UNIVERSIDADE FEDERAL DE PERNAMBUCO
CENTRO DE TECNOLOGIA E GEOCIÊNCIAS
DEPARTAMENTO DE ENGENHARIA DE PRODUÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA DE PRODUÇÃO

THIAGO DE ALMEIDA RODRIGUES

DRY PORTS DEVELOPMENT IN SEAPORT-HINTERLAND NETWORK: risk assessment approach and shipping cost optimization to aid decision-making

Recife

2022

Thiago de Almeida Rodrigues

DRY PORTS DEVELOPMENT IN SEAPORT-HINTERLAND NETWORK:

risk assessment approach and shipping cost optimization to aid decision-making

A thesis presented to the Universidade Federal de Pernambuco to the achievement of PhD degree as part of the requirements from Postgraduate Program in Management Engineering.

Main Area: Production Management.

Advisor: Profa. Caroline Maria de Miranda Mota, PhD.

Co-Advisor: Prof. Udechukwu Ojiako, PhD.

Recife

2022

Catalogação na fonte:
Bibliotecária Sandra Maria Neri Santiago, CRB-4 / 1267

R696d Rodrigues, Thiago de Almeida.

Dry ports development in seaport-hinterland network: risk assessment approach and shipping cost optimization to aid decision-making / Thiago de Almeida Rodrigues. – 2022.

207 f.: il., figs., tabs.

Orientadora: Profa. Dra. Caroline Maria de Miranda Mota.

Coorientador: Prof. Dr, Udechukwu Ojiako.

Tese (Doutorado) – Universidade Federal de Pernambuco. CTG. Programa de Pós-Graduação em Engenharia de Produção, Recife, 2022.

Inclui referências e apêndices.

1. Engenharia de produção. 2. Rede porto-interior. 3. Porto seco. 4. Gestão de riscos. 5. Custo de transporte de contêiner. 6. Modelo de otimização de custos. I. Mota, Caroline Maria de Miranda (Orientadora). II. Ojiako, Udechukwu (Coorientador). III. Título.

UFPE

658.5 CDD (22. ed.) BCTG/2022-116

THIAGO DE ALMEIDA RODRIGUES

DRY PORTS DEVELOPMENT IN SEAPORT-HINTERLAND NETWORK:
risk assessment approach and shipping cost optimization to aid decision-making

Tese apresentada ao Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal de Pernambuco, Centro de Tecnologia e Geociências, como requisito parcial para a obtenção do título de Doutor em Engenharia de Produção. Área de concentração: Gerência da Produção.

Aprovada em: 03/03/2022.

BANCA EXAMINADORA

____
Prof. Dra. Caroline Maria de Miranda Mota (Orientadora)
Universidade Federal de Pernambuco

____
Prof. Dra. Luciana Hazin Alencar (Examinador Interno)
Universidade Federal de Pernambuco

____
Prof. Dr. Cristiano Alexandre Virgínio Cavalcante (Examinador Interno)
Universidade Federal de Pernambuco

____
Prof. Dr. Fernando Augusto Silva Marins (Examinador Externo)
Universidade Estadual Paulista

____
Prof. Dr. Maxwell Chipulu (Examinador Externo)
Edinburgh Napier University

ACKNOWLEDGMENTS

This thesis is undoubtedly an achievement built by many hands. It’s the result of years of hard work facing challenges and obstacles along the way, which would be impossible for me to surpass without the support of many people which I would like to express my gratitude.

First, I thank God for guiding me and supporting me every moment. I could feel His presence, encouraging me in all decisions along my way. Second, I would like to thank the person that was literally always on my side during the doctorate, laughing, crying, dreaming, and achieving together, my wife and partner for life Fernanda. There are no words to explain everything that we have lived together. You supported me during the hard times; you have believed me even when I was hopeless. I’ll always remember every time you brought me coffee when I was writing papers. Thank you for all you did. I love you.

More than contributing during my doctorate, my family was always the nature of who I am. I would like to thank my mom, Marialva, for dedicating her life to his sons; my dad, Evton, for teaching me the principles of honesty, dignity, respect, and faith; my brother, Arthur, for wish more for me than I could. Furthermore, this thesis was supported by my grandmother, my godmother, many uncles, and my family-in-law. I’m also thankful for the old friends and new ones, in special Adonys, Carlos, Adolfo and Daniel.

I would to especially thank my supervisor, Dr. Caroline Mota, for her constant encouragement in my career, for giving me the freedom to choose my research field, and for being so comprehensive in many issues along with the doctorate. I also thank the examining board, Prof. Luciana Hazin, Prof. Cristiano Cavalcante, Prof. Maxwell Chipulu, and Prof. Fernando Marins for all considerations and contributions to this thesis; all professors from PPGEP/UFPE for the knowledge shared; FACEPE and CAPES for the financial support.

During the doctorate, I also had the privilege to be co-supervised by two inspired professors from the University of Sharjah, Dr. Ojiako (Udi) and Dr. Fikri Dweiri. I would like to thank the reception that you gave me during my stay in Sharjah, and mainly for the example that you set me as a researcher. In my last day in UAE, when I asked for a last advice, Dr. Fikri said: ‘avoid shortcuts; usually the difficult way is the right way’. I was not expecting such deep advice but for sure I will take this one for life.

I strongly believe that you are the average of the people you spend the most time with. During the last four years as a doctorate student, surrounded by books, I had the privilege to spend my time learning with outstanding minds which survived throughout the time in different fields. Concerning my spirituality, I thank Jesus Christ for always being my mentor and lord, guiding me and teaching me to become a better person through the example of love. From the philosophy side, I thank Seneca *the younger*, for teaching me the concepts of stoicism. Improving my mindset, I thank Napoleon Hill and his laws of success for teach me that the world will forgive me if I make mistakes, but it will never forgive me if I make no decisions. Sharing knowledge about the humanity, I thank Yuval Harari for show me a brief history of the past and over a possible future. Lastly, I would like to thank Nassim Taleb for teaching me the *antifragility* concepts and for showing me that *black swans'* events happen.

This thesis is a little contribution for society for all educational opportunities that I have. Despite to acknowledge, I would like to share three pieces of thoughts from the stoicism which guided me during the doctorate which could aid future researchers. First, the *Momento Mori*, to always remember the finitude of life; second, the *Amor Fati*, to love our life, independently of the obstacles faced; and third, to keep our minds in the present, since we suffer more in imagination than in reality.

My sincere gratitude to you all!

ABSTRACT

Maritime transportation has played a huge and important role in connecting global trade in goods. Such relevance has been evidenced by the outstanding increase of containerized dry cargo transportation, which has putting enormous pressure to bear upon container terminals' efficiency. Particularly challenging are seaport-hinterland issues which entail broader inland geographical distribution of seaport operations. In this context, dry ports infrastructures have emerged as an option to fix efficiency problems in seaports, optimizing the shipping network of goods. Despite the relevance of such logistic infrastructure, dry ports facilities developments are not aware of failures, especially regarding the transitions from 'project' to 'operations' phases. Considering the perspective of importers/exporters, another critical issue remains in the service provider choice decision-making, which may vary according to specificities of each customer. Bearing this in mind, this thesis seeks to attend three main topics: (i) to make an overall discussion on seaport-hinterland subject, especially regarding dry ports developments; (ii) to assess the risk factors weighting and interdependences in dry ports' projects transition phase from multiple-stakeholders perspective; and (iii) to propose a flexible cost model to aid customer to select their services providers into the seaport-hinterland. Toward these objectives, the thesis was developed aggregating multiple complementary articles, in which eight papers on the subject of seaport-hinterland and dry ports were presented in adapted versions. As practical contribution, the thesis presented a framework to enhance the efficiency of dry ports in the Brazilian context and highlighted the main factors which could affect the shipping cost. Moreover, the results also evidenced for managers and policy makers in which case dry ports or seaports seems to become the best option in terms of cost. Academically, this thesis enhances the literature of dry port developments, proposing a typology of risks for dry port 'project' to 'operations' transitions comprising eight interdependent risk factors. Lastly, the study also discusses the competitiveness environment throughout the main actors in the seaport-hinterland in light of the literature, bringing relevant insights for all stakeholders and practitioners.

Keywords: seaport-hinterland network; dry ports; risk management; container shipping cost; cost model optimization.

RESUMO

O transporte marítimo tem exercido um importante papel na conexão do comércio global de mercadorias. Tal relevância tem sido evidenciada pelo aumento notável do transporte de cargas em contêineres, o que tem colado enorme pressão sobre a eficiência dos portos marítimos. Particularmente desafiadoras são as questões relacionadas à rede porto-interior, que implicam em uma distribuição geográfica mais ampla das operações portuárias. Neste contexto, os portos secos tem surgido como opções para solucionar problemas de eficiência dos portos, otimizando a rede de transporte marítimo de cargas. Apesar da relevância deste operador logístico, o desenvolvimento de portos secos não está isento de falhas, especialmente em relação à fase de transição de 'projeto' para 'operação'. Considerando a perspectiva dos importadores /exportadores, outra questão crítica refere-se à escolha do operador logístico, que pode variar de acordo com as especificidades de cada cliente. Tendo isto em mente, esta tese busca atender três principais tópicos: (i) fazer uma discussão geral sobre a rede porto-interior, especialmente no que diz respeito ao desenvolvimento de portos secos; (ii) avaliar a ponderação dos fatores de risco e as interdependências na fase de transição dos projetos dos portos secos a partir da perspectiva de diferentes *stakeholders*; por fim, (iii) propor um modelo de custos flexível para auxiliar a tomada de decisão dos clientes na seleção de seus prestadores de serviços ao longo da rede porto-interior. Na direção destes objetivos, a tese foi desenvolvida agregando múltiplos artigos complementares, nos quais oito estudos sobre o tema porto-interior e portos secos foram apresentados em versões adaptadas. Como contribuição prática, a tese apresentou um *framework* para aumentar a eficiência dos portos secos no contexto brasileiro e destacou os principais fatores que podem afetar os custos importação. Além disto, os resultados também evidenciaram aos gestores e tomadores de decisão de políticas públicas os cenários em que portos secos ou portos marítimos se tornam economicamente a melhor opção para os clientes. Academicamente, esta tese aprimora a literatura sobre o desenvolvimento de portos secos, propondo uma tipologia de riscos para a transição de 'projeto' para 'operação' compreendendo oito fatores de risco interdependentes. Por fim, o estudo também discute a competitividade entre os principais atores da rede porto-interior à luz da literatura, trazendo informações relevantes para os *stakeholders* envolvidos.

Palavras-chave: rede porto-interior; porto seco; gestão de riscos; custo de transporte de contêiner; modelo de otimização de custos.

LIST OF FIGURES

Figure 1 – Problems, research questions and objectives of the thesis 21
Figure 2 – Logistic infrastructure of seaports (container terminals) and dry ports in Brazil 24
Figure 3 – Research method approach 26
Figure 4 – Thesis structure 27
Figure 5 – Containerized import/export network 38
Figure 6 – Steps of systematic review 46
Figure 7 – Evolution of researches on dry port subject 48
Figure 8 – Keywords most cited in systematic review 50
Figure 9 – Main topics covered in systematic review 51
Figure 10 – Chapter strategy 64
Figure 11 – Classification of dry ports in Brazil 69
Figure 12 – Means-end network of dry port A 73
Figure 13 – Means-end network of dry port B 75
Figure 14 – Steps of Chapter 5 92
Figure 15 – Factors and sub factors structure from EFA 99
Figure 16 – Diagrammatical representation of the chapter approach 111
Figure 17 – Net influence matrices, by stakeholder group 119
Figure 18 – Influential Relation Map 120
Figure 19 – Seaport-hinterland network of São Paulo state 127
Figure 20 – Scenarios of simulations 129
Figure 21 – Results of simulation 1 143
Figure 22 – Results of simulation 2 145
Figure 23 – Comparison between SIM1 and SIM2 147
Figure 24 – Variation of the total logistic cost 150
Figure 25 – Macro regions of São Paulo state 154
Figure 26 – Influence zone of dry ports in São Paulo state 167
Figure 27 – Evidences and density function per day of import process 169

LIST OF TABLES

Table 1 – Most cited papers, authors and case studies 49
Table 2 – Main issues discussed in the database papers 52
Table 3 – Papers distribution and main issues 52
Table 4 – Main software used in database papers 54
Table 5 – Main actors in dry ports’ development 55
Table 6 – Dry port factors that support decision making 55
Table 7 – Full data of Brazilian dry ports 70
Table 8 – Framework to assess the achievement of dry ports’ objectives 77
Table 9 – Risk factors and EFA result 89
Table 10 – Sample characteristic 94
Table 11 – EFA boundaries 97
Table 12 – Descriptive statistics 100
Table 13 – Kruskall-Wallis and post-hoc results for hypothesis H 2.a 101
Table 14 – Results of post-hoc testes for H2.b 102
Table 15 – Ranking of factors and sub-factors by stakeholder group 103
Table 16 – Mann-Whitney rejected hypotheses (H3 and H4) 104
Table 17 – Rank of factors and sub-factors by classification of DPO 105
Table 18 – Fuzzy linguistic scale 114
Table 19 – Total effects by factors for FRS external stakeholders 117
Table 20 – Total effects by factors for ‘Customer’ external stakeholders 117
Table 21 – Total effects by factors for DPEs internal stakeholders 118
Table 22 – Total effects by factors of all stakeholders ‘Aggregated’ 118
Table 23 – Factors rank 122
Table 24 – Set of cost factors 128
Table 25 – Cities fulfilled considering emission cost factor 146
Table 26 – Dry port cities and multimodal cities recommended 148
Table 27 – Goodness of fit and distributions parameters 160
Table 28 – Variables and parameters of the cost model simulation 161
Table 29 – Process time in days of each step for import cargo 164
Table 30 – Statistics tests for the import process 165
Table 31 – Cost difference between seaport and the best dry port option 168
Table 32 – Import cost using road and rail transportation for all logistic operators 170

CONTENTS

1 INTRODUCTION 14

1.1 RESEARCH PROBLEM 16

1.2 RESEARCH DESIGN 18

1.2.1 Research questions and objectives 18

1.2.2 Theoretical and practical justification 21

1.2.3 Research context 23

1.2.4 Research method 25

1.3 THESIS STRUCTURE 27

2 THEORETICAL BACKGROUNDS 29

2.1 DRY PORT LITERATURES 29

2.1.1 Dry port functions 29

2.1.2 Dry port development 30

2.1.3 Dry port classification 32

2.2 RISK MANAGEMENT IN COMPLEX INFRASTRUCTURE PROJECTS 33

2.2.1 Risk management from a multi-stakeholder perspective 35

2.2.2 Project phase transitions 36

2.3 SEAPORT-HINTERLAND NETWORK LITERATURE 37

2.3.1 Seaport-hinterland network choice 38

2.3.2 Seaport-hinterland network competition 40

2.3.3 Previous optimization models 42

3 CRITICAL FACTORS FOR DRY PORT' DEVELOPMENT 45

3.1 CONTEXTUALIZATION 45

3.2 MATERIALS AND METHODS 45

3.3 RESULTS 47

3.4 DISCUSSION 60

3.5 REMARKS 61

4 ASSESSING THE OBJECTIVES OF DRY PORTS 62

4.1 CONTEXTUALIZATION 62

4.2 MATERIALS AND METHODS 63

4.2.1 Value-Focused Thinking approach 66

4.3 RESULTS 67

4.3.1 Characteristics of dry ports in Brazil 67

4.3.2 Assessing the objectives of dry ports ... 72
4.3.3 Framework to assess the achievement of the objectives of dry ports ... 76
4.4 MAIN ISSUES, CHALLENGES AND OPPORTUNITIES ... 80
4.5 REMARKS ... 81
5 ASSESSING RISK FACTORS IN DRY PORTS PROJECTS ... 83
5.1 CONTEXTUALIZATION ... 83
5.2 RISK FACTORS IN DRY PORTS' PROJECTS ... 86
5.2.1 Hypothesis propositions ... 90
5.3 MATERIALS AND METHODS ... 92
5.3.1 Step 1 – literature research ... 92
5.3.2 Step 2 – survey test ... 93
5.3.3 Step 3 – data collection and EFA ... 93
5.3.4 Exploratory Factor Analysis (EFA) ... 95
5.3.5 Step 4 – Statistical results and analysis ... 98
5.4 RESULTS ... 98
5.5 DISCUSSION ... 105
5.6 REMARKS ... 108
6 RISK FACTORS INTERDEPENDENCE IN DRY PORTS PROJECTS ... 110
6.1 CONTEXTUALIZATION ... 110
6.2 MATERIALS AND METHODS ... 111
6.2.1 Stage 5 - Analysis ... 112
6.2.1.1 Fuzzy sets ... 113
6.2.1.2 Fuzzy-based DEMATEL ... 114
6.3 RESULTS ... 117
6.4 DISCUSSION ... 121
6.5 REMARKS ... 123
7 SEAPORT-HINTERLAND DECISION MAKING: A CONTAINER SHIPPING COST OPTIMIZATION ... 125
7.1 CONTEXTUALIZATION ... 125
7.2 STUDY CONTEXT ... 126
7.3 MATERIALS AND METHODS ... 128
7.3.1 Service cost (*SC*) ... 130
7.3.1.1 Terminal handling cost (*HC*) ... 130
7.3.1.2 Storage Cost (*SC*) ... 131

7.3.1.3 Value-added service cost (*VA*) 132
7.3.1.4 Customs clearance cost (*CC*) 133
7.3.2 Time cost (*TIC*) 134
7.3.2.1 Inventory cost (*IC*) 135
7.3.2.2 Demurrage and detention costs (*DDC*) 135
7.3.2.3 Container leasing cost (*CLC*) 136
7.3.3 Transportation cost (*TRC*) 136
7.3.3.1 Delivery cost (*DEC*) 137
7.3.3.2 Back empty container cost (*BECC*) 138
7.3.3.3 Emission cost (*EMC*) 138
7.3.4 Total Logistic Cost (*TLC*) 139
7.3.5 Simulations' assumptions 140
7.4 RESULTS 142
7.5 DISCUSSION 151
7.6 REMARKS 152
8 SEAPORT-HINTERLAND COMPETITION IN TERMS OF 'COST' AND 'TIME' 153
8.1 CONTEXTUALIZATION 153
8.2 HYPOTHESIS PROPOSITIONS 155
8.3 MATERIAL AND METHODS 156
8.3.1 Step 1 – Import process description 157
8.3.2 Step 2 – Data and tools 158
8.3.3 Step 3 – Statistical results and analysis 158
8.3.4 Step 4 – Cost model simulation 159
8.3.5 Cost model approach 160
8.4 RESULTS 163
8.4.1 In terms of time 163
8.4.2 In terms of cost 166
8.5 DISCUSSION 170
8.6 REMARKS 173
9 CONCLUSIONS 174
9.1 CONCLUDING REMARKS AND MAIN FINDINGS 174
9.2 THEORETHICAL AND MANAGERIAL CONTRIBUTIONS 176
9.3 ECONOMIC IMPACTS 177

9.4 SOCIAL AND ENVIRONMENTAL IMPACTS 178
9.5 THESIS LIMITATIONS 179
9.6 FUTURE RESEARCH DIRECTIONS 180
REFERENCES 182
APPENDIX A – SURVEY QUESTIONNAIRE 202
APPENDIX B – RESULTS OF TESTS FOR H2.a, H3 AND H4 204
APPENDIX C – VARIABLES AND PARAMETERS OF THE MODEL 205

1 INTRODUCTION

Maritime transportation has played a huge and important role in connecting global trade in goods. A look at how the various market segments have evolved since 1990 shows that growth in maritime trade over the past three decades has been sustained by bullish trends in containerized trade volumes, coinciding with the wave of hyper globalization (UNCTAD, 2020). With the economy of scale resulted from the maritime transport, shippers/consignees have broken distances barriers and started to seek providers that fulfill better their expectations, enhancing the competitiveness throughout the world (HARALAMBIDES, 2019). Despite this grown of maritime operations, some complexities emerge when customers expand their analysis from a 'seaport to seaport' to a 'door to door' perspective. In this context, particularly challenging is the seaport-hinterland network.

Seaport-hinterland is a complex logistic network that exist in very different forms and arrangements under different terms around the world, especially including multiple actors as seaports, dry ports, carriers, and customers (shippers/consignees) that may differ in location, functionality, maturity level, ownership, and initiation processes (KHASLAVSKAYA; ROSO, 2020). This step of international trade of goods is defined as all service/operation that take place from the customer facility until the containerized cargo be loaded in the vessel (from the export side) our since the container is discharged in the seaport yard until reach the customer facility (from the import side) (BENTALEB; MABROUKI; SEMMA, 2015; FAZI; ROODBERGEN, 2018; SARMADI et al., 2020; SONG; DONG, 2012; TSAO; LINH, 2018). Considering that the portion of inland costs in the total import/export container shipping would range from 40% to 80%, and it could be reduced by one third with appropriate regionalization strategies, the interest of shippers and consignees about the hinterland transport chain has been increasing (NOTTEBOOM; RODRIGUE, 2005).

The most important and indispensable actor in seaport-hinterland is the seaport, logistic operator composed of a terminal facility with docks and yard, where containers are positioned, temporarily stored and arrive/leave by means of vessel operation or inland transportation (truck or rail) (FAZI; ROODBERGEN, 2018; HARALAMBIDES, 2019; YEO; THAI; ROH, 2015). In particular, seaports are ecosystems in which a large and heterogeneous set of stakeholders interact and implement a variety of articulated and interconnected business operations and processes (SIMONI et al., 2020). However, nowadays container terminals such as seaports are much more than places for transferring cargo between different modes of transport as they offer a wide range of services to exploit potential economies of scale, acting as gateways to access international markets which requires an alignment of seaside, intermodal/multimodal and landside logistics to achieve an efficient movement of the physical (goods) and non-physical (information) flows (HA et al., 2017). A recent report of international maritime transportation reinforced that currently, seaports are showing more interest in strengthening connections with the hinterland to get closer to the shippers and tap the cargo volumes that could be committed to capture local market volumes (UNCTAD, 2020).

Following the increased international trade of goods, many issues started to affect the seaports such operational and documental congestion, delays in the supply chain, increased transport, logistics cost and environmental impacts. In this context dry ports have emerged playing a key role, advancing seaport-hinterland connectivity, mitigating problems caused by constraints related to land and others that limit seaports' growth, coordinating the operation of the seaport supply chain and supporting regional economic development (FENG et al., 2013; ROSO; LUMSDEN, 2010). The most widely used definition is that dry port is an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardized units as if directly to a seaport (ROSO; WOXENIUS; LUMSDEN, 2009). More than that, dry ports extends the gates of the seaport inland, offering services such as storage, consolidation, depot, maintenance of containers, track and trace, customs clearance, and others additional services that should be available at the dry port (ROSO, 2007).

As an effect of the global competition, customers are looking for the entire supply-chain to optimize their operations, reducing the total logistic cost, ensuring reliability and avoiding shortages (SAMSON; GLOET, 2018). Essentially, any failure or unreliability in a seaport-hinterland services results in unhappy customers as a consequence of the disruption in the smooth import/export process (YEO; THAI; ROH, 2015). As the competition in globalized markets forces organizations to focus on their core competencies and outsource other activities (RASOULI et al., 2019), the complexity of services required by the customers, not only in flexible and customized operational services but also in real-time information and smooth customs process, have opened opportunities for dry ports in the supply-chain. Despite multiple actors in seaport-hinterland enhance the competitiveness of the entire supply-chain, such infrastructure make complex the customers' choice in select their services providers, requiring more deep analysis.

Despite the relevance of seaport-hinterland, to establish an effective network node for global trade depends upon not just its geographical context but also many further potentially interdependent contextual factors. These relate for example to the national and broader regional economy, central and local public policy and regulation, and financial opportunities for funding seaports, dry ports and multimodal transport infrastructure development, especially on a large scale and over the longer term (DO; NAM; LE, 2011; MURAVEV; RAKHMANGULOV, 2016; WANG; CHEN; HUANG, 2018). All of this entails drawing from the literature (CHIPULU et al., 2019), that the multi-stakeholder contexts for collaborative working towards making an effective hinterland network may be highly complex. This accomplishment is relatively difficult due to the existence of many different sources of risk that vary by stakeholder exposure, experience and perception (BENTALEB; MABROUKI; SEMMA, 2015). With the above context in mind, many research problems/opportunities emerge, which are described in next section.

1.1 RESEARCH PROBLEM

The outstanding increase of dry cargo transportation in international trade of goods has putting enormous pressure to bear upon seaports, experienced commonly as co-emergent challenges related to terminal capacity, fairway drafts, equipment to handle vessels and their cargo. Particularly challenging are hinterland issues which entail broader inland geographical distribution of seaport operations (KHASLAVSKAYA; ROSO, 2020; NGUYEN; NOTTEBOOM, 2019). In this context, dry ports have played a strategic role in the seaport-hinterland structure, which makes decision making regarding dry ports developments a critical factor that can positively or negatively impact the stakeholders involved. With this in mind, it stated as the first research problem the criticality of dry ports developments decision making as an option to improve the seaport-hinterland network, requiring a deep investigation.

Despite the benefits, investments on dry ports depend very much on existing logistic network connection infrastructure, political, social and financial regulations besides multiple stakeholder interests (DADVAR; GANJI; TANZIFI, 2011; KHASLAVSKAYA; ROSO, 2020). Achieve the best benefits of dry ports remains more difficult in countries with a poor railway connection, losing the scale economy generated through direct connections between the seaport and the hinterland. This is the current scenario of many developing economies as the case of Brazil. Just few dry ports in Brazil operate through a railway connection, as requested by the main definitions in the literature (ROSO; LUMSDEN, 2010; KHASLAVSKAYA; ROSO, 2020). Beyond the poor railway connection and a transportation network based on road modal, dry ports in Brazil also face challenges with bureaucratic customs process, the lack of legislation, and the competitive environment between seaport and dry ports, requiring improvements (RODRIGUES et al., 2021). However, it is not possible to change the characteristics of dry ports in Brazil to meet the best benefits in a short time. In this way, it stated as the second research problem the current context/challenges of dry ports in Brazil and the lack of definition regarding the role of this logistic player in the studied seaport-hinterland.

As complex logistic projects, dry ports facilities are not aware of failures, especially regarding the transitions from ‘project’ to ‘operations’ phases, which suggests that complex multi-stakeholder infrastructure projects frequently experience ‘*disastrous openings*’ (BRADY; DAVIES, 2010). This expression refers narrowly and precisely to serious and reputational compromising operational failures on the first day, following project delivery, when operations commence (AL-MAZROUIE et al., 2020; MARSHALL et al., 2020). The previous literature has reported many cases of ‘*disastrous openings*’ in dry port projects as, for example, the Multan dry port project in Pakistan that has failure to integrate the rail link, resulting in capacity underutilization and operational inefficiencies that preclude significant further development (ALAM, 2016). The same happened with Amal dry port in Sweden, that has recorded a longstanding low volume of container throughput since 2005, due to poor transport integration. Other examples of failed dry port ‘project’ to ‘operations’ phase transitions include the My Dinh dry port in Vietnam, facing overcapacity challenges due to poor strategic location, and the Cikarang dry port in Indonesia which has experienced extended cargo inspection durations (JEEVAN, 2016). Both the Codapar and Maringá dry ports (both in Brazil), were not able to continue operations due to very low handling volume (CATVE, 2020; MARINGAPOST, 2018). In sum, the consequences of risk in complex multi-stakeholder infrastructure projects can be quite negative and severe. Hence, risk factors that may cause ‘*disastrous openings’* in dry port projects is stated as the third research problem.

The complexity of the seaport-hinterland actors/functions may affect shippers and consignees in choice their services providers. A wrong decision may result in operational disruption, delivery delays, and excessive costs throughout the import/export process. Some recent events have touched the relevance of some factors as predictability, reliability and supply chains disruption for customers' decision-making in selecting their services providers as evidenced during the Covid-19 pandemic and the blockade of the Suez' channel in Egypt in 2021, which brought import/export instabilities and shortages around the world (UNCTAD, 2021). Therefore, choosing the wrong service provider in seaport-hinterland network is stated as the fourth and last research problem.

1.2 RESEARCH DESIGN

This thesis is designed as a multi article approach (JEEVAN, 2016; LIMA, 2020). For each research problem discussed in Item 1.1, there is research questions and specifics objectives discussed in order to bring theoretical and practical contributions. Each article was built under a distinct method and the context of the study was the case of dry ports and seaport-hinterland in Brazil. Given the research design stated, the research questions and objectives, the theoretical and practical justification, the research context and methods are described next.

1.2.1 Research questions and objectives

The research questions and objectives are defined in order to contribute fixing the research problems stated above. The main objective of the thesis is stated as follows.

- Main objective: Making an overall discussion on seaport-hinterland subject, especially regarding dry ports, highlighting the risk factors weighting and interdependences in projects transition phase, and proposing a cost model to aid customer to select their services providers throughout the seaport-hinterland.

As the criticality of dry ports development decision making requires a deep investigation, it is defined as the first specific objective identify the critical factors that affect dry ports developments. Toward this objective, the first research question seeks to identify the main topics of dry ports discussed in the literature, working as a typology for next studies, while the second research question aim to find the main criteria that should be considered in dry ports' development decision making. With that in mind, the specific objective and research questions follow.

- Specific objective 1: Identify critical factors that affect dry ports developments.
    - Research question 1: How was the development of dry ports' literature and the main topics discussed?
    - Research question 2: Which are the main criteria that should be considered in dry ports' developments?

The second research problem brings the thesis to the specific case of dry ports in Brazil. Focusing on define the role of this logistic operator, the main issues, challenges and opportunities as the second specific objective, the third and fourth research questions are defined as follow.

- Specific objective 2: Defining the role, main issues, challenges and opportunities of dry ports in Brazil.
    - Research question 3: What is the role of dry ports in Brazil and how it could be assessed?
    - Research question 4: Which are the main characteristics, issues, challenges and opportunities related to dry ports in Brazil?

The third research problem evidenced the relevance of risk analysis/assessment in dry port projects in order to avoid '*disastrous openings*', especially in the transition phase from 'project' to 'operations'. Regarding this problem it was stated as the third objective to assess the risk factors and interdependences for dry ports' transition phase from a multi-stakeholder perspective. Hence, the fifth and sixth research questions follow.

- Specific objective 3: Assessing the risk factors and their interdependence for dry port's transition from 'projects' to 'operations' from a multi-stakeholder perspective.
    - Research question 5: What are the similarities and differences between the stakeholder groups, in their selections and weightings of risk factors for dry port projects, and what implications arise as a result, both for

stakeholder-collaborative project risk management in general and for operational readiness transitions in particular?

