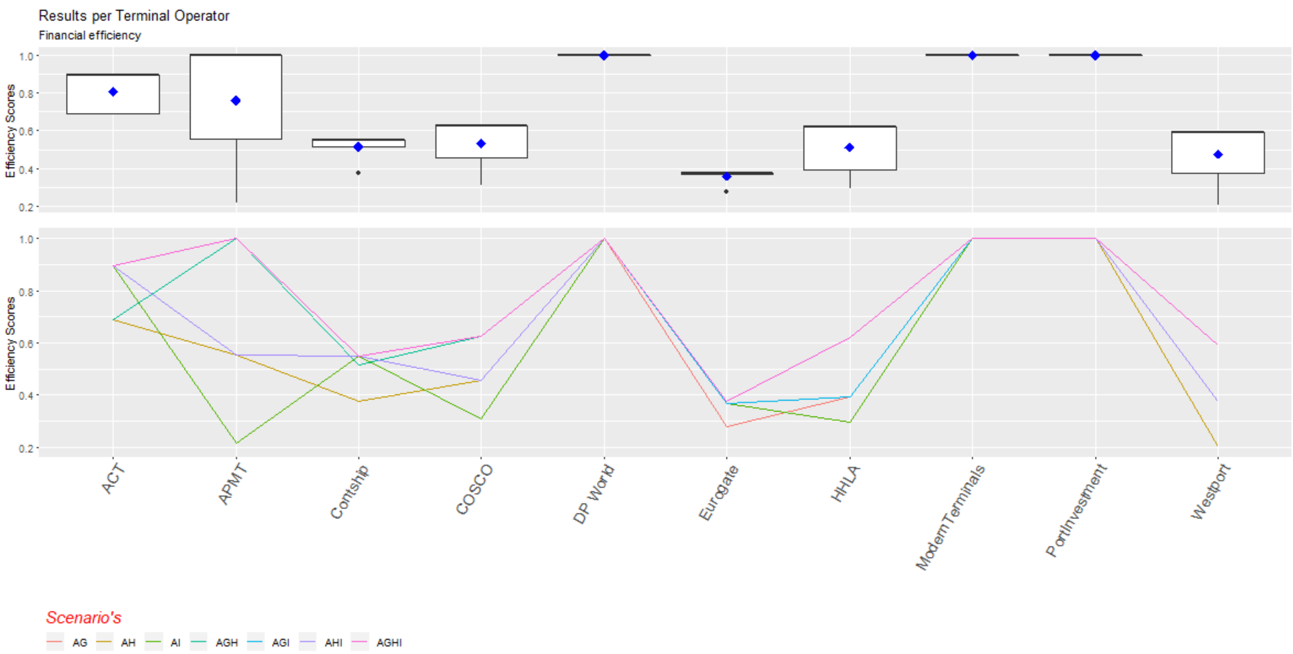


Figure 6.4: Financial dimension results

6.3 Implications for Individual Terminal Operators

This section is devoted to a brief transcription of the results of the DEA application per terminal operator. Not every operator is analyzed in exhaustive detail. Instead, the implications of the results for three operators, the high performer *DP world*, the low performer *Eurogate*, and the average performer *ACT*, are discussed. For a full-scale reporting of the results per terminal operator, reference is made to Appendix VI.

6.3.1 DP World

As mention in the previous paragraph, *DP world* is evaluated as being amongst the best performers in each of the dimensions, ranking first, second and second on the environmental, social and financial dimension respectively. An overview of *DP Worlds'* efficiency scores per scenario for each of the dimensions is provided in Figure 6.5.

The operator is deemed efficient (meaning, scoring an efficiency score of 1) for almost all scenarios in the environmental dimensions, except for the scenarios BG, CG, DG, BCG, BDG, CDG, and BCDG. These letters refer to the combination of scenarios with *Total energy consumption*, *Total GHG emission*, *Water consumption*, and *Consolidated Throughput* as input and output variables. As in each of these scenarios *Consolidated Throughput* is regarded as the only output of the model iteration, one could infer that *DP Worlds'* metric of *Consolidated Throughput* is moderate compared those of the other output indicators like *Revenue* and *Profit*. This would indicate that DP World is performing well when it comes to limiting their negative environmental externalities per unit of revenue and profit as well as their revenue and profit margins per unit of throughput. However, their negative environmental output per unit of throughput still has ample room for improvement.

When reviewing the social dimension, *DP World* shows some large drops in their efficiency scorings. Especially in the scenarios EJ, FJ and EFJ *DP World* appears to be performing very badly, with obtained efficiency scores close to zero. Notably, the output indicator J (*Gender diversity*) is a common output in all these scenarios. This indicates that *DP World* does not have a high gender diversity ratio amongst its employees relative to its *Reported Incidents* and *Lost Time Injury Frequency Rate*. In order to increase their performance on the social dimension of sustainability, *DP World* should enlarge its ratio of females among its workforce. The financial dimension of sustainability reveals no indications for improvement. The operator is efficient under every scenario of the financial dimension existing in this study.

Figure 6.5: Efficiency scores of DP World for each dimension of sustainability

6.3.2 Eurogate

Figure 6.6 illustrates the efficiency performance of *Eurogate* in each of the dimensions of sustainability. It can be inferred from the graph that *Eurogate* is performing moderately in comparison with any of its counterparts. In neither of the scenarios in any of the dimensions, *Eurogate* is deemed efficient. Its highest efficiency score, a 89 percent efficiency, it scores for the scenario BCHI, which refers to the input's *Total energy consumption*, *Total GHG emission* and outputs *Revenue* and *Profit*. Furthermore, a positive sequence of efficiency scores is obtained for all the scenarios with the inputs B and C (*Total energy consumption* and *Total GHG emission* respectively), except for the scenario BCG (output G = *Consolidated Throughput*). This infers that the ratio *Total energy consumption* and *Total GHG emission* versus the outputs *Revenue* and *Profit* is relatively good. However, as was one of the weaknesses of *DP World* as well, the *Consolidated Throughput* lags behind compared to its other output indicators.

In the social and financial dimensions of sustainability, *Eurogate* does not reveal any sign of positive performance under any of the scenarios. Therefore, it is not possible to emphasize particular indicators that require improvements. For improved sustainable performance, *Eurogate* should concentrate on improving all of the input/output combinations' ration in order to leverage their performance relative to those of others.

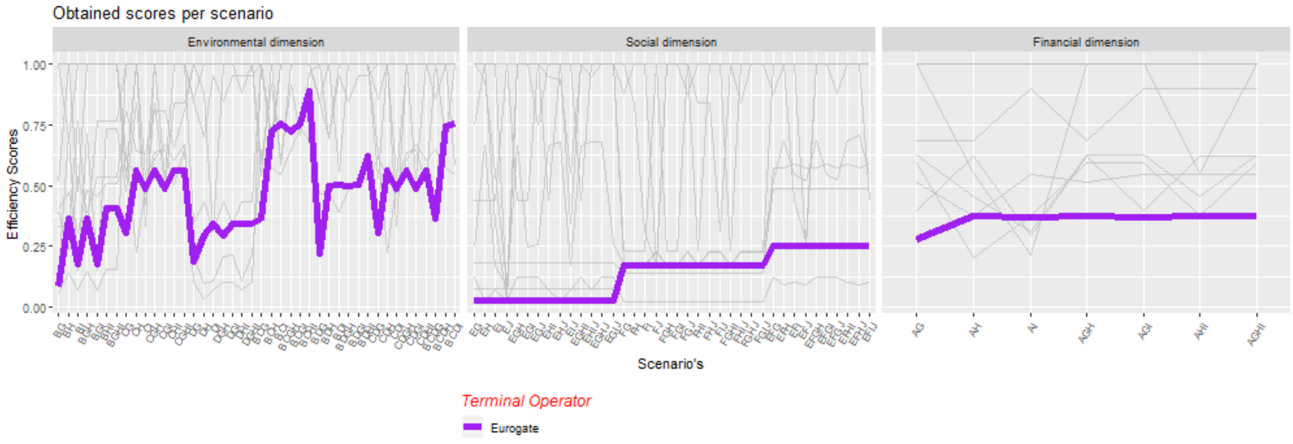


Figure 6.6: Efficiency scores of Eurogate for each dimension of sustainability

6.3.3 Aqaba Container Terminal

Figure 6.7 illustrates the performance of *ACT* for the three dimensions of sustainability. As one can observe, in the environmental domain *ACT* is performing well with just e few scenarios resulting in a low-efficiency score; the social dimension is a weakness of *ACT*; in the financial sense they are performing relatively high, despite never being deemed efficient. As for the environmental dimension, it is obvious that just a brief amount of scenarios result in an inefficient score for *ACT*. These scenarios are BG, BH, BI, BGH, BGI, and BHI. All these scenarios have in common that they share the single input B, which refers to *Total Energy Consumption*. Furthermore, the outputs G, H and I, refer to *Consolidated Throughput*, *Revenue*, and *Profit* respectively, representing the only available output indicators for the environmental dimension of sustainability. Because on each of the other scenarios (which share the same set of output variables) *ACT* scores efficiently, it is likely to assume that the input variable, *Total Energy Consumption*, is *ACT*s weakness.

The social dimension of sustainability is much less bright for *ACT*. For not a single scenario in the social domain is it considered efficient and its mean efficiency score barely exceeds 0.25. One can infer, however, that for all the scenarios with the input variables E and F, being *Reported Incidents* and *Lost Time Injury Frequency rate* (the only two input variables for the social dimension), the efficiency score of *ACT* is relatively high. This implies that both the input variables are a potential weakness of *ACT*, but when analyzed collectively appear to perform somewhat better. As more terminal operators' efficiency scorings seem to behave in a similar fashion (Appendix VI), it becomes apparent that this behavior is triggered by the model itself. This may be triggered by the multiple variables used as inputs and outputs in these scenarios, which decrease the capacity of the model to inflict nuances between the various operators (review the narrative regarding the fist rule about this matter, as is being described in paragraph 3.2).

The financial dimension shows relatively good performance of *ACT*, ranking 4th overall. Only the scenarios with outputs G and H, being *Consolidated Throughput* and *Revenue*, do not perform very well when offset against *FTE's*.

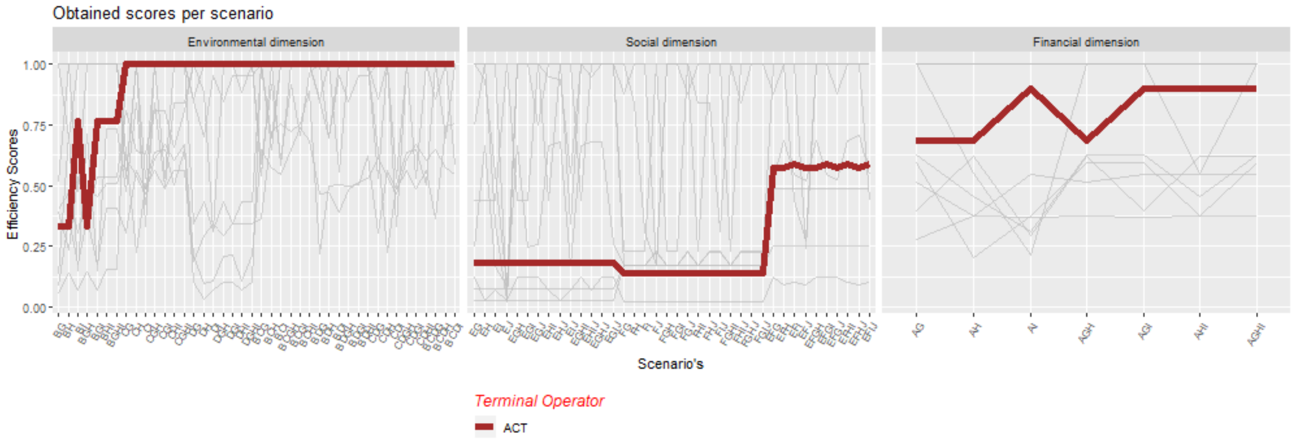


Figure 6.7: Efficiency scores of ACT for each dimension of sustainability

6.4 Validity Testing

This chapter addresses the validity aspect of the DEA model application for this particular study. It is worth mentioning that a DEA model interprets a process merely as a black box and disregards the internal dynamics underlying each of the DMU's. Hence, it is not meant to resemble reality as such, but merely review homogeneous processes from an aggregated perspective and compare them. Therefore, this validity assessment is to evaluate the validity of the underlying assumptions and the correctness of the computational analysis. For this evaluation two techniques are applied commonly applied in validation evaluations: extreme value testing and code of the model is reexamined.