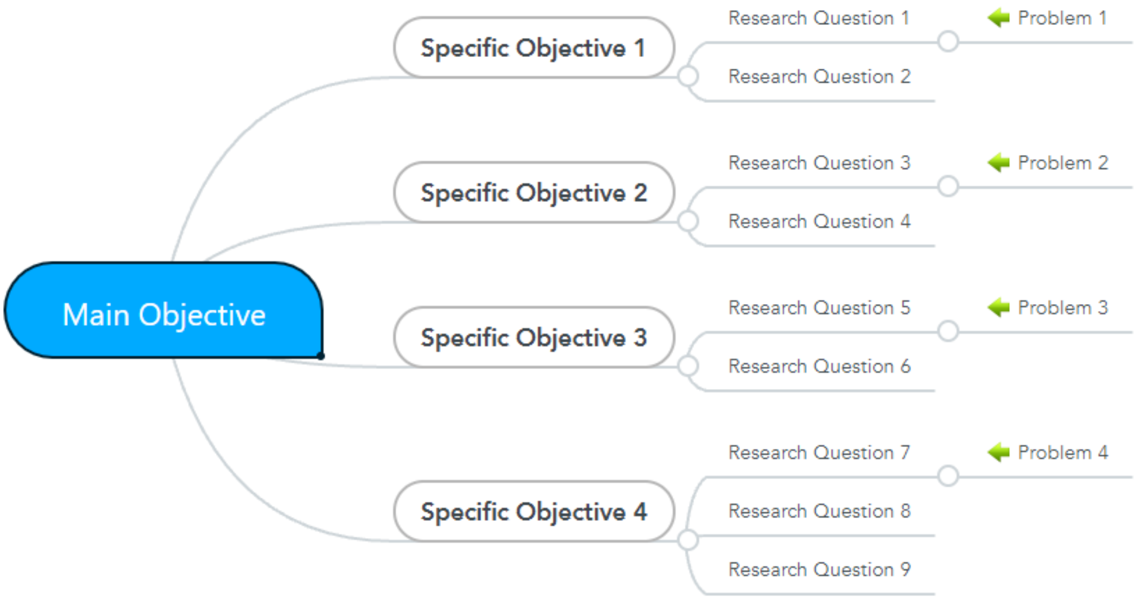
  - Research question 6: What are (and the nature of interdependence) of the most commonly experienced risk factors impacting upon the success of phase transition from 'projects' to 'operations' of dry port projects?

The complexity of choosing the right service provider throughout the seaport-hinterland network was highlighted in the fourth research problem. To overcome this problem, it was stated as fourth specific objective to discuss the customer's choice in selecting the service provider in terms of 'cost' and 'time', offering a flexible tool to assess the container shipping cost throughout seaport-hinterland. Toward this objective, first the 'cost' factors were identified, then the cost model was proposed and tested following the customers' specificities, lastly it was discussed the effect of these factors on seaport-hinterland competitiveness. Therefore, the last specific objective and research questions follow.

- Specific objective 4: Discussing the customer's choice in selecting the service provider in terms of 'cost' and 'time', offering a flexible tool to assess the container shipping cost throughout seaport-hinterland network.
  - Research question 7: Which are the cost factors that customers should consider in choosing the service provider in seaport-hinterland network?
  - Research question 8: How do customer's specificities drive the joint seaport-hinterland network decisions in terms of total container shipping cost?
  - Research question 9: How 'cost' and 'time' influence the seaport-hinterland customer's choice and what is the effect of these factors on competitiveness.

In general, this thesis works as a tool to aid customers, policy-makers and seaport-hinterland actors in making decisions. The defined problems were discussed from multiple perspectives, and various methods and tools was applied in order to bring relevant insights for all stakeholders in the seaport-hinterland. The scheme to achieve the main objective, starting from the problems stated is detailed in Figure 1.

Figure 1 – Problems, research questions and objectives of the thesis



Source: This thesis (2022).

1.2.2 Theoretical and practical justification

Shipping is a global service industry that provides the connection among international markets. Suffice it to say that, due to the morphology of our planet, 90% of international trade takes place by sea (HARALAMBIDES, 2019). Looking at how the various market segments have evolved since 1990 shows that growth in maritime trade over the past three decades has been sustained by bullish trends in containerized trade volumes starting in the 2000s, expanding the trade volume in 129% since then, coinciding with the wave of hyper globalization (UNCTAD, 2020). Considering that, the relevance of maritime transportation for international trade of goods, especially regarding the containerized cargo is the first justification of this thesis.

With the increased international trade of goods and the consequent effect of it in the seaport zones, shippers and logistics practitioners started to watch out to optimize the transport of goods, focusing mainly in the seaport-hinterland (HARALAMBIDES, 2019; NOTTEBOOM; RODRIGUE, 2005). This movement is evidenced in UNCTAD (2020), showing that seaports are currently more interest in strengthening connections with the hinterland to get closer to the shippers and tap the cargo volumes that could be committed, providing intermodal access, warehousing and other logistics services. This is illustrated by the large development of dry ports and rail connections projects, building a network that may bring a set of 37 benefits for the supply-chain as described by (KHASLAVSKAYA; ROSO, 2020). Therefore, the vital importance of seaport-hinterland network and the growing development of dry ports facilities are the second justification of this thesis.

Focusing on the theoretical justification, while studies of seaport choice has been strongly discussed in maritime cargo transportation literature (MOYA; VALERO, 2016; SLACK, 1985), the seaport-hinterland choice has remained neglected. What emerges from the above sketch of seaport-hinterland, especially in dry ports infrastructure, is that there are significant potential opportunities for research developments. While studies about dry ports have become more significant, the main research was applied in countries of Asia, Europe and North America (RODRIGUES et al., 2021). However, this scenario of growth on dry port research is not the same in Latin-America, especially in Brazil. Only a few studies have described the context of dry ports in Brazil over the last years, despite the relevance of the country to the international trade market (PADILHA; NG, 2012; NG; PADILHA; PALLIS, 2013; RODRIGUES et al., 2021). Considering that, the literature gap is defined as the third justification of this thesis.

Despite some gaps in the literature, in the last 10 years, several authors have proposed models to support decision making in dry ports environment. Among the main problems approached in the literature were the dry port location-allocation decision (CHANG; NOTTEBOOM; LU, 2015; KOMCHORNRIT, 2017; NGUYEN; NOTTEBOOM, 2019; WANG; CHEN; HUANG, 2018; WEI; SHENG, 2017); the network between dry port, hinterland and seaport (CHEN et al., 2018; KRAMBERGER et al., 2018; TSAO; LINH, 2018; WEI; SHENG; LEE, 2018); the dry port performance (HARALAMBIDES; GUJAR, 2012; JEEVAN et al., 2017; NG; TONGZON, 2010); evaluation about the transportation system (LÄTTILÄ; HENTTU; HILMOLA, 2013; QIU; LAM, 2018); analysis of the viability of dry ports (DADVAR; GANJI; TANZIFI, 2011) and its environmental impact (MURAVEV; RAKHMANGULOV, 2016; ROSO, 2007). The recent interest of scholars on dry port subject, making it a hot topic, is the fourth justification of this thesis.

Dry port developments are complex multi-stakeholder infrastructure projects associated with financing design, construction and ongoing management and maintenance (WANG; CHEN; HUANG, 2018; KHASLAVSKAYA; ROSO, 2020). The management challenges on such projects deserve to be considered through the view of risk in complex multi-stakeholder infrastructure projects (AL-MAZROUIE et al., 2020; MARSHALL et al., 2020). Considering the range of interdependence risk factors that could affect the operational success/failure of dry ports projects (BENTALEB; MABROUKI; SEMMA, 2015), and the evidence of dry port '*disastrous openings*' detailed in Item 1.1, it is imperative to further explore these issues. Hence, the necessity for a deep understands of risk in dry port projects transition phase is the fifth justification of this thesis.

Lastly, as dry port works as a seaport in the hinterland (BENTALEB; MABROUKI; SEMMA, 2015), one of the most important decisions of shippers and consignees concern in choosing their services providers. As mentioned by Lattila, Hentu and Hilmola (2013), in order to a dry port to be successful, customers need to be able to operate with lower (or at least equal) costs compared to a seaport. However, this decision may vary according to many factors. These includes the value and type of cargo (consolidated or deconsolidated), the distance of the delivery route, the kind of transportation mode to be employed, the dwell-time of the container stored, the amount of additional-services required, and so on. This complexity is enhanced by the competitiveness among the main actors of the seaport-hinterland, each one struggling to enlarge their market-share. Despite the relevance of customers decision-making, this topic still remains a literature gap requiring more clarification, as evidenced in two recent systematic reviews covering dry port's researches (KHASLAVSKAYA; ROSO, 2020; RODRIGUES; MOTA; SANTOS, 2021). Therefore, explore these issues in order to aid customers to choose the logistic operator that best fit their requirements is the sixth justification of this thesis.

1.2.3 Research context

The study is set within the context of dry port and seaport-hinterland in Brazil, covering the risk and container shipping cost assessment. Brazil is the largest country in South America and the world's fifth-largest country by area. With a population estimated at over 211 million, it is also the sixth most populous country in the world (IBGE, 2020). Economically, Brazil is the 9th economy in the world, with a GDP of US$7.4 trillion, exporting US$209 billion and importing US$158 billion in 2020 (MDIC, 2021; WORLD BANK, 2020). Furthermore, Brazil is the 20th largest container-handling economy in the world, handling more than 10 million TEUs per year, where only Santos seaport hub in São Paulo state is responsible for

34% of this volume (ANTAQ, 2021; UNCTAD, 2019). Given the above factors, Brazil very clearly plays a major role in global international trade and maritime cargo transportation.

The configuration of seaports in Brazil is as follows. There are a little over 134 seaports currently operational in Brazil. Approximately 34 of these are publicly owned, with the rest privately owned (GOVERNMENT OF BRAZIL, 2017). Focusing on container terminals, there are currently 29 operational seaports, being 14 of that responsible for 95% of the volume handled in 2019 (ANTAQ, 2021). Santos seaport highlights as the most important container terminal in Brazil, responding for 37% of the total volume of TEUs handled in 2019, followed by Paranaguá seaport (8.3%) and Itapoá seaport (7%) (ANTAQ, 2021). Most volume of containerized cargo is handling in public seaports (69.6%), while the private seaports respond for 30.4%. The geographical distribution of seaports in Brazil follows in Figure 2.

Figure 2 – Logistic infrastructure of seaports (container terminals) and dry ports in Brazil

Source: This thesis (2022).

Based on ANTAQ (2021) and Rodrigues et al. (2021).

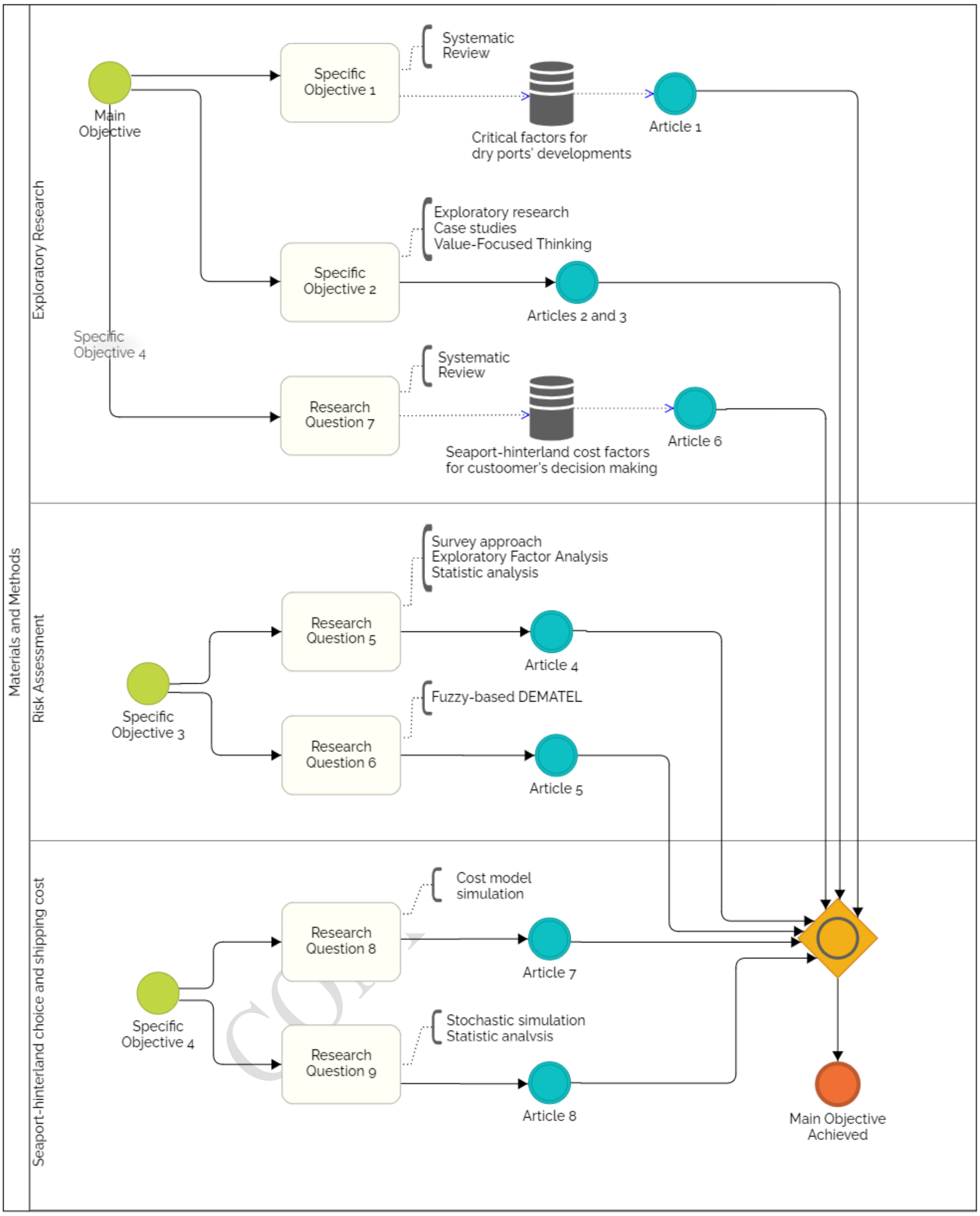
From the hinterland side, there are currently 56 dry ports in Brazil (ECONOMY MINISTRY, 2020), characterized by handling especially import cargo (RODRIGUES et al., 2021) and mainly located in the southeast (29) and south (17) of the country. The connection between seaports and hinterland is dominated by road (65% of the transport share). With15% participation in the transport matrix and focused on transport commodities as iron ore and grains (80% of total volume), Brazil has a low density of rail network compared to continental countries such as Canada, India, USA, China and even other developing countries in Latin America, such as Mexico and Argentina (ANTF, 2019). The geographical distribution of dry ports in Brazil is presented in Figure 2. What emerges from this brief sketch of dry port and seaport-hinterland infrastructure in Brazil is that there are significant potential opportunities for logistic project developments.

1.2.4 Research method

This thesis approach is divided in three main groups: (i) exploratory research; (ii) risk assessment; and (iii) seaport-hinterland choice and shipping cost as presents Figure 3. In order to achieve the main objective stated, specifics methods was applied in each step of the research. Fulfilling the first specific objective and the seventh research question, two systematic review were conducted following the 3-stage and 9-phase model described by NHS Centre for Reviews and Dissemination (2001), adapted by Tranfield, Denyer and Smart (2003). As result of this method, two databases were built, one with the critical factors for dry ports' developments and the other with the seaport-hinterland cost and service level factors for customers' decision making. Completing the exploratory research group, two case studies were carried on in Brazilian context based on Voss, Tsikriktsis and Frohlich (2002), applying the Value-Focused Thinking approach (KEENEY, 2001) to attain the second specific objective.

The methods in second research group aim to reach the third specific objective. First, answering the fifth research question, the critical factors for dry ports' developments identified previously were analyzed by the view of risk and assessed through a survey approach with logistics experts in Brazil. The inputs were aggregated using the Exploratory Factor Analysis method and tested statistically. Second, to reach the sixth research question, the Fuzzy-based DEMATEL approach, following Si et al. (2018), was applied to identify the interrelationship among the risk factors in dry ports project transition phase.

Figure 3 – Research method approach



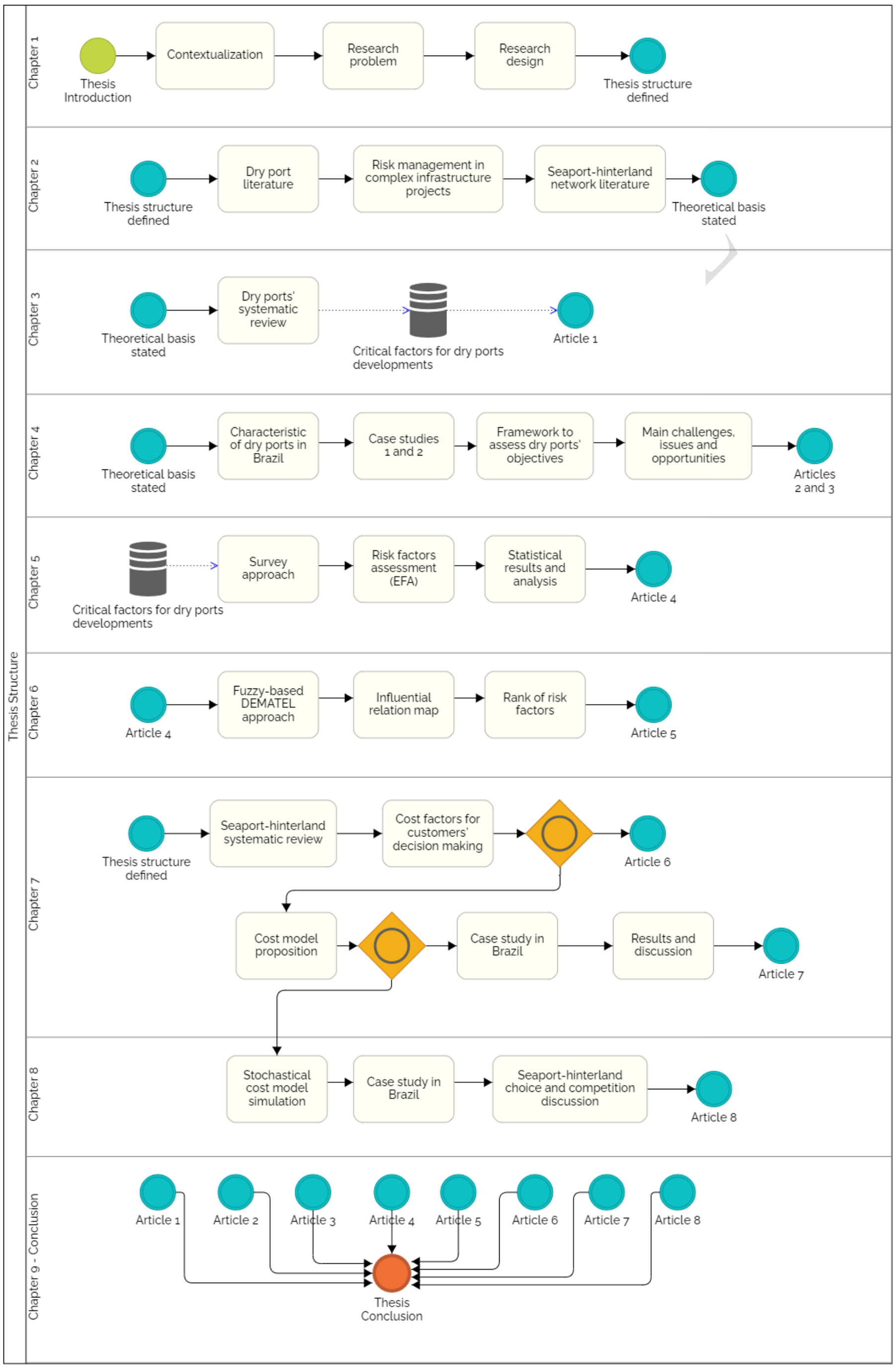
Source: This thesis (2022).

The last group of articles aims to reach the fourth specific objective. Answering the eight research question, a cost model approach was proposed and simulated in a case study in Brazil. Then, the cost model was simplified and simulated stochastically (Monte-Carlo approach) in another case study in Brazil. Answering the ninth research question, statistical analysis was run and the results were discussed. The process in Figure 3 shows the thesis approach from a holistic view, stating the main methods required to develop the thesis. The details of the method applied are described in the next chapters.

1.3 THESIS STRUCTURE

The structure of the thesis follows in Figure 4.

Figure 4 – Thesis structure



Source: This thesis (2022).

The first chapter contextualized the research, defining the problems addressed, the main objective, stating the research questions and the methods applied. Working as the basis of the thesis, the second chapter details the theoretical background, highlighting topics of dry ports literature, risk management in complex infrastructure projects and the seaport-hinterland literature.

The first result of the thesis is presented in Chapter 3. Through a systematic review of the literature, the critical factors for dry ports' developments were presented in a revised version of the first article. Focusing in the Brazilian case, the Chapter 4 presents a revised version of the articles 2 and 3, discussing the main role, challenges and opportunities for dry ports in a developing country. Chapter 5 and 6 start to discuss dry ports' projects through the view of risk. First, a revised version of the article 4 presents risk assessment in dry ports' project transition phase from multiple stakeholders' perspective. Second, the interrelationship among the risk factors is discussed.

Chapters 7 and 8 approach the seaport-hinterland network, mainly the customers' choice in selecting their services providers. Chapter 7 highlights the main cost factors regarding the choice between dry ports and seaports, proposing a cost model for container shipping considering multiples delivery routes and actors. Lastly, Chapter 8 analyses the customer's choice in terms of cost and time, discussing the competitiveness throughout the seaport-hinterland. Hence, the last Chapter concludes the thesis emphasizing the practical and theoretical contributions, the economic, social and environmental impact, as well the limitations and suggestions for future researches.

2 THEORETICAL BACKGROUNDS

This chapter introduces the theoretical foundations of this thesis divided in three main sections. First, dry port literatures are detailed, presenting the development of this logistic operator in some countries, highlighting the main functions and classification approach. Second, dry ports is discussed in light of risk management literature, especially regarding complex infrastructure projects from a multi-stakeholder perspective and the transition phase from 'project' to 'operation'. Lastly, the literature is extended to the seaport-hinterland subject, focusing on the customers' choice in selecting the service provider and in previous optimization models that served as basis for the cost model proposed in this thesis.

2.1 DRY PORT LITERATURES

Dry port was originally defined as an inland terminal to and from which shipping lines can issue their bills of lading (UNCTAD, 1982), but the most widely used definition is that dry port is an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardized units as if directly to a seaport (ROSO; WOXENIUS; LUMSDEN, 2009). Existing in very different forms and arrangements under different terms around the world, they are sometimes called Inland Ports, Inland Container Depots (ICDs) and, in a limited number of cases, Container Freight Stations (CFS) (NGUYEN; NOTTEBOOM, 2019; UNESCAP, 2015). Despite some controversy regarding the dry port definition, the term 'dry port' is becoming more popular worldwide, assuming a prominent position in the international logistic network.

2.1.1 Dry port functions

As the name implies, a dry port provides all of the services of a seaport except for the loading of cargo to and from seagoing ships. The concept of dry port thus denotes logistics centers established inland, offering core service functions of customs declaration, inspection declaration and insurance on bills of lading (KA, 2011). Further added services such as storage, consolidation, depot, maintenance, track and trace, customs clearance, etc., should also be available at dry ports, simplifying the import and export procedures (ROSO, 2007).

Dry ports can serve a number of unique functions. The most obvious is containerization (onward transport of sea cargo via containers) (RODRIGUE et al., 2010). When located approximately less than 100km from the seaport, a dry port can also be used as a satellite terminal (WAKEMAN, 2008). Satellite terminals are basically extensions of a main seaport, which allows for extra loading and unloading at lower cost. Dry ports can also serve as load centers and hubs (WAKEMAN, 2008). These are primarily deemed intermodal, in that they provide a hub for the loading and unloading of cargo across road, inland water and rail within a reasonable distance from major production hubs. Finally, and extending this notion of inter-modality, dry ports can also serve as trans-modal centers (BERESFORD et al., 2012), providing a source of interchange for cargo that is transported between road, inland water, air and rail.

Noting the various functions mentioned above, dry ports provide a number of logistical advantages for global supply chains (WAKEMAN, 2008). For example, they offer points of cargo consolidation (achieved from loading) and deconsolidation (unloading). Furthermore, they also offer warehousing, so as to relieve seaports from capacity challenges and allow for more efficient end customer order fulfillment. Additional benefits of dry ports include relief of storage and customs space limitations. Other services such as, depot, maintenance of containers, track and trace, customs clearance, and others additional services should be available at the dry port. Focusing on security and control by the use of information and communication systems (ROSO, 2007), dry ports not only expand seaport hinterland areas and increase its cargo sources, but also simplify import and export procedures. The smooth coordination between a seaport and its dry ports directly impacts the effective operation throughout the logistics supply chain. Driven by global economic integration and inland-oriented logistics services, the cooperation between seaports and their dry ports is getting increasingly close, changing the dynamics of interaction between seaports and hinterlands (CHEN et al., 2018).

2.1.2 Dry port development

The development of dry ports are most advanced in Europe (NOTTEBOOM; RODRIGUE, 2009). Currently, a wide array of rail operators makes up the supply of rail products out of European container seaports. From a network perspective, intermodal rail transport in Europe has undergone a transition from a meshed network to a hub-and-spoke network based on intermediate rail hubs and then finally the replacement of the network by a system of direct lines (RODRIGUE; NOTTEBOOM, 2012). In the United States there are large inland terminals, commonly around metropolitan areas, commanding a regional manufacturing base and distribution system through the double stack train (NOTTEBOOM; RODRIGUE, 2009; RODRIGUE; NOTTEBOOM, 2012). Compared to Europe, North American's dry ports tend to be larger and cover a much more substantial market area. Another characteristic regarding the setting of a dry port, or at least the intermodal terminal component, is mostly in the hands of rail operators due to a different ownership and governance structure (RODRIGUE; NOTTEBOOM, 2012).

On the other hand, China started to build dry ports later and many of them were developed to improve local economies in central and western China, consistent with the 'Go West' strategy produced in 2000 (LI; DONG; SUN, 2015; KA, 2011). In Russia, the construction of inland terminals was at a very early stage of development due to a lack of infrastructure development in seaport cities and existing regulations which impeded container seaport development and their inland connections (KOROVYAKOVSKY; PANOVA, 2011). Other studies detailed the development of dry ports in India (HARALAMBIDES; GUJAR, 2011; HARALAMBIDES; GUJAR, 2012); Vietnam (NGUYEN; NOTTEBOOM, 2016; NGUYEN; NOTTEBOOM, 2017) and Malaysia (JEEVAN; CHEN; CAHOON, 2018; JEEVAN, 2016), discussing challenges, government policies, location-decision and investment strategies.

Initially called 'Depósitos Alfandegados Públicos' (Public Bonded Warehouses) and later 'Estação Aduaneira do Interior' (Inland Customs Station), dry ports were introduced in Brazil in 1976 at secondary zones, which are zones without foreign direct contact as seaports, airports or boundaries zones (PADILHA; NG, 2012). However, the term 'Porto Seco' (Dry Port) was only adopted in 2002 (PADILHA; NG, 2012). In the same year, the use of dry ports for industrial operations was introduced by the Normative Instruction 241/02. In 2006, responding to the protracted legal disputes, the Provisional Measure 320 (MP320) was introduced, attempting to allow dry ports to operate by means of licenses issued by the Brazilian Federal Revenue, expanding the scope of dry port to the Logistic and Industrial Customs Centre (CLIA) (PADILHA; NG, 2012). However, that provisional measure was considered unconstitutional and rejected by the Brazilian Senate (NG; PADILHA; PALLIS, 2013). In 2013 another Provisional Measure (MP 612/13) brought this subject to the discussion again and several companies that were under the dry port regime requested to change to CLIA, but the MP 612/13 also expired without being converted into a law (NG; PADILHA; PALLIS, 2013). Therefore, there is no standard normative for the creation of new CLIAs in Brazil and, in this thesis the terms CLIA and dry port are considered the same logistic operator.

With the advent of dry ports, the competitiveness between the main actors along the seaport-hinterland has increased, forcing seaports to implement various means to control the container flow and gain competitiveness (CHEON; SONG; PARK, 2018). Recently, a new strategy used by seaports is extending the terminal gate to include selected hinterland locations, enabling the movement of containers into those locations without prior involvement of the shipping company, the ship- per/receiver or customs (VEENSTRA; ZUIDWIJK; VAN ASPEREN, 2012). This inland terminals managed by the seaports is called extended gate. Implementation of the extended gate concept is seen as a good solution for ports in East Africa, but it would require a joint effort by multiple stakeholders, both private and governmental (KHASLAVSKAYA; ROSO, 2020).

Developing a dry port requires a high investment level and there could be many options for obtaining funds. Some countries adopted the concession policy, as applied in China (BERESFORD et al., 2012). Another option is the public and private cooperation through Public–Private-Partnership (PPP) agreements, as discussed by (HARALAMBIDES; GUJAR, 2011) in India, (PANOVA; HILMOLA, 2015) in Russia and (NGUYEN; NOTTEBOOM, 2017) in Vietnam. In Brazil, dry ports operate under the concession regime, after a bidding process managed by the Brazilian Federal Revenue (NG; PADILHA; PALLIS, 2013). Until now, there is no record of PPPs applied to dry port development in Brazil.

2.1.3 Dry port classification

Considering the different developments of dry ports around the world, classify dry ports becomes a difficult mission. Regarding the distance between the dry port and the seaport, Roso, Woxenius and Lumsden (2009) proposed to classify dry ports as long distance (>500 Km), midrange (between 100-500 Km) and close distance (<100 Km). The long distance is the most conventional of the three and the main reason for implementing it is simply that the distance and the size of the flow make rail viable from a strict cost perspective; a midrange dry port is then situated within a distance from the seaport generally covered by road transport and serves as a consolidation point for different rail services, implying the use of administration and technical equipment specific for sea transport; the close dry port consolidates road transport to and from shippers outside the city area offering a rail shuttle service to the seaport relieving the city streets and the port gates.

Despite the above classification, the size and logistics infrastructure will vary in different countries, making vast the difference of distances involved. Some of the major inland manufacturing and commercial centers of China and India are 1,400 – 1,800 km from the seaports, while the international trade of Central Asia must travel between 1,000 and 8,000 km to find an outlet to the sea. By contrast, in other countries, such as the Republic of Korea and those of Southeast Asia, distances between trade origins or destinations and seaports are comparatively short, in some cases being in the range of 100-300 km (UNESCAP, 2015).

Also in relation to the location function, China's dry ports are classified into three groups, namely seaport-based, city based and border dry ports (BERESFORD et al., 2012). Seaport-based refer to facilities which are sited at the coast with a major function of pre-customs clearance and find to capture more cargo flowing along the inland supply chain and to relieve capacity constraints at the seaport. The city-based is typically positioned within a larger logistics cluster which serves production and consumption besides offering a wider range of value-added logistics services than the seaport-based. On the other hand, a border dry port refers to one located in the border area, with the major function of being a transshipment center or custom clearance service. In another view, Notteboom and Rodrigue (2009) proposed seven dimensions characterizing inland nodes as transport modes served, ranging from unimodal, when it is connected only by road; bimodal, when there are another options as railways or barge; and trimodal, when the dry port is connected with the seaport by three transportation modes.