6.4.1 Extreme Value Testing

As for the extreme value testing, the general idea is to parse an extreme value into the model and determine whether it behaves as expected. In the context of this study, the extreme value persists in the definition of an extreme DMU. Hence, besides the existing terminal operator, a hypothetical one is defined that possesses extreme characteristics in terms of the indicators selected for this study.

For the sake of illustration, the hypothetical operator is called "*#11*". For the evaluation the values of *#11* are drawn up being very positive, meaning that the throughput figures and the financial ratios are high in relation to their other (negative) indicators. The exact value of the indicators characterizing *#11* are presented in Table 6.3. In Figure 6.8, the significance of these values can be observed, as *#11* seems to be much better performing in based on the variables *Consolidated Throughput*, *Total energy consumption*, and *Total GHG emission* (the scenario using these idicators is used for illustrative purposes in this paragraph).

Indicator	Unit	#11
Consolidated Throughput	Million TEU	60
FTE	#	10,000
Revenue	Million Euro	6,000
Profit	Million Euro	1,500
Total Energy Consumption	Giga Joules	1,000,000
Total GHG Emission	Tonnes	100,000
Water Consumption	Cubic meters	600,000
Reported Incidents	#	1
Gender Diversity	% female	0.60
Lost Time Injury Frequency Rate	# of days/200.000 worked hours	0.01

Table 6.3: Values of the indicators for DMU #11

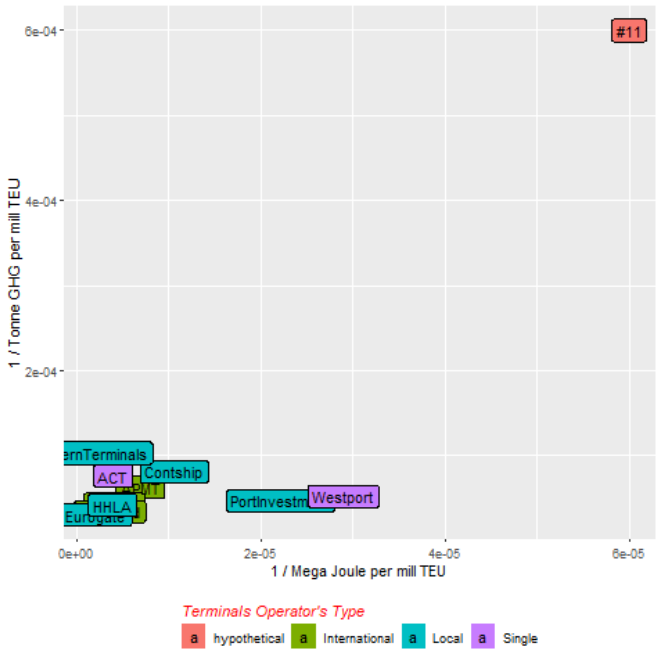


Figure 6.8: Relative position of operators based on three indicators

To demonstrate the DEA model behavior, one scenario is selected. As in Figure 6.8, the BCG scenario (input variables are *Consolidated Throughput* and *Total energy consumption*; output variable is *Total GHS emission*) is used for demonstration. In Figure 6.9 and Figure 6.8 the frontier plot of the particular scenario and the efficiency scores for the terminal operators are presented. As one can observe, the imaginary #11 terminal operator outperforms the other operators, implying that the DEA model behaves according to expectation.

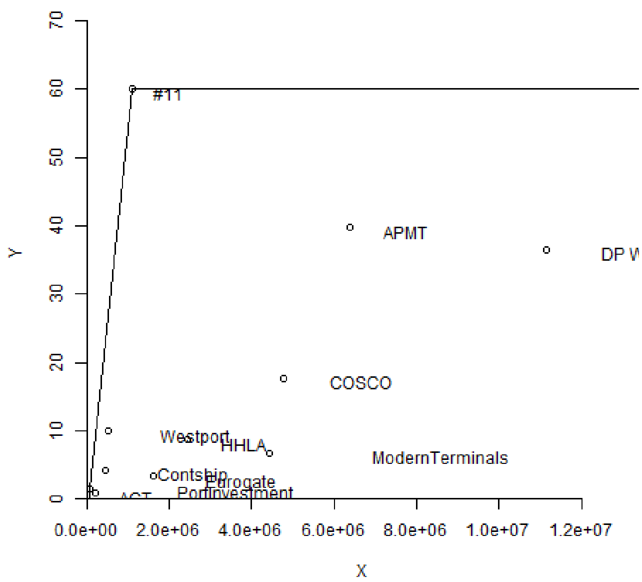


Figure 6.10: Extreme value DEA frontier

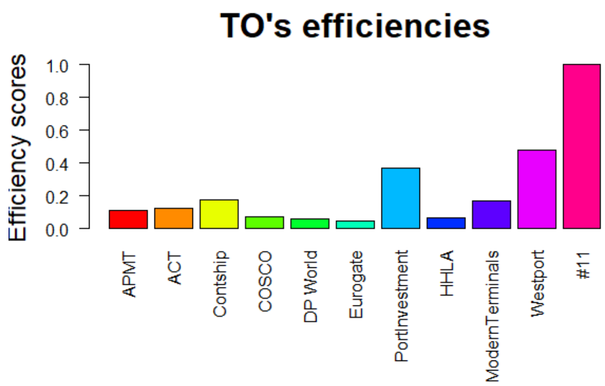


Figure 6.9: Extreme value DEA efficiency scores

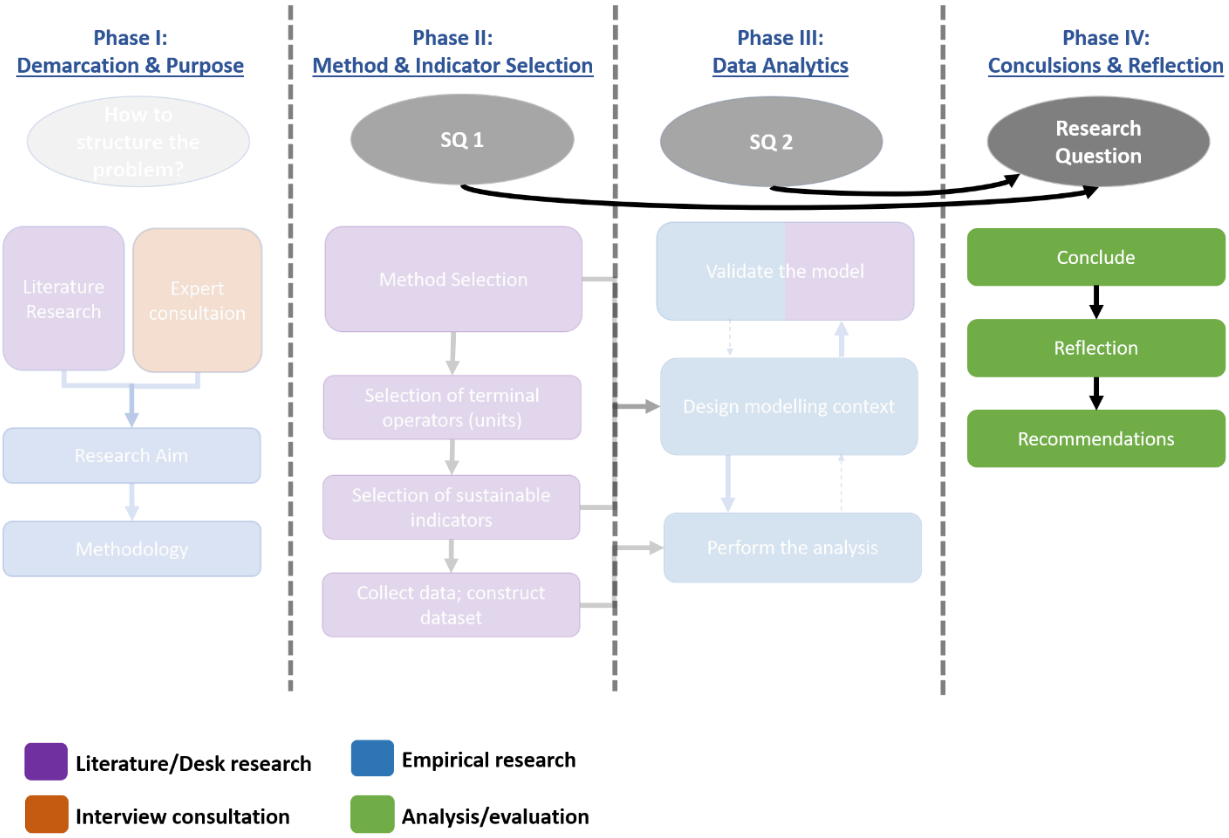
6.4.2 Syntax Evaluation

The syntax evaluation consists of checking the syntax of the DEA model for errors. Because the DEA is run in the coding environment written in R script, one needs to be aware that a minor mistake in the syntax of the model may have far-reaching consequences. Mistakes in the syntax may cause the script to not work, or it may work differently than anticipated. As a tool for coding and debugging, the R studio platform facilitates numerous opportunities. One such opportunity is the R debugger tool. This tool helps in identifying mistakes in the syntax and offers suggestions for resolving. In the model script, no mistakes were identified by the R debugger tool. Neither did any of the code produce any highly conspicuous outcomes. In order to verify that further, various scenarios were run manually in order to see if the same results were retrieved. The findings supported the claim that the model syntax is functioning as it should.

Both validation techniques indicate that there is no reason to doubt the model results as being presented in Chapter 6.

Phase IV . Conclusions & Reflection

In this concluding phase the conclusions and implications of this research are drawn. The following diagram illustrates the systematic way in which this is performed.



The purpose of the steps is the following:

- **Conclude;**
  The conclusion includes a synthesis of the findings and the answers to the research questions.
- **Reflect;**
  The reflection includes a reflection in the contribution of the research for the society and a reflection on the process of this research.
- **Recommend.**
  The dissertation will conclude with some implications and suggestions for further research.

These three steps are divided into three chapters; Chapter 7: 'Conclusions', Chapter 8: 'Reflection' and Chapter 9: 'Recommendations'.

Chapter 7. Conclusions

The intention of this chapter is to present the communicate the conclusions of this research. It provides for the synthesis of the findings and provides for answers to the sub-questions and the main research question. Furthermore, the chapter provides a discussion on the limitation prevalent to this study.

7.1 Synthesis of Findings

Terminal operators fulfil a roll in port governance that is of paramount importance. Due to their role as complex logistical hubs in ports, their impact on ports' performance and sustainability cannot be omitted. Terminals are the areas within a port territory where cargo, existing in many categories of transhipment, is transferred from one mode of transport to another. They combine various forms of transport and are therefore regarded as complex logistical hubs. In the recent paradigm of private interference is port governance, businesses are commonly in charge of logistical processes of ports. Contemporary terminals are subject to a variety of fiscal structures, ranging from fully owned subsidiaries of a terminal operating company to a vast list of private entities sharing the ownership in a joint-venture arrangement. The Large Terminal Operators, often comprising a global terminal portfolio, alongside with major shipping lines, dominate the terminal market.

Terminals are regarded as strategic assets of terminal operators. These operators try to leverage their competitive advantage through the bundling of resources in unique competences. Sustainable performance metrics for a terminal are often confidential in nature and therefore, if at all existent, difficult to collect. Terminal operators, on the contrary, do sometimes issue sustainable performance statistics to various degrees. Terminal operators find themselves in an environment increasingly demanding them to morally justify their business practices and hence issue reports for the purpose of garnering public support. These performance statistics provide a basis for conducting comparative analysis and allow us to gain insight into their relative stance in relation to other rivals in the sector. Almost all terminal operators have devoted attention to the notion of Cooperate Social Responsibility, most profoundly on their public websites. For sustainable performance metrics, a search for sustainability reports was at the forefront. However, despite the increasing awareness of the importance of sustainable business practices, reporting on sustainable performance practices is still a rare occurrence. As a consequence, the indicators that were deemed eligible for comparative analysis were little in number. Moreover, the suitability of the indicators to describe the concerned sustainable dimensions is, next to being merely operational indicators, also debatably prone.

Based on the performance parameters reported by terminal operators, a comparative analysis was conducted. The methodology employed to accomplish this was the DEA methodology. Collected data on various performance indicators was used as the input for the comparative analysis. In order to account for missing values, data deficiencies were substituted through a data processing technique. The DEA methodology requires input and output indicators to be identified for each iteration of the model. Hence, for the dimensions of sustainability (environmental, social and financial) scenarios have been set up based on a categorization of the performance metrics as inputs and outputs. For this study an input-oriented DEA approach is employed. This is legitimized due to the categorization of input indicators as negative externalities and output indicators as positive consequences.

The outcome of the quantitative comparative analysis study provided a ranking based on the mean efficiency scores per dimension for each of the terminal operators. Furthermore, scores for each of the scenarios (which are based on a certain combination of input/output variables) can provide for insights into the relative performance of terminal operators on the various metrics in use.

Taking the technical limitation of the DEA application into account, several scenarios composed of input indicator(s) and output indicator(s) were drawn, belonging to a specific dimension of the sustainable triple-bottom-line principle.

7.2 Answering the Research Questions

The research aim, including the defined sub questions, were made explicit in paragraph 2.2 of this report. This paragraph intents to provide consolidated answers to these questions in a storyline format.

The first sub-question deemed to address the matter of method selection and sustainable performance practices and metrics used by terminal operators. The question raised to pinpoint this matter was addressed in Phase II.

SQ 1: <u>What is a suitable way of comparison and how do terminal operators communicate their sustainability matters?</u>

In the contemporary world, as the notion of sustainability gains significance, terminal operators must adapt to more sustainable business practices in order to safeguard their legitimacy as operator. Awareness of the importance of sustainability for a terminals' image perception is duly existent. CSR practices garnered a widely acknowledged significance in a terminals (operator) day-to-day communication with the public. In this study, all terminal operators which been included in the assessment applied some form of sustainability/CSR campaigning. The most profoundly applied method for that is to devote a section of their public websites advocating their sustainability or CSR practices. Often this section was given prominent place on the websites, such that it appears as being among their core competencies. In a few cases this section of the website was not so well campaigned (especially the case so with *DP World* and *PSA World*). Roughly two thirds of the terminal operators subjected in this study utilized a practice of sustainable reporting; issuance of sustainability or CSR reports conveying some degree of sustainable performance statistics. Among these operators, a significant share of them do only publish in the language of their country of origin. Hence, a multitude of reports are solely existing in foreign languages (such as Chinese, Korean and Spanish), and were therefore omitted in this study.

Merely 10 terminal operators have been considered eligible for incorporation in this study. Due to the sensitive nature of the sustainability performance statistics, reports often remained vague when it comes to the exact implication of these statistics. Consequently, the correct interpretation these statistics is often a difficult practice. The case of *COSCO Shipping Ports* could be used to illustrate this matter. *COSCO Shipping Ports* used a varying set of terminals for every iteration of their sustainability report, making it difficult to deduce the exact meaning of their performance figures.

Another difficulty persisting with the sustainability reports is their level of inconsistency. Up to now, no cohesive methodology is in place, for businesses in general and thus also for the ports and terminal operation sector, that guides in the reporting on sustainability practices and statistics. Despite the presence of initiatives to standardize the reporting practices such as the PORTOPIA, PRIMS and the PIANC framework (see paragraph 4.2.1), the indicators communicated in the scrutinized reports are mostly unique and inconsistent. The effect of this being that no coherent set of indicators exists, making cross comparison on sustainable performance burdensome. Nevertheless, for the fulfilment of the requirement under this research project, indicators have been selected that are most common in the analysed reports. These indicators are categorized based on their perceived dimension of sustainability.

- **The financial indicators**:
  Consolidated Throughput, *Revenue*, and *FTE*.

- **The environmental indicators**:
  Total Electricity Consumption, *Total GHG Emission*, and *Water Consumption*.
- **The social indicators**:
  Reported Incidents, *Gender Diversey* and *Lost Time Injury*, and *Frequency Rate*.

The validity of these indicators and their capacity to define their respective sustainable dimension is up for debate. However, as no alternatives to this list of indicators exists that are uniformly shared by a large set of operators the list provides the best we have to assess relative sustainable performance.

SQ 2: *<u>What can be inferred from the data issued by terminal operators regarding their sustainable performance metrics?</u>*

The quantitative comparative analysis method chosen for this study was the Data Envelopment Analysis (DEA) technique. Cross-comparison analysis applying the DEA methodology results in an overall efficiency score for each terminal operator for each of the dimensions. Figure 7.1 depicts the relative positions of terminal operators in both financial, environmental and social dimensions in one chart. The three dimensions are incorporated in the diagram as follows: the x axis labels the environmental efficiencies, the y axis the social efficiencies and the colour scale indicates the financial efficiencies (with a low-efficiency and a high efficiency being represented by the red colour and the green colour respectively).

It can be inferred from Figure 7.1 that a linear correlation seems to exist between the three dimensions of sustainability. The case of *DP World* and *Eurogate* are used as an example to exemplify this matter; *DP World* performs relatively good on each of the three dimensions, whereas *Eurogate*, on the contrary, performs weak on all dimensions. This, in itself, is not particularly odd, considering that for the each of the scenarios some similar (financial) indicators have been used to constitute those scenarios. The indicator *Consolidated Throughput*, for instance, has been used in all the dimensions as a proxy for the vastness of the terminal operators' business. However, a positive linear relation between environmental and financial interest may seem counterintuitive, but this study seems to provide no scientific proof that a pure market orientation is victimizing the environmental and social causes.

Another tendency that one can infer from Figure 7.1 is that the LTO terminal operators, being *APMT*, *COSCO* and *DP World*, are all deemed relatively efficient in terms of the sustainability dimensions, especially so for the social and environmental dimension. Only the financial efficiency of *COSCO* lags behind compared to the other operators. This pattern is not particularly odd, as one would expect a larger business to be more efficient when it comes to the utilization of resources due to the economics of scale principle. However, this study does not entail any conclusive conformation behind this assumption.

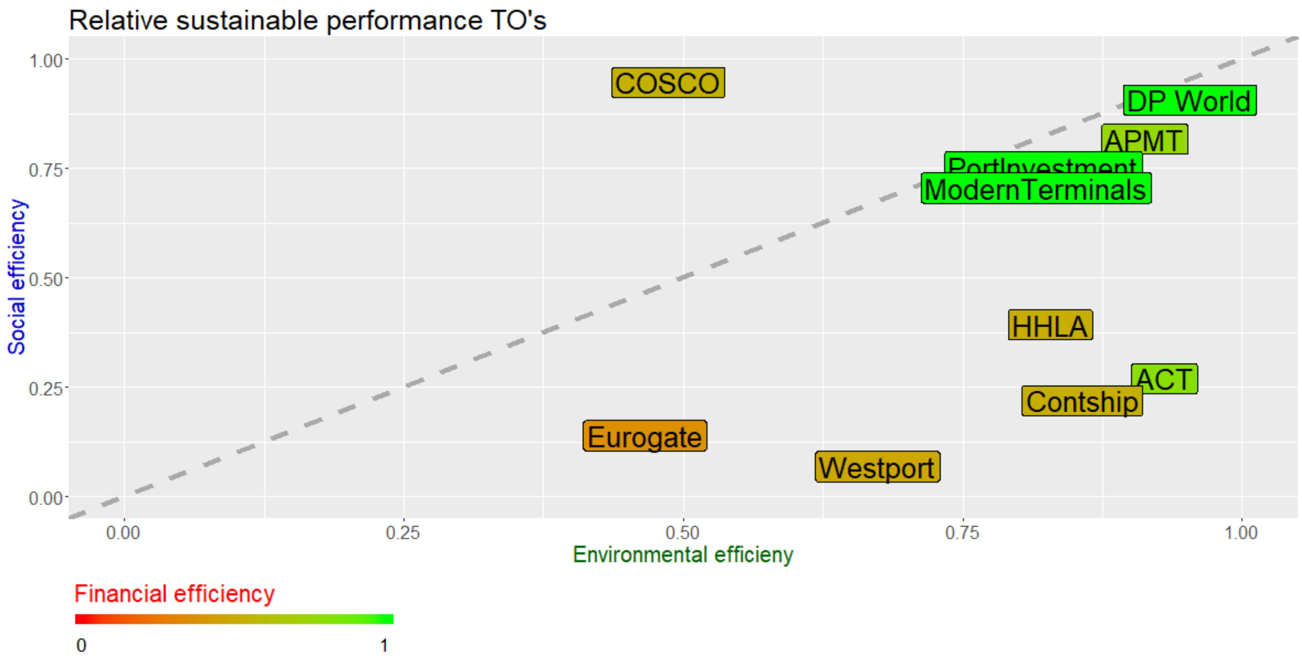


Figure 7.1: Relative sustainable performance terminal operators

Now the sub questions of the research have been addressed, the main research question can be answered. The main research question is the following:

"What insights can we garner when comparing sustainable practices and performances of terminal operators?"

This study proves that a quantitative comparative analysis of terminal operators' sustainable performance is possible. Previous literature elaborations have shown that a comparative analysis of container terminals is feasible, as is illustrated by the ample amount of exemplifying literature (Cheon, 2009; Cho, 2014; Tongzon & Heng, 2005; to name a few). Similarly, literature has also shown the feasibility of indicator identification that influence terminal operators' performance or competitiveness (Esmer, 2008; Lu, Lai, et al., 2016; Wiegmans & Witte, 2017; Yeo, 2015; to name a few). This research could be added to these literature elaborations, as the outcome of the model has revealed that benchmarking sustainable performance of terminal operators based on indictors that are enclosed in their CSR and sustainability publications is viable.

Sustainability is, being for the sake of commercial benefits or moral awareness, addressed throughout the terminal operating industry. However, despite the efforts by, for instance, the Global Reporting Initiative, no framework is in place that has sufficient leverage to steer the debate of sustainable reporting to the level at which quantitative comparative analysis become insightful. This research effort is an attempt to gather data on sustainable performance metrics of a multitude of terminal operators and objectively compare these with one another and benchmark them based on their sustainable conducts.