2.2 RISK MANAGEMENT IN COMPLEX INFRASTRUCTURE PROJECTS

The success or failure of a project may well be determined by the quality of its risk management (WRIGHT, 2018). According to Marshall et al. (2019), risk management needs to be concerned with building corporate nervous systems along which information can flow, not primarily to drive strategy and agility per se, but more pressingly to engage complex threats that often have some social and reflexive aspect. This idea has profound general implications for stakeholder-collaborative management on projects; specifically, it implies that conceivably any spontaneous or planned interaction on projects between interested internal and/or external stakeholders might constitute an occasion where risk information is either generated for, or pushed through, the corporate nervous system upon which effective risk management depends.

Most academic guidance on project risk management also emphasizes a need to identify risk and underlying uncertainty early in the process (CHAPMAN; WARD, 2003). This principle is especially apt for risk management in complex projects where there are many planning matters to be addressed both at the outset and iteratively throughout, en route towards achieving clarity on what specific project activities and associated risks might require management prioritization at different points in time. In this thesis, we consider these challenges as pertaining to a '*complex system*' of dynamically interrelated project activities and associated risk and uncertainty issues, recognizing that the characteristics and behavior of the whole system can be extremely difficult to deduce from its various parts when these are framed in isolation as system inputs (SIMON, 1982). This problem is widely recognized as making the evaluation of risk in real projects difficult (WILLIAMS, 2017). Notably, the problem is not just that risks synergize, but also that the activities that require risk management are themselves changing and also subject to ongoing re-framing, such that associated risk can then be viewed differently. The thesis contend, accordingly, that these challenges are sufficiently fraught as to explain much of the widely recognized problem whereby complex multi-stakeholder infrastructure projects frequently experience '*disastrous openings*' (BRADY; DAVIES, 2010), as stated before. Beyond the cases of 'disastrous openings' in dry ports already pointed, the literature also presents such occurrence in other complex infrastructure projects, as for London Heathrow's Terminal 5 airport (BRADY; DAVIES, 2010), and for the underground rail projects in Singapore (HWANG; ZHAO; YU, 2016).

In order to avoid '*disastrous openings*' amidst complexity in project-to-operations transition phases, some formal risk analysis can be helpful , recognizing of course that systemicity challenges may often limit what is achieved (WIILLIAMS, 2017; ROTHENGATTER, 2019); furthermore, the subjectivity and heterogeneity of risk factors may impede stakeholder collaboration within such endeavor (CHIPULU et al., 2014). Moreover, the approaches generally used for such risk analysis are mono-criterion, which means that risks are considered as if they were independent, while in practice they often present interdependencies. More specifically, we contend that an understanding of pertinent risk categories and their tendencies to interrelate, offers the prospect of a more structured approach to exploring the complexity and fluidity of risk issues in circumstances where stakeholders are often likely to hold diverging perceptions. In effect, this entails collaborative stakeholder co-working where an agreed set of categories together with a common understanding of their key interdependencies, can constitute a distinctive ‘top down approach to risk identification’ (MARSHALL et al., 2019), which forms the basis thereafter for more focused and coordinated collaborative risk management practice (TESTORELLI; LIMA; VERBANO, 2020).

2.2.1 Risk management from a multi-stakeholder perspective

Managing risk in complex infrastructure projects is commonly understood as requiring great integration of effort and careful sensitivity to, as well as management of, stakeholders’ interests (NGUYEN; SKITMORE; WONG, 2009). Some management challenges, e.g. (i) multidimensional and asymmetric constructs of risk employed; (ii) stakeholder multiplicity, which amplifies the first challenge; and (iii) the contradictory individual logics that must also be addressed, can present significant obstructions to successful multi-stakeholder project risk management (AL-MAZROUEI et al., 2021). Furthermore, Chipulu et al. (2014) found that the level of importance that stakeholders assign to project outcomes was dependent on a number of individual demographic factors such as age, gender and national cultural identity. This heterogeneity emerges because within project and operational contexts, individual stakeholders focus on different socially constructed parameters of outcomes, depending on a number of individual factors that may include their individual perceptions of risk and the degree to which they may ascribe priority to individual project success and/or failure dimensions (CHIPULU et al., 2019). Crucially, divergent views on preferred outcomes strongly imply divergent views on the risks that threaten the outcomes.

Project success is also well known to depend very much on fulfilling stakeholders’ needs and expectations (NGUYEN; SKITMORE; WONG, 2009). This significantly complexifies the classic project management practice which frames project success in terms of preferred trade-offs between cost, time and quality (CHIPULU et al., 2014). Such subjectivity in risk perception, complexified both by variance along the life-cycle of the project, and by the coming-and-going of stakeholders over that life-cycle, creates a range of unexpected and novel risks that require constant re-evaluation through the simplifying lens of project readiness (AL-MAZROUEI et al., 2021). Project managers must therefore identify stakeholders, giving thought to how they may rotate in and out of projects, understand their expectations/interests, and be accurately aware of their potential influences on the project (NGUYEN; SKITMORE; WONG, 2009). As an alternative risk management approach, the recent framework proposed by Testorelli, Lima, and Verbano (2020) explicitly incorporates stakeholder perspectives, focusing more particularly on control-of-bias pertaining to risk perception and evaluation, understanding of stakeholders' needs and expectations, and providing for continuous, systematic and transparent communication and consultation between interested stakeholders at all steps in the process.

Clearly, therefore, risk management in infrastructure projects depends on multiple stakeholder interactions within a complex network which the earlier mentioned 'corporate nervous system' metaphor (MARSHALL et al., 2019) helps us to explore in terms of the critical risk deliberation and risk knowledge transfer that is continually at issue. All participating stakeholders may have discordant categorically structured views of what the risks are, why they matter, and how they should be prioritized for management purposes.

2.2.2 Project phase transitions

Logistic infrastructures like dry ports and seaports, like most complex multi-stakeholder infrastructure projects, are delivered over a finite period of time, by temporally and uniquely organized teams consisting of multiple actors and stakeholders that are likely to be dispersed on project completion (GRABHER, 2004; VAN MARREWIJK et al., 2016; MCGIVERN et al., 2018). Typically, an input-process-outcome view of project delivery suggests that on completion of the 'front end' project, a process of transition commences leading to the commencement of a distinct 'back end' operations phase. Herein, transitions entails the process of bridging two very distinct architectures of organizing (VAN MARREWIJK et al., 2016). Drawing from Maylor et al. (2018), such transitions involves the bridging of work which is temporary, unique and novel (projects) and work which is repetitive, permanent and ongoing (operations). Organization studies point to significant tensions in terms of how to adequately balance the likely contradictory needs for different forms of organizing; management flexibility, learning, governance and strategizing that are simultaneously applicable to the temporality of projects and permanence of operations. Thus, the literature espouses the susceptibilities of complex multi-stakeholder infrastructure projects to phase transition failures (BRADY; DAVIES, 2010; MARSHALL et al., 2020; WHYTE; NUSSBAUM, 2020; AL-MAZROUIE et al., 2021).

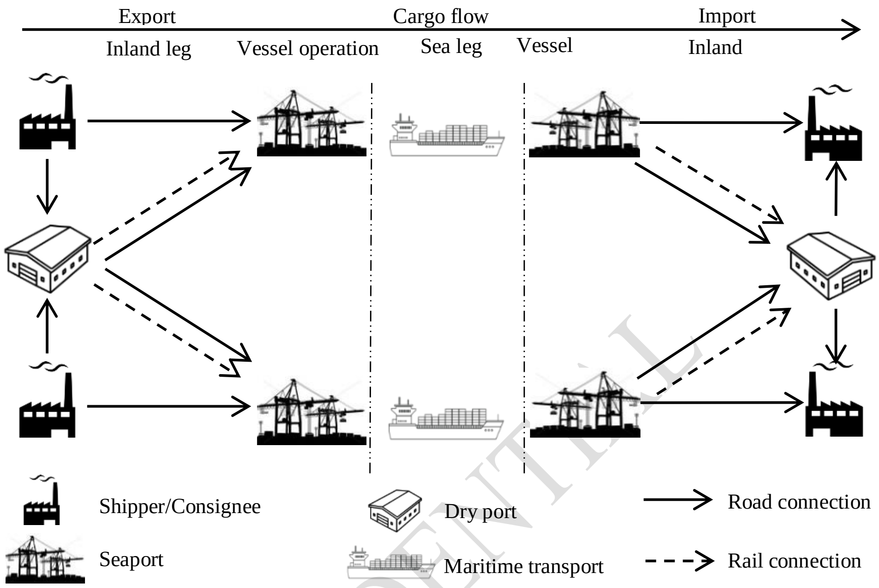
Various specific reasons have been advanced in the literature to explain why such failures do occur. Marshall et al. (2020), for example, contend that these failure emanate from the uncertainty associated with need to constantly make adjustments to the back end of projects (to which operations falls within), in light of gradual knowledge and awareness of specific risks at the front end of the project. Their work is drawn in part from Whyte and Nussbaum (2020) who observe the need for management to constantly vary and refocus priorities, processes, procedures and forms of managing. Phase transition failures in complex multi-stakeholder infrastructure projects will therefore often occur due to their long planning durations (which inevitably will mean changes original requirements and complex independencies between the various facets of the projects and the desired operations).

2.3 SEAPORT-HINTERLAND NETWORK LITERATURE

The traditional flow of goods, where shippers and consignees could leave and pick their products from and to a seaport directly by road transportation is changing. The advent of dry ports in the last 40 years has modified the traditional network to a new structure, as presents the Figure 5. A generic description of the different stages of cargo flow considering dry ports is based on Bentaleb, Mabrouki and Semma (2015), Tsao and Linh (2018), Fazi and Roodbergen (2018), and Sarmadi et al. (2020) as follows: (i) inland leg: in export and import, the shippers and consignees has the option to deliver or pick their containers to/from a dry port or directly to a seaport by road transportation; using a dry port, this container could be deliver/pick to/from seaport by rail or road transportation; in this step, the inland transportation, cargo storage, customs clearance process and additional services take place. (ii) Vessel operation: this step begins when the container is planned and loaded/discharged to/from a vessel, depending only of the seaport operator and shipping line. (iii) Sea leg: this step portrays the deep-sea transport, connecting the international trade of goods.

Taking into account the new transportation network, customers and freight forwarders are looking for supply chain effectiveness, reducing the total logistic cost with a high service level (NOTTEBOOM; RODRIGUE, 2005). This new structure enhance the competitiveness among the main actors in seaport-hinterland network and brings complexity in customer' choice. Such issues are discussed in this section.

Figure 5 – Containerized import/export network



Source: (RODRIGUES et al., 2020).

2.3.1 Seaport-hinterland network choice

The preference among different stakeholders for seaport-hinterland to operate through either a dry port or a seaport may involves numerous considerations (CASTELEIN; GEERLINGS; VAN DUIN, 2019). In general, there are two viewpoints in terms of how the preference for seaport-hinterland to operate through either a dry port or a seaport is usually decided. The first viewpoint involves shippers selecting an ocean carrier and turning over the route and seaport choice decisions to that ocean carrier. That means that the shippers in this instance will not be involved in making the final decisions about individual seaports (carrier haulage). As relates to the second viewpoint, the ultimate decision about the route, landside transportation including the dry port and seaport choice will reside with the customer (merchant haulage) (CASTELEIN; GEERLINGS; VAN DUIN, 2019).

Customers in seaport-hinterland networks tend to be grouped against priorities or size. For example, based on priorities, customers can be grouped into three consisting of the first group, in effect, those who maintain long-term contracts with shipping lines. These groups of customers are generally very committed to a particular carrier. They would have maintained a high level of customer interaction spanning a number of years to a particular carrier and are therefore dependent on the shipping lines' chosen of seaport and hinterland transport/services. The second group of customers is those who use freight forwarders and in the process, tend to delegate the responsibility for route selection to the freight forwarders. The final group of customers is those who are independent shippers. This group of customers are usually engaged in the route selection (TONGZON, 2009). Customer in seaport-hinterland networks may also be grouped based on size. For example, studies by Slack (1985) suggest that smaller customers appear to be influenced by price differentials while for the larger customers undertaking regular shipments the question of quality of service is more relevant. Furthermore, Steven and Corsi (2012) found that large shippers emphasize the factors affecting speed of delivery more than the freight charges compared to small shippers.

A review of prior research on dry port and seaport choice conducted by Rodrigues et al. (2020) suggest that research on seaport choice that touches upon parameters such as seaport effectiveness and maritime line optimization are well established in the literature. Examples of this literature being Talley and Ng (2013), Moya and Valero (2016) and Hsu, Lian, and Huang (2020). In addition to studies focused on seaport effectiveness and maritime line optimization, other studies have examined intermodal connection decision and network optimization (TRAN; HAASIS; BUER, 2017). However, despite these studies, little attention has been given to the entire seaport-hinterland network choice. More especially, such studies that takes into consideration not only multimodal transportation and dry port as an option, but also the choice among a set of dry ports the one that best fit the customers' perspective have been neglected. The thesis, however, acknowledge that there are some relevant studies in these areas. For example, Onwuegbuchunam and Ekwenna (2008) found that the service level, security, efficiency, infrastructure and proximity to market are the most important factors influencing choice of dry ports by shippers. Lättilä, Henttu, and Hilmola (2013) undertook studies focusing on assessing whether cargo should be channeled through dry ports or should be channeled directly to the seaport. Most recently, Jiang et al. (2020) formulated a model to describe the joint choice of shippers on seaport, transport mode and dry port. Their study found evidence that the competitiveness of a hinterland transport chain is jointly determined by seaports, transport modes, dry ports, and the services that are provided by shipping lines at seaport and dry port.

Despite the vast literature about seaports (from a sea leg perspective), many costs and service level factors are related to the hinterland side, making it possible for dry ports and seaports to be compared as services providers. A number of studies undertaken in this area have found that factors such as total logistics cost, responsiveness, satisfaction with previous service, reputation of the logistics operator, intermodal connectivity, and speed are the most important factors in choice the service operator from the hinterland side (BASK et al., 2014; REZAEI et al., 2019; VALLS et al., 2020). As customers are looking for reduce their total logistics cost (TALLEY, 2019), in order for a dry port be successful and competitive, it should be able to offer customers a lower or at least equal total logistics costs compared to those operated through seaports (CULLINANE; BERGQVIST; WILMSMEIER, 2012). Some of these logistics costs that should be considered include storage cost, transportation cost, handling cost, inventory cost, and demurrage and detention cost (NUGROHO; WHITEING; JONG, 2016; REZAEI et al., 2019; JIANG et al., 2020). A recent study by Rodrigues et al. (2020) has synthesized the above literatures.

2.3.2 Seaport-hinterland network competition

Competitiveness is an aspirational attribute of operations because it enables firms to survive and thrive (OLIVEIRA; CARIOU, 2015; DURUGBO et al., 2021). The competition in fact occurs based on the competitive priorities, which are goals and choices that reflect aspirational, conditional and preferential emphasis in manufacturing and operations strategy to select, develop and use competitive capabilities in reinforcing competitive advantage and satisfying customer and market demands (DURUGBO et al., 2021). There are a range competitive priorities, or factors, that determine the choice behavior of customers; the core dimensions described in the literature are cost, quality, time and flexibility (DURUGBO et al., 2021).

Integrating the same supply-chain, dry ports and seaports may build a competitive cargo shipping environment, depending on the objectives and the relationship among various stakeholders (actors). The literature reinforces the notion that the efficiency of supply chains may be impacted by conflicting objectives among stakeholders. For example, (i) while shipping lines design their service network in a manner that makes most of the scale economies, (ii) the aim of freight forwarders is to provide value-added services to their final customers, (iii) seaports and dry ports seek to maximize their hinterland chain throughputs, while (iv) intermodal carriers generally focus on maximizing their hinterland chain profits while importers and exporters focus on minimizing the hinterland chain logistics costs of their cargoes (TALLEY; NG, 2017; TALLEY; NG, 2018).

Competition within the cargo shipping environment may also exist within steps that are carried out during the import/export process. First there is intra competition, which is the competition inside the same seaport-hinterland network, concerning the competition (i) among dry ports in the hinterland, (ii) among seaports, (iii) among dry ports and seaports, and (iv) among road and rail carriers. Second exist the inter competition, concerning the competition among different seaport-hinterland networks, which may happen in the same country (among states) or among countries. The intra competition may be expressed as the example of seaports and dry ports competing to store the container cargo, which happens mainly when the throughput of containers in the seaport is low, having yard capacity to store containers available (RODRIGUES et al., 2021). Going beyond, an example of inter competition between countries or seaport-hinterlands will exist where different ones offers tax benefits to attract the import/export service (CHEON; SONG; PARK, 2018; RODRIGUES et al., 2020).

With increased competition in the global market, companies are required to be efficient not only within their organization but throughout their supply chains (MASKEY; FEI; NGUYEN, 2020; RASOULI et al., 2019). Empirical studies on seaports in the United States find evidences that the competition between seaport-hinterland actors is associated with high efficiency, since it provides incentives for companies to improve their operation (OLIVEIRA; CARIOU, 2015; WAN; YUEN; ZHANG, 2014). With this in mind, while importer/exporters are looking to reduce their logistic cost, the actors in the seaport-hinterland network struggle to improve their services to first gain the intra competition and enlarge their actuation zone. The intra competition may be stated in terms of ‘cost’ and ‘time’. Some evidences of this are found in the studies of Lirn and Wong (2013), that defined ‘cost’ as the most important service dimension influencing freight transport choice behavior for import/export of grains; Alonso, Monios, and Pinto (2017) and Moura, Alonso, and Olmedo (2017) delimited the seaport competition through hinterland accessibility based on cost and distance, which is therefore often a determinant of ‘time’; lastly, Rezaei et al. (2019) defined ‘cost’ and ‘time’ along the transport chain as the dominant factors for seaport competitiveness.

Despite that, it was observed that the sole efforts to improve service quality or reduce the logistic cost by an unique actor in the supply chain looks ineffective and, despite the challenging task due the interest conflicts of different stakeholders, higher integration and coordination between the players in supply chains lead to a higher competitiveness of the entire hinterland (HA; AHN, 2017). In this way, seaport-hinterland collaboration may significantly enhance seaports' competitiveness, especially through information and risk sharing, improving the reliability and, coordination among stakeholders (JEEVAN; CHEN; CAHOON, 2019). Despite the benefits, this integration is not an easy task and is not only limited to setting up systems and processes but also on the functional activities (HA; AHN, 2017). The results from the index of cooperation performance evaluation system developed by Li and Jiang (2014) identified weakness between dry port and seaport cooperation related to shared information, cargo throughput and regional policy restriction. Other examples of lack of information and collaboration emerges in India and Brazil (NG; GUJAR, 2009; RODRIGUES; MOTA; OJIAKO, 2020). A strategy that seaports are taking to overlapping hinterland and to gain competitive edges is developing their own dry port (JIANG et al., 2020), called "extended gate" as stated before.

2.3.3 Previous optimization models

Previous research have contributed to the discussion of the seaport-hinterland network as Iannone and Thore (2010) which built a model to minimizes the sum of all container related logistic costs throughout the entire seaport-hinterland distribution network in Italy context, subject to balancing conditions at all nodes and capacity constraints over railway links. The results confirmed the importance of dry ports and inland logistic systems for the distribution of international maritime containers. Based on the same model, Iannone (2012) demonstrated how the competitiveness of the regional container seaport cluster can be boosted by an dry port-based extended gateway system with adequate customs facilities and improved railway connections. The author highlighted that the future competitiveness of the regional seaports and their hinterland distribution system will depend on a further improved supply of dry port services.

Important highlights for the dry port-seaport network literature came from Tran, Haasis and Buer (2017) that proposed a model to optimize container flows between two continents via an end-to-end service minimizing total costs. The authors identified that inland/feeder transport costs are the highest among supply chain costs and they are influenced much by the selection of ports. Taking into account the importance of the hinterland network, the majority of previous studies have focused on transport optimization. The study of Janic (2007) developed a model considering internal and external costs of intermodal and road freight transport networks. The results have shown that intermodal transport cost has benefits of economies of scale for large distances. Moreover, Kapetanis, Psaraftis and Spyrou (2016) have presented a parameterized model to continuously assess, even during the transportation event, all the alternative transportation modes for a given destination in terms of time, cost and emissions. In other approach, Qiu and Lam (2018) have proposed a shared transportation system that could bring significant profit improvement to the dry port and cost savings to shippers, compared with the direct transportation system. Lastly, Crainic et al. (2015) have defined optimal routes and schedules for the fleet of vehicles providing transportation services between terminals of a dry port intermodal system, minimizing the overall logistic cost. Despite the relevance of transportation cost in shippers' hinterland network decision, the different transport modes should not only be optimized separately, but they should also be attuned to the entire hinterland and consider multiple and, sometimes, conflicted criteria (CARIS; MACHARIS; JANSSENS, 2013).

Going beyond the transportation cost, hinterland networks composed by dry ports and multimodal transportation also have effects on CO2 emissions. This subject also has been covered in previous studies. From hypothetical dry port facilities simulations, Henttu, Lättilä and Hilmola (2011) estimated the quantity of dry ports which optimizes the transportation network in Finland context. Furthermore, the authors identified that replacing road transport with rail transport the environmental impacts can be lowered considerably. From the same perspective, Lättilä, Henttu and Hilmola (2013) analyzed the option to deliver the cargo directly to a seaport compared to using a dry port. The authors have found that by implementing dry ports network the CO2 emissions decreases and the transportation cost savings are about 4–16%. This result is aligned with Oey and Setiawan (2017), that compared dry ports and seaports in terms of cost and time for the shipper and concluded that cost saving is possible when using a dry port.

Other subjects were also carried in previous researches. Related to the storage cost, Kim and Kim (2007) discussed a method of determining the optimal price schedule for storing inbound containers proposing three analytic models for the free-time-limit and the storage price for the storage beyond the free-time-limit. Going beyond, Qiu, Lam and Huang (2015) proposed a theoretical basis for guiding shippers in choosing dry port or seaport for storing outbound containers and have found that the seaport's storage pricing strategy has significant influence on the performance of dry port and shippers. The authors also observed that dry port's profit may decrease with the increase of container delivery frequency from shippers when the frequency is high, since the storage duration of containers at the dry port is significantly reduced. Assessing the impact of different demurrage and detention regimes on the inland transport systems, Fazi and Roodbergen (2018) have shown how these variables do not motivate shippers to move containers out of the seaport. Furthermore, they have suggested that dry ports associated with combined demurrage and detention fees can be a major solution to relieve seaports from congestion and promote the use of high capacity means of transport. Also considering the empty containers problem, Sarmadi et al. (2020) have proposed a dry port network design model that integrates strategic and operational decision making. The results have shown that the direct transportation of laden containers between the seaport and manufacturers was mostly performed by rail, whereas road was mainly employed for the movement of empty containers between the seaport and manufacturers through dry ports, confirming the pivotal significance of dry ports relevant to empty container reposition in the container shipping networks.

The literature background stated in this chapter worked as the base for the thesis development. More specific literature follows in the adapted version of the articles in next chapters.

3 CRITICAL FACTORS FOR DRY PORT' DEVELOPMENT

A reviewed version of the paper: RODRIGUES, T.; MOTA, C.; SANTOS, I. Determining dry port criteria that support decision making. *Research in Transportation Economics*, v. 88, p. 1-10, 2021. DOI: https://doi.org/10.1016/j.retrec.2020.100994.

3.1 CONTEXTUALIZATION

Integrating a complex environment with multiple actors, many criteria can impact the development of dry ports. Some well-known issues that arise are the intensity and irregularity of the input freight flows and vehicles; the dry port size, capacity and location; the seaport-hinterland network transport capacity; the costs related to dry port construction; the operation cost throughout the seaport-dry port system; and the social and ecological impact for seaport and city zones (MURAVEV; RAKHMANGULOV, 2016). Considering the relevance of dry ports development and the growth interest of scholars in this subject, such criteria may be identified from the relevant literature on this topic. With that in mind, this chapter aims to fulfill the first objective of the thesis, identifying the critical factors that affect dry ports' developments.

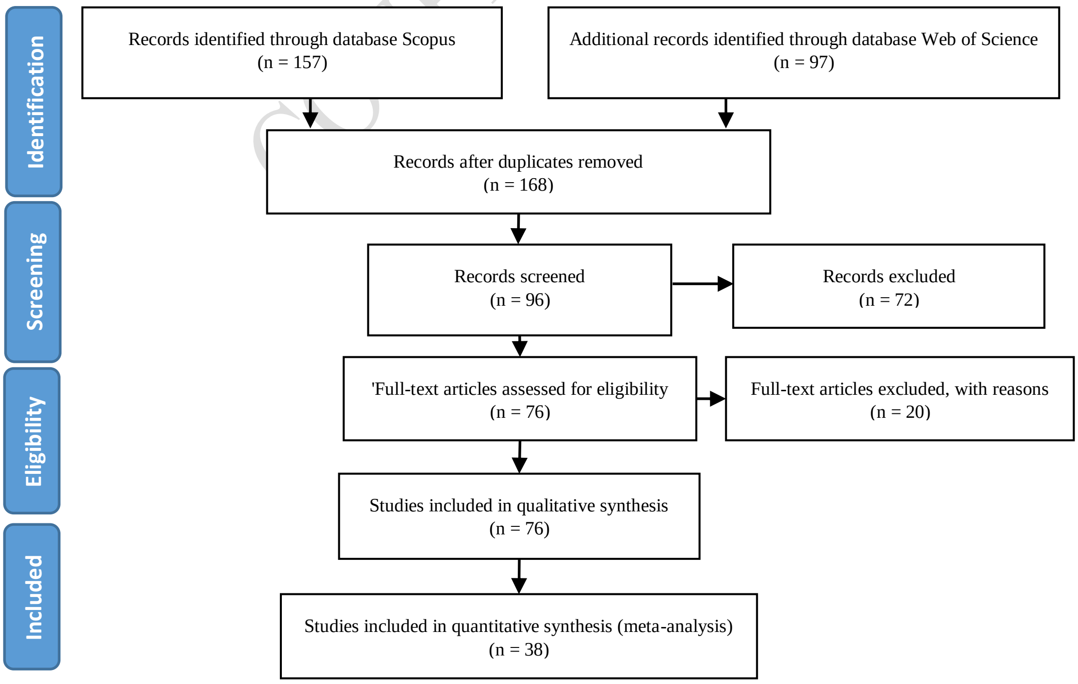
In order to aggregate the criteria from multiples cases and answer the first and second research questions of the thesis, a systematic review was performed with papers published from 2000 on found in the Scopus and Web of Science databases. Looking from a holistic perspective, 76 papers that reported research on dry ports were analyzed to identify gaps in the literature and to build a framework composed by the criteria which should be considered in the dry port development/decision making. The next items of this chapter details the systematic review process, the main results and the insights from the aggregated factors.

3.2 MATERIALS AND METHODS

The systematic review followed the 3-stage and 9-phase model described by NHS Centre for Reviews and Dissemination (2001), adapted by Tranfield, Denyer and Smart (2003), and was supported by the PRISMA Statement information flow (MOHER et al., 2009). The data collection and analysis period was from December 10, 2018 to April 8, 2019, limited to published research from the year 2000-2018. The databases used in this review were Scopus and Web of Science, in surveys published in English or Spanish. For a wide coverage, key terms referring to the dry ports used were those described by (NGUYEN; NOTTEBOOM, 2016; ROSO, 2007; ROSO; WOXENIUS; LUMSDEN, 2009): Dry Port, Inland Clearance Depot (ICD), Intermodal Freight Centre, Intermodal Freight Terminal, Freight Nodal Terminal, Inland Port and Container Freight Station (CFS). The search for keywords was limited to the title of the paper, using only articles and reviews of the databases defined.

The flowchart detailed in Figure 6 describes the different phases of the systematic review, mapping the number of records identified, included, excluded, as well as the reasons for exclusion. The criteria selection included articles that focused on dry ports developments, models to support decision making, research relating to dry port-seaports connection and hinterland. The exclusion criteria were papers that focused on seaports, hub ports, container terminals, which were not considered; papers including the inland port keyword, which referred to inland waterway and inland river port only were not included in this review.

Figure 6 – Steps of systematic review



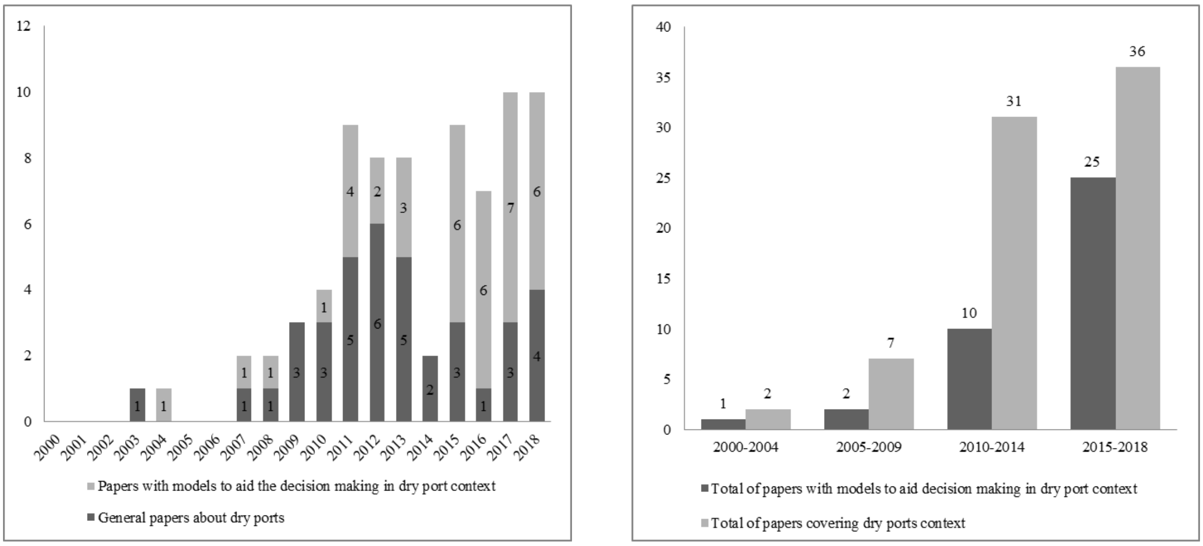
Source: (RODRIGUES; MOTA; SANTOS, 2021).

The search in the Scopus and Web of Science databases resulted in 157 and 97 articles respectively. After filtering all articles resulting from the search and removing duplicates, 168 papers were obtained. At the Screening stage of the 168 articles, 96 were selected after reading the title and abstract. In this phase, the goal was to select articles that focused on dry ports, following the previously defined selection criteria. At this stage, 72 articles were eliminated, since they were not part of the scope of the research, addressing topics such as Dry Bulks, Container Security, Rail Transport, Inland Waterway, Inland River Port, among others. The process followed with the Eligibility stage, in which 96 articles were read. This stage resulted in the selection of 76 articles that fit the criteria of the papers focusing on dry ports, composing the qualitative analysis of the review, while 20 were excluded. Out of the 76 articles, 38 refer to models to aid the decision making and address the more specific scope of the research, being included for the quantitative analyses.