The results signify a significant degree of discrimination between terminal operators' sustainable performance (as is shown in Figure 7.1). However, to what extent the results obtained from the comparative analysis are sensible and insightful is debatable. The research is subject to ample limitations discrediting the outcomes of the comparative analysis. The limitations also yield valuable insight for the ports/terminal industry, as it contemplates the wrong conducts in the industry hindering the execution of quantitative benchmarking analysis that yield potential suggestions for improved sustainable efficiency.

7.3 Limitations of the Study

The credibility of the conclusions stated in the previous paragraph are jeopardized by a sequence of limitations. The first two limitations address the issue of sustainability reporting in the terminal industry, stipulating the shortcomings of the analysis.

1. **The number of units and indicators subjected in this study;**
   For a comprehensive quantitative comparative analysis, a sample set containing more units is desirable. Furthermore, the indicators which were commonly reported in sustainability publications of terminal operators were scarce in number. Only 10 indicators have been used to describe the entire realm of sustainable performance, which resulted in the dimensions being subject to only a few indicators not highly capable of defining that sustainable dimension.

   In the field of reporting and measuring on sustainable indicators ample literature is published. Albeit the port community has launched quite some initiative in recent years with respect to reporting on sustainable indicators, the PIANC institution and the GRI initiatives are two such example, the terminal industry has failed up to now to cohesively adopt a systematic way of measuring and reporting on sustainable matters. For terminal operators to embark on the journey towards more sustainable business routines, constitutional environments need to be altered such that operators are forced to report on metrics that represent a genuine proxy of sustainable performance.

2. **Possibility of misinterpretation;**
   It is likely that the data that was abstracted from the sustainability reports issued by the terminal operators is misinterpreted. Often the meaning or the applicability of certain performance statistics are very vaguely described, making it difficult to abstract the exact meaning of a value. This can range from unit interpretation to abstracting the representativeness of a value.

   In general, no conventions exist with regards to sustainable reporting and measuring that are imposed on terminal operators other than the EMS framework implemented by the Port Authority. Hence, a systematic approach of measuring performance is utopian at current stage. Some global initiatives do lead the way, and an increasing crowd is joining the practices and conventions as they are laid out by such initiatives. The Global Reporting Initiative, which is principally a framework for sustainability measuring for businesses, is one such examples to establish an institution to agree upon convention in respect to sustainable reporting. Furthermore, adding to a conclusion drawn by Schipper et al. (2017), the lack of a common set of indictors for ports, including the port community members like operators and industry, is prohibiting objective assessment of sustainable practices in ports.

Moreover, other limitations are also persistent. The following limitations stress the consequences of the particular method used for this study, as well as some other deceiving matters.

3. **Limitations of the method;**
   The method itself, quantitative comparison analysis of terminal operators, poses some serious limitations. As Rolstadås (2013) puts it, "even if the averages of the reported characteristics are enhanced by their standard deviations, the reason for a difference between the values of one company and those of the whole branch can hardly be discovered" (p. 312). Furthermore, the author reasons that "gathering the required data and its adequate evaluation is in many cases a great burden within the benchmarking process" (p. 313).

4. **One comparative analysis technique**;
   With the application of only one method to evaluate relative sustainable performance of terminal operators, the level of accuracy of the retrieved results remain open for discussion.

5. **Publicly available data**;
   The use of publicly available data, a necessity in my case, limited the bandwidth that was used for the identification of sustainable metrics.

6. **Model layout used in this probe**;
   In this research quantitative comparative analysis is structured in a particular way. Each of the dimensions of sustainability are assessed individually, under the premise that for the environmental and social dimension the negative externalities are inputs to the process and the financial indicators are positive outputs of the process. This presents a rather shallow definition of the dimensions and undermines the any correlation that these dimensions have with each other.

7. **Personal bias**;
   Another limitation is the difficulty to remain independent at any given time during the process. The excess literature and expert consultations guided me towards a perceptional way of understanding how the ports and terminal industry functions. Despite the awareness of such a bias to exists, one cannot deny it has its effects on certain decisions, emphasizes during this study. Undoubtedly that carries consequences for the credibility of the research itself, however, by trying to adhere to an academic standard this has been mitigated as much as possible.

Overcoming the latter limitations would ultimately result in more insightful conclusions from the analysis. In the succeeding chapter a reflection is provided which underpins the consequences of the research design choices.

Chapter 8. Reflection

In this chapter a reflection on this research is provided. This reflection is subdivided into a reflection on the contribution to science and a reflection on the process.

8.1 The Method & Contributions to Science

This study proposes a model that allows for the comparison of businesses on the basis of quantitative performance indicators. In this study, the model was employed to determine the relative sustainable performance of terminal operators based on a brief set of indicators. This research provided for the construction of an engine to benchmark sustainable performance of terminal operators. This engine can be employed more extensively for the evolution of sustainable performance. As the exploration of the sustainability realm with the DEA methodology is scarce, this research could be used as a guide for researchers aiming to address issues of sustainability with the DEA technique. DEA lends itself for large sample comparisons. This signifies that the addition of more units of analysis (DMU in DEA terms) potentially increases the strength of DEA by providing a higher degree of discrimination between the various DMU's.

An element that is case specific is the indicator selection process. Due to the secrecy of information in the terminal sector, the approach adhered to in this study seemed the only practical method to garner quantitative statistical data on terminal operators' performance. More thorough cooperation with the terminal operators would potentially have provided more and more accurate data but would be a difficult endeavour for a vast range of terminal operators. Either, alternative methods for comparison had likely resulted in diverging outcomes. As quantitative metrics have proved to be of ill quality, the inclusion of more quantitative measures would have provided for a more accurate representation of sustainable performance. Alternatively, a method like Quantitative Comparative Analysis might have been a better fit for the sake of this analysis, given the relative brief number of units and the incorporation of some qualitative contextual elements.

8.2 The Process

An overview of the process undertaken to arrive at these conclusions is presented in Figure 8.1. For a detailed description of the individual steps reference is made to Appendix VII. The paragraph proceeds with a reflection on all the stages of the research as they are outlined on the left of Figure 8.1.

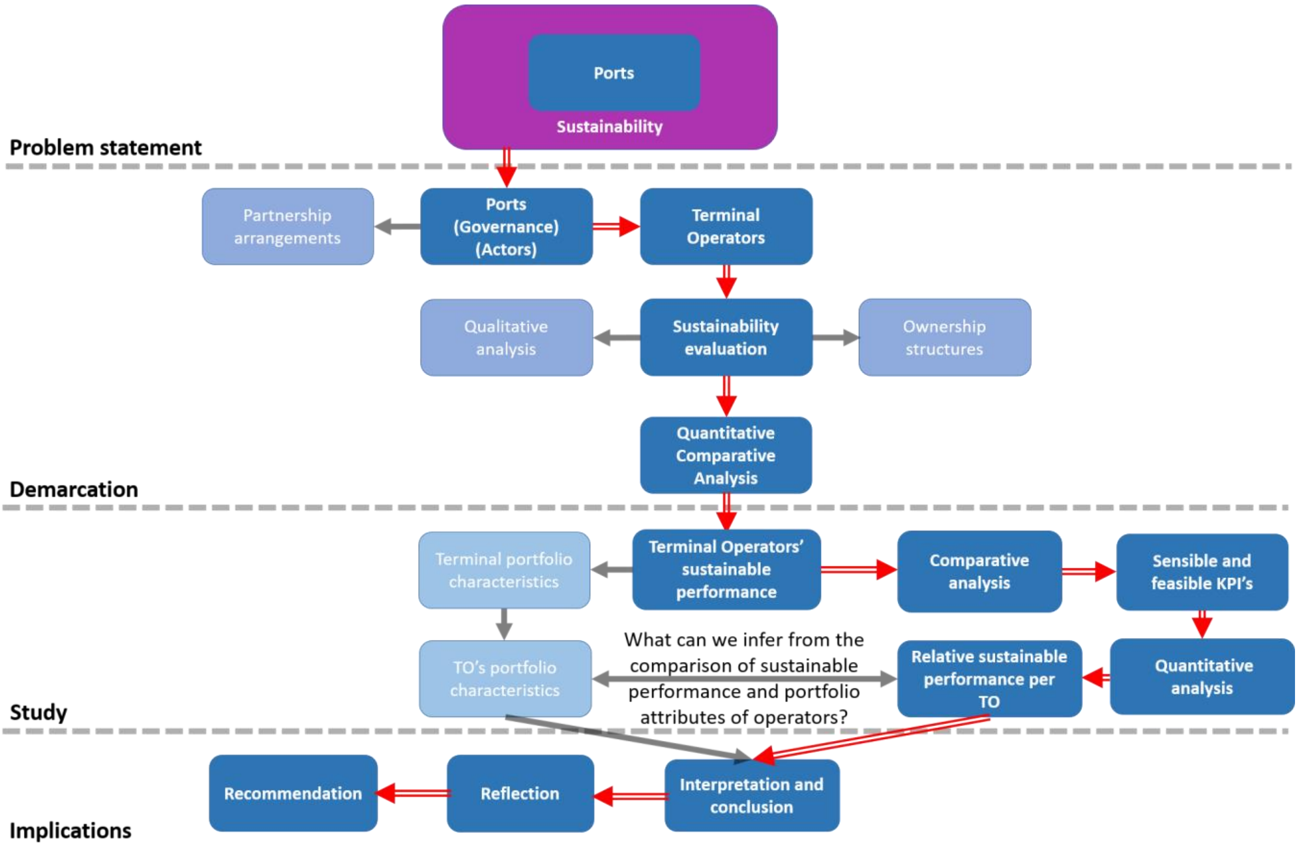


Figure 8.1: Graduation journey

1. Initial problem & Demarcation;

Given that the concept of port sustainability is broad and ill-defined, finding and agreeing on an approach angle is a troublesome process. Lots of avenues have been explored before one was considered fruitfull enough to move on. This process of exploring and making considered decisions about leads for potential research interest has exhausted most of the time I devoted to this research. Despite it being the longest lasting phase of the research, the resulting problem definition potentially not the most senseful angle to approach the problem of port sustainability. Someone having more experience in the field of port academics will certainly be able to demarcate the problem in a swifter fashion and would have likely ended up on a different problem definition.

Throughout the demarcation phase I also conducted some interviews with experts in the field with both an academic perspective and an operations perspective. These meetings were insightful, but I often had the impression that I left with more potential leads than I came with, not having tempered my desire to proceed in a certain direction.

An example of research leads which have proven to be fruitless after a while is provided by Figure 8.2. It presents a simplified, imaginary overview of the contemporary terminal market. Initially the level of the analysis was at the micro level, implying the level of the independent terminals, as this level would allow for the research into causation and correlation variables. However, due to deficiencies of data at this level, it was impossible to carry on the endeavor of focusing on independent terminals. Interesting is that two of the terminal operators included in the quantitative comparative analysis effort of this study are operators of a single terminal. This indicates that performance statistics at micro-level is monitored and to some extent open to the public.