3.3 RESULTS

After consolidating the data of the systematic review, a concentration of publications in the last decade was observed, which evidences that the research in this area is still in the initial phase with increasing importance. Figure 7(a) shows the evolution per year of the articles on the stated scope, while Figure 7(b) shows the accumulated amount of articles every five years. Additionally, the articles were categorized into two types of studies for further comparison: (i) papers concerned with the general context of dry ports development, when the focus was dry port concept, definitions and main characteristics for instance; and (ii) papers that present models to support the decision making process, dealing with location and allocation problems, network system, dry port performance and so on. Accompanying this evolution, it was observed that papers in the general context of dry ports were mainly published between 2010 and 2014 (21 papers) and models to support the decision making since 2015 (25 papers), which shows that researches on dry ports are changing towards quantitative models. Furthermore, 67 out of 76 articles were published since 2010, mainly in the year 2017 and 2018 when 10 papers were published each year, which means that researchers are more interested in problems that evolve dry ports, looking for solutions and improvements in the supply chain network.

Figure 7 – Evolution of researches on dry port subject



(a) (b)

Source: (RODRIGUES; MOTA; SANTOS, 2021).

One of the most relevant papers in the dry ports literature was developed by Roso, Woxenius and Lumsden (2009) that extend the theory behind the dry port concept to define three dry port categories: (i) distant, (ii) midrange and (iii) close. Another important study was put forward by Rodrigue et al. (2010), who explored how the transport and supply chain functions and the various actors involved in their setting and operations are filtered and materialized in inland ports, as shown in Table 1. Regarding models that support decision making, the highlights are for Roso (2007), who performed a comparison between two logistic models, one with a dry port and the other without dry port, evidencing, through simulations the benefits that the use of a dry port can bring to the system as a whole; and Rahimi, Asef-Vaziri and Harrison (2008) measured the current scenario of road freight transport and proposed a second scenario with dry port, verifying a reduction in the number of miles transported. Table 1 also shows that the most cited authors in the papers selected (cross-reference) were Violeta Roso, Theo Notteboom and Jean-Paul Rodrigue as the main researchers on dry ports. Among the articles in the database, 57 are case studies conducted mainly in China and India. In addition, the concentration of case studies in Asia and Europe was evident, while American and African countries had low representativeness. This result is in line with UNCTAD (2020) that presents Asia and Europe with the highest container handling and a developed port and rail structure.

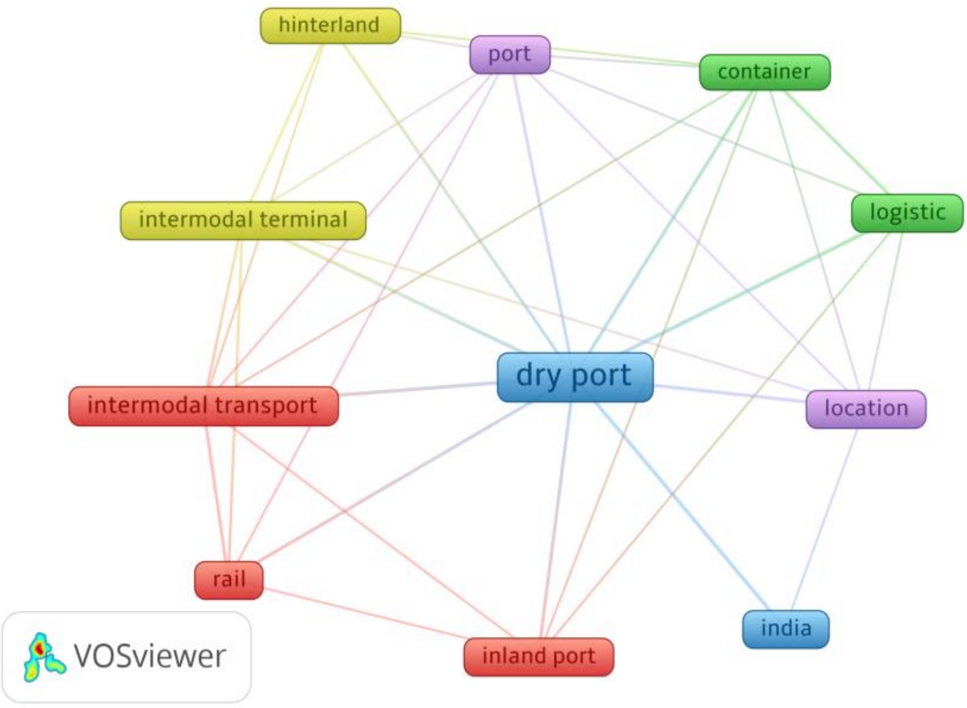
Table 1 – Most cited papers, authors and case studies

General papers	Citations	Decision models papers	Citations	Main authors	Cross-reference	Case Studies	Quantity	Case Studies	Quantity
(ROSO; WOXENIUS; LUMSDEN, 2009)	187	(ROSO, 2007)	65	Violeta Roso	81	China	10	Asia	29
(RODRIGUE et al., 2010)	109	(RAHIMI; ASEF-VAZIRI; HARRISON, 2008)	52	Theo Notteboom	47	India	6	Europa	18
(VEENSTRA; ZUIDWIJK; VAN ASPEREN, 2012)	71	(LATTILA; HENTTU; HILMOLA, 2013)	42	Jean-Paul Rodrigue	45	Finland	4	Oceania	4
(ROSO, 2007)	65	(NG; CETIN, 2012)	31	Johan Woxenius	40	Spain	4	North America	2
(ROSO, 2008)	58	(KA, 2011)	29	Kenth Lumsden	36	Australia	3	Africa	2
(NG; GUJAR, 2009)	55	(HARALAMBIDES; GUJAR, 2012)	27	Adolf K.Y. Ng	28	Italy	3	South America	2
(RAHIMI; ASEF-VAZIRI; HARRISON, 2008)	52	(NG; TONGZON, 2010)	20	Teodor Crainic	26	Sweden	3		
(ROSO; LUMSDEN, 2010)	48	(DOTOLI et al., 2016)	18	Ville Henttu	24	Vietnam	3		
(JARZEMSKIS; VASILIAUSKAS, 2007)	46	(HENTTU; HILMOLA, 2011)	18			Brazil	2		
(LATTILA; HENTTU; HILMOLA, 2013)	42	(NGUYEN; NOTTEBOOM, 2016)	15			Netherlands	2		
(BERESFORD et al.,2012)	38	(CRAINIC et al., 2015)	14			Thailand	2		
(HANAOKA; REGMI, 2011)	36	(QIU; LAM; HUANG, 2015)	10			United States	2		

Source: (RODRIGUES; MOTA; SANTOS, 2021).

The VOSViewer tool was applied to the keywords and abstracts of the 76 papers in order to portray the main topics covered in the research database. The keywords with more than 4 occurrences are presented in Figure 8, where dry port (51), intermodal transport (10), inland port (8) and logistic (8) were the most cited. This output also confirms the relationships among important topics as the network between the dry ports, seaports, and hinterland, as well as the logistic factors as location and transportation mode. As the concept of dry ports is connect the seaport with the hinterland through high capacity transportation mode, mainly rail (ROSO; LUMSDEN, 2010), this result is aligned with the main topics discussed in theoretical background. The intermodal transport is the way to reduce transportation cost through scale economy, making dry ports attractive to shippers and consignees. However, achieve an intermodal infrastructure requires high level of investments in long terms projects as well the cooperation of several stakeholders, which is not the reality mainly in developing countries, which have a poor transport infrastructure, challenging the benefits of dry ports implementation (NG; PADILHA; PALLIS, 2013; NGUYEN; NOTTEBOOM, 2016; PADILHA; NG, 2012).

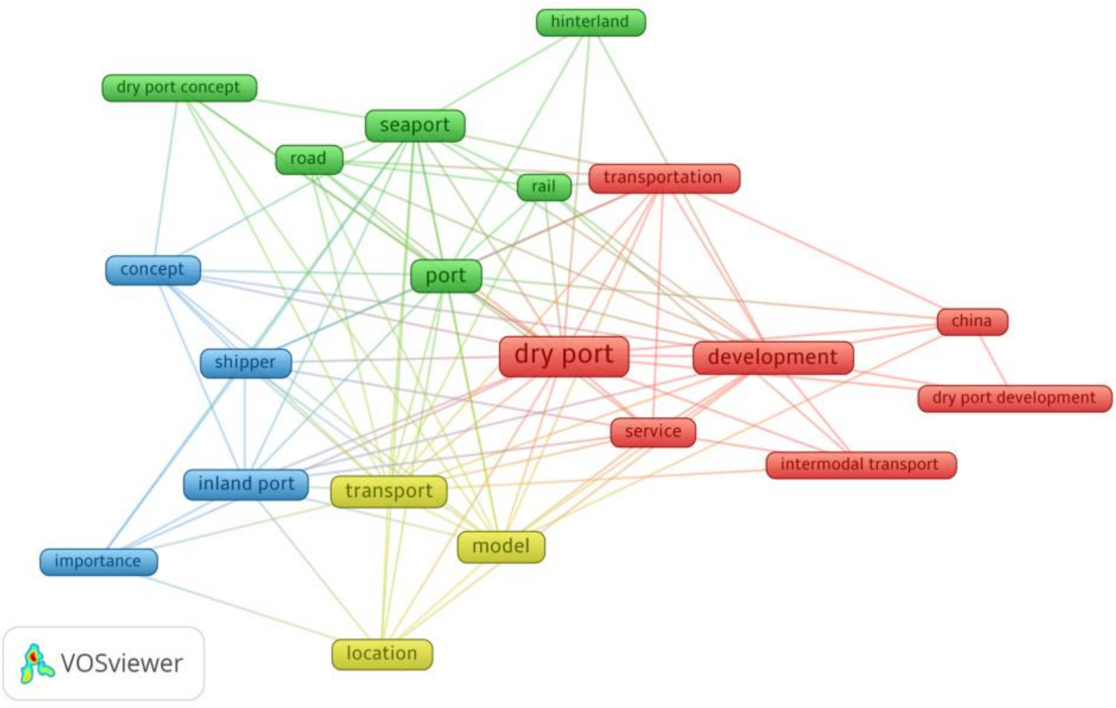
Figure 8 – Keywords most cited in systematic review



Source: (RODRIGUES; MOTA; SANTOS, 2021).

By analyzing the abstract of the papers, it was revealed four (4) clusters of terms most used in dry port studies. Figure 9 shows the relationship between the main terms that had more than 12 occurrences. In addition to the term dry port, with 181 occurrences, seaport (59), model (59), transport (46) and inland port (42) also had relevance. Going deep into cluster analysis, cluster red shows relationship among dry port development, mainly in China, dry port services and intermodal transport. Cluster green has seaport as the main topic, connected with hinterland and transportations mode as road and rail. Furthermore, cluster yellow emphasizes articles with models to aid decision making, highlighting transport and location as main issues discussed. Lastly, cluster blue connects shippers with dry ports (inland ports) and seaports, and highlights the concept and importance of dry ports as main topics in the abstract of articles from the systematic review.

Figure 9 – Main topics covered in systematic review



Source: (RODRIGUES; MOTA; SANTOS, 2021).

The main issues discussed by the selected papers are the dry port development (BERESFORD et al., 2012; LI; DONG; SUN, 2015; RODRIGUE; NOTTEBOOM, 2012; ROSO, 2009) models to aid de decision making in dry port location and allocation (KA, 2011; KOMCHORNRIT, 2017; NG; CETIN, 2012; NGUYEN; NOTTEBOOM, 2016; RAHIMI; ASEF-VAZIRI; HARRISON, 2008) the dry port concept (CULLINANE; BERGQVIST; WILMSMEIER, 2012; NOTTEBOOM; RODRIGUE, 2009; ROSO, 2007; ROSO; WOXENIUS; LUMSDEN, 2009) the network among dry ports, seaports and hinterland system (BASK et al., 2014; HASSAN, 2016; RODRIGUE; NOTTEBOOM, 2012; TSAO; LINH, 2018), dry port performance (CARBONI; DEFLORIO, 2018; DOTOLI et al., 2016; JEEVAN et al., 2017; NG; TONGZON, 2010), the environment evaluation (HARALAMBIDES; GUJAR, 2012; LATTILA; HENTTU; HILMOLA, 2013; MURAVEV; RAKHMANGULOV, 2016; ROSO, 2007) among others presented in Table 2.

Table 2 – Main issues discussed in the database papers

Issues	Articles
Dry port development	15
Dry port location and allocation	14
Dry port concept	8
Dry port performance	7
Network among dry port, seaport and hinterland system	6
Environment evaluation	5
Distribution system and transport optimization	5
Impact of dry port implantation	2
Dry port investment	2
Dry port public-private partnership	2
Dry port competition	2
Evaluation of dry port as an alternative	2
Ranking dry ports	2
Carriers and shippers view about dry ports	2
Storage pricing strategy	1
Government policies	1

Source: (RODRIGUES; MOTA; SANTOS, 2021).

The discussion about dry port development led many researchers to analyze the questions and factors involved in this issue in many countries, considering their environment and context specificities. The second most discussed issue was dry port location, which requires a thorough decision making process once it is too costly to relocate the facility in the short term. More details about the main issues discussed in the articles follow in Table 3.

Table 3 – Papers distribution and main issues

Year	*GDPP	*DMP	Total	Main issues covered	References
2003	1	0	1	Comparison between carriers and shippers desired attributes about dry ports.	(WALTER; POIST, 2003)
2004	0	1	1	Shippers' perceptions and preferences for a proposed dry port.	(WALTER; POIST, 2004)
2007	1	1	2	Dry ports concept, definitions and transport mode system.	(JARZEMSKIS; VASILIAUSKAS, 2007; ROSO, 2007)
2008	1	1	2	Challenges of dry port implementation and location-allocation model to optimize hinterland network.	(RAHIMI; ASEF-VAZIRI; HARRISON, 2008; ROSO, 2008)
2009	3	0	3	Dry port concept and classification considering the environmental perspective; furthermore, papers	(NG; GUJAR, 2009; ROSO, 2009; ROSO, WOXENIUS; LUMSDEN, 2009)

				overcome dry port competition and government policies.	
2010	3	1	4	Dry port concept, taxonomy, functions and actors. Some papers also cover efficiency, pricing and dry port competition.	(BOSSCHE; GUJAR, 2010; NG; TONGZON, 2010; RODRIGUE et al., 2010; ROSO; LUMSDEN, 2010)
2011	5	4	9	Dry port development, models to aid location decision, measurement of dry port feasibility, quantity of dry ports facilities, transportation mode optimization and dry port governance.	(DADVAR; GANJI; TANZIFI, 2011; DO; NAM; LE, 2011; HANAOKA; REGMI, 2011; HARALAMBIDES; GUJAR, 2011; HENTTU; HILMOLA, 2011; HENTTU; LATTILA; HILMOLA, 2011; KA, 2011; KOROVYAKOVSKY; PANOVA, 2011; MONIOS, 2011)
2012	6	2	8	Dry port development and concept, impact of dry port implementation, location and efficiency model.	(BERESFORD et al., 2012; CULLINANE; BERGQVIST; WILMSMEIER, 2012; GONZÁLES; BLANCA; MELLADO, 2012; HARALAMBIDES; GUJAR, 2012; NG; CETIN, 2012; PADILHA; NG, 2012; RODRIGUE; NOTTEBOOM, 2012; VEENSTRA; ZUIDWIJK; VAN ASPEREN, 2012)
2013	5	3	8	Dry port development, location-allocation model, challenges and feasibility of dry port implementation.	(DOOMS; HAEZENDONCK; VALAERT, 2013; FENG et al., 2013; LATTILA; HENTTU; HILMOLA, 2013; MONIOS; WANG, 2013; NG; PADILHA; PALLIS, 2013; RATHNAYAKE; JING; WIJERATNE, 2013; ROSO, 2013; ZENG et al., 2013)
2014	2	0	2	Dry port city challenges and dry port-seaport dyads development.	(BASK et al., 2014; WITTE et al., 2014)
2015	3	6	9	Risk factors in dry port-seaport system, dry port development, investment and governance, dry port location, freight distribution planning and storage price strategy.	(NÚÑEZ; CANCELAS; ORIVE, 2015; BENTALEB; MABROUKI; SEMMA, 2015; CHANG; NOTTEBOOM; LU, 2015; CRAINIC et al., 2015; JEEVAN; CHEN; LEE, 2015; LI; DONG; SUN, 2015; PANOVA; HILMOLA, 2015; QIU; LAM; HUANG, 2015; RATHNAYAKE; JING; ERANDI, 2015)
2016	1	6	7	Dry port location, performance optimization, environmental factors in transportation mode using dry ports and network design.	(NÚÑEZ et al., 2016; CAVONE; DOTOLI; SEATZU, 2016; DOROSTKAR; SHAHBAZI; NAEINI, 2016; DOTOLI et al., 2016; HASSAN, 2016; MURAVEV; RAKHMANGULOV, 2016; NGUYEN; NOTTEBOOM, 2016)
2017	3	7	10	Dry port development, location-allocation model, dry port performance,	(JEEVAN et al., 2017; KOMCHORNRIT, 2017; KWATENG; DONKOH;

				public-private partnership, logistic network and factors of dry ports operations.	MUNTAKA, 2017; NGUYEN; NOTTEBOOM, 2017; OEY; SETIAWAN, 2017; SOUZA; LARA; SILVA, 2017; WANG; CHEN; HUANG, 2018; WEI; SHENG, 2017; WEI; SHENG; LEE, 2018)
2018	4	6	10	Seaport-dry port network and competitiveness, selection of seaports considering dry ports, transportation services, factors influencing location and timeframes, dry port benchmark and best practices.	(BLACK et al., 2018; CARBONI; DEFLORIO, 2018; CHEN et al., 2018; JEEVAN; CHEN; CAHOON, 2018; KRAMBERGER et al., 2018; OLÁH et al., 2018a; OLÁH et al., 2018b; QIU; LAM, 2018; TSAO; LINH, 2018; VEJVAR et al., 2018)

**GDPP – General dry port paper*
**DMP – Decision model papers*

Source: (RODRIGUES; MOTA; SANTOS, 2021).

The main computational tools used in the studied models were Cplex (5), which is an optimization software package, Matlab (4), an interactive programming system, ArcGis (3), which is a geographic information system, among others highlighted in Table 4. This software aids in modeling problems resulting in relevant information to support decision making. These tools converge with the main issues discussed in the papers as optimization and dry port location, allowing a wide application.

Table 4 – Main software used in database papers

Software	**Papers**
CpleX	5
Matlab	4
ArcGis	3
M-Macbeth	2
Hipre	2
Amos, AnyLogic, Deap 2.1, Expert Choice, G*Power, Lambit, Mathematica 7.0, Quantum Gis, Visual Promethee	1

Source: (RODRIGUES; MOTA; SANTOS, 2021).

In addition to the main issues discussed and the computational tools applied, this review sought to identify the decision makers and criteria that influence the processes involving dry ports. Each country has its dry ports structure, governance model and transportation logistics network. This fact influences the actors present in the decision process as well as their relative importance. According to Nguyen and Notteboom (2016), the main stakeholders in a dry port setting include seaport actors, shippers, forwarders, investors, terminal operators, central and local government, infrastructure managers, local residents and road users. The general identification of the actors as summarized in Table 5.

Table 5 – Main actors in dry ports' development

Decision Makers and Stakeholders	References
Dry port operator Seaport operator Railway operator Road operator Airport operator Shipper and Importers Port authority Expert in logistics Shipping lines Government agents Stakeholders (society, forwarders, service providers, third-party companies)	(NÚÑEZ et al., 2016; DADVAR; GANJI; TANZIFI, 2011; FENG et al., 2013; KA, 2011; KRAMBERGER et al., 2018; KOMCHORNRIT, 2017; NG; PADILHA; PALLIS, 2013; NGUYEN; NOTTEBOOM, 2016; KWATENG; DONKOH; MUNTAKA, 2017; QIU; LAM, 2018; ROSO; WOXENIUS; LUMSDEN, 2009; TSAO; LINH, 2018).

Source: (RODRIGUES; MOTA; SANTOS, 2021).

Through the systematic review, 45 criteria were identified to be considered in the dry ports decision processes. These were divided into 6 groups: (i) cost factors, (ii) location, installation and infrastructure factors, (iii) accessibility factors, (iv) operational factors, (v) social and policy factors, and (vi) environmental factors, as detailed in Table 6.

Table 6 – Dry port factors that support decision making

Dry port factors	Sub-factors	References
Cost Factor	Congestion cost Installation cost (opening, closing, land, built and maintenance cost of dry port and network infrastructure) Port and dry port charge cost Transportation cost Storage cost	(NÚÑEZ; CANCELAS; ORIVE, 2015; FENG et al., 2013; KA, 2011; KRAMBERGER et al., 2018; NG; CETIN, 2012; NGUYEN; NOTTEBOOM, 2016; MURAVEV; RAKHMANGULOV, 2016; QIU; LAM, 2018; RAHIMI; ASEF-VAZIRI; HARRISON, 2008; WANG; CHEN; HUANG, 2018; WEI; SHENG, 2017).
Locational and Infrastructure Factors	Availability of land and growth capacity Demand for dry port services (volume of exporting and importing) Distances to the inland destinations	(NÚÑEZ; CANCELAS; ORIVE, 2015; FENG et al., 2013; HENTTU; HILMOLA, 2011; KA, 2011; KOMCHORNRIT, 2017; KRAMBERGER et al., 2018; MURAVEV; RAKHMANGULOV, 2016; NG; TONGZON, 2010; NGUYEN; NOTTEBOOM, 2016;

	Distances to the production base Distances to the seaport Dry port area and capacity (size of total area) Dry port capacity (exploitation in %) Infrastructure facilities (security of infrastructure, logistics center) Proximity to other logistics platform Storage Capacity Weather, Orography, Geology and Hydrology	KWATENG; DONKOH; MUNTAKA, 2017; QIU; LAM, 2018; ROSO, 2007; WANG; CHEN; HUANG, 2018; WEI; SHENG, 2017).
Accessibility Factors	Accessibility to airports Accessibility to inland waterway Accessibility to ports Accessibility to railway Accessibility to road Accessibility to supplies and services Capacity of transport communications between a seaport and dry port Transportation condition	(NÚÑEZ et al., 2016; CHANG; NOTTEBOOM; LU, 2015; KOMCHORNRIT, 2017; MURAVEV; RAKHMANGULOV, 2016; NGUYEN; NOTTEBOOM, 2016; WEI; SHENG, 2017; WEI; SHENG; LEE, 2018).
Operational Factors	Information system Number of TEUs per day transported Range of services Rate of input and consolidation Security management Storage price in the dry port and seaport Transportation capacity Transportation time Terminal utilization in %	(JEEVAN et al., 2017; KRAMBERGER et al., 2018; NG; TONGZON, 2010; NGUYEN; NOTTEBOOM, 2016; OLÁH et al., 2018a; QIU; LAM, 2018; RAHIMI; ASEF-VAZIRI; HARRISON, 2008; ROSO, 2007).
Social and Political Factors	Customs clearance policies Employment generation (number of employees and employees per exploited area)	(CHANG; NOTTEBOOM; LU, 2015; HENTTU; HILMOLA, 2011; KA, 2011; NG; TONGZON, 2010; NGUYEN; NOTTEBOOM, 2016; OLÁH et al., 2018a; KWATENG; DONKOH; MUNTAKA, 2017; WEI;

	Financial support Political environment (policy-oriented and regional cooperation environment) Social and economic development Population of destination	SHENG, 2017; WEI; SHENG; LEE, 2018).
Environmental Factors	Green logistic policy Impact on natural and urban environment during dry port placement and operation Noise and visual impact Policy Environment Transportation congestion Transportation pollution (road and rail carbon emission)	(NÚÑEZ; CANCELAS; ORIVE, 2015; CHANG; NOTTEBOOM; LU, 2015; MURAVEV; RAKHMANGULOV, 2016; NGUYEN; NOTTEBOOM, 2016; OLÁH et al., 2018a; ROSO, 2007; ROSO, 2013; WEI; SHENG, 2017).

Source: (RODRIGUES; MOTA; SANTOS, 2021).

Among the most relevant factors to the dry port users are those related with cost: transportation, installation, congestion, and storage costs. Operational costs include, in addition, cost for build and maintenance infrastructure facilities, as well as operating cost of transport, storage, and handling containers. Some losses from congestion, dwell time, and violation of the requirements of timely freight delivery are considered costs (MURAVEV; RAKHMANGULOV, 2016). The most reduction of transport cost and time may be achieved when customers use dry port that are directly connected with seaports by rail, taking advantage of the economy of scale (NGUYEN; NOTTEBOOM, 2016).

The location analysis should follow a multiple stakeholder perspective selection. Any new dry port facility project should meet the demand of the market, or dry port users; be compliant with public planning and create value for the community in order to receive public support; and in the end be financially viable for investors and operators (NGUYEN; NOTTEBOOM, 2016). Furthermore, dry port developments should take into account factors as land and labor availability, information technology level, regional trade facilitation level and reliability (NÚÑEZ et al., 2016; RODRIGUE et al., 2010). In general, the problem of evaluating possible locations for dry ports can be considered as a particular case of the hub location problem and most research works present an objective of minimizing the total cost or maximizing the total profit, considering different variables and parameters along the research purposes (WANG; CHEN; HUANG, 2018).

Like any transport facility of significance, a dry port requires an appropriate site with good access to the rail, road or the barge terminal as well as available land for development. Access to a large population base is of importance, since it will be linked to the level of import and export activities handled by the dry port (RODRIGUE; NOTTEBOOM, 2012). The criteria related to the accessibility to a transport mode measure how easily different inland transport infrastructures can be accessed from the dry port location. For road transport, we consider the distance to the nearest highway exit, average daily traffic and level of service (NÚÑEZ; CANCELAS; ORIVE, 2015). On the other hand, rail accessibility to gateway seaports is at the heart of the functioning and development of most dry ports around the world (JEEVAN et al., 2017; RODRIGUE; NOTTEBOOM, 2012).

Some factors as the number of containers transported per day, the transportation distance, capacity and time to the destination are considered in the dry port decisions. Furthermore, a dry port operation aggregates a range of services as customs clearance, which reduces transportation costs and provides time advantages to customers, container storage, warehousing, maintenance, empty containers depot and transfer facilities between nodes (NG; CETIN, 2012; ROSO; LUMSDEN, 2010). The availability of such a full range of services in dry ports promotes the concept of ‘through-transport’ which encourages dry ports as common user facilities that support the transfer of containers from the seaport of origin to the hinterland of destination (JEEVAN et al., 2017).

Considering the complex flow of goods moving through different actors in the supply chain, the management of information highlights as a crucial part of operational factors and achieve coordination and reliable information remains a challenge to dry ports operations (JEEVAN et al., 2017). According to Jeevan (2016) a different approach has been implemented in Valencia dry port, Spain, which introduced a Port Community System (PCS) to integrate different stakeholders in seaport operations and maritime transport by giving support, and managing information and administrative procedures in the dry port operation. The PCS covers the information from various stakeholders, particularly shippers, rail operators and seaports, producing integration and coordination between dry ports and their clients. This integration provides significant advantages for customers in some dry ports in Russia (KOROVYAKOVSKY; PANOVA, 2011) and Malaysia (JEEVAN; CHEN;

CAHOON, 2018). However, it is missed in other developing countries like Brazil and India, which have bureaucratic customs process and a lack of information through the supply chain (JEEVAN, 2016; NG; GUJAR, 2009; NG; PADILHA; PALLIS, 2013).

The results advocate that dry port’s developments should take into account a number of qualitative factors such environmental and social factors. Government policies such as those relating to transport and trade facilitation, infrastructure, environment, investment, seaports, multi-modal transport, logistics and land can influence dry port operations (HANAOKA; REGMI, 2011). As an option, investment policy, allowing private and public partnerships (PPP) in dry port operations, has been widely adopted, involving the private sector in financing dry port development, while the public sector provides land for development and plays a regulatory role in operations (NGUYEN; NOTTEBOOM, 2017). The effectiveness of this government policy cannot be achieved without an infrastructure policy. Therefore, investment in transport infrastructure to increase collaboration between seaports, dry ports and other stakeholders becomes a crucial factor for logistics infrastructure development (JEEVAN et al., 2017; NG; CETIN, 2012). According to Black et al. (2018) the main success factor in dry ports development, given the multiplicity of agents involved, is to discuss operational agreements in advance within a market driven development framework that is supported by the Government logistics policies. Hence, there must be coordination among various government agencies and the willingness of the transport system actors to cooperate.

Considering the environmental factors, a reduced number of trucks on the roads generates less congestion, fewer accidents, lower road maintenance costs, and less vehicle CO2 emissions (BLACK et al., 2018). The development of dry ports can mitigate problems caused by constraints related to land and others that limit the growth of seaports. Dry ports can also coordinate the operation of the seaport-hinterland and support regional economic development. Consequently, dry ports are changing the dynamics of interaction between seaports and hinterlands (FENG et al., 2013). With dry port implementation, CO2 emissions should decrease, congestion at seaport terminals and seaport city roads should be avoided, and the risk of road accidents reduced (ROSO, 2007). Besides the general benefits to the ecological environment and the quality of life by shifting flows from road to rail, the dry port concept mainly offers seaports the possibility of securing a market in the hinterland, increasing the throughput without physical port expansion as well as better services to shippers and transport operators. The seaport cities, and also often the port authority, benefit from less road congestion and/or less need for infrastructure investments (ROSO; WOXENIUS; LUMSDEN, 2009).

3.4 DISCUSSION

The research related to dry ports is recent and has a wide field of exploration. The challenges in this theme involve simple questions like an understanding of the definition and concept of dry ports and their characteristics until the use of complex models to optimize the logistics structure in a seaport-hinterland network. The literature focused mainly on location problems and case studies covering the development of dry ports, leaving important gaps such as the analysis of governance models; the impact of public policies on infrastructure as well as on bureaucratic and legislative issues; the optimal quantity of dry ports as well as their relation with the other members of the seaport-hinterland in order to optimize the distribution of products; the evaluation of the transport systems, searching for interactions among dry ports, seaports, road and railway connections to reduce delivery cost; as well the customer choice in select the service provider in a seaport-hinterland network.

Another challenge for dry ports is their development in emerging economies. Most research was carried out in European and Asian countries that have a large container handling and developed railway infrastructure. However, few papers dealt with dry ports models in countries with poor rail infrastructure and with bureaucratic barriers as pointed above. A broad approach in different countries may expand understanding of the barriers, opportunities and characteristics of dry ports in different contexts.

Among the 45 factors that should be considered in dry ports' development, some of them were more explored such as transportation costs, distance between dry port and seaport, and the impact of using railways in the logistics integration system, allowing cost reduction, congestion and CO_2 emission. However, few papers have portrayed the operational dry ports systems, optimization models and tools to improve the productivity as well as information systems integrated with government agents, seaports, rail carriers, shippers among other stakeholders. Moreover, it is not possible to determine the levels of importance of the factors, and it is up to each decision maker to assess which factor will be considered in their analysis, since factors that are rarely used in the models described in the literature, as well as other specificities of a given country, may impact on decision processes involving dry ports.