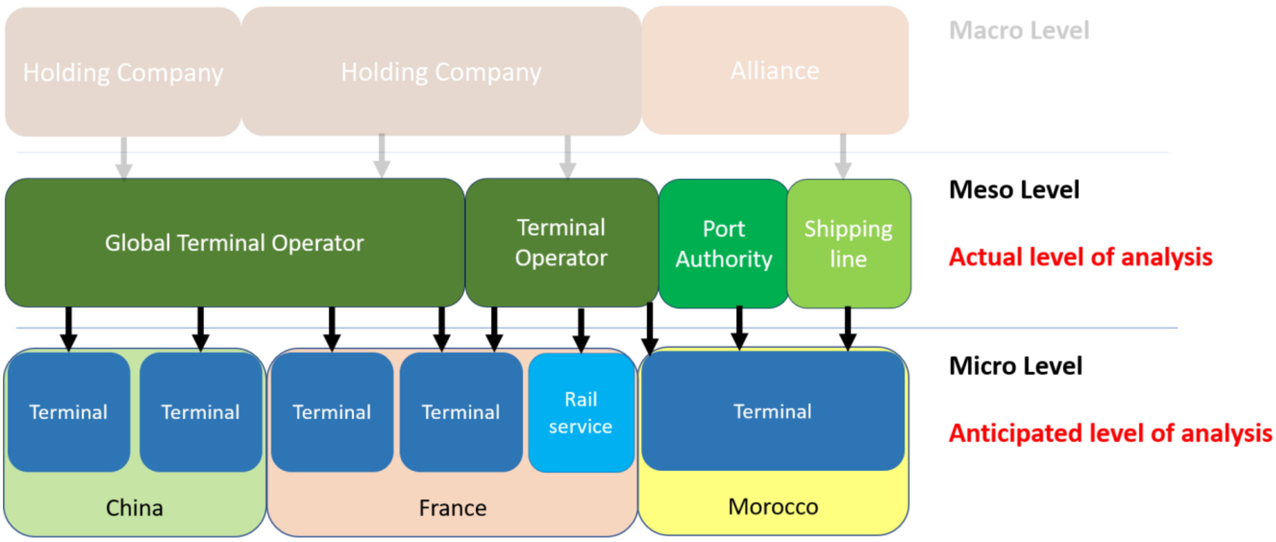


Figure 8.2: Level of analysis

Due to the outline of the terminal market (as being sketched in Figure 8.2), together with the fact that current reporting and publication is only facilitated at the meso-level, it is impossible to draw conclusion on matters that are subject to the micro-level. Throughout interviews conducted for the sake of this study, emphasis has been laid on the seemingly obvious correlation between sustainable performance of terminals and geography. However, due to the level of analysis of this study, it does not wield the capacity to draw conclusions on such relationship's existent in the micro-level. Furthermore, a focus on the level of the individual terminals would have allowed for the inclusions of more units of analysis, and would potentially wield more contrasting insights.

2. Study;

In the subsequent phase of the research, called the 'study' phase in Figure 8.1, most of the effort was devoted to the collection of the data. I underestimated the difficulty of data collection because of the unexpected encounter of data inconsistencies and interpretation issues. During the data collection process, I came to the realization that it would prove an enormous challenge to derive sensible results from the abstracted data, as they are unreliably.

Another, slightly underestimated, process was the data analytics part in the R programming language implemented in the RStudio application. Developing a practical skill requires duly dedication, trial and error, and is not a matter of typing some code and execute it. The DEA analysis was not the difficulty for the R implementation per see, as the illustrations of the results required a more thorough understanding of the R coding-language. It was nevertheless a very valuable and interesting endeavor and, apart from the coding requiring more time than expected, suited the context of this dissertation. The use of other methods for conducting the analysis would not have impacted the research outcomes significantly, other than a slightly more complex implementation process.

3. Implications.

Due to the early realization of the corruptness of the abstracted data, it remains difficult to draw implications from the findings of this study. Nevertheless, the benchmarking process revealed that a comparative analysis of sustainable performance can yield interesting insights with respect to best practice identification and strategy outlining. The engine constructed for the sake of this study could potentially be utilized to garner more sensible conclusions once a validated and more cohesive dataset is used at the base.

Chapter 9. Recommendations

This concluding chapter communicates some of the implications of this research for both academia and practice.

9.1 General Remarks

The following depict the implications based on the findings of this research:

- International agreement on sustainable metrics (such as Global Reporting Initiative) and a systematic, science-led methodology of monitoring these metrics should be negotiated. The enforcing could be obtained through a top-down mechanism which imposes legislation through international bureaucracy.
- Greater level of cooperation and exchange between terminal operators to enlarge the capacity to learn from each other and to overview and monitor sustainable performance at a micro-level.
- Kim and Chiang (2014), who are supporting the collaboration at port level to achieve sustainable targets, plea for extended transparency and knowledge sharing amongst stakeholders in port communities to establish a common port level "port sustainability strategy", which would enhance environmental awareness, skills and motivation for the managerial cause. This dissertation arguments in harmony with this recommendation, as knowledge sharing and transparency would benefit all in working towards improved sustainable performance.
- Environmental Management Systems (EMS) are enforced by domestic jurisdictions on the port sector. As they also apply to terminal operators, they are obliged to monitor and communicate about their sustainable endeavours to some extent.
- As was inferred from Korbee (2015) and the interview conducted with the author herself, a significant contribution in terms of fostering sustainable port development practices is the inclusion a large variety of stakeholders in the design and decision making processes prior to port and terminal expansions.

9.2 Leads for Further Research

The following depicts suggestions for future research:

- One major drawback of this study was the invalidity of the data. This research attempt could be used as a leverage tool to convince terminal operators that transparently enclosing their sustainable performance statistics may hold strategic benefits for their personal sake. As such, new iterations of the engine constructed in this research may yield more valuable insights.
- By performing analysis on the micro-level rather than on the meso-level of the terminal sector, conclusions may carry more significance in terms of accuracy. Future efforts can look in alternative ways to address this level of analysis.
- Despite many research efforts into the paradigm of indicator identification, a comprehensive methodology to assess sustainability of terminal operators has not yet materialized. More research should address the issue persisting in sustainability evaluations and provide a definition for the various dimensions of sustainability.
- In order to scientifically verify the results of this research, further research initiatives could complement this study by means of employing alternative methodologies to assess the sustainable performance of terminal operators. An example could be qualitative in nature, and allow for one-on-one interviews and other similar data acquisition strategies to be utilized. An interesting lead would then be to compare the conclusions of both studies to determine whether they are sound.

- Besides replicating this research with a more qualitative fashion, alternative multi-criteria decision-making techniques to assess and compare the sustainable performance of terminal operators are required to verify the results retrieved form the DEA comparative analysis.
- Albeit the fact that the validity of the results is arguable, this research revealed that a certain linear relation between the three dimensions of sustainably exists. Because this linear relation is counterintuitive, it would be interesting to unravel the truth relationship between the three dimensions of sustainability across various industries and the prevailing conditions impacting the relation.

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Appendices

Appendix Tables

Appendix I. The terminal market

The debate surrounding the public-private realms have gained significant attention in literature in recent decennia. Turhan (2005) gives a historical overview of the dynamics of public and private ownership of assets. As at the end of the Second World War the state was in possession of a significant share of the production resources, the privatization trend, as it was termed by Margaret Techer, gained genuine momentum from the 1980s onwards. The argument favoring an influential state halfway the 20th century was that in imperfect market conditions, the state should intervene, as private players would not be able to handle its inconsistencies (also called the market failure argument). This way of reasoning is called the 'social view' (Turhan, 2005). Privatization, on the contrary, is pursued due to the fact it is profit driven rather than tailored to social welfare maximization (Jiang & Wang, 2017); claiming that inconsistencies in political markets, caused by agency problems and self-fulfilling politicians and bureaucrats, result in lower efficiencies and reduced social welfare creation. The imperfect political markets may lead to the usage of state-owned enterprises as a tool to garner political support regardless of its economic implications. A fierce debate exists among scholars whether or not privatization leads to enhanced performances. Jiang and Wang (2017) analyze public and private ownership structures' role in contractual relationships based on external risks, internal corruption and the relative importance of owners (policymakers) versus managers (bureaucrats). In a private firm arrangement, the owner and managers' interests are to a large extent aligned, hampering the occurrence of agency problems.

In the stevedoring industry, a similar tendency can be observed. A fiercely regulated port environment was common throughout the world, and it wasn't until the 1980s until private investments in port infrastructure were allowed (Parola & Musso, 2007). In the era of privatization, public port facilities were in many cases sold to private investors, accelerated by the financial crisis of the '80s which caused national budget deficits. Rapid transition of local stevedores who turned into private entities and exploited the possibility to invested in terminals outside of their local area of business took place; vastly expanding their share in the stevedoring industry. In the global terminal market, and in North-Western European market in particular (also often referred to as The Hamburg-Le Havre port range[7]) large stevedoring companies conquered the market and rapidly garnished the majority share of the market in ports. Due to the expansion of global trade, vessel size increased to exploit economies of scale benefits, leaving only a few terminals with the capacity to process these vessels (Midoro et al., 2005). Shipping companies were confronted with little intra-port competition and high prices due to this scarcity in capacity putting them in an awkward position. A reduced bargaining power led to the ambition of liners to intrude in the stevedoring industry. This dynamic pattern is described by Notteboom and Rodrigue (2012) (also described by other scholars such as Midoro et al. (2005) and Araujo et al. (2005)), metaphorically naming it the 3 waves of container terminal globalization.

[7] The Hamburg-Le Havre port range in most references includes the ports of Felixstowe, Hamburg, Bremen, Amsterdam, Rotterdam, Antwerp, and Le Havre. They are characterized by the fact that they serve more or less the same hinterland market and are often compared with each other in the literature (Bowden & De Jong, 2006; Parola & Musso, 2007).

The first wave, emerging throughout the 1980s, posed the first investments of major stevedore operators in terminal facilities outside their regional scope. Due to the increasing privatization patterns and the seemingly successful strategy of the first' wave operators, the second wave of stevedores penetrates into the global terminal market. The third wave is characterized by shipping lines who felt the need to increase their leverage against the terminal operators and face capacity shortage for their ever-larger sized vessels[8]. The container terminal business is confronted with a heavily competitive driven environment since the emergence of container trade (Hyuksoo & Sangkyun, 2015; Yeo, 2015), where terminals benefit from a high container volume to justify their large infrastructure investments.

[8] The players who are involved in the waves described by Midoro et al. (2005) and Notteboom and Rodrigue (2012) are the following; **first wave**: HPH, P&O Ports, SSA, ICTSI, Eurokain; **second wave**: PSA, CSX, BLG, HHLA, Dubai P.A., Dragados, TCB; **third wave**: Maersk-Sealand, Evergreen, Hanjin, K-Line, NYK, MSC. Note that many of these terminal operators are known under a different name or are taken over by others due to an evolution of mergers & acquisitions in the past decades.

Appendix II. Expert consultations

In this appendix, the interview descriptions and transcripts are references which have contributed to the idea development and perception of this research. A concise overview of the interviewees is provided in Table II-A. In some cases, the entire transcript of the interview may be posted, whereas in others the main findings or insights gained from an individual are presented. In case the case of Tom Paver, the transcript is provided in Dutch to avoid any linguistic mistakes which may corrupt the interpretation of the interview.

Interviewee	Branch	Type of Interview
Korbee, Dorien	Academia	Semi-structured
Paver, Tom	Crane technology	Structured
Pielange, Ben Jaap	Consultant	Unstructured
Vellinga, Tiedo	Academia	Unstructured

Table II-A List with interviewees

II.a. Dorien Korbee

Dorien Korbee conducted a Ph.D. research in the area of marine infrastructure and its soundness with 'building with nature' principles. She is the author of the thesis report 'Greening the construction of maritime infrastructure: a governance approach' (Korbee, 2015). This thesis addresses the building with nature principle in the context of marine infrastructure. The research draws a relation between the construction process of marine infrastructure, viewed from a governance perspective, and the existence principles qualify as 'building with nature' attributes. The methodology she applied for this study was a comparative case study assessment. One of the key findings of the study is that a multi-stakeholder approach for project initiation and design are critical for the projects' containment of sustainable principles.

The interest of meeting with Dorien was triggered due to her knowledge in the realm of marine infrastructure, including terminal projects, and her prior focus on the sustainability matters in ports. Questions were in the direction of clarifying some elements of her study, and her take on the prior aim of this study.

Dorien's' projection in terms of sustainability assessments is that is is fairly difficult to objectively assess sustainable performance due to the great variety of indicators used in the field. Het PhD thesis focused on sustainable indictors in the implementation phase of infrastructural projects, which is a different story that assessing operational sustainability. She contends that a study into the sustainable practices of maritime infrastructure is very valuable, also as a complementation to her PhD thesis, to determine the prevailing implementation dynamics to safeguard sustainable performance.

II.b. Tom Paver

Tom Paver is an employee of Siemens, where he works on crane technology endeavors. Siemens is one of the world's leading actors when it comes to technological development for seaport terminal cranes, such as the ones used in Terminal facilities at Maasvlakte II in Rotterdam (known for being the most state of the art terminal facilities, especially when it comes to automation). Via mail, I was able to ask him some questions with regards to his knowledge in the terminal sector.

Question 1: Welke proxy parameters zijn volgens jou het meest geschikt om duurzaamheid van container terminals aan te duiden? (wat wordt er gemeten?) (enkele voorbeelden zouden kunnen zijn; People: # complaints filed from local residents/local economic impact (how to quantify?); Planet: CO_2 emmission, waste production, energy usage; Proffit: TEU troughput, TEU capacity, turnover).

Answer 1: "Ik heb zelf energy and environmental studies gedaan in Groningen. Ben bekend met de topics die je noemt. Desalniettemin is het wel een erg lastige vraag die je stelt. Uiteindelijk wordt met PPP gesteld dat het een equilibrium is. Als er aan 1 P wordt gesleuteld, zullen de andere twee hier last van hebben. Ik zou voor People eerder QoL (welvaart, gezondheid, scholing) als variabele nemen. Echter is dit ook weer zeer lastig meetbaar. Wat neem je allemaal mee en wat niet? Hoe kom je aan uitgangspunten en wat wordt er uberhaupt gemeten. Volgens mij zijn er wel onderzoeken in gebieden wat de QoL is. Heb het alleen even niet zomaar paraat... Planet: je zou hier het liefst "footprint" willen hebben, toch? Een gewogen getal van alle soorten emissie en verbruik die je hebt: niet alleen CO2, maar ook bouwmaterialen, waterverbruik, andere emissies. Ook hiervoor geldt: als je dit wil gaan berekenen kan je je sociale leven vaarwel zeggen. Profit: Dit zou m.i. inderdaad TEU throughput zijn. Das uiteindelijk de belangrijkste parameter. Voor je onderzoek zul je concessies moeten doen in je scope bepaling. Ik zou dan inderdaad voor #complaints (DCMR heeft hier vast wel wat over) vs CO2 emissie of energy use vs throughput gaan."

Question 2: Zijn er database(s) die dergelijke data verzamelen en welke publiek toegankelijk zijn dat je weet?

Answer 2: "Allicht dat DCMR [environment regional cluster Rijnmond] een en ander voor je heeft."

Question 3: Wat weet je van de rol van de havenautoriteit in terminal operations? Is het enkel het aanbieden van tenders voor terminals of ken je ook voorbeelden van terminals waar een havenautoriteit aandeelhouder is? (oftewel: wat is de rol van de publieke sector vandaag de dag in container terminals?)

Answer 3: "Mijns inziens is de havenautoriteit (Port of Rotterdam) niet veel anders dan een overkoepelend orgaan welke voor de belangen van de gehele haven opkomt. Soort schakel tussen de uitbaters / Terminal owners en overheid inclusief overkoepelende diensten (piloten, sleepdiensten e.d.). Maar de precieze ins en outs weet ik hier niet van. Zij kopen geen remote control van mij en zijn daardoor dus geen partij waar ik mij in heb verdiept."

Question 4: Is er volgens jou een wezenlijk verschil tussen zo genamende 'dedicated terminals' (shipping lines) en terminals van terminal operators en hybrids (in Rotterdam bijvoorbeeld APM Terminals en ECT Delta (owned by Hutchison port holdings) en RWG); bijvoorbeeld in operationele zaken maar ook in dingen als sustainable policy etc..?

Answer 4: "Dat lijkt mij niet. Uiteindelijk is mijn perceptie dat de P van Profit altijd veruit de meeste aandacht en nadruk zal hebben en de People en Planet hier uiteindelijk altijd het onderspit tegen zullen delven. Allicht beetje sombere blik, echter heeft mijn ervaring mij deze les wel geleerd en maakt het niet veel uit waar he terecht komt. Aan de overheid om hier iets aan te doen, echter is er een goede reden dat Nederland het een-na-slechtste duurzaamheids jongetje in de klas is: de P van Profit die ook voor de overheid belangrijker is."

Question 5: In welke mate zijn terminals verantwoordelijk voor de constructie/ontwikkeling/exploitatie van terminal infrastructuur en superstructure in verschillende havens (welke jij gezien hebt), en in local infrastructuur als spoorlijnen en wegennet?.

Answer 5: "Gisteren was ik op een terminal in Rotterdam waar ze de kade opnieuw aan het asfalteren waren. Ze zeiden dat dat gewoon voor rekening van de terminal komt. Volgens mij pachten de terminals grond van de gemeente/havenbedrijf en zorgen die vervolgens weer dat de terminals uiteindelijk worden aangesloten op de rest van de infrastructuur. Op de terminal zelf is het voor kosten van de terminal. Dit is echter alleen een vermoeden, ik weet dat niet zeker."

Question 6: Is er een wezenlijk verschil in aanbestedingsprocedure voor terminals in verschillende havens (of terminals in havens) (bijvoorbeeld i.v.m. looptijd of risk seperation)? Een voorbeeld is de ECT terminal in Rotterdam waarbij de tender nadruk legde op een sustainability target door een bepaalde modal split (truck/train/barge) te vereisen van de huurder en daarmee (naar PoR zelf beweert) de eerste was in zijn sort die sustainability criteria meenam in de tender overweging.

Answer 6: "Ik zie veel tenders voorbij komen. Hierin is doorgaans erg weinig (lees niks) te vinden over MVO-achtige onderwerpen. Ik heb ook begrepen dat ECT probeert een soort cradle-to-cradle / RAMS(HE) (met Health and Environment in de afkorting) in haar aanbestedingen te zetten om toch MVO op de kaart proberen te zetten."

II.c. Tiedo Vellinga

Tiedo Vellinga is a professor at the Technical University of Delft in terminals and waterways. He has a vested career working for the Rotterdam Port Authority for a large part of his career. Additionaly he is a member of the committee steering the PIANC, which is the world association for waterborne transport infrastructure. In this role, he is actively campaigning for the deployment of a universal practice so measure sustainability throughout the industry.

Due to his long career at the Port of Rotterdam Port Authoridy, Tiedo Vellinga was able to share many insights with regards to the sustainability programs existing in the Rotterdam harbor community. One of the insight he shared was the fact that the port authority Rotterdam (PoR) is investing substantially in offshore windfarms to diversify their energy matrix, expressing that these kind of investment were very common in the port industry in the foster for a higher degree of sustainability.

Another interesting remark Tiedo Vellinga made was a recent trend that is emerging with respect to the cooperation of operators in ports (a phenomenon also addressed by de Langen & Haezendonck, 2012; de Langen & Pallis, 2006). Cooperation between members of a port cluster may lead to more efficient use of resources. One such initiative in the Rotterdam port a barge sharing project which is set up to utilize the barging vessels as best as possible by means of allowing other terminals to utilize the same barge vessels.

Tiedo Vellinga also made reference to the Global Reporting Initiative, which is a community which is concerned with standardizing sustainability reporting practices throughout businesses and institutions globally.

II.d. Ben Jaap Pielange

Ben Jaan Pielange works as a consultant at Witteveen and Boss in the office in Rotterdam. Ben Jaap has a long vesting career in the terminal industry, predominantly as a consultant on terminal designs throughout the world. He has contributed to the design proposal of APM Terminals for their bid on a tender for a concession at the second Maasvlakte, which is often considered as the first fully sustainable container terminal in the world.

According to Ben Jaap, the ownership composition of a terminal is not so relevant for its sustainable performance. This implies that it does not matter, from the sustainability side of things, whether a terminal is fully dedicated or multi-user.

The terminal of the second Maasvlakte and the Rotterdam World Gateway container terminal have seen similar tender procedures with similar conditions. This infers that the concession for the second Maasvlakte terminals in the Rotterdam were both tight to an environmental condition which they had to comply with, making it the first terminal concession of its kind.

The terminal operator himself is not responsible for deciding on the modal split distribution, as the freight forwarders are the main entities exercising their desires on this decision. Interestingly however, is the model split metrics utilized by the port authority to operationalize sustainable performance targets, as can be seen in the paper by de Langen, Van Den Berg, and Willeumier (2012).

Appendix III. Indicator Descriptions

This appendix provides descriptions of the indicators used for the initial iteration wave of data acquisition. Table III-A lists the indicators per sustainable dimension. The subheadings of the appendix provide descriptions for all the indicators listed in the table segmented per dimension. Note that for the descriptions of the variables the definition commonly used in the sustainability reports has been used. In some cases, the exact value of a particular parameter of an operator had to be manipulated in order to comply with the definition as is stated hereunder. This may jeopardize the validity of the obtained information, as incorrect interpretation of information may lead to corrupted alterations of the values.

The indicators which are selected for the analysis (2nd iteration wave) are marked in bold.

Financial	Environmental	Social
Adjusted EBITDA	GHG emissions per TEU	**Reported Incidents**
Revenue	GHG emissions Scope 1	Injury Rate
Adjusted EBITDA margin	GHG emissions Scope 2	Lost Time Injuries
Profit	**Total GHG emissions**	**Lost Time Injury Frequency Rate**
Net value added	Energy usage per TEU	Absentee days
Revenue per TEU	**Total Energy usage**	Absentee rate
Consolidated capacity	**Water consumption**	Average training per employee
Consolidated throughput	Waste production	**Gender diversity**
Gross capacity		
Gross throughput		
Consolidated capacity utilization		
Gross capacity Utilization		
Full-Time Equivalent (FTE)		

Table III-A First wave variables per dimension of sustainability

III.a. Financial indicators

In Table III-B the financial indicators included in the first wave of indicator selection are presented.

	Unit	Description
Adjusted EBITDA	mill EUR	The Earnings Before Interest, Tax, Depreciation, and Amortization including the share of profit from equity-accounted investees before separately disclosed items
Revenue	mill EUR	The revenue the operator gains out of its operating activities
Adjusted EBITDA margin	% adjusted EBITA of revenue	The EBITA margin refers to the income before tax as a margin of the revenue
Profit	mill EUR	The Profits which are attributable to the owners of the company
Net Value added	mill EUR	The revenue minus the labor costs and resource costs; the added value to the GDP of a country
Revenue per TEU	EUR	The revenue per TEU (consolidated throughput)

Consolidated Capacity	mill TEU/mill Tonnes	The annual capacity in TEU/Tonnes (containers or dry bulk load) of the operator measured in ownership per terminal (shares/gross capacity of the terminal)
Consolidated Throughput	mill TEU/mill Tonnes	The annual processed TEU/Tonnes (containers or dry bulk load) of the operator measured in ownership per terminal (shares/gross capacity of the terminal)
Gross Capacity	mill TEU/mill Tonnes	The annual capacity in TEU/Tonnes (containers or dry bulk load) of the terminals included in the operators' portfolio (including a minority shareholding)
Gross Throughput	mill TEU/mill Tonnes	The annual processed TEU/Tonnes (containers or dry bulk load) of the terminals included in the operators' portfolio (including a minority shareholding)
Consolidated Capacity utilization	% utilized consolidated capacity	The percentage of consolidated capacity being utilized based on the consolidated throughput
Gross Capacity utilization	% utilized gross capacity	The percentage of gross capacity being utilized based on the gross throughput
Full-Time Equivalent (FTE)	#	The number of contracted full-time employees working on the operators' behalf.