3.5 REMARKS

The importance of dry ports in the logistics system is undeniable. However, the large number of variables involved in the process as well as the various decision-makers and stakeholders create a complex decision-making environment, which is often neglected by simplifying the models. This chapter evidenced the relevance of a detailed analysis of the decision process, adding more criteria and information to the decision support models. In this way, this chapter contributed to aggregate 45 criteria in a framework to be considered in the decision processes of dry ports' developments, divided into 6 groups: cost factor, location and infrastructure factors, accessibility factors, operational factors, social and policy factors, environmental factors.

Research on dry ports is still in an early stage; most of the papers still focus on the concept development and definition of the activities attributed to dry ports, which differ due to each author's perspective and each country application. This chapter also highlighted the complexity of decisions in dry port processes due to a large number of criteria and decision-makers involved and can be useful for managers, governments and other players in the logistics chain. Furthermore, there are gaps in the literature that can be developed in future research such as the analysis of the role and characteristic of dry ports in developing countries, and the risk assessment in dry port projects. Such issues are approached in the next chapters.

4 ASSESSING THE OBJECTIVES OF DRY PORTS

A reviewed version of the papers:

RODRIGUES, T.; MOTA, C.; OJIAKO, U.; DWEIRI, F. Assessing the objectives of dry ports: main issues, challenges, and opportunities in Brazil. *The International Journal of Logistics Management*, v. 32, n. 1, p. 237-261. DOI: https://doi.org/10.1108/IJLM-10-2020-03862020.

RODRIGUES, T.; MOTA, C.; OJIAKO, U. (2020). Exploratory evaluation of dry ports in Northeast of Brazil. *International Conference on Industrial Engineering and Operations Management (IEOM)*, Dubai, United Arab Emirates, 10-12 March 2020.

4.1 CONTEXTUALIZATION

Developing a supply-chain infrastructure is one of the greatest challenges faced by governments, trying to achieve an efficient logistic network, and organizations, which worldwide strive to incorporate effective management into their existing competitive strategies (ARORA; ARORA; SIVAKUMAR, 2016). Such infrastructure demands a high investment and cooperation of multiple stakeholders, which may occur by many ways. The variety of possibilities to develop a seaport-hinterland make some definitions of the main role of the actors a complex issue, requiring more studies applied in different contexts. This call remains in the necessity to evaluate current and former practices and provide guidance to practitioners and policy makers on what to do and how to act regarding present and future challenges (NILSSON, 2019).

Despite the benefits which dry ports could bring to the supply-chain and the economic relevance of Brazil to the international trade market, there is a lack of information on this subject in the scientific literature as well in government regulatory reports in Brazil. To overcome these issues, this chapter discusses the main characteristics, challenges and opportunities of dry ports in Brazil, providing relevant information and insights into it to improve logistics network. Additionally, this chapter provides a structured framework to drive further dry port decision-making situations, identifying and assessing a network of means-end objectives through a Value-Focused Thinking (VFT) approach, applied in two case studies.

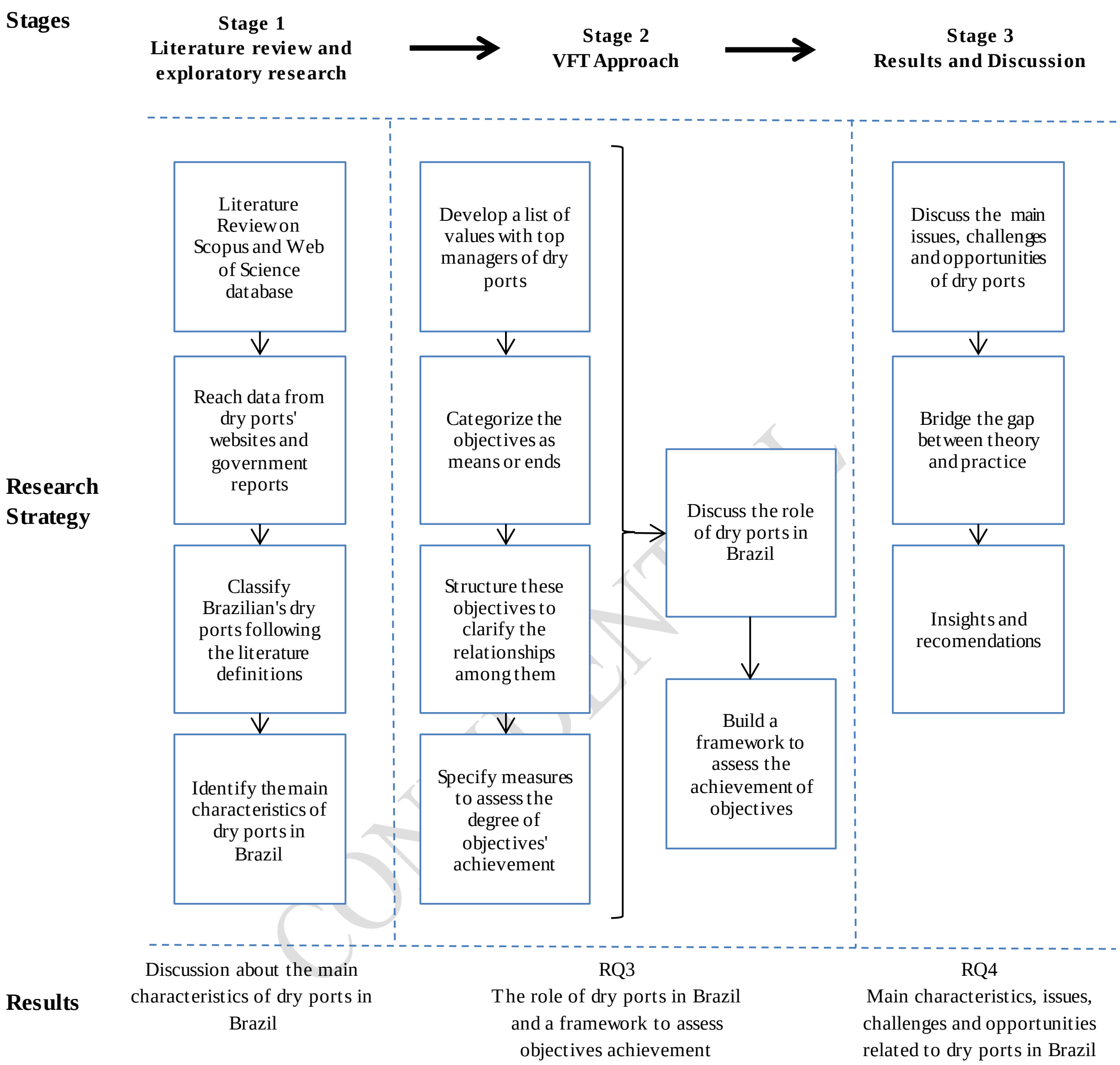
By addressing the second objective of the thesis, answering the third and fourth research questions stated, this chapter provides a useful insight to policymakers and dry port managers, in particular concerning the development of dry ports in Brazil and the issues that should be improved, as well for shippers and forwarders that use this logistic infrastructure as an alternative to become more competitive. The findings here contribute to the theme not only for providing a tool to assess the achievement of dry ports' objectives in Brazil, but also by describing the process which can be applied by other researchers in different contexts and countries. Furthermore, many positive and negative lessons could be learned from the experience of dry port development and operations in Brazil. As mentioned above, since only a few studies were developed in Latin-America on dry ports subject, this chapter fulfills a literature gap, reaching the call for more qualitative research on this subject (KHASLAVSKAYA; ROSO, 2020).

4.2 MATERIALS AND METHODS

This chapter followed the strategy presented in Figure 10. The 'Stage 1' begins based on the 76 articles selected from the systematic review in Chapter 3. Aiming at identifying the main characteristics of dry ports in Brazil, exploratory research on secondary data such institutional websites of dry ports operators and on reports from the Brazilian Federal Revenue and the Ministry of Economy, Industry and Foreign Trade was carried out from June to July, 2019. The objective of this step was to bridge the literature of dry ports classification and the current context in Brazil, classifying dry ports according to three definitions: (i) the distance between dry port and seaport as close, midrange and long distance (ROSO; WOXENIUS; LUMSDEN, 2009); (ii) the main reference for the dry port as seaport based, city based or border based (BERESFORD et al., 2012); and (iii) the transportation mode connecting the seaport with the dry port as unimodal, bimodal or multimodal (NOTTEBOOM; RODRIGUE, 2009).

The 'Stage 2' seeks to identify the role of dry ports in Brazil and proposes a framework to assess the achievement of their main objectives. Investments in dry ports are expensive and depend on network connections, multiple regulations and stakeholders interests (DADVAR; GANJI; TANZIFI, 2011; KHASLAVSKAYA; ROSO, 2020). Thus, covering the main characteristics of dry ports in Brazil and proposing new tools to improve the current environment are important issues to be taken into consideration before new developments and policy changes. As the research was exploratory in nature, a qualitative method was deemed appropriate (EISENHARDT, 1989).

Figure 10 – Chapter strategy



Source: This thesis (2022).

According to Voss, Tsikriktsis and Frohlich (2002), case study research is a powerful research methodology that can be used to exploratory investigations where the variables are still unknown and the phenomenon not at all understood. With that in mind, this chapter focuses on a deep analysis in a prominent seaport-hinterland in Brazil, the northeastern state of Pernambuco. Strategically located in the middle of the northeast region with 9.5 million inhabitants, Pernambuco highlights as a container hub, handling approximately 40,000 TEUs per month. The seaport-hinterland is composed by two main dry ports, which are currently facing cargo volume difficulties. To obtain higher external validity, both dry ports in Pernambuco were analyzed following the case study methodology described by Voss, Tsikriktsis and Frohlich (2002), and the Value Focused Thinking (VFT) approach, which is detailed next.

To ensure the reliability of the case study, an interview protocol with open-ended questions was developed. To achieve qualitative data, the author of the thesis was the facilitators of the VFT approach, interviewing six top managers of both dry ports through a semi-structured questionnaire with 69 open-ended questions. Two experts work as operational managers of dry ports, acting as decision-makers in daily and strategic issues. Other three experts work as commercial and customer satisfaction managers, dealing with customers' demands on a daily basis. Finally, one of the experts works as a custom manager, being a specialist in Brazilian customs' process. All experts are graduated and four of them post-graduated. Two of them have more than 20 years of experience in dry ports, supply-chain management and international trade; the other four managers have between 10 and 20 years of professional experience, validating the quality of the decision-makers as key references in both dry ports analyzed.

The interviews and discussions were carried out individually and in group with the experts between August and October, 2019; the meetings happened at the dry ports facilities separately, focusing on the experts' daily experiences and perceptions about the role and objectives of the dry port. Following the companies' compliance, both dry ports analyzed were referenced as Dry Port A (DP A) and Dry Port B (DP B). The results of 'Stage 2' were the means-end objective network and the framework to measure the achievement of the objectives of the dry ports.

Dry port A is located between Suape container seaport (22 km) and Recife downtown (29 km), the capital of the state. Under a concession regime, DP A is classified as a close dry port, connected with container terminal only by road. Handling 650 TEUs per month, DP A utilizes 18% of its occupancy average, moving mainly import cargo (98%), including products like tire, rubber, beverage and healthcare equipment. Dry port B is also located between Suape container seaport (13 km) and Recife downtown (49 km), connected by road. Classified as a close dry port under a concession regime, DP B has 39,000 square meters total facility area and a warehouse with 8,000 square meters. With capacity for 1,515 TEUs, dry port B handles 460 TEUs per month on average, operating mainly import cargo (95%).

Lastly, 'Stage 3' carried on a discussion of the main issues, challenges and opportunities of dry ports, bridging the gap between the literature and the practice, aiding decision-makers to improve the current environment of this logistic player in Brazil and attending the second specific objective.

4.2.1 Value-Focused Thinking approach

Value-Focused Thinking (VFT) provides a systematic approach to structure complex decisions for subsequent analysis (KEENEY, 1996) and has been largely applied in several issues as energy transition scenario evaluation (HÖFER; MADLENER, 2020), security technology (TSHERING; GAO, 2020), strategic research funding decision (PARREIRAS et al., 2019), urban water supply system (MONTE; MORAIS, 2019), waste management (ALENCAR; MOTA; ALENCAR, 2011) and sustainability perspectives in e-commerce channels (SHUKLA; MOHANTY; KUMAR, 2018). This method focuses on the decision maker's values, which provide the foundation for interest in any decision situation and are made explicit by the identification of objectives (KEENEY, 1992).

Value-focused thinking includes numerous procedures to guide decisions. First, several techniques help compile an initial list of objectives. The process of identifying objectives requires significant creativity and hard thinking about a decision situation (KEENEY, 1992). Second, these objectives are categorized as means-end objectives and logically structured. Fundamental objectives concern the ends that decision makers value in a specific decision context while means objectives are methods to achieve ends (KEENEY, 1996). Third, several procedures assist in using the objectives to create alternatives and Fourth, the objectives are examined to identify worthwhile decision opportunities (KEENEY, 1996). This chapter narrows the VFT approach up to the second step, identifying the role of dry ports in Brazil and assessing fundamental and means-end objectives.

To summarize the main steps to build the model of values and the framework to measure the achievement of objectives, it was followed four steps as detailed in Figure 10 (KEENEY, 2001). The steps are described as: (i) developing a list of value through a wish list, indicating what decision-makers care about in the particular context of dry port operations; (ii) converting the list of values into objectives following three features which define an objective: decision context, an object and direction of preference; and (iii) structuring the objectives tracing means–ends relationships. To define the objective as means or fundamental objectives, specialists were asked "Why is this objective important in the decision context?" If the objective is an essential reason for interest in the situation, it is a fundamental objective; however, if the objective is important because of its implications to achieve some other objective, it is a means objective.

The last step (iv) was specify measures to indicate the degree to which the objectives are achieved. Essentially there are three types of attributes to measure the achievement of the fundamental objectives: natural attributes, constructed attributes, and proxy attributes (KEENEY, 1992). The author explains that natural attributes are those that have a common interpretation to everyone. However, if a natural attribute does not exist or if it seems to have inappropriate built-in value judgments, there are construct attributes, to measure the associated objective directly, or proxy attribute to measure the associated objective indirectly. Although an attribute may seem obvious for a given objective, a good deal of thought should be given to appraising the value judgments built into that attribute. However, sometimes it is difficult to figure out an appropriate attribute for an objective, but it cannot be neglected (KEENEY, 2001). Based on the VFT approach described, the means-end network and the measurement framework were built based on the experts' suggestions as outputs from the case studies.

4.3 RESULTS

4.3.1 Characteristics of dry ports in Brazil

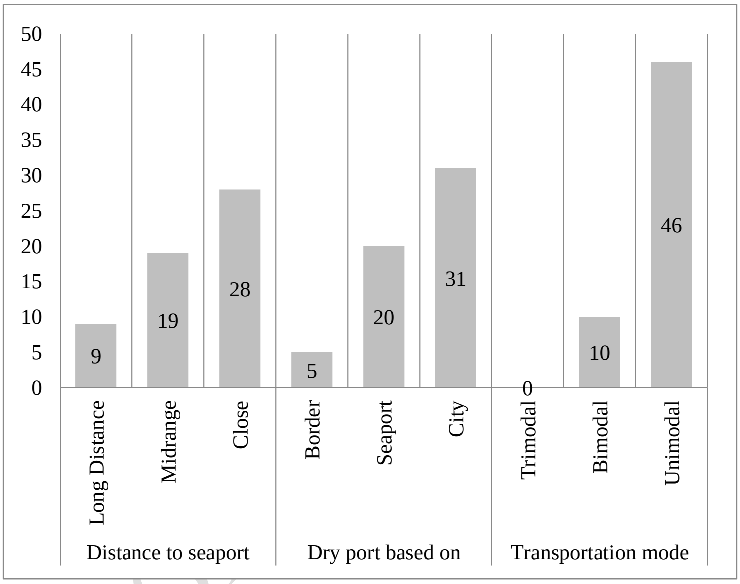
Brazil is essentially an exporter of commodities as soya, crude oil and iron ore, and an importer of manufacture products such as medicines, fuel, drilling rigs, vehicle parts, and electronic circuits, which represent the highest value in the trade balance (MDIC, 2019). While 50% of the value exported was commodities and 36% was manufacture products in 2018, almost 86% of the value imported in the same year was manufacture products (MDIC, 2019), which influences directly the way that dry ports operate in Brazil, characterized by handling import cargo. In the same direction of the international trade growth, seaports in Brazil handled more than 10 million TEUs in 2018, representing an increase of 7.22% over 2017 (ANTAQ, 2021) and positioning the country as the largest container-handling economy in South America (UNCTAD, 2019).

Responsible for 65% of the transport share in Brazil, the road sector is the most used for freight transport and connection between seaports and hinterland, which results in high logistical costs, congestion of roads and cities, as well as increased air pollution (KHASLAVSKAYA; ROSO, 2020). Despite this, the Brazilian road network has shown a small evolution in recent years, stagnating around 1.7 million kilometers since 2001 (CNT, 2017). A survey conducted by the National Confederation of Transport showed that 28.2% of the highways in Brazil presented a poor or bad state, 33.6% regular and only 38.2% good or great, which shows the necessity of improvements in that sector (CNT, 2017). On the other hand, container transportation using waterways is not explored to its full in Brazil, with less than 2% of the total number of containers handled in 2018 (ANTAQ, 2021). With 15% participation in the transport matrix and focused on transport commodities as iron ore and grains (80% of total volume), Brazil has a low density of rail network compared to continental countries such as Canada, India, USA, China and even other developing countries in Latin America, such as Mexico and Argentina (ANTF, 2019).

Dry ports in Brazil work under concession regime or, when applicable, permission. In addition, tax inspection activities on foreign trade operations are supervised and carried out by the fiscal-auditors of the Brazilian Federal Revenue, that are installed inside the dry port facility, controlling the import and export dispatches and allowing all steps of customs clearance to be done in the same place. According to Ng, Padilha and Pallis (2013), dry ports in Brazil are generally understood as bonded warehouses of public use where cargoes under customs control can be moved, stored and cleared, besides some additional services. In addition to the possibility of removing goods from seaports earlier, when the cost of storing in dry ports is lower, imported goods can be stored for up to 120 days, which in seaport would be 90 days. Another advantage is that companies operating through dry ports can close the export of their products with exchange clearance before the shipment of goods, being stored at the disposal of the importer. Furthermore, dry ports specialize in providing solutions tailored to customer needs and are located close to major industrial and commercial centers in Brazil.

There are currently 56 dry ports operating in Brazil classified as shown in Figure 11, mainly located in the southeast (29) and south (17) of the country. Among them, 28 are classified as close dry ports, 19 midranges, and 9 long distance; those dry ports are located on average 30 km, 248 km and 831 km, respectively, far from seaports by road. In addition to the distance classification, 20 dry ports are classified as seaport based, with emphasis on 5 in the state of Santa Catarina, which assist operations at the seaports of Itapoá and Itajaí, as well as 5 dry ports in Santos, where largest seaport in Brazil is located; another 31 dry ports are classified as city based, with emphasis on the 20 located in the state of São Paulo, which is the largest commercial and population center in the country. This fact reinforces that dry ports in developing countries are situated in the proximity, or even inside industrial zones to serve the many small local shippers, or in the middle of the chain for transloading between two transport networks (NGUYEN; NOTTEBOOM, 2016). The remaining 5 dry ports are classified as border based, with emphasis on Uruguaiana and Foz do Iguaçu, which are two of the largest dry ports in Brazil, bordering Paraguay and Argentina.

Figure 11 – Classification of dry ports in Brazil



Source: (RODRIGUES et al. 2021).

The results shows that, although Brazil is a country with continental dimensions, most dry ports are located near seaports and the main consumer markets, connecting to the hinterland through a weak transportation system. Indeed, currently there are 10 bimodal dry ports, 9 connected by railway and 1 by barge, and 46 unimodal. This result highlights the challenge that Brazil has to face to improve the connections among dry ports and seaports to achieve efficiently the hinterland market. However, the current scenario is not encouraging, as the dry ports of Uruguaiana and Santana do Livramento, which were managed by Rumo Logística, the company that owns the largest rail network in Brazil, ceased to operate by rail in 2017 (EXAME, 2017). Lastly, the full classification data of Brazilian dry port is detailed in Table 7.

Table 7 – Full data of Brazilian dry ports

City	Company name	Closest seaport	Distance to seaport (Km)	Distance: Long Distance	Distance: Midrange	Distance: Close distance	Based on: Seaport based	Based on: City based	Based on: Border based	Transport: Unimodal	Transport: Bimodal	Transport: Trimodal
Anápolis	Porto Seco Centro-Oeste	Santos	1046	●				●			●	
Barueri	Multilog	Santos	133		●			●		●		
Bauru	Brado	Santos	443		●			●		●		
Belém	Porto Seco Metrobel	Belém	3			●	●				●	
Betim	Tora	Rio de Janeiro	458		●			●			●	
Brasília	Logserve	Santos	1073	●				●			●	
Cabo de Santo Agostinho	JSL	Suape	22			●	●			●		
Campinas	Libraport Campinas	Santos	170		●			●			●	
Campinas	Multilog	Santos	19		●			●		●		
Canoas	Banrisul	Rio Grande	328		●			●		●		
Cariacica	Tegma, Terca e Silotec	Vitória	26			●	●			●		
Cascavel	CODAPAR	Paranaguá	549	●				●			●	
Caxias do Sul	Serra Gaúcha	Rio Grande	440		●			●		●		
Corumbá	AGESA	Paranaguá	1512	●					●		●	
Cuiabá	Porto Seco de Cuiabá	Santos	1609	●				●		●		
Curitiba	Multilog	Paranaguá	102		●			●		●		
Curitiba	Multilog	Paranaguá	103		●			●		●		
Foz do Iguaçu	Multilog	Paranaguá	733	●					●	●		
Guarujá	Santos Brasil Logística	Santos	8			●	●			●		
Ipojuca	Wilson Sons Logistica	Suape	13			●	●			●		
Itajaí	Brasfrigo	Itajaí	3			●	●			●		
Itajaí	Localfrio	Itajaí	12			●	●			●		
Itajaí	Multilog	Itajaí	12			●	●			●		
Jacareí	Universal	Santos	150		●			●		●		
Jaguarão	Multilog	Rio Grande	189		●				●	●		
Joinville	Multilog	Itapoá	72			●		●		●		
Juiz de Fora	Multiterminais	Rio de Janeiro	206		●			●			●	
Manaus	Porto Seco Graman	Manaus	7			●	●			●		
Mesquita	Porto Seco Nova Iguaçu	Rio de Janeiro	30			●	●			●		
Novo	Multi Armazéns	Rio Grande	351		●			●		●		

Hamburgo											
Pouso Alegre	CLIA Sul de Minas	Santos	290		●			●		●	
Resende	Multiterminais	Rio de Janeiro	163		●			●		●	
Rio de Janeiro	Multiterminais	Rio de Janeiro	15			●	●			●	
Salvador	Empório	Salvador	12			●	●			●	
Santana do Livramento	Multilog	Rio Grande	401		●				●	●	
Santo André	Wilson Sons Logistica	Santos	71			●		●		●	
Santos	Deicmar	Santos	5			●	●			●	
Santos	Eudmarco	Santos	4			●	●			●	
Santos	Multilog	Santos	8			●	●			●	
Santos	Santos Brasil Logística	Santos	22			●	●			●	
São Bernardo do Campo	AGESBEC	Santos	66			●		●		●	
São Bernardo do Campo	Lachmann	Santos	75			●		●		●	
São Francisco do Sul	Fastcargo	Itapoá	7			●	●			●	
São Francisco do Sul	Porto Seco Rocha	São Francisco do Sul	6			●	●			●	
São Paulo	CNAGA	Santos	90			●		●		●	
São Paulo	EMBRAGEN	Santos	85			●		●		●	
São Paulo	Multilog	Santos	71			●		●		●	
São Sebastião	CNAGA	São Sebastião	2			●	●			●	
Simões Filho	TPC	Salvador	26			●	●			●	
Sorocaba	Aurora	Santos	190		●			●		●	
Suzano	CRAGEA	Santos	80			●		●			●
Taubaté	EADI Taubaté	Santos	190		●			●		●	
Uberaba	Porto Seco do Triângulo	Santos	583	●				●			●
Uberlândia	Supplog	Santos	658	●				●		●	
Uruguaiana	Multilog	Rio Grande	614	●					●	●	
Varginha	Porto seco Sul de Minas	Rio de Janeiro	395		●			●		●	

Source: (RODRIGUES et al. 2021).

Despite some dry ports are directly connected with seaports through multimodal transportation, most of them are not in fact operating with defined delivery schedules, mainly due the low volume and the competitive cost and flexibility of road transportation. Such issues are simulated and discussed in next chapters.

4.3.2 Assessing the objectives of dry ports

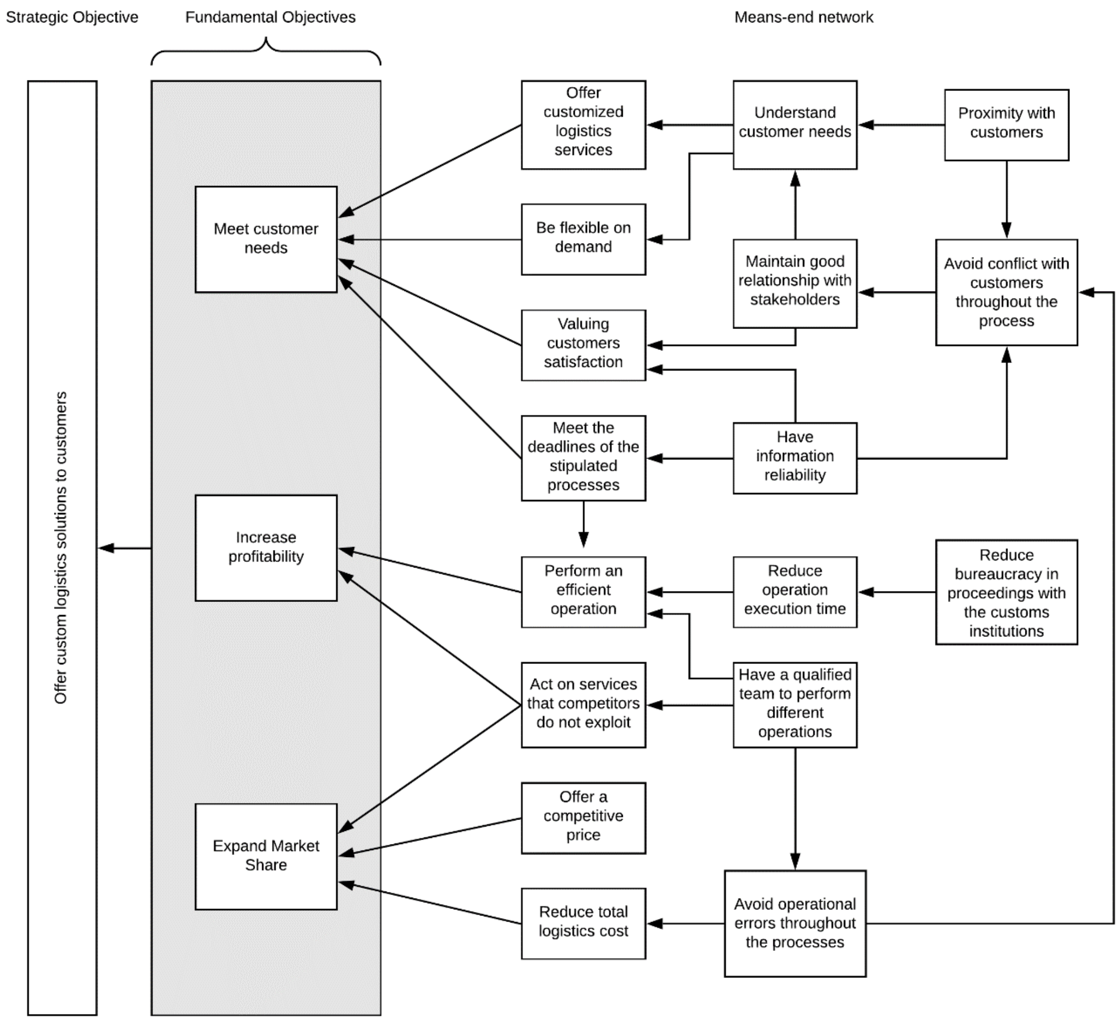
The dry ports in Pernambuco present similar characteristics. Both are classified as close dry ports, seaport based and unimodal. These logistics structures work as a support to the seaport, reducing the congestion and occupancy in the yard and transferring some customs process to the hinterland area. As in the northeastern region there are no railways to hub the cargo in the hinterland and transport to the seaport in high capacity, the main advantages to operate through dry ports are the reduction of storage cost, additional services offer and customs special process. The main objectives of dry ports in Pernambuco and the framework to assess them are detailed below.

4.3.2.1 Case study in dry port A

As Brazilian dry ports have a different logistic function, compared with developed countries, identifying dry port strategic positioning is fundamental to understand their social and economic role in the supply chain. In this way, the strategic objective of DP A is to offer customized logistic solution to customers. As in Brazil there is not a railway infrastructure that could support the container transportation through hinterland, reducing the logistic cost and the congestion in seaport facility, DP A fulfills the role of support the customers' demand of customs warehousing, bonded warehousing, container handling, packaging, labeling, sealing, palletizing of goods and other activities. To achieve this strategic goal, the managers listed three fundamental objectives, namely: to meet customer needs, to increase profitability and to expand market share; and 17 means-end objectives, which represent the main values of this logistic player. The means-end network for dry port A follows in Figure 12.

With the Brazilian economy downturn in recent years, along with the current world recession, accompanied by the rising dollar rate, the volume of the import cargo handled by DP A decreased, while the competition with the seaport, which reduced storage rates to keep the container in their yard and maintain the storage profit, increased. In this context, DP A looks for competitive differential meeting specifics demands as: cargo handling and storage, weighing, cleaning and disinfecting, sampling collection, sealing, stuffing and stripping container cargo, repacking, palletizing, lashing cargo, customs process and so on. Furthermore, DP A works in a flexible and personalized way, which does not happen between seaport and customers due to the high volume of container processes. To meet the demand, DP A keeps a close relationship with customers to understand their needs and offer personalized logistics services, what is also a challenge to be flexible on demand, meeting customers' deadlines.

Figure 12 – Means-end network of dry port A



Source: (RODRIGUES et al. 2021).

One of the most important values in DP A regards customers' satisfaction. To achieve it, a good relationship with stakeholders is required as well as the prevention of conflicts during the operational process, which is possible through the information reliability. Besides that, to continue working inside the competitive business environment, DP A must be profitable; in this way, the managers believe that performing an efficient operation, decreasing the execution time, and working to reduce the bureaucracy in proceedings related with customs institutions as Brazilian Federal Revenue are the main means. On the other hand, exploiting different operation services could also bring more profits to DP A, as happened in the beginning of the operations, when DP A specialized in handling oversized containers and special cargo. However, in any situation, it is necessary to have a qualified team, avoiding operational mistakes and achieving the deadline agreements.

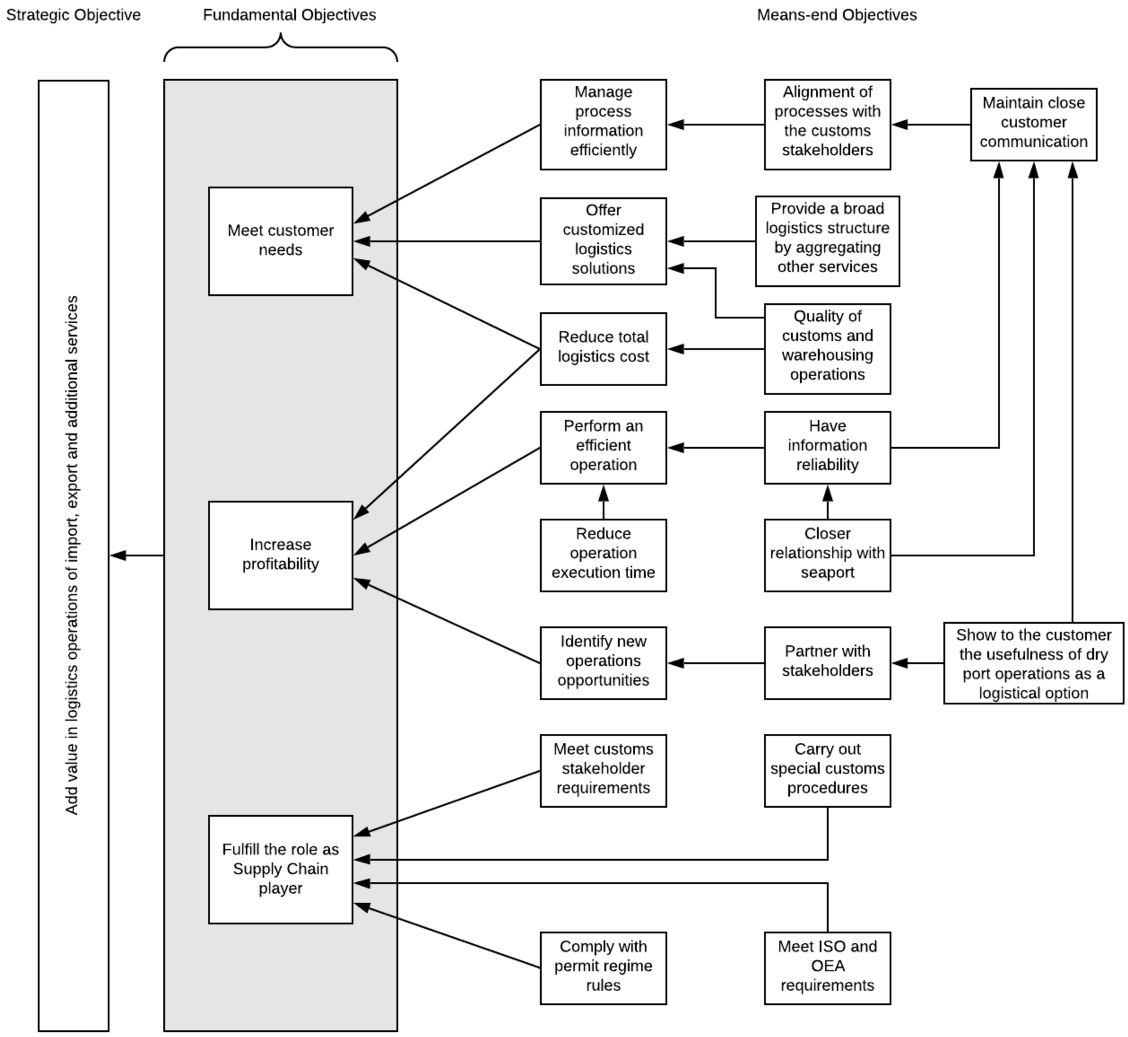
As an additional logistic player, DP A must offer a competitive price and promote a reduction in total logistic cost to customers. Considering that it is not possible to obtain cost reduction through railway transport, DP A works to overcome this challenge offering a better storage price to bring volume cargo. To the managers, understanding customers' needs, keeping a close relationship and offering a competitive logistic price are the challenges to achieve the strategic objective, justifying the positioning of dry ports as a logistic player in the supply chain.

4.3.2.2 Case study in dry port B

The strategic objective of DP B is adding value in logistic operations of import, export and additional services. The managers believe that it is the main function of a dry port as a supply chain player, supporting the import and export processes with services which are not the core business of seaports. To assess this strategy, the managers listed: meeting costumers' needs, increasing profitability and fulfilling the role as a supply chain player as three fundamental objectives that express the main values of DP B and 18 means-end objectives, as presents in Figure 13.

Customs bureaucracy process is a problem faced in developing economies as Brazil and it impacts directly dry ports to meet customers' needs. The managers identified that maintaining close customer communication and alignment of process between stakeholders enable DP B to manage process information efficiently. Other means-end objectives are providing a broad infrastructure to offer additional services and the quality of warehousing operations, which reduce the total logistic cost to clients. As mentioned before, the customers of dry ports in Brazil look for suppliers that offer additional services and take care of import and export process in a personalized way in the secondary zone, avoiding the congestion in seaports and reducing storage cost.

Figure 13 – Means-end network of dry port B



Source: (RODRIGUES et al. 2021).

To increase profitability in the competitive environment between seaport and other players, DP B works to offer information reliability to customers and perform an efficient operation reducing the execution time. With the complexity of import and export process in Brazil, dry ports need to manage information and deadlines between customers and customs stakeholders, as the Brazilian Federal Revenue, to offer specific services that the seaports are not able to provide. The managers stated that if dry ports are not able to fulfill this gap, customers will not identify benefits in operating through this player and the profitability of the dry port could reduce. In this way, the managers work to show to the customers the usefulness of dry port operations as a logistic option.

As dry ports are an additional player in the supply chain, according to the managers, many shippers avoid using it because it will add a new step to manage in their process. Despite this weakness, DP B works to create a partner relationship with stakeholders and customers to identify new operation opportunities besides keeping a close relationship with the seaport, considering that if the seaport offers a good service, clients could intensify investments in the region, increasing the profitability of dry ports.

As in the northeast of Brazil the population is concentrated near the coast and the main customers are located in the seaport influence zone, DP B takes on an important role reducing the logistic cost, achieved by the low storage cost and additional services, which stimulate the import and export process. However, as dry ports in Brazil operate in a concession or permit regime, some rules and procedures must be met. In this way, the managers pointed the customs procedures, ISO, OEA (Authorized Economic Operator) and stakeholders' requirements as means-end to achieve their fundamental objectives. It is also a challenge to DP B fulfill those requirements considering that customs rules are changing constantly, and the customers have demanded more agility in the import and export process. However, the managers affirm that customs processes are becoming less bureaucratic, adding new technology to offer information reliability.

4.3.3 Framework to assess the achievement of the objectives of dry ports

Extending the discussion about the role of dry ports in Brazil, the fundamental and means-end objectives resulted from the VFT were aggregated to propose a framework to assess the achievement of objectives, validated by the experts interviewed as shown in Table 8. As a first step to future debates, the framework can enhance the process and benefits of VFT, providing useful insights as clarifying objective meaning in addition to measuring the achievement of fundamental and means-end objectives, working as a guide to decision-makers.

Most of the attributes in Table 8 are natural, becoming easier to calculate. However, this facility may not result in less discussion about the objectives. Furthermore, there are constructed attributes that should be in a rating scale, which can be numeric or verbal. Among the numerical scales there are ratio, interval and ordinal scales, while Likert is a widely verbal scale used (ALMEIDA, 2013). As there are many ways to build a constructed attribute, this article is limited to specifying them as a 'Satisfaction scale', which is open to adjust to each case to identify the objective achievement level.

Table 8 – Framework to assess the achievement of dry ports' objectives

Objective	Attribute	Type of Attribute	Unit of measurement	Attribute measurement	Attribute range
1. Meet customers' needs	*Satisfaction scale*	*Constructed Attribute*	*Category*	*Satisfaction scale*	-
1.1 Offer customized logistics services	Percentage of customized operations compared with standard operations	Natural	Percentage	Customized Operations - CO; Standard Operation - SO; Attribute = [CO / (SO + CO)]*100	Min = 0%; Max = 100%
1.2 Be flexible on demand	Quantity of customer demand not met	Natural	Percentage	Demand Not Met - DNM; Total Demand - TD; Attribute = (DNM / TD)*100	Min = 0%; Max = 100%
1.3 Valuing customers' satisfaction	Satisfaction scale	Constructed Attribute	Category	Satisfaction scale	-
1.4 Meet the deadlines of the processes	Percentage of deadline compliance	Natural	Percentage	Process Met on Deadline - PMD; Process Met Out of Deadline - PMOD; Attribute = [PMD / (PMD + PMOD)]*100	Min = 0%; Max = 100%
1.5 Information reliability	Quantity of claims caused by information mistakes	Proxy	Units	Claims Caused by Information Mistakes - CCIM; Attribute = CCIM	Min = 0; Max = unlimited (ultd)
1.6 Avoid conflicts	Quantity of conflicts identified	Natural	Units	Conflicts Identified - CI; Attribute = CI	Min = 0; Max = ultd
1.7 Maintain a good relationship with stakeholders	Satisfaction scale	Constructed Attribute	Category	Satisfaction scale	-
1.8 Quality of operations	Revenue over cost Percentage of deadline compliance	Proxy	Percentage	Monthly Revenue - MR; Monthly Total Operational Cost - MTOC; Attribute = (MTOC / MR)*100 Percentage of deadline compliance = Attribute in objective 1.4	Min = 0; Max = ultd
1.9 Provide a broad logistics structure	Yard availability Warehouse availability	Proxy	Percentage	Yard Occupancy - YO; Yard Capacity - YC; Attribute = (YO / YC)*100 Warehouse Occupancy - WO; Warehouse Capacity - WC; Attribute = (WO / WC)*100	Min = 0%; Max = 100%
2. Increase profitability	*Profit increase per year*	*Natural*	*Percentage*	*Profit in the Current Year - PCY;* *Profit in the Last Year - PLY;* *Attribute = (PCY / PLY)*100*	*Min = 0%;* *Max = 100%*
2.1 Reduce operation execution time	Operation execution time	Natural	Percentage	Execution Time - ET; Standard Time - ST; Attribute = (ET / ST)*100	Min = 0%; Max = ultd
2.2 Perform an efficient operation	Operational cost Quantity of operational outliers activities	Proxy	Percentage Units	Standard Operational Cost per Activity - SOCA; Activity Operational Cost Realized - AOCR; Attribute = (AOCR / SOCA)*100 Quantity of Operational Outliers Activities = QOOA; Attribute = QOOA = count	Min = 0%; Max = ultd Min = 0; Max = ultd

				occurrences out of standard operation (ST ± σ)* *Quantity of 'σ' defined by the managers.	
2.3 Partner with stakeholders	Quantity of partnership	Natural	Units	Quantity of Partnership Agreements - QPA; Attribute = QPA	Min = 0; Max = ultd
2.4 Customers perception about necessity of dry ports	Satisfaction scale	Constructed Attribute	Category	Satisfaction scale	-
2.5 Qualified team	Operational cost Quantity of operational outliers activities	Proxy	Percentage Units	Attribute = same of objective 2.2	Min = 0%; Max = ultd Min = 0; Max = ultd
2.6 Reduce bureaucracy	Historical evolution of customs process time	Proxy	Percentage	Standard Time of Customs Process - STCP; Average Time of Customs Process in the Currenty Month - ATCM; Attribute = (ATCM / STCP)*100	Min = 0%; Max = ultd
3. Expand market share	*Percentage of container volume handled in the region*	*Natural*	*Percentage*	*Total Container Handled in the Influence Area - TCHIA;* *Total Container Handled by the Dry Port - TCHDP;* *Attribute = (TCHDP / TCHIA)*100*	*Min = 0%;* *Max = 100%*
3.1 Offer a competitive price	Storage price Handling price Additional services price	Natural	Percentage	Storage Price - SP Handling Price - HP Additional Services Price - ASP; Average Storage Price by Competitors - ASPC Average Handling Price by Competitors - AHPC; Average Additional Services Price by Competitors - AASPC; Attribute = (SP / ASPC)*100; Attribute = (HP / AHPC)*100; Attribute = (ASP / AASPC)*100.	Min = 0%; Max = ultd
3.2 Reduce total logistic cost	Logistic cost using dry port compared with seaport	Natural	Percentage	Total Logistic Cost Using Dry Port - TLCUDP; Total Logistic Cost Using Seaport - TLCUS; Attribute = [(TLCUS - TLCUDP) / TLCUS]*100	Min = 0%; Max = 100%
3.3 Reduce operational mistakes	Percentage of deadline compliance Percentage of damage cargo	Proxy	Percentage	Percentage of deadline compliance = Attribute in Objective 1.4 Quantity of Container Handling by Month - QCHM; Quantity of Container Damaged by Month - QCDM; Attribute = (QCDM / QCHM)*100	Min = 0%; Max = 100%
3.4 Act on services that competitors do not exploit	Quantity of operations doesn't provided by competitors	Natural	Percentage	Quantity of Operations Provided by the Dry Port - QOPDP; Quantity of Operations Doesn't Provided by Competitors - QODPC; Attribute = (QODPC / QOPDP)*100	Min = 0%; Max = 100%
4. Fulfill the role as supply chain player	*Satisfaction scale*	*Constructed Attribute*	*Category*	*Satisfaction scale*	-
4.1 Comply with permit regime rules	Quantity of customs agents' notifications	Proxy	Units	Quantity of customs' agents Notifications - QFRN; Attribute = QFRN	Min = 0; Max = ultd
4.2 Meet customs stakeholders' requirements	Satisfaction scale	Constructed Attribute	Category	Satisfaction scale	-
4.3 Carry out special customs' procedures	Quantity of customs agents' notifications	Proxy	Units	Quantity of customs agents' Notifications = QFRN; Attribute = QFRN	Min = 0; Max = ultd
4.4 Meet ISO and OEA requirements	Quantity of nonconformities	Natural	Units	Quantity of Nonconformities = QNC; Attribute = QNC	Min = 0; Max = ultd

Source: (RODRIGUES et al. 2021).

The framework aggregated four fundamental objectives as increase profitability and expand market share, both well-known objectives which dry ports work to reach, as mentioned by (NGUYEN; NOTTEBOOM, 2016; KA, 2011; KRAMBERGER et al., 2018). Furthermore, meet customers' needs and fulfill the role as supply chain player were listed as fundamental objectives of dry ports in Pernambuco, which should be explored to achieve the best benefits of these logistic players in that region, since the reduction of transportation cost using railways is not achieved. The experts also defined 23 objectives as means-end to reach the fundamental objectives; it means that the framework reflected the policy context, network infrastructure, competitive environment, operational issues and other characteristics of dry ports northeast of Brazil.

Besides the unavailable multimodal connection, dry ports in Pernambuco were also facing low volume of cargo, handling only 1,100 TEUs per month compared to 40,000 TEUs of Suape seaport in 2019. In this way, this thesis advocate against the development of new dry port facilities in the state of Pernambuco as an option to improve seaport-hinterland. A solution to enhance the feasibility of dry ports remains in customs policy changes to improve the bureaucratic process of import/export of goods; however, it takes time and depends on the Federal Revenue and Brazilian Senate. Another option is to improve the network infrastructure, building railways to reduce the transportation cost and connecting dry ports to seaports and hinterland; however, it is a long term and expensive project that involves multiple stakeholders.

As an alternative to overcome the current problems and improve the operation of dry ports in Pernambuco, the proposed framework works as a feasible tool to drive dry ports operators' decisions toward the main role of the dry port. However, the usefulness of the attributes will depend on the maturity of the dry port. As a proposal, the managers and governments should not limit the discussion about the role of dry ports in Brazil at the listed attributes, being necessary to define to each case the control limits and the level of quality of each attribute, to convert data into useful information. Furthermore, the implications of the results are not limited to the case studies presented; all steps followed above could lead other studies within different contexts and countries, since our study presented the VFT approach as an applicable option to assess the objectives of dry ports. Hence, this chapter fulfills the literature gap presented by Khaslavskaya and Roso (2020) and Witte, Wiegmans and Ng (2019) regarding tools to drive dry port decisions.

4.4 MAIN ISSUES, CHALLENGES AND OPPORTUNITIES

Dry ports perform functions that depend on geographic, political and economic factors and even the current logistics infrastructure, which makes defining global standards and concepts a difficult activity (KHASLAVSKAYA; ROSO, 2020). As the research on this topic is concentrated in countries of Europe and Asia, which have a high container handling volume and a consolidated railway infrastructure, the adequacy of models and definitions to the reality of developing economies is more subject to errors, as in the research that disregards Latin American structures as dry ports (ROSO; LUMSDEN, 2010). This chapter fulfills this gap in the literature.

Brazil is a country with an old seaport structure. Despite of the seaport law nº 12.815 of 2013, which allows the private operation of seaports through a concession bid (NG; PADILHA; PALLIS, 2013), the development of new facilities is still in the early stage, presenting difficulties as overcapacity and congestion which could be improved by dry port facilities. As shown in the results, 84% of dry ports are concentrated close or midrange distance from seaport and 91% of them are city or seaport based. This result shows that dry ports in Brazil are concentrated on the sea coast, which is also the most populated region, performing road transport to connect the logistics players, despite the fact that Brazil is a country with continental dimensions.

Through the case studies and the VFT approach, it was possible to identify that the dry ports in Pernambuco are specialized in offering additional and personalized logistic solutions with a reduced storage cost, relieving bureaucratic processes and the occupancy in seaports. However, in Brazil this scenario changes when the container handling decreases, making dry ports and seaports start to compete for storage cargo. This happens when the seaport occupancy is low, which makes them reduce rates to retain more containers and increase their profits (JEEVAN et al., 2017; NG; GUJAR, 2009).

Summarizing the main issues, the author concludes that dry ports in Brazil support exporters and importers offering storage capacity and additional services in a customs area, located mainly near the coast, connecting the hinterland to the seaport through highways. Furthermore, the main challenges faced in Brazil are the bureaucratic customs process, the lack of legislation, the competitive environment between seaport and dry ports besides the poor intermodal infrastructure, concluding that the current environment of dry ports should be improved to achieve the best benefits of this logistic structure.

Despite the benefits, investments on dry ports depend very much on existing logistic network connection infrastructure, political, social and financial regulations besides multiple stakeholder interests (DADVAR; GANJI; TANZIFI, 2011; KHASLAVSKAYA; ROSO, 2020). In this way, it is not possible to change the characteristics of dry ports in Brazil to meet the best benefits in a short time. To bridge the literature and practice, the framework proposed could drive dry port decisions as a management tool. Moreover, dry port operators should focus on the main role that this logistic player holds in the current supply chain, reaching more container cargo and adding value to the customers. In this way, a better use of the current dry ports in Brazil is fundamental to justify new developments and policy changes.

4.5 REMARKS

The results showed that dry ports in Brazil fulfill a different role, when compared with developed countries, offering cheapest custom storage services, performing additional and personalized logistic solutions, reducing bureaucratic processes and the occupancy in seaports. Moreover, this chapter identified the challenges faced by dry ports in Brazil as the poor network infrastructure, bureaucratic customs process, lack of legislation and a competitive environment, bringing relevant information to the society and policy makers. Furthermore, the framework to assess the objectives of dry ports works as an option to improve the current operation context, without the need for high investments, policy changes or multiple stakeholders' action.

This chapter also brought theoretical and practical implications for researchers, investors, dry ports operators and the society. The first theoretical achievement was the classification of dry ports in Brazil and the promotion of a discussion about their main issues, challenges and opportunities. As the research about dry ports in Brazil still remains in an early stage and there is lack of information from government institutions, the current context of dry ports in Brazil was completely unknown. This chapter fulfilled this gap working as a first step for future developments. The managerial contribution was the proposed framework to assess the achievement of the objectives of dry ports in Pernambuco. The findings showed that the VFT approach could guide dry port operators towards decision-making on the main role of the dry port in the studied region. Besides the lessons which could be learned from the development of dry ports in Brazil, the framework proposed could be applied in different contexts and countries, in order to achieve the best benefits from dry port operations.

5 ASSESSING RISK FACTORS IN DRY PORTS PROJECTS

A reviewed version of the paper:

RODRIGUES, T.; MARSHALL, A.; OJIAKO, U.; MOTA, C.; DWEIRI, F. Dry port infrastructure projects in Brazil: assessing risk factors from a collaborative multi-stakeholder operational readiness perspective. Under review.

5.1 CONTEXTUALIZATION

To establish a seaport as an effective network node for global trade depends upon not just its geographical context but also many further potentially interdependent contextual factors which inevitably associate to a broad range of diverse risk management concerns whenever interested stakeholders collaborate within network development projects. These factors relate for example to the national and broader regional economy, central and local public policy and regulation, and financial opportunities for funding port infrastructure development, especially on a large scale and over the longer term (DO; NAM; LE, 2011; MURAVEV; RAKHMANGULOV, 2016; WANG; CHEN; HUANG, 2018). Correspondingly, academic research into pertinent project risk management challenges entails drawing from literature, see for example Chipulu et al. (2019), emphasizing the complexity of multi-stakeholder contexts for collaborative working aimed at building and maintaining effective hinterland networks.

What are termed ‘dry ports’ have become popular in recent years as a means by which diverse interested stakeholder groups may collaborate to develop seaport networks by more efficiently. Dry ports can be viewed, in more specific infrastructural project terms, as enlarging seaport operations through connectivity to newly constructed inland facilities, thereby overcoming immediate geographic limitations to seaport growth and supporting regional economic development by providing new cargo transport hubs that integrate efficiently with both existing and planned transport infrastructures at both national and broader regional level (ROSO; LUMSDEN, 2010; FENG et al., 2013). Correspondingly, the successful accomplishment, via dry port infrastructure projects, of dry port-seaport system logistics operations, is relatively difficult due to the existence of many different sources of risk (which can be ordered for practical risk management purposes into various broad risk factors or categories) that vary by stakeholder exposure, experience and perception (BENTALEB; MABROUKI; SEMMA, 2015). Moreover, these risks may impact at any time throughout the project or they may occur at critical moments of transition to operations when project planning is fully tested for the first time.

Irrespective of when the risks matter within or following the timeline of the project, as Costa Sperb and Marshall (2020) observe, throughout projects there is always a categorically formed 'view of risk' which is required for basic risk management purposes, requiring continual revision through the scanning of complex risk environments, and which can be expected to impact stakeholders very differently, as well as through varying perceptual lenses. Looking more critically, this view of risk may be interpreted as artefactual; that is, manifest within risk registers and manifestly instrumental within risk management discourse and practice. On the other hand, and more problematically, it can also represent an aspirational ideal, and not just a practical compromise or an imposition, where a risk-perceptual consensus has been achieved through stakeholder collaboration. This chapter engages with this problem by developing practical management proposals for collaborative striving towards true consensus on risk within complex multi-stakeholder infrastructure projects for building and developing dry ports.

More specifically, the present chapter theoretically emphasizes and empirically seeks to explore the complexities of dry port projects by focusing on how – and to some extent, on why - views of dry port project risks vary between participating stakeholder groups. Its technique is to employ empirical study of incongruence among stakeholder views of risk, as a touchstone for theoretical discussion of why the resulting academically generated knowledge can also offer practical managerial value within contexts of both dry port project risk management in general and managing for operational readiness in particular. Central to the conclusion will be the idea that diversity among stakeholder risk exposures, perceptions, interests, management priorities and risk control skills should all be recognized and valued, while there nonetheless remains some strong element of stakeholder-collaborative striving towards not just a consensus on what the risks are and how they should be prioritized, but also towards consensual, principles-based risk allocations between involved parties (OJIAKO et al., 2015a, 2015b, 2016; CHIPULU et al., 2019).

Effective risk allocation is clearly fundamental to multi-stakeholder collaboration on large-scale infrastructure projects (NG; LOOSEMORE, 2007). In particular, the need for effective principles-based risk allocations between stakeholders arises from the un-foreseeability of many risks, and hence from failure to recognize these within risk-sharing contracts on complex and longer-term projects in particular, given that these offer less scope for foreseeing all significant risks. This means that methods must be found to allocate risks extra-contractually as projects roll forward, through risk deliberations which both reflect critically on incongruent risk perceptions, and which promote mutual understanding between stakeholders as well as a more thorough holistic understanding of project risk. It is however surprising, we would contend, that project management literature has so far paid little attention to stakeholder incongruences in risk perception and prioritization.

While studies focused on dry ports have increasingly attracted the attention of scholars (WITTE; WIEGMANS; NG, 2019; KHASLAVSKAYA; ROSO, 2020; RODRIGUES; MOTA; SANTOS, 2021), representations of the set of risk factors required for project risk management have not taken into account diverse stakeholder perspectives (KHASLAVSKAYA; ROSO, 2020). Relevant stakeholders are likely to include government planning agencies, regulatory authorities, terminal operators, freight forwarders, transport operators and port authorities, who may sometimes present divergent interests, experiences and perceptions (RODRIGUE et al., 2010; JEEVAN et al., 2017; KWATENG; DONKOH; MUNTAKA, 2017; NGUYEN; NOTTEBOOM, 2017, 2019). Furthermore, dry ports face temporally varying challenges as they move through projects and ensuing operations. Varying conditions, although often unpredictable in individual cases, are likely to relate to technological innovations or land release opportunities for developing infrastructure, and for associated financial investment opportunities, any combination of which may well reorder the competitive business environment (BLACK et al., 2018). These possibilities for significantly changed conditions can, in theory, be viewed as complexifying and liquifying the matrix of risk or readiness factors that stakeholders may orient to dis-consonantly, hence giving rise to a multiplicity of stakeholder views and prioritizations regarding project risks that should, in the varying opinions of stakeholders, be the focus for collaborative project risk management.

To define the structure of potential underlying latent variables that compose the risk environment, recognizing this complexity and fluidity, and to reduce our data set of variables to a manageable size, we recognize that Exploratory Factor Analysis (EFA) has been successfully applied in many complex management contexts such as supply chain management (SHAW; GRANT; MANGAN, 2021; SONI; KODALI, 2012; JADHAV; ORR; MALIK, 2019), airline network management (ROUCOLLE; SEREGINA; URDANOZ, 2020), building projects (YAP et al., 2018), risk perception (XU; FAN, 2019), urban mobility (BEZERRA; SANTOS; DELMONICO, 2020), food logistic systems (LUTHRA et al., 2018) and many others. Researching dry ports in particular, Jeevan et al. (2017) applied EFA to investigate the impact of dry ports operations on container seaport competitiveness in Malaysia. Wei, Sheng and Lee (2018) ranked logistics properties by dry port city, by establishing an evaluation index system with Principal Component Analysis (PCA). This chapter similarly adopts an EFA approach in order to achieve the third specific objective, answering the fifth research question stated.

5.2 RISK FACTORS IN DRY PORTS' PROJECTS

Recognizing the above complexities, the present chapter must nonetheless work with a risk factor ontology rooted in the literature. Existing research has highlighted that prominent among risks to dry port projects is financial risk for infrastructural investment (WALTER; POIST, 2004). This literature has pointed towards Public-Private Partnership (PPP) as an important and yet controversial financing option for dry port development, which by its nature leads to financial risk ownership ambiguities among contracting parties (DO; NAM; LE, 2011; NGUYEN; NOTTEBOOM, 2017; KHASLAVSKAYA; ROSO, 2020). Also highlighted are the risk of saturating the market by logistics services, the risk of a decrease of the tariffs for transportation and transshipment operations, the relocation risk of reducing container flows, and the more fundamental risks of economic crisis and inflation (PANOVA; HILMOLA, 2015). Furthermore, there are also more particular risks associated with dry port size and goods-dependent requirements for equipment and infrastructure (RODRIGUE; NOTTEBOOM, 2012). Bentaleb, Mabrouki and Semma (2015) organized a list of 101 risks structured in six broad categories as follows: operational risks, professional risks, organizational risks, technical risks, security risks and financial risks. They regarded risks arising within all these categories as threatening to perturb dry port systems.

Recognizing the above variation, Black et al. (2018) presented 24 critical risk factors by meta-review. In finding 'cost' (F1) to be the most important high level factor leading stakeholders to itemize sub-factors, they concur largely with similar research (CHANG; NOTTEBOOM, LU, 2015) by itemizing sub-factors for this 'F1' as 'facility cost' for land, buildings, infrastructure and equipment (SF1) (WEI; SHENG, 2017; MURAVEV; RAKHMANGULOV, 2016; WANG; CHEN; HUANG, 2018), 'transportation costs' between seaports and dry ports (SF2) (QIU; LAM, 2018; WANG; CHEN; HUANG, 2018; NGUYEN; NOTTEBOOM, 2016), 'storage costs' for yards or warehouses (SF3) (QIU; LAM, 2018), and 'costs of additional services' such as consolidation, track-and-trace, maintenance and palletization, sealing, etc. (SF4) (KRAMBERGER et al., 2018). Building on this framework, there are also 'costs caused by road congestion' (SF5) which can also be considered as opportunity costs in circumstances of latent rail demand where there is road congestion (WEI; SHENG, 2017; WANG; CHEN; HUANG, 2018).

Regarding Black et al. (2018) second factor, called 'location' (F2), it is notable that several researchers have proposed models for optimizing locations for dry port installations (FENG et al., 2013; KA, 2011; KOMCHORNRIT, 2017; NG; CETIN, 2012; NÚÑEZ et al., 2016). Among the sub-factors considered in the literature we found: the 'demand for dry ports' services' (SF6) (KA, 2011; KRAMBERGER et al., 2018; KOMCHORNRIT, 2017), the 'distance between dry ports and customers' (SF7), as well as between 'dry port and seaport' (SF8) (KWATENG; DONKOH; MUNTAKA, 2017; WANG; CHEN; HUANG, 2018; HENTTU; LATTILA; HILMOLA, 2011; KOMCHORNRIT, 2017; KA, 2011), 'proximity with other logistic facilities' (depots, warehouses and carriers) (SF9) (NGUYEN; NOTTEBOOM, 2016; WEI; SHENG, 2017; HENTTU; HILMOLA, 2011), the 'size of hinterland population' considered as a consumer market (SF10) (KWATENG; DONKOH; MUNTAKA, 2017; OLÁH et al. 2018a, 2018b) and finally, the 'cargo transportation time' (SF11), measuring how long takes to transfer cargo to and from dry ports (NGUYEN; NOTTEBOOM, 2016; KRAMBERGER et al., 2018; QIU; LAM, 2018).