Table III-B Financial variables

III.b. Environmental indicators

In Table III-C the environmental indicators included in the first wave of indicator selection are presented.

Indicator	Unit	Description
GHG emissions per TEU	kg	The emitted GHG per processed TEU
GHG emissions per Scope 1	Tonnes	The emitted GHG as a consequence of its immediate business operations
GHG emissions per Scope 2	Tonnes	The emitted GHG as a secondary consequence of its business operations
GHG emissions per total	Tonnes	The total annual emitted GHG (scope 1 + scope 2) as a consequence of its business operations
Energy usage per TEU	Mega Joules	The utilized energy (electricity + fossil fuels) per processed TEU
Energy usage total	Giga Joules	The total annual utilized energy (electricity + fossil fuels) as a consequence of its business operations
Water consumption	m3/year	The total annual consumed fresh water as a consequence of its business operations
Waste production	Tonnes	The total annual waste production as a consequence of its business operations

Table III-C Environmental variables

III.c. Social indicators

In Table III-D the financial indicators included in the first wave of indicator selection are presented.

Indicator	Unit	Description
Reported incidents	# of incidents	Number of incidents occurred on duty
Injury rate	# of injuries/200,000 worked hours	The number of injuries incurred per 200,00 hours worked, which is the equivalent of 100 employees working 50 weeks a year, 40 hours a week
Lost Time Injuries	# of days	Number of lost days due to work-related accidents and diseases
Lost Time Injury Frequency Rate	# of days/200,000 worked hours	The lost days due to work-related injuries per 200,000 hours worked, which is the equivalent of 100 employees working 50 weeks a year, 40 hours a week
Absentee days	# of days	The number of days that an employee was absent
Absentee rate	% of absentee days	The absentee rate indicates the number of absentee days (as a result of non-occupational injuries and illnesses) as a percentage of the total number of work days scheduled for the workforce
Average training per employee	# Hours	The average number of hours that an employee received training
Gender diversity	% Female	The percentage of female amongst the workforce (FTE)

Table III-D Social variables

Appendix IV.
Scenario overview

In Table IV-A the scenarios are presented for each of the dimensions of sustainability. The first column of each dimension portrays the input variable(s), the second column the output variable(s) and the third column presents the scenario, as it merges the letters of the input variable(s) and output variable(s). These scenario names are also used for the communication of results per scenario. The letters refer to input and output variables, as can be observed from Table 5.2 in paragraph 5.2.

Table IV-A *Scenario constellation*

Environment			Social			Financial		
In	Out	Scenario	In	Out	Scenario	In	Out	Scenario
	G	BG		G	EG		G	AG
	H	BH		H	EH		H	AH
	I	BI		I	EI		I	AI
B	GH	BGH		J	EJ	A	GH	AGH
	GI	BGI		GH	EGH		GI	AGI
	HI	BHI		GI	EGI		HI	AHI
	GHI	BGHI	E	GJ	EGJ		GHI	AGHI
	G	CG		HI	EHI			
	H	CH		HJ	EHJ			
	I	CI		IJ	EIJ			
C	GH	CGH		GHI	EGHI			
	GI	CGI		HIJ	EHIJ			
	HI	CHI		GHJ	EGHJ			
	GHI	CGHI		GIJ	EGIJ			
	G	DG		G	FG			
	H	DH		H	FH			
	I	DI		I	FI			
D	GH	DGH		J	FJ			
	GI	DGI		GH	FGH			
	HI	DHI		GI	FGI			
	GHI	DGHI	F	GJ	FGJ			
	G	BCG		HI	FHI			
	H	BCH		HJ	FHJ			
BC	I	BCI		IJ	FIJ			
	GH	BCGH		GHI	FGHI			
	GI	BCGI		HIJ	FHIJ			
	HI	BCHI		GHJ	FGHJ			
	G	BDG		GIJ	FGIJ			
	H	BDH		G	EFG			
BD	I	BDI		H	EFH			
	GH	BDGH		I	EFI			
	GI	BDGI		J	EFJ			
	HI	BDHI	EF	GH	EFGH			
	G	CDG		GI	EFGI			
	H	CDH		GJ	EFGJ			
CD	I	CDI		HI	EFHI			
	GH	CDGH		HJ	EFHJ			
	GI	CDGI		IJ	EFIJ			
	HI	CDHI						
	G	BCDG						
BCD	H	BCDH						
	I	BCDI						

Appendix V. R Syntax for the DEA analysis

This appendix provides the syntax used in this report to execute the data analytics, including the DEA rendering and the visualizations. The syntax is presented in chronological order, with the descriptions of each step colored in green indicated with a hash symbol or a double hash symbol. The hash symbol represent a hierarchy in instructions. The double hash illustrates a description on a more aggregated level, superior to the single hash description lines.

```
#Call the necessary packages for this analysis
library(KraljicMatrix)
library(xlsx)
library(readxl)
library(Benchmarking)
library(tidyverse)
library(reshape2)
library(ggh)

##importing the terminal data in the R environment
#Change the path to your desired directory
setwd('C:/Users/Daan-_000/Google Drive/Sustainable Port Development')
#Read the excel dataframe into R
td.dea <- read_excel('Phase II/CompanyData.xlsx', sheet= "DEA Input")

#Read the Terminal Operators names for proper referencing
TOnames <- c("APMT", "ACT", "Contship", "COSCO", "DP World",
"Eurogate","PortInvestment","HHLA","ModernTerminals","Westport")
td.dea <- data.frame(td.dea, row.names = TOnames)

## Data processing; fill in the blanc spots
# Gender diversity and Lost Time injury values are assigned the means of the
variable
# the remaining variables are assigned the means value relative to their throughput
for(i in 1:ncol(td.dea)){
  if (i < 9){
    for (n in 1:nrow(td.dea)){
      if (td.dea[n,i] == 0){
        value <- td.dea[n,1]/mean(td.dea[,1])
        td.dea[n,i] <- (value * mean(td.dea[,i], na.rm = TRUE))}}}
  else {td.dea [0 == (td.dea[,i]), i] <- mean(td.dea[,i], na.rm = TRUE)}
}

# Rounding all the values except for throughput and gender diversity and lost time
injury rate
td.dea[2:8] <- td.dea[2:8] %>% round()

# Defining a dataset for each of the three dimensions and with the appropriate
letters
environmental.dea <- td.dea[c(1,3:7)]
colnames(environmental.dea) <- c('G','H','I','B','C','D')
social.dea <- td.dea[c(1,3:4,8:10)]
colnames(social.dea) <- c('G','H','I','E','J','F')
financial.dea <- td.dea[c(1:4)]
colnames(financial.dea) <- c('G','A','H','I')
```