Relating to 'infrastructure' (F3), some authors nuance this further by 'total area of dry port' (SF12), 'yard capacity' (SF13), 'warehouse capacity' (SF14) and 'capacity for expansion' (SF15) (NG; TONGZON, 2010; MURAVEV; RAKHMANGULOV, 2016; OLÁH et al. 2018a; NÚÑEZ; CANCELAS; ORIVE, 2015). Moreover, it has been argued that 'multimodal capacity' (SF16) and 'equipment infrastructure' (SF17) also matter (KA, 2011; NGUYEN; NOTTEBOOM, 2016; NÚÑEZ et al. 2016).

As with infrastructure, 'accessibility' (F4) has also been further nuanced to produce a range of sub-factors. This nuance accessibility in relation to 'airports' (SF18), 'seaports' (SF19), 'railways' (SF20), 'highways' (SF21), 'other facilities' (SF22) and 'customers' (SF23) (KOMCHORNRIT, 2017; WEI; SHENG, 2017; NGUYEN; NOTTEBOOM, 2016; NÚÑEZ et al., 2016; KA, 2011). Other sub-factors considered to impact accessibility are ‘transportation capacity’ (SF24) (NGUYEN; NOTTEBOON, 2016; KRAMBERGER et al., 2018), ‘quality of transportation infrastructure’ (SF25) (CHANG; NOTTEBOOM; LU, 2015). This latter quality factor has also been further nuanced by time, cost and reliability of cargo transport, with the expectation that wide variation is likely to relate in particular to developing countries, which have a poor transportation infrastructure (PADILHA; NG, 2012).

Many studies have also been conducted on optimizing dry ports ‘operations’ (F5) from different perspectives (KHASLAVSKAYA; ROSO, 2020). Sub-factors discussed in optimizations models include: the ‘set of operational services offered’ (SF26), the ‘number of containers handled per day’ (SF27), the ‘information and technology system’ (SF28) and the ‘operational execution time’ (SF29) (NGUYEN; NOTTEBOOM, 2016; ROSO, 2007; NG; TONGZON, 2010; JEEVAN et al., 2017; QIU; LAM, 2018). Operationally speaking, ‘yard and warehouse usage’ (SF31) is clearly also important, recognizing in particular the fair use issues that are likely to arise in common user facilities characterized by limited capacity. A further sub-factor, ‘cargo security and monitoring’ (SF30), is of course mandatory for all dry port operations (OLÁH et al. 2018a; KRAMBERGER et al., 2018).

Besides particular operational risk issues, a range of more fundamental global economy risk issues are also considered linked to dry ports. The ‘Gross Domestic Product’ (GDP) (SF32) and ‘dollar rate’ (SF33) are two sub-factors considered to influence international ‘trade market’ (SF34) in particular (CHANG; NOTTEBOOM; LU, 2015; WEI; SHENG, 2017; WANG; CHEN; HUANG, 2018; KA, 2011). Some authors also consider the ‘purchasing power of hinterland populations’ (SF35) highly significant (KWATENG; DONKOH; MUNTAKA, 2017; OLÁH et al., 2018a).

It is arguably harder to specify a small and manageable range of qualitative sub-factors for Nguyen and Notteboom’s (2016) notably very broad and interconnected ‘political, social’ (F7) and ‘environmental’ (F8) domains. However, from literature we can list some as ‘uncertainties around bureaucratic process’ (SF36) and ‘the ever shifting scope and focus of regulation’ (SF40). Prospects for dealing with such issues are likely to depend on a favorable ‘political environment’ (SF39) (WEI; SHENG; LEE, 2018; KRAMBERGER et al., 2018; KHASLAVSKAYA; ROSO, 2020). Another important issue linked to level of political support for dry port operations is the ‘government financial incentive’ (SF38). Looking more closely, the key issue may often be that where political support is for public-private partnership projects, political support may serve to expedite private sector in financing dry port development, while directing the public sector to provide the necessary land for development and also ensuring a favorable regulatory environment for the interdependent financial benefit of all parties (NGUYEN; NOTTEBOOM, 2017; KHASLAVSKAYA; ROSO, 2020).

Exploring that context of multi-stakeholder financial interest still further, political development of 'environmental policies' (SF43), despite problematizing negotiations of consent between dry port stakeholders, may at least make very significant efforts in that direction by reducing by congestion, road traffic and other accidents, road maintenance costs, and of course CO2 emissions and air pollution more generally. Accordingly, 'emissions can be considered as a further factor' (SF44) (BLACK et al., 2018). Closely related to that, the 'reduction of noise and visual impact' in seaport cities (SF42) as well the 'urban and environmental impact of dry port facility implementation' (SF41) have been considered distinct sub-factors (CHANG; NOTTEBOOM; LU, 2015; NÚÑEZ; CANCELAS; ORIVE, 2015; MURAVEV; RAKHMANGULOV, 2016; NGUYEN; NOTTEBOOM, 2016).

Although detailed exploration of the boundary issues around these various categories and sub-categories is beyond the scope of the present research, we can at least note that ambiguity appears to vary directly with sub-factor granularity. In doing so it becomes highly problematic in particular for tightly inter-related economic, social, political, regulatory and environmental issues which are probably too numerous to list in terms of the causal mechanisms that may be involved. Taking stock and valuing reasonable thoroughness for high-level categories in particular, Table 9 is provided as a convenient structural visualization for the risk factors and sub-factors considered in the present chapter.

Table 9 – Risk factors and EFA result

Code	Factors/Sub-factors	Factor loadings	Dimensions (PA)	KMO	Bartlett's sphericity			Explained variance
					Chi-square	df	p-value	
F1	**Cost**		1	0,730	209,6	10	0,000	65,39%
SF1	Facility cost	0,510						
SF2	Transportation cost	0,691						
SF3	Storage cost	0,937						
SF4	Additional services cost	0,884						
SF5	Cost caused by road congestion	0,638						
F2	**Location**		1	0,790	100,4	6	0,000	77,40%
SF6	Demand for DP's services (Excluded run 2)	0,496						
SF7	Distance between DP and customers	0,745						
SF8	Distance between DP and Seaport	0,613						
SF9	Proximity with other logistic facilities	0,753						
SF10	Size of hinterland population (Excluded run 1)	0,463						

SF11	Cargo transportation time	0,749						
F3	**Infrastructure**		1	0,678	919,1	6	0,000	82,72%
SF12	Dry ports’ total area	0,834						
SF13	Dry ports’ yard capacity	1,014						
SF14	Dry ports' warehouse capacity	0,771						
SF15	Dry ports' expansion capacity	0,629						
SF16	Multimodal infrastructure (Excluded run 2)	0,378						
SF17	Equipment infrastructure (Excluded run 1)	0,378						
F4	**Accessibility**		1	0,793	431,4	28	0,000	63,24%
SF18	Accessibility to airports	0,777						
SF19	Accessibility to seaports	0,875						
SF20	Accessibility to railways	0,665						
SF21	Accessibility to highways	0,700						
SF22	Accessibility to other facilities	0,731						
SF23	Accessibility to customers	0,606						
SF24	Transportation capacity between DP and Seaport	0,847						
SF25	Quality of network transportation infrastructure	0,763						
F5	**Operational**		1	0,810	221,6	15	0,000	74,33%
SF26	Set of operational services offered	0,789						
SF27	Container handling capacity (per day)	0,745						
SF28	Information and technology system	0,596						
SF29	Operational execution time	0,806						
SF30	Cargo security and monitoring	0,742						
SF31	DP's occupation (yard and warehouse)	0,689						
F6	**Economic**		1	0,781	126,6	6	0,000	78,63%
SF32	Gross Domestic Product (GDP) rate	0,848						
SF33	Dollar rate	0,646						
SF34	Trade market (export and import)	0,770						
SF35	Purchasing power of hinterland population	0,735						
F7	**Political and Social**		1	0,799	159,6	10	0,000	70,56%
SF36	Customs' rules	0,582						
SF37	Job creation	0,750						
SF38	Government financial incentive	0,757						
SF39	Political and business environment	0,861						
SF40	Bureaucracy for opening new companies and dry ports	0,653						
F8	**Environment**		1	0,799	243,7	6	0,000	86,01%
SF41	Urban and environmental impact due DP facility	0,812						
SF42	Noise reduction and visual impact in seaport cities	0,916						
SF43	Environmental politics	0,899						
SF44	Reduction of congestion and CO2 emission	0,845						

Source: This thesis (2022).

5.2.1 Hypothesis propositions

Recognizing, from the above discussion, the need for academic research, which develops a more structured view of these factors and sub-factors, we determined that through an Exploratory Factor Analysis (EFA) approach we would be able to test:

- H1: There are latent constructs that permit stakeholder views of dry port project risks to be presented within a clear factor structure.

Notably, relatively few articles were found in the literature that considered multi-stakeholder perspectives (JEEVAN; CHEN; CAHOON, 2019; NGUYEN; NOTTEBOOM, 2017, 2019; KWATENG; DONKOH; MUNTAKA, 2017). Indeed, a recent review conducted by Khaslavskaya and Roso (2020) has confirmed that dry port research predominantly comprises qualitative cases with some quantitative modeling and optimization studies, with very few publications undertaking surveys of multiple stakeholders and exploring differences found perspectives. Hence, we formulated two separate hypotheses pertaining to stakeholder incongruence as follows:

- H2.a: Factors and sub-factors vary by salience between key stakeholder groups.
- H2.b: Factors vary by salience within each key stakeholder group.

A further hypothesis was formulated, relating to varying dry port specifications. Dry ports differ by location, functionality, maturity level, ownership, and initiation processes (KHASLAVSKAYA; ROSO, 2020). To create a common factor structure covering all permutations, some authors have defined classification standards, as the dry port classification by distance stated before (ROSO; WOXENIUS; LUMSDEN, 2009). Recognizing this fundamental variation by dry port purpose, and further appreciating that risk factor saliences must inevitably vary by dry port purpose, we hypothesized further as follows:

- H3: Factors and sub-factors will vary by salience for close, midrange or long distance dry ports.

Despite the existence of an uncontroversial overarching definition for dry ports suggested by Roso, Woxenius and Lumsden (2009), emphasizing high capacity (mainly rail) connections to seaports, there remains no consensus about definitions for dry port sub-types. Following the previous discussion on dry port's classification by transportation mode, defining dry ports as unimodal, bimodal, and trimodal (bimodal and trimodal are bundled as multimodal) and recognizing this variation as likely to create varying management challenges, a further hypothesis we endeavored to test was:

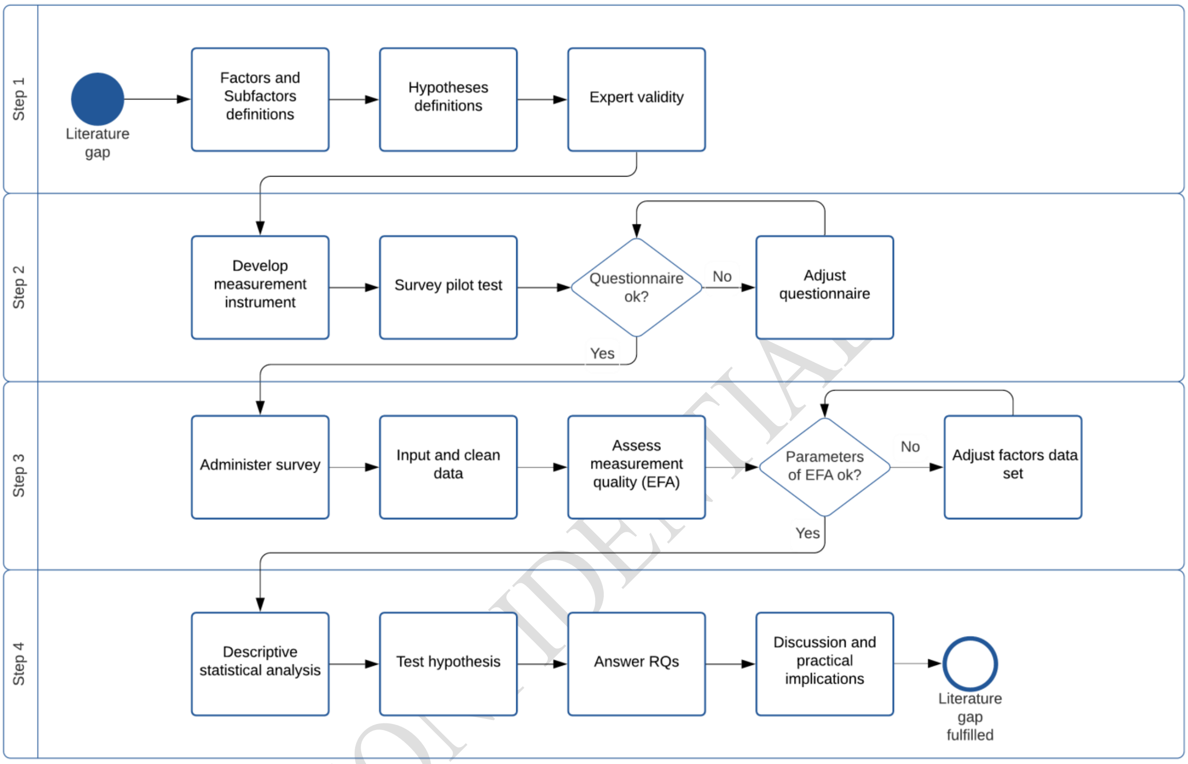
- H4: Factors and sub-factors will vary by salience for unimodal and multimodal dry ports.

The following section explains the research process of this chapter.

5.3 MATERIALS AND METHODS

We adopt the survey research process described by Flynn et al. (1990) and Forza (2002). This entails following the 4 main steps described in Figure 14.

Figure 14 – Steps of Chapter 5



Source: This thesis (2022).

5.3.1 Step 1 – literature research

The database of literature used to identify the (sub)factors was the 76 papers summarized in the systematic review detailed in Chapter 3, resulting in a list of 44 sub-factors. Upon consolidating the factors (44 sub-factors were aggregated into 8 general factors), it was deemed appropriate to seek some professional judgment on the appropriateness of the 8 factor solution. This was also deemed appropriate for the 5 hypotheses described above, and so the two consultative exercises were combined. This entailed contacting 6 senior managers in two Brazilian dry ports in August, 2019, the same specialists from the case studies in Chapter 4.

5.3.2 Step 2 – survey test

Step 2 comprised developing the measurement instrument and conducting pilot tests t. Two distinct pilot exercises were conducted in March 2020. First of all, senior managers with relevant experience and dry port management roles were contacted to ensure conceptual integrity for the 8 factor solution arising from the literature review. Then, students were contacted to test the reliability and validity characteristics of the research instrument.

The preliminary survey instrument was emailed to them as a Portuguese language questionnaire built using Google Forms. This employed a 5 point Likert-type scale spanning '0' (very low importance) and '5' (very high importance) (DU; ZHOU, 2019). Then, a small number of Doctoral and Masters Candidates in Brazil were contacted to ascertain feedback on the reliability and validity characteristics of the resulting research instrument. In total, 13 respondents made some helpful suggestions for refining the instrument, which was composed by 16 closed questions, requesting to the specialist to expose their relative importance perception of each risk factor, as follows in Appendix A.

5.3.3 Step 3 – data collection and EFA

Data collection was administered from March 9th to June 1th, 2020. The sample was divided into three groups of participants, following Nguyen and Notteboom (2016): (i) 'Dry ports operators' (DPOs), (ii) 'Customers', which includes shippers and forwarders and (iii) government entities in the form of the 'Federal Revenue Superintendence' (FRS). The basis of identifying three groups of stakeholders at transition phase are based in the fact that in Brazil, FRS regulates dry ports projects and operations (open and close) and DPOs operationalize the daily work and execute the transition phase from 'project' to 'operation'. At least, the customers are the final decision-maker, choosing the logistic operator to import and export. Sample characteristics are provided in Table 10.

Noting that there are 56 operational dry ports in Brazil, managed by 38 DPOs (RODRIGUES et al., 2021), the author emphasizes that all 38 DPOs were contacted. It was received 33 adequate answers from 26 DPOs (68% of the population). Assessing the representativeness of the dry port customers (shippers and forwarders) was more problematic.

There is, at present, no database in Brazil listing companies that use dry ports as logistics operators. Nonetheless, we engaged with using the dataset of 8,556 companies from CIB (2016) and Brazilian Suppliers (2020), a total of 1,385 e-mail accounts were harvested and used for contact purposes, eliciting 44 responses. Regarding the regulatory stakeholder input, the FRS in Brazil is divided into 10 macro regions for superintendence purposes. All were contacted by e-mail and 6 regional offices opted to participate.

Table 10 – Sample characteristic

Sample Characteristic		**DPO**	**Customer**	**FRS**	**Total**
Sample	Participants	33*	44	6	83
	Population	38	-	10	-
Actuation zone	South	7	34**	-	41
	Southeast	20	21**	3	44
	Northeast	6	13**	2	21
	North	-	9**	0	9
	Meddle-west	-	10**	1	12
Gender	Male	30	37	6	73
	Female	3	7	-	10
Age	More than 50 years	12	7	2	21
	Between 40-49 years	8	19	4	31
	Between 30-39 years	12	10	-	22
	Between 20-29 years	1	8	-	9
Experience	More than 20 years	15	18	4	37
	Between 15-19 years	8	9	-	17
	Between 10-14 years	4	7	2	13
	Between 5-9 years	3	5	-	8
	Between 0-4 years	3	5	-	8
Position	Owner	-	10	-	10
	CEO/Director	10	6	-	16
	Superintendent	-	-	6	6
	Top Manager	17	11	-	28
	Top Specialist	6	17	-	23
Educational Level	Post Graduated	21	25	3	49
	Graduated	10	19	3	32
	Other	2	-	-	2

*33 participants from 26 DPOs

**Customers act in many regions of the country

Source: This thesis (2022).

From Table 10, the major data are from South and Southeast zones (67%). Unsurprisingly, these are also the economic and population centers, where Brazil’s biggest seaports are concentrated. The sample is characterized by male gender (88%). Most are over 30 years old (89%). Most also have more than 10 years of experience (80%) as senior managers engaging with dry ports. Furthermore, 97% were graduates with experience of strategic management in general. After inputting the data, no missing values or outliers were identified. Step 3 entailed assessing the measurement quality of the questionnaire by assessing unidimensionality, reliability, validity and replicability, as follows.

5.3.4 Exploratory Factor Analysis (EFA)

Data analysis began by testing the following 8 factors for relative salience: ‘cost’ (F1), ‘location’ (F2), ‘infrastructure’ (F3), ‘accessibility’ (F4), ‘operational’ (F5), ‘economic’ (F6), ‘political and social’ (F7) and ‘environment’ (F8), in relation to dry port risk. For simplifying analysis purposes, we regarded our options as being to select among the three most widely used dimension-reduction techniques: Principal Component Analysis (PCA), Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) (ROUCOLLE; SEREGINA; URDANOZ, 2020). Many researchers mistakenly believe that PCA is a type of EFA when in fact these procedures are distinct statistical methods designed to achieve different objectives (FABRIGAR et al., 1999). PCA aims to explain most of the total variance observed in the dataset by a smaller set of new components, called principal components. The goal of EFA, by contrast, is to understand which factors (latent constructs) underlie the covariance between the original variables (ROUCOLLE; SEREGINA; URDANOZ, 2020).

Looking for the CFA, it’s similar to EFA in some respects, but philosophically it is quite different. While the EFA explores the data and provides information about how many factors are needed to best represent the data, with CFA, the researcher must specify both the number of factors that exist for a set of variables and which factor each variable will load on before results can be computed. So, CFA is applied to test the extent to which a researcher’s a-priori, theoretical pattern of factor loadings on pre-specified constructs represents the actual data. In a sense, CFA is a tool that enables to either “confirm” or “reject” the preconceived theory (HAIR et al., 2014).

As the factors considered in this chapter came from the literature of dry ports development, detailed in Chapter 3, there was no preconceived theory of factors structure from the view of risk to be confirmed. Furthermore, as the chapter’s aim was explicitly to define the structure of potential underlying latent variables so that managers might benefit from a clear specification of risk issues requiring attention from multiple stakeholder perspectives, an EFA approach was selected. A critical consideration, here, was that defining relevant factors necessarily supersede all ranking issues. Furthermore, EFA can be used for factor ranking purposes. Accordingly, EFA was performed using FACTOR 10.10.03 software. There is no literature consensus for EFA sample sizes. Recommendations range from 50 (WINTER; DODOU; WIERINGA, 2009) to 150-300 cases (HUTCHESON; SOFRONIOU, 1999). Situating the present research comfortably within this range, the author performed 8 EFAs with a sample of 83 top managers. Results were presented in Table 9.

The 8 factor model was then adjusted to fit the parameters described in the literature for guaranteeing validity, reliability and replicability of the constructs. First, the integrity of the 8 dimensions was assessed by Parallel Analysis (PA). This reaffirmed that the most plausible number of factors, using the very widely accepted eigenvalues-greater-than-1 rule (TIMMERMAN; LORENZO-SEVA, 2011), was indeed 8. Results presented in Table 9 attest to this. Secondly, to ensure suitability of sample size, the Kaiser-Meyer Olkin (KMO) test for sampling adequacy and Bartlett's Test of Sphericity were employed, which entailed disregarding p values below 0.05 (FIELD, 2013). Thirdly, factor loadings for the 44 sub-factors with weightings below 0.4 were excluded; loadings at or exceeding 0.71 were considered excellent, 0.63 very good, 0.55 good, 0.45 fair and 0.32 poor (TABACHNICK; FIDELL, 2007). Moreover, the 8 latent constructs satisfied the criterion of together explaining more than 60% of the total variance, as required by Hair et al. (2014).

The goodness of measures is mainly evaluated in terms of validity and reliability (FORZA, 2002). In testing the reliability of the scale, a Cronbach's alpha value exceeding the suggested minimum acceptable level of 0.5 indicates internal consistency and the acceptability of each construct, whereas a value exceeding 0.7 is considered good (HAIR et al., 2014). Construct Reliability (CR) higher than 0.7 also indicates internal consistency (HAIR et al., 2014). Construct validity was calculated by the test of Average Variance Extracted (AVE) higher than 0.5 (HAIR et al., 2014).

Uni-dimensionality was tested by Unidimensional Congruence (UniCo) larger than 0.95, Explained Common Variance (ECV) larger than 0.85 and Mean of Item Residual Absolute Loadings (MIREAL) lower than 0.3, using FACTOR software (FERRANDO; LORENZO-SEVA, 2017). Construct replicability was measured by H-Index (HANCOCK; MUELLER, 2000), that evaluates how well a set of items represents a common factor, with high H values (> 0.80) suggesting a well-defined latent variable that is more likely to be stable across studies.

The EFAs were performed with Polychoric Correlations due the ordinal Likert scale of inputs. The method selected for factor extraction was Robust Diagonally Weighted Least Squares (RDWLS). The first run of EFAs resulted in ‘multimodal infrastructure’ (SF16) and ‘facility equipment’ (SF17) with factor loadings below 0.4 in the parent ‘infrastructure’ domain (F3). Hence, these were excluded. The AVE, UniCo and ECV were lower than the boundaries in ‘location’ (F2), and therefore the ‘size of hinterland population’ (SF10) was also excluded. The ECVs in F1, F4 and F5 were very close to the boundaries. However, the other parameters of unidimensionality worked well, and so the authors did not exclude any further sub-factors. In the second run following these exclusions, the factor loading for SF16 fell below 0.4 and was therefore excluded. The AVE for F2 then fell below 0.5, entailing that ‘demand for dry port services’ (SF6) was also excluded. In the third run of EFA, all sub factors loaded> 0.5; KMO > 0.65; Bartlett’s sphericity $p < 0.05$; as indicated in Table 9.

Further statistics for the factor solution were explained variance > 60%; Cronbach's alpha > 0.7; CR > 0.7; AVE > 0.5; uni-dimensionality index (UniCo, ECV and MIREAL) and H-index > 0.8. To assess the model’s goodness of fit we used the Comparative Fit Index (CFI), considered by Hair et al. (2014) as the most widely used fit index. The CFI was found to be > 0.90. Summing up, the statistics for each of the above variables are presented for each of our 8 factors below in Table 11. Taken together, the following 8 unidimensional factors are, in effect, aggregations of the 40 sub-factors that we retained for our analysis, after jettisoning our 4 most poorly performing sub-factors.

Table 11 – EFA boundaries

Code	Factors	Cronbach's alpha	CR	AVE	UniCo	ECV	MIREAL	H-INDEX	CFI
F1	Cost	0,804	0,859	0,561	0,965	0,846	0,239	0,927	1,003
F2	Location	0,757	0,808	0,515	0,978	0,873	0,235	0,816	1,013
F3	Infrastructure	0,827	0,891	0,678	0,990	0,899	0,237	1,000	0,998
F4	Accessibility	0,860	0,910	0,563	0,955	0,847	0,258	0,924	0,981
F5	Operational	0,798	0,872	0,535	0,948	0,831	0,225	0,881	1,006
F6	Economic	0,804	0,839	0,567	0,983	0,893	0,207	0,855	1,002
F7	Political and Social	0,788	0,846	0,528	0,979	0,866	0,274	0,871	0.986
F8	Environment	0,891	0,925	0,755	0,988	0,897	0,243	0,933	0,999

Source: This thesis (2022).

5.3.5 Step 4 – Statistical results and analysis

Step 4 concluded this chapter approach with analysis of results and discussion. First, a descriptive statistical analysis was performed to identify the mean, median, variance and standard deviation of the sample. Second, and recognizing that H1 had already been addressed through the 8 factor solution, the remaining hypotheses were tested in IBM SPSS® 1.0.0.1327 software. As Likert-type scales are ordinal (WU; LEUNG, 2017), these hypothesis tests were performed non-parametrically; however, recognizing that some authors consider it reasonable to calculate means rankings by using Likert-type scales as interval scales (FORZA, 2002; FLYNN et al., 1990), this was also undertaken. To test H2.a and H2.b, Kruskal-Wallis 1-way tests were performed for 3 groups (Customers, DPO and FRS), followed by post hoc tests with Bonferroni correction, for reducing type 1 error. To answer H3 and H4, a 'U' test (Mann-Whitney) explored differing DPO perceptions by dry port classification. The sample comprised 20 close dry ports vs 13 midrange or long distance dry ports, by distance classification, and 26 unimodal vs 7 multimodal dry ports, by multimodality classification. The significance level for all tests was 0.05 in the bi-tailed tests. In view of the confirmation of all the hypotheses, the article had already achieved a significant part of its research ambition; however, what remained was a richer and more qualitative engagement with the RQ which further explores and discusses theoretical and practical implications in terms of specific factor weightings and stakeholder differences. Furthermore, the subjectivity in risk perceptions vis a vis the causal interrelationships between many risk factors, as might be captured within a comprehensive 'risk map', were not considered in the risk factor/statistical analysis.

5.4 RESULTS

Of critical importance, within the present research, are the 8 latent constructs and their relative importance. To reiterate, testing parameters by measuring reliability, validity and replicability, as described above, supported H1. A convenient visualization, juxtaposing and ranking the 8 factors, further structuring the 40 sub-factors around these, follows in Figure 15, to nuance this 8 factor solution further, by stakeholder. Table 12 will later provide the main statistic parameters for each factor and sub-factor by stakeholder.

Figure 15 – Factors and sub factors structure from EFA

Source: This thesis (2022).

Table 12 – Descriptive statistics

	Customer				DPO				FRS			
Factors	Mean	Median	Variance	Sd	Mean	Median	Variance	Sd	Mean	Median	Variance	Sd
F1	3,705	4,000	0,446	0,668	3,606	4,000	0,309	0,556	2,333	2,000	1,067	1,033
SF1	2,955	3,000	1,207	1,099	3,182	3,000	0,591	0,769	2,167	2,000	1,367	1,169
SF2	3,409	4,000	0,712	0,844	3,091	3,000	0,960	0,980	2,333	3,000	2,267	1,506
SF3	3,568	4,000	0,484	0,695	3,121	3,000	0,922	0,960	2,833	3,000	1,367	1,169
SF4	3,136	3,000	0,958	0,979	2,758	3,000	1,189	1,091	1,833	2,000	1,767	1,329
SF5	2,523	3,000	1,930	1,389	2,333	2,000	1,792	1,339	2,000	1,500	2,800	1,673
F2	3,364	3,500	0,516	0,718	3,455	4,000	0,506	0,711	3,333	3,000	0,267	0,516
SF6	-	-	-	-	-	-	-	-	-	-	-	-
SF7	2,841	3,000	1,393	1,180	2,818	3,000	0,841	0,917	2,667	2,500	1,467	1,211
SF8	2,636	3,000	1,725	1,313	2,818	3,000	0,778	0,882	2,167	2,500	2,167	1,472
SF9	2,864	3,000	1,097	1,047	2,364	2,000	0,801	0,895	1,833	2,000	1,367	1,169
SF10	-	-	-	-	-	-	-	-	-	-	-	-
SF11	3,205	4,000	0,957	0,978	3,152	3,000	0,633	0,795	2,000	1,500	2,800	1,673
F3	3,409	4,000	0,480	0,693	3,424	4,000	0,502	0,708	3,667	4,000	0,267	0,516
SF12	2,568	3,000	0,949	0,974	2,879	3,000	0,672	0,820	2,833	3,000	0,567	0,753
SF13	2,773	3,000	0,784	0,886	2,758	3,000	0,689	0,830	3,000	3,000	0,400	0,632
SF14	2,932	3,000	0,902	0,950	3,152	3,000	0,695	0,834	3,167	3,000	0,567	0,753
SF15	2,364	2,000	1,353	1,163	2,818	3,000	0,903	0,950	2,333	2,000	1,067	1,033
SF16	-	-	-	-	-	-	-	-	-	-	-	-
SF17	-	-	-	-	-	-	-	-	-	-	-	-
F4	3,295	3,500	0,632	0,795	3,121	3,000	0,610	0,781	2,833	3,000	0,167	0,408
SF18	2,909	3,000	1,061	1,030	3,091	3,000	0,960	0,980	2,000	2,000	1,200	1,095
SF19	3,205	3,500	0,957	0,978	3,303	3,000	0,655	0,810	2,333	2,500	1,867	1,366
SF20	2,273	2,000	1,784	1,336	2,485	2,000	1,195	1,093	1,167	1,000	0,567	0,753
SF21	3,295	3,000	0,585	0,765	3,636	4,000	0,239	0,489	2,667	2,500	0,667	0,816
SF22	2,159	2,000	1,579	1,256	2,212	2,000	0,922	0,960	0,833	1,000	0,567	0,753
SF23	3,205	3,000	0,818	0,904	3,121	3,000	0,672	0,820	2,500	2,500	1,100	1,049
SF24	3,091	3,000	1,294	1,137	3,273	3,000	0,642	0,801	2,500	3,000	1,900	1,378
SF25	3,250	3,000	0,657	0,811	3,030	3,000	0,593	0,770	2,500	3,000	1,500	1,225
F5	3,386	4,000	0,568	0,754	3,455	4,000	0,381	0,617	3,333	3,000	0,267	0,516
SF26	3,364	3,500	0,516	0,718	3,485	4,000	0,320	0,566	2,833	2,500	0,967	0,983
SF27	3,068	3,000	0,763	0,873	2,939	3,000	0,746	0,864	2,667	2,500	0,667	0,816
SF28	3,000	3,000	0,930	0,964	2,909	3,000	0,960	0,980	3,333	3,500	0,667	0,816
SF29	3,432	4,000	0,763	0,873	3,455	3,000	0,256	0,506	3,333	3,000	0,267	0,516
SF30	3,523	4,000	0,488	0,698	3,515	4,000	0,445	0,667	3,833	4,000	0,167	0,408
SF31	2,705	3,000	0,818	0,904	2,939	3,000	0,871	0,933	2,500	2,500	1,100	1,049
F6	3,318	3,000	0,455	0,674	3,212	3,000	0,672	0,820	2,833	2,500	0,967	0,983
SF32	2,159	2,000	1,439	1,200	3,333	4,000	0,604	0,777	2,500	3,000	3,100	1,761
SF33	2,909	3,000	1,666	1,291	3,212	3,000	0,735	0,857	2,167	2,000	1,767	1,329
SF34	2,818	3,000	1,548	1,244	3,515	4,000	0,383	0,619	3,167	3,500	0,967	0,983
SF35	1,614	2,000	1,173	1,083	2,364	2,000	0,864	0,929	1,667	1,500	1,467	1,211
F7	2,182	2,000	1,036	1,018	2,242	2,000	0,814	0,902	1,667	2,000	1,067	1,033
SF36	3,432	4,000	0,670	0,818	3,455	4,000	0,631	0,794	3,833	4,000	0,167	0,408
SF37	2,364	2,000	1,307	1,143	2,455	3,000	0,693	0,833	1,833	2,000	0,967	0,983
SF38	2,614	3,000	1,638	1,280	2,333	2,000	1,604	1,267	1,500	1,500	1,900	1,378
SF39	2,614	3,000	1,033	1,017	2,636	3,000	1,114	1,055	2,167	3,000	1,767	1,329
SF40	2,682	3,000	1,571	1,253	2,788	3,000	1,360	1,166	2,333	2,000	1,067	1,033
F8	2,364	2,000	1,586	1,259	2,394	2,000	0,934	0,966	1,667	2,000	0,267	0,516
SF41	2,409	2,000	1,689	1,300	2,364	3,000	0,864	0,929	2,333	2,000	0,267	0,516
SF42	2,159	2,000	1,532	1,238	2,303	2,000	1,155	1,075	1,167	1,000	0,567	0,753
SF43	2,523	2,500	1,558	1,248	2,424	3,000	1,002	1,001	1,500	2,000	0,700	0,837
SF44	2,545	3,000	1,649	1,284	2,182	2,000	1,653	1,286	1,167	1,000	0,567	0,753

Source: This thesis (2022).

Once more, to reiterate, to test H 2.a, Kruskall-Wallis test had produced a positive result. Accordingly, varying saliences of the 8 factors, by stakeholder, follow in Appendix B. Summing up, essentially what Appendix B shows is that there are statistically significant differences among stakeholders in ‘cost’ (F1) and in 10 SFs: SF3, SF4, SF9, SF20, SF21, SF22, SF32, SF34, SF35, SF44. A post-hoc test was also carried out to highlight significant differences, as summarized below in Table 13. From this post-hoc (p-value) analysis, the major difference arising is between FRS and Customer perspectives. They disagreed on 9 SFs and on F1. By contrast, DPO and Customer groups presented differences on only 2 sub-factors: ‘storage cost’ (SF3) and ‘proximity with other logistic facilities’ (SF9). Similarly, the FRS and DPO stakeholder groups disagreed on just 2 SFs: ‘accessibility to railways’ (SF20) and ‘accessibility to other facilities’ (SF22), and to some extent on F1. Also worth noting here, and highlighted within Table 13 below, is that following Bonferoni’s correction, SF3 and SF9 didn’t present significant statistical differences, indicating they should be excluded from the final analysis and discussion.

Table 13 – Kruskall-Wallis and post-hoc results for hypothesis H 2.a

	Kruskall-Wallis result (p-value)		**Post Hoc (p-value)**			**Bonferoni’s correction (p-value adjusted)**		
Factors	p-value	Decision	FRS - DPO	FRS - Customer	DPO - Customer	FRS - DPO	FRS - Customer	DPO - Customer
SF3	0,028	Reject null hypothesis	0,578	0,071	0,020	1,000	0,214	0,059
SF4	0,023	Reject null hypothesis	0,103	0,011	0,101	0,310	0,034	0,304
SF9	0,022	Reject null hypothesis	0,358	0,035	0,027	1,000	0,105	0,081
SF20	0,040	Reject null hypothesis	0,027	0,011	0,480	0,081	0,034	1,000
SF21	0,011	Reject null hypothesis	0,064	0,005	0,062	0,192	0,016	0,186
SF22	0,021	Reject null hypothesis	0,009	0,006	0,779	0,026	0,019	1,000
SF32	0,000	Reject null hypothesis	0,366	0,000	0,192	1,000	0,000	0,577
SF34	0,036	Reject null hypothesis	0,578	0,010	0,429	1,000	0,030	1,000
SF35	0,008	Reject null hypothesis	0,853	0,002	0,160	1,000	0,007	0,481
SF44	0,031	Reject null hypothesis	0,068	0,011	0,204	0,204	0,034	0,611
F1	0,001	Reject null hypothesis	0,003	0,000	0,231	0,009	0,001	0,694

Source: This thesis (2022).

The second hypothesis tested (H 2.b) strove to produce a ranking order of factors by stakeholder group. The null hypothesis performed by Kruskall-Wallis was F1=F2=F3=F4=F5=F6=F7=F8, which was rejected for all groups as follows: ($X^2(7) = 81.713$, $p < 0.000$ for Customer; $X^2(7) = 70.904$, $p < 0.000$ for DPO; $X^2(7) = 25.759$, $p < 0.001$ for FRS). To identify remaining statistical differences, a post-hoc test was performed, with results provided below in Table 14. There were 28 pairwise comparisons in this post-hoc test, which increased probabilities of type I errors. Results with adjusted p-value through Bonferoni's correction < 0.05 are highlighted in grey, indicating rejection of null hypothesis and significant stakeholder differences in each case. Moreover, Table 14 findings also highlight similarities between Customer and DPO perspectives, boding well for shared risk management agendas.

Table 14 – Results of post-hoc testes for H2.b

Null Hypothesis	Customer		DPO		FRS	
	p-value	Adjusted p-value	p-value	Adjusted p-value	p-value	Adjusted p-value
F1=F2	**0,032**	0,902	0,479	1,000	0,059	1,000
F1=F3	0,057	1,000	0,375	1,000	**0,012**	0,331
F1=F4	**0,015**	0,426	**0,014**	0,392	0,358	1,000
F1=F5	0,052	1,000	0,401	1,000	0,059	1,000
F1=F6	**0,013**	0,362	0,055	1,000	0,393	1,000
F1=F7	0,000	0,000	0,000	0,000	0,364	1,000
F1=F8	0,000	0,000	0,000	0,000	0,230	1,000
F2=F3	0,809	1,000	0,858	1,000	0,531	1,000
F2=F4	0,775	1,000	0,080	1,000	0,331	1,000
F2=F5	0,843	1,000	0,895	1,000	1,000	1,000
F2=F6	0,731	1,000	0,226	1,000	0,300	1,000
F2=F7	0,000	0,000	0,000	0,000	**0,005**	0,144
F2=F8	0,000	0,002	0,000	0,000	**0,002**	0,056
F3=F4	0,598	1,000	0,117	1,000	0,110	1,000
F3=F5	0,965	1,000	0,962	1,000	0,531	1,000
F3=F6	0,558	1,000	0,303	1,000	0,096	1,000
F3=F7	0,000	0,000	0,000	0,000	0,001	0,017
F3=F8	0,000	0,001	0,000	0,000	0,000	0,006
F4=F5	0,629	1,000	0,106	1,000	0,331	1,000
F4=F6	0,954	1,000	0,591	1,000	0,948	1,000
F4=F7	0,000	0,000	0,000	0,010	0,068	1,000
F4=F8	0,000	0,008	**0,004**	0,099	**0,034**	0,957
F5=F6	0,588	1,000	0,281	1,000	0,300	1,000
F5=F7	0,000	0,000	0,000	0,000	**0,005**	0,144
F5=F8	0,000	0,001	0,000	0,000	**0,002**	0,056
F6=F7	0,000	0,000	0,000	0,001	0,078	1,000
F6=F8	0,000	0,009	0,001	0,016	**0,040**	1,000
F7=F8	0,207	1,000	0,512	1,000	0,770	1,000

Source: This thesis (2022).

Recognizing the above differences, it now became appropriate to summarize stakeholder differences in factor rankings in Table 15, below. This, it was considered, might provide considerable practical assistance to project risk managers wishing to sensitize themselves to stakeholder differences of outlook that might obstruct collaborative project risk management. Summarizing this, and as mentioned earlier, Customer and DPO views are largely congruent insofar as for both, 'cost' (F1) was considered the most relevant factor, while 'political and social' (F7) as well 'environment' (F8) were considered the least important. Notably, this shared perspective elevates particular over fundamental risk. For the FRS stakeholder group, by contrast, 'infrastructure' (F3) was considered the most important factor, thus revealing the general focus of their regulatory effort. Table 15 also further provides sub-factor rankings. For Customers, 'storage cost' (SF3), 'cargo security and monitoring’ (SF30), ‘operational execution time’ (SF29) and ‘customs' rules’ (SF36) were considered the most salient. For DPOs, ‘accessibility to highways’ (SF21), ‘cargo security and monitoring’ (SF30), ‘trade market’ (SF34) and the ‘set of operational services offered’ (SF26) emerged as the most prominent sub-factors, clearly reflecting the hands-on management view.

Table 15 – Ranking of factors and sub-factors by stakeholder group

	Customer				**DPO**				**FRS**			
Rank	Factor		Sub-factor		Factor		Sub-factor		Factor		Sub-factor	
1	F1	3,705	SF3	3,568	F1	3,606	SF21	3,636	F3	3,667	SF30	3,833
2	F3	3,409	SF30	3,523	F2	3,455	SF30	3,515	F2	3,333	SF36	3,833
3	F5	3,386	SF29	3,432	F5	3,455	SF34	3,515	F5	3,333	SF28	3,333
4	F2	3,364	SF36	3,432	F3	3,424	SF26	3,485	F4	2,833	SF29	3,333
5	F6	3,318	SF2	3,409	F6	3,212	SF29	3,455	F6	2,833	SF14	3,167
6	F4	3,295	SF26	3,364	F4	3,121	SF36	3,455	F1	2,333	SF34	3,167
7	F8	2,364	SF21	3,295	F8	2,394	SF32	3,333	F7	1,667	SF13	3,000
8	F7	2,182	SF25	3,250	F7	2,242	SF19	3,303	F8	1,667	SF3	2,833
9			SF11	3,205			SF24	3,273			SF12	2,833
10			SF19	3,205			SF33	3,212			SF26	2,833
11			SF23	3,205			SF1	3,182			SF7	2,667
12			SF4	3,136			SF11	3,152			SF21	2,667
13			SF24	3,091			SF14	3,152			SF27	2,667
14			SF27	3,068			SF3	3,121			SF23	2,500
15			SF28	3,000			SF23	3,121			SF24	2,500

Source: This thesis (2022).

Looking in more detail, Table 15 also reveals some further important stakeholder similarities and differences. ‘Transportation cost’ (SF2) and ‘quality of network transportation infrastructure’ (SF25) are paramount only for Customers; ‘dollar rate’ (SF33) and ‘facility cost’ (SF1) only for DPOs; ‘dry ports’ total area’ (SF12) and ‘dry ports’ yard capacity’ (SF13) only for FRS. Looking more closely within F1 (‘Cost’), it can be seen that ‘storage cost’ (SF3) is the most important for the Customer and FRS groups, while, understandably, for DPOs it was ‘facility cost’ (SF1). For F2 (‘Location’), ‘cargo transportation time’ (SF11) was the most relevant for Customers and DPOs, while ‘distance between dry port and customers’ (SF7) is paramount for the FRS. For F3 (‘Infrastructure)’, F4 (‘accessibility’) and F5 (‘operational’), it can be seen that for all stakeholders, the rank order of ‘dry ports' warehouse capacity’ (SF14), then ‘accessibility to highways’ (SF21) and then ‘cargo security and monitoring’ (SF30) are paramount. For F6 (‘Economic’), it can be seen that ‘trade market’ (SF34) is paramount for DPO and FRS stakeholders, while ‘dollar rate’ (SF33) is paramount for Customers. For F7 (‘Political and social’) all stakeholders agree that ‘customs’ rules’ (SF36) are paramount, and, we can further speculate, perhaps how social and political factors are most likely to manifest and impact dry ports.

Finally, for (F8) 'Environment', DPOs and FRS stakeholders highlighted 'urban and environmental impacts due to dry port facility operations' (SF41) as most important, while for Customers the 'reduction of congestion and CO2 emissions' (SF44) was the chief consideration. Of particular interest, however, summing up Table 15, is that for all stakeholders, 'operational factors' (F5) are ranked third. Prima facie, the significance of this may not be apparent. However, a case may be made that collaborative project risk management meetings might usefully focus on these risk issues first. This may be a viable means to ensure the meetings proceed with a positive tone through early assertions of homophily. That is, with tabled management issues likely to elicit commonalities of outlook that can help build stakeholder trust and goodwill, placed before management issues that are more likely to divide opinions and therefore perhaps undermine such benefits.

Looking more closely at factor and sub-factor analysis for different types of dry port, specifically in relation to H3 and H4, two Mann-Whitney tests ('U' test) were performed to identify if there are statistical differences of importance level between dry ports classified as 'unimodal' and 'multimodal', as well as for dry port variance along the 'close', 'midrange' and 'long distance' axis. Results presented in Table 16 revealed that only 'accessibility to highways' (SF21) and 'urban and environmental impact due dry port facility operations' (SF41) presented statistically significant differences, when comparing dry ports by distance parameters (with significances levels better than 0.05). This outcome entailed rejecting only two sub-factors in H3 and supporting all of them in H4. Relaxing the significance level still further to 0.1, some further sub-factors did vary by distance parameter (SF19, SF25, SF26, SF35) and by 'transportation mode parameter' (SF8). These various sub-factors do arguably deserve some limited attention but, crucially, do not impede general statements of findings covering dry ports of all modality and distance parameter permutations. Full results of the 'U' tests follow in Appendix B, with above mentioned key findings summarized below for convenience in Table 16.

Table 16 – Mann-Whitney rejected hypotheses (H3 and H4)

Dry Ports' sub-factors by distance			Dry Ports' sub-factors by transportation mode		
Factors	p-value	Decision	Factors	p-value	Decision
SF19	0,068	Support null hypothesis	SF8	0,074	Support null hypothesis
SF21	0,048	Reject null hypothesis			
SF25	0,094	Support null hypothesis			
SF26	0,080	Support null hypothesis			
SF35	0,087	Support null hypothesis			
SF41	0,048	Reject null hypothesis			

Source: This thesis (2022).

Table 17 further confirms the appropriateness of general findings, by summarizing the average ranking of factors and sub-factors by each kind of dry port. Comparing ‘close’ ‘midrange’ and ‘long distance’ dry ports, ‘accessibility to highways’ (SF21), ‘set of operational services offered’ (SF26) and ‘cargo security and monitoring’ (SF30), are highlighted as more important for ‘close’ dry ports, while for ‘midrange’ and ‘long distance’ dry ports, ‘customs' rules’ (SF36), ‘operational execution time’ (SF29) and ‘trade market’ (SF34) headed the ranking. The major average differences are seen to pertain to the most important sub-factors (SF21, SF26 and SF36), with weighting differences of 0.419, 0.415, 0.392 for ‘close’ ‘midrange’ and ‘long distance’ parameters. Also notable is that ‘accessibility to seaports’ (SF19) and ‘storage cost’ (SF3) only show significant variation for ‘close’ dry ports, while ‘dry port warehouse capacity’ (SF14) and ‘cargo transportation time’ (SF11) show significant variation only for ‘midrange’ and ‘long distance’ dry port permutations.

Clearly, for all three distance permutations, F1 is paramount and F2, F3 and F5 follow closely, all towards the top of the three rank orders. This strongly reinforces the primacy of cost factors within the general findings, and indeed the criticality towards the top of the list of F5 (operations) sub-factors for all stakeholders.

Table 17 – Rank of factors and sub-factors by classification of DPO

	Close				**Midrange and Long Distance**				**Unimodal**				**Multimodal**			
Rank	Factor		Sub-factor		Factor		Sub-factor		Factor		Sub-factor		Factor		Sub-factor	
1	F1	3,70	SF21	3,80	F1	3,46	SF36	3,69	F1	3,62	SF21	3,62	F1	3,57	SF21	3,71
2	F5	3,50	SF26	3,65	F2	3,46	SF29	3,54	F2	3,50	SF30	3,62	F3	3,57	SF11	3,57
3	F2	3,45	SF30	3,60	F3	3,46	SF34	3,46	F5	3,42	SF34	3,54	F5	3,57	SF29	3,57
4	F3	3,40	SF19	3,55	F6	3,46	SF21	3,38	F3	3,38	SF26	3,50	F6	3,43	SF33	3,57
5	F4	3,25	SF34	3,55	F5	3,38	SF30	3,38	F6	3,15	SF29	3,42	F2	3,29	SF36	3,57
6	F6	3,05	SF24	3,40	F4	2,92	SF32	3,38	F4	3,08	SF36	3,42	F4	3,29	SF14	3,43
7	F8	2,60	SF29	3,40	F7	2,23	SF1	3,31	F8	2,50	SF32	3,35	F7	2,29	SF24	3,43
8	F7	2,25	SF3	3,30	F8	2,08	SF14	3,31	F7	2,23	SF19	3,31	F8	2,00	SF26	3,43
9			SF32	3,30			SF33	3,31			SF24	3,23			SF34	3,43
10			SF36	3,30			SF11	3,23			SF1	3,19			SF19	3,29
11			SF18	3,25			SF26	3,23			SF3	3,15			SF23	3,29
12			SF2	3,20			SF23	3,15			SF33	3,12			SF32	3,29
13			SF25	3,20			SF7	3,08			SF2	3,08			SF1	3,14
14			SF33	3,15			SF24	3,08			SF14	3,08			SF2	3,14
15			SF1	3,10			SF31	3,00			SF18	3,08			SF15	3,14

Source: This thesis (2022).

5.5 DISCUSSION

Generally speaking, the above findings detail how the represented stakeholder groups differently perceive and weight risk. The findings may serve as a touchstone, this chapter concludes, to help guide conceivably any instances of collaborative stakeholder interaction on dry port projects, certainly in Brazil and also, conceivably, further afield. Firstly, and most obviously, they provide valuable intelligence on what risks stakeholders are most likely to want to see addressed in meetings by one another. Expressions of sensitivity to these stakeholder concerns, extending to include proactive effort within stakeholder-collaborative management meetings to test, probe and better understand these concerns can, we would suggest, build stakeholder trust and good will, and enrich any risk discussion to ensure greater thoroughness in the range of risks addressed and understood by all participating stakeholders.

Secondly, and just as importantly, the above findings are significant by drawing attention to the risks which stakeholders are more likely to de-prioritise. This information also offers managerial value by calling attention to possible risk blindspots that may turn out to matter at points of transition to operations in particular. Such possible blindspots have become visible in this chapters' findings in two forms: (i) low weighted risks for particular stakeholders and (ii) incongruences between particular stakeholders which can be explored for any cross-cutting risks whose managerial neglect might count as tragedies of the commons in the absence of clear lines of risk ownership. This section will now apply this general interpretive framework to more detailed discussion of findings below.

Consider, firstly, that overall stakeholder congruence for factor rankings is strong, especially for DPOs and their customers, and to a lesser extent between DPOs and regulators. This implies a strong element of common ground for addressing risk within varied contexts of stakeholder-collaborative management. However, there is also a notable hiatus between customers and the regulator. This may imply a risk blindspot characterized by some lack of regulatory attunement to the customer experiences that ultimately determine how successful dry ports become.

One debating point arising is that this could have implications for regulatory practice. Perhaps Brazil's dry port regulatory stakeholder should make greater use of regulatory impact assessments focused on customer costs issues in particular. After all, regulatory practice around the world has, in recent years, moved towards politico-technical stances which acknowledge the burdens that regulators themselves impose, as is manifest within growing use of regulatory impact assessments for new items of regulation. Arguably this is no bad thing where it leads to a more balanced appreciation of regulatory costs and benefits. Looking at this issue through an operational readiness lens concerned to reduce risk blindspots, might simply entail a stronger regulatory focus on fostering customer experiences at points of transition to operations, aimed at giving confidence that everything possible has been done to ensure that costs become sustainably affordable for customers.

To a lesser degree, similar arguments can be made, based on the findings, regarding how DPOs might focus more on the customer perspective and its associated risks, both within project risk management generally and when managing for operational readiness transitions in particular. Recognizing the strong ranking congruence of DPOs and their customers which can be construed as affording these stakeholders strong common ground for collaborative management, it was nonetheless the case that ‘proximity with other logistics facilities’ (SF9) and ‘storage cost’ (SF3) presented statistical differences; the latter being the most important sub-factor from the customer perspective. This result aligns to one of the main dry port challenges cited in the literature: that of whether and to what extent they can succeed by charging lower storage prices than seaports, considering high customer demand for long-term storage in particular (QIU; LAM; HUANG, 2015). Arguably, and especially in the light of our findings, these two particular stakeholders would be well advised to focus their risk discussions around how they might collaboratively address the risks associated with this challenge.

A critical DPO – customer congruence is, of course, that ‘cost’ emerges from the research as the key factor for both stakeholders. This agrees well with the literature (CHANG; NOTTEBOOM; LU, 2015; LIRN; WONG, 2013). The strongest emphasis on ‘cost’ is, however, expressed by customers in particular. This is consistent with literature emphasizing that customers are strongly focused on reducing total logistics costs (CHANG; NOTTEBOOM; LU, 2015; NGUYEN; NOTTEBOOM, 2016). This indicates that these two stakeholders may be predisposed to collaborate in the above risk discussions by agreeing to look through the financial risk lens which is salient for both of them – and yet this can also be understood as suggesting non-financial risk as a blindspot in its own right. The point is, the chapter interpretive framework, in the light of the findings, invites critical thinking about this possibility.

More fully, the author consider it important to affirm that in our theoretical emphasis on operational readiness over and above project risk management in general, the concern has been to promote a thoroughness in risk management effort which recognizes that even the slightest possible risk blindspot might easily be the one that turns out to matter most at critical points of transition to operations. Correspondingly, we need to be clear that the primacy of 'cost' as a risk factor across the represented stakeholder groups should not be taken to imply that other types of factor within our 8 factor solution are of lesser importance. Rather, it simply means that these are viewed as being managerially more significant in terms of their cost impacts. This further implies that what managers are doing, when they emphasize cost, is expressing a management framing, which is preferred for purposes of practical management simplification within complex multifactor risk environments and associated collaborative management contexts.

Looking beyond 'cost', it is also notable that DPOs emphasize 'accessibility to highways' (SF21) as the sub-factor with higher importance level. This contrasts with what is more normal within developed countries, where railway accessibility to gateway seaports is at the heart of the functioning and development of dry ports (RODRIGUE; NOTTEBOOM, 2012; JEEVAN et al., 2017). Hence it indicates a need for caution when generalizing findings beyond Brazil, where, distinctively, inter-modality has been poorly developed and there has been almost no use of rail for container transportation, while high-capacity road corridors have tended to prove insufficient to meet customer demand for higher volumes to be handled (PADILHA; NG, 2012). Accordingly, some authors have pointed to the lack of rail infrastructure as a key challenge for dry port implementation (ROSO, 2008; KWATENG; DONKOH; MUNTAKA, 2017).

Further grounds for caution when generalizing findings beyond Brazil are as follows. It is very notable that all stakeholders relegated 'political and social' (F7) and 'environment' (F8) factors to the bottom of their factor rankings. This conflicts with some literature on dry port implementation within developed countries which engages strongly with these factors in their representations of the management challenges (ROSO, 2008; NÚÑEZ et al., 2016; BLACK et al., 2018; KHASLAVSKAYA; ROSO, 2020). This has important implications, the author contends, for how dry port managers should forecast their changing risk environments as their operations grow and mature.

5.6 REMARKS

Economies around the world are looking for supply-chain optimization strategies to permit them to be more competitive amidst extreme global competition. This of itself creates a rationale for nationally orchestrated collaborative stakeholder participation within the project risk management of dry ports, commencing from before project inception and extending into ongoing operations. This Chapter concludes by emphasizing that a critical concern with the significance of cost-framing as a focus for collaborative project risk management is warranted, for dry port projects. This requires much critical nuance. In the present Brazilian case, for example, on the one hand there is perhaps a danger of overemphasis, involving relative neglect of environmental risks, and on the other hand focusing more on some costs might prove valuable, as the author has argued as suggestion of how regulatory impact assessment might be used to help the regulator take the customer cost view.

In narrower terms of our more academic-theoretical contribution, this chapter offers a set of factors and sub-factors for assessing dry port risks in a unidimensional, reliable and replicable framework, derived using Exploratory Factor Analysis. The resulting set of 8 main factors and 40 sub-factors could, the author suggests, be applied in other countries to assess the risk of dry ports projects, while being careful to nuance variations for national conditions.

6 RISK FACTORS INTERDEPENDENCE IN DRY PORTS PROJECTS

A reviewed version of the paper:

RODRIGUES, T.; OJIAKO, U.; MOTA, C.; MARSHALL, A.; DWEIRI, F. The interdependence of key risk factors impacting the success of dry ports 'project'-to-'operations' phase transitions. Under review.

6.1 CONTEXTUALIZATION

Reflecting on specific financing considerations (WANG; CHEN; HUANG, 2018), as well as design, and maintenance challenges faced by dry ports, the literature presents a picture of substantial failure to successfully manage their 'project'-to-'operations' transitions phases. Much of this failure appears to relate to the opacity and complex risk interrelatedness or interdependence, a substantial proportion of which might not be anticipated and planned for in early stages of operations, and which can also be generated through risk management activity at any stage. Such 'risk reflexivity' is arguably best regarded as continually arising amidst ongoing management adjustment to changing circumstances, and as threatening to impact not only phase transitions to operations but also ongoing operations themselves. Simply put, scope for successful ongoing operations can therefore be regarded as path-dependent on earlier successful risk management effort.

Recognizing that phase transitions are often theorized with a forward-looking temporal focus on the first day of operations, a key concern that has arisen within the literature is that of how best to ensure that the phase transition risk that gets managed is not just 'abstract' but also 'concrete' in character. Drawing from Marshall et al. (2019), this concern implies that for the purpose of this chapter, risk factors are representative of more than simply theoretical and abstract risk that can be imagined. Instead, these risk factors represent 'concrete' management knowledge arising through lived management experience, in order words; real, ordered and meaningful understanding of potential (and often imminent) impediments to successful 'project'-to-'operations' transitions phase, derived from real experiences. Thus, set within the context of dry ports in Brazil, this chapter aim to answer the sixth research question stated, fulfilling the third specific objective.

6.2 MATERIALS AND METHODS

Figure 16 is a diagrammatical representation of the methodology adopted in this chapter. The stages 1, 2, 3 and 4 are the same described in Chapter 5. Assuming that, the methodology of this chapter starts from the Stage 5, detailing the Fuzzy-based DEMATEL.

Figure 16 – Diagrammatical representation of the chapter approach

STAGES	**Description**
STAGE 1	We set out to identify the risk factors impacting on the successful phase transitions from '*project'* to *operations'* of dry ports. This entailed a detailed review of the academic literature. On completion, we re-arranged the emergent literature into basic organizing themes reflecting distinct practical management concerns with clear enablement significance for project success.
STAGE 2	We further refined the above practical enablement themes in terms of their logical connectedness to successful transitions to operations. This process involved an examination of the face validity of all failure and/or project risk factors highlighted in 76 pertinent articles, resulting in 44 sub-factors.
STAGE 3	We now undertook further aggregated sub-factors mentioned in the identified literature into eight major risk factors through face validity. These risk factors were to include: (i) Cost, (ii) Location, (iii) Infrastructure, (iv) Accessibility, (v) Operational factors, (vi) Economic factors, (vii) Political and social imperatives and (viii) Environmental considerations. The validity of these 8 factors was then checked utilizing Exploratory Factor Analysis (EFA).
STAGE 4	This stage involved a questionnaire survey of key dry port stakeholders. We sampled project and operations managers and practitioners across all 56 dry ports in Brazil. The purpose of the survey was to elicit professional judgment on rank ordering and interdependence for the pre-selected risk factors.
STAGE 5	Data analysis was undertaken utilizing a *Fuzzy* -based DEMATEL method.
STAGE 6	We obtained the results, articulated the net influence and then drew a casual diagram to provide a simplified representation of key risk factor interdependencies and relative weightings. Finally, we analyzed the results, discussed the causal diagram, and then discussed the implications of the results with a practical management focus on how project risk management might be improved for dry port projects both in Brazil and more generally.

Source: This thesis (2022).

6.2.1 Stage 5 - Analysis

Assuming the results from the EFA with the 8 major risk factors stated, the second part of the survey followed the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method (FONTELA; GABUS, 1976; WARFIELD, 1976). It involved assessing major risk factor interdependence in order to analyze relationships among selected criteria. DEMATEL can be used for gathering expert knowledge and forming structured models allowing decision-makers to recognize criteria for greater influence in terms of causal interdependence (SELEEM; ATTIA; EL-ASSAL, 2016). Non-random purposive sampling was used as it is particularly useful for exploring complex phenomena (as in this instance). Furthermore, it is particularly well suited to eliciting specialist skillsets or knowledge (SMITH, 1983).

The scale employed was the standard for DEMATEL, with '0' = 'very low influence' factor to '4' = 'very high influence' (DU; ZHOU, 2019). To ensure scale reliability, Cronbach's alpha was calculated for the DEMATEL by survey respondent category, resulting in FRS = 0.854, DPO = 0.973, Customer = 0.964, exceeding 0.7, which is considered good (HAIR et al., 2014).

On completion of the data gathering, a fuzzy-based DEMATEL analysis was undertaken. Our approach drew upon Si et al. (2018). Fuzzy-based DEMATEL has been utilized in several supply chain-related studies (KHOMPATRAPORN; SOMBOONWIWAT, 2017; MANGLA et al., 2018). The need for this arose in recognition of the fact that standard DEMATEL has significant limitations, especially relating to its use of numeric values to rate relationships between pairs of factors, which is limited in particular by the subjectivities of evaluator judgments (KHOMPATRAPORN; SOMBOONWIWAT, 2017). Fuzzy set theory was introduced by Zadeh (1965, 1976), offering a means to move beyond these limitations by catering for the vagueness, ambiguity, and subjectivity of human judgment. Working to develop such practice, multiple criteria decision-making methods have been designed to better model subjectivity, especially regarding individual or group preferences (MANGLA et al., 2018). In summary, then, human judgments regarding preferences or influences are widely understood by researchers working within this tradition as often being unclear and hard to estimate by specific numerical values; hence growing use in recent