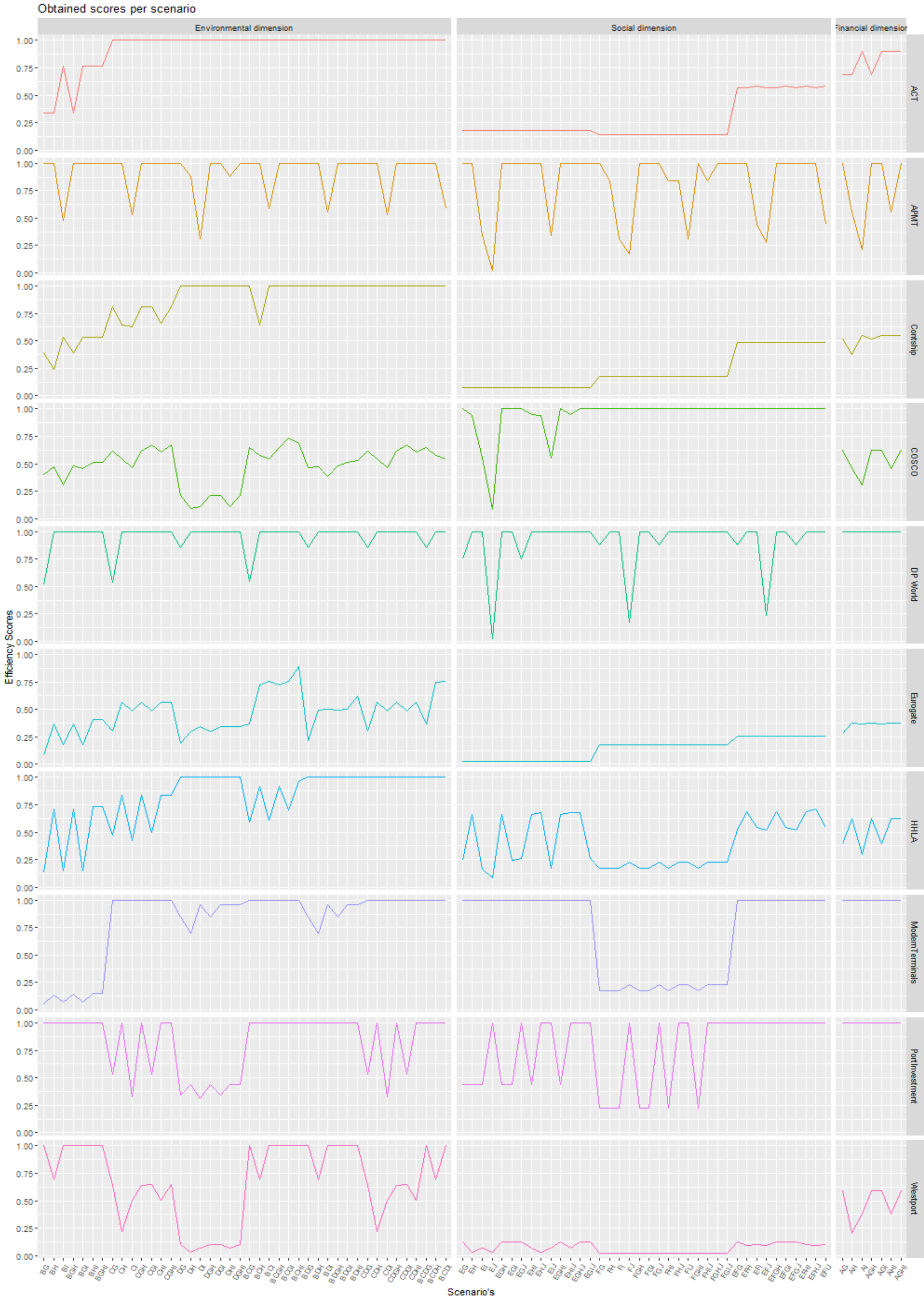
```
##Set the scenarios
#Read the scenarios from an excel data table
dea.scenarios <- read_excel('Phase II/TablesPhaseII.xlsx', sheet= "Scenarios")
dea.scenarios <- as.data.frame(dea.scenarios)
#Assign the scenarios to the corresponding dimension of sustainability
scenarios.env <- dea.scenarios[,1:2]
scenarios.soc <- na.omit(dea.scenarios[,4:5])
scenarios.fin <- na.omit(dea.scenarios[,7:8])

##Perform the DEA analysis
#First, create three empty dataframes to store the efficiency scores for each
dimension
Efficiencies.env <- data.frame(matrix(nrow=10, ncol=0))
Efficiencies.soc <- data.frame(matrix(nrow=10, ncol=0))
Efficiencies.fin <- data.frame(matrix(nrow=10, ncol=0))
#Performing the DEA iteration's of the environmental dimension
for (i in 1:nrow(scenarios.env)){
  y <- str_split(scenarios.env[i,2], "")[[1]]
  x <- str_split(scenarios.env[i,1], "")[[1]]
  y <- environmental.dea[,c(y)]
  x <- environmental.dea[,c(x)]
  e <- dea(x,y, ORIENTATION = 'in')
  Efficiencies.env <- cbind(Efficiencies.env, e$eff)
  colnames(Efficiencies.env)[ncol(Efficiencies.env)]                        <-
paste(scenarios.env[i,1],scenarios.env[i,2], sep = "")
}
#Performing the DEA iteration's of the social dimension
for (i in 1:nrow(scenarios.soc)){
  y <- str_split(scenarios.soc[i,2], "")[[1]]
  x <- str_split(scenarios.soc[i,1], "")[[1]]
  y <- social.dea[,c(y)]
  x <- social.dea[,c(x)]
  e <- dea(x,y, ORIENTATION = 'in')
  Efficiencies.soc <- cbind(Efficiencies.soc, e$eff)
  colnames(Efficiencies.soc)[ncol(Efficiencies.soc)]                        <-
paste(scenarios.soc[i,1],scenarios.soc[i,2], sep = "")
}
#Performing the DEA iteration's of the financial dimension
for (i in 1:nrow(scenarios.fin)){
  y <- str_split(scenarios.fin[i,2], "")[[1]]
  x <- str_split(scenarios.fin[i,1], "")[[1]]
  y <- financial.dea[,c(y)]
  x <- financial.dea[,c(x)]
  e <- dea(x,y, ORIENTATION = 'in')
  Efficiencies.fin <- cbind(Efficiencies.fin, e$eff)
  colnames(Efficiencies.fin)[ncol(Efficiencies.fin)]                        <-
paste(scenarios.fin[i,1],scenarios.fin[i,2], sep = "")
  row
}

#Converging the layout of the efficiency score dataframes to make them suitable
for visualization
Efficiencies.env <- Efficiencies.env %>% cbind(Cat=TOnames) %>% melt(id.vars =
"Cat") %>% cbind(Dimension='Environmental dimension')
Efficiencies.soc <- Efficiencies.soc %>% cbind(Cat=TOnames) %>% melt(id.vars =
"Cat") %>% cbind(Dimension='Social dimension')
```

```
Efficiencies.fin <- Efficiencies.fin %>% cbind(Cat=TOnames) %>% melt(id.vars =
"Cat") %>% cbind(Dimension='Financial dimension')

Efficiencies.all <- rbind(Efficiencies.env, Efficiencies.soc, Efficiencies.fin)

#Filters to select individual Terminal Operators or scenarios for individual groups
p <- Efficiencies.env %>%  group_by(Cat) %>% filter(Cat == "ACT") %>% ungroup()
b <- Efficiencies.soc %>%  group_by(variable) %>% filter(variable == "EGHJ") %>%
ungroup()

##Three plots which are used for the visualization of the results
#Plot presenting the performance of the various terminal operators in respect to
each scenario
plot1 <- ggplot(Efficiencies.all)+
  geom_line(aes(variable, value,group=Cat), colour = alpha("grey", 0.7))+
  theme(axis.text.x  =  element_text(angle  =  60,  hjust  =  1,  size  =  8),
legend.position = "bottom")+
  geom_line(aes(variable, value,group=Cat, colour = Cat), data = p, size = 2)+
  facet_grid(~Dimension, scales = "free_x")+
  #facet_grid(Cat ~ Dimension, scales = "free_x", space="free_x")+
  guides(colour=guide_legend(title="Terminal
Operator",ncol=10,title.position='top',title.theme = element_text(size = 12, face
= "italic",colour = "red")))+
  labs(title="Obtained  scores  per  scenario",x  =  "Scenarios",y  =  "Efficiency
Scores", colour = "TO's")
#Plot presenting the dynamics of the scenarios based on the terminal operators
plot2 <- ggplot(Efficiencies.env)+
  geom_line(aes(Cat, value,group=variable, colour=variable))+
  theme(plot.title = element_text(size = 18),axis.text.x = element_text(angle =
60,  hjust  =  1,size  =  14),  legend.position  =  "bottom",  legend.justification  =
'left')+
  labs(title=NULL,subtitle=NULL,x = "",y = "Efficiency Scores")+
  guides(colour=guide_legend(title = "Scenarios",ncol=21, title.position = 'top',
title.theme = element_text(size = 15, face = "italic",colour = "red")))#+
  #geom_line(aes(Cat, value,group=variable, colour = variable), data = b, size =
2)
#Plot presenting the boxplot representations of the efficiency scores per scenario
for each of the terminal operators
plot3 <- ggplot(Efficiencies.env, aes(x=Cat, y=value))+
  geom_boxplot()+
  #geom_line(aes(Cat, value,group=variable, colour = variable), data = b, size =
2)+
  #theme(plot.title = element_text(size = 18),axis.text.x = element_text(angle =
60, hjust = 1, size = 14), legend.position = "bottom")+
  theme(axis.title.x=element_blank(),
axis.text.x=element_blank(),axis.ticks.x=element_blank())+
  labs(title="Results    per    Terminal    Operator",    subtitle="Environmental
efficiency",x = "",y = "Efficiency Scores")+
  stat_summary(fun.y=mean, geom="point", shape=18, size=4, colour="blue")
  #geom_dotplot(binaxis='y', stackdir='center', dotsize=.2)
```

Appendix VI.
DEA results per terminal operator

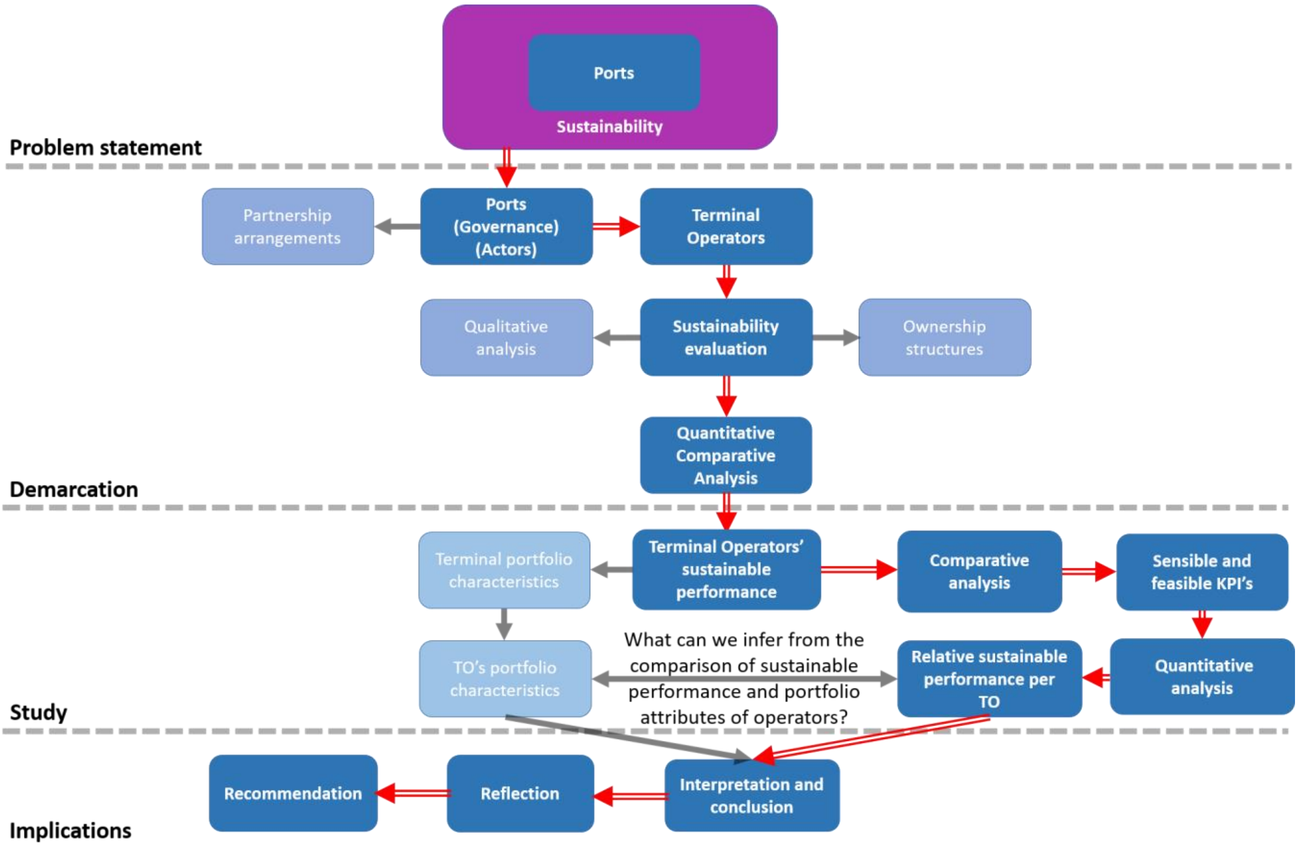
In the figure bellow the result of the DEA analysis per terminal operators are presented. The first column represents the environmental dimension, the second column represents the social dimension and the last column reflects the scores on the financial dimension. Each row represents a terminal operator, ranked from top to bottom in alphabetical order.

The scales on the left are equal over all the rows ranging from 0 to 1 and represent the efficiency scores of the terminal operators based on corresponding scenario.


Obtained scores per scenario
Environmental dimension
Social dimension
Financial dimension
ACT
APMT
Contship
COSCO
DP World
Eurogate
HHLA
ModernTerminals
PortInvestment
Westport
Efficiency Scores
Scenario's

Appendix VII. Graduation Journey

In the diagram bellow my graduation journey is depicted. The steps as they are described on the left (reading: Introduction, Demarcation, Study and Implications) do not align with the phases of this thesis report, as these phases are the internal phases encompassing only the *Demarcation*, *Study* and *Implication* steps.



In the subsequent sections I elaborate on the choices made throughout the process which resulted in the trajectory as it is.

Initial problem;

My interpretation of how the problem initially was framed, as described in the research objection on the Sustainable Ports In Africa webpage. I was interested by it due to infrastructural involvement and the notion of the sustainability concept.

Demarcation;

I was keen on diving into the governance structure of ports and their consequences for sustainable performance. Initially my focus was on partnership structures in ports but then I came across the importance of port devolution and private sector participation in the industry. I also learned that the effects of private sector participation were to a large degree unresearched, especially in the sustainability domain.

Via my search for private sector penetration in the ports industry I came across terminals, as they form the most prominent group of private actors involved in port governance. In light of trying to combine the notion of governance and sustainable performance, I attempted to draw a relation between ownership structures (as a proxy for private sector engagement) and sustainable performance of terminals.

Study;
Due to the scarce amount of data available at the (individual) terminal level, I decided instead to focus on the level of terminal operators. I found (only) 10 terminal operators sufficiently reporting on their sustainable practices to be incorporated in my analysis. In order to discriminate between type of terminal operator that one represents I chose to portray their terminal portfolio characteristics (ownership and operational efficiency) and see whether any trend could be observed between sustainable performance and type of container terminal operators. However, due to the brief amount and diversity of the units such a conclusion is highly volatile.

Implications.
The final phase of the research way primarily a continues reiterating of the conclusions, as new concluding remarks would come to mind throughout the editing process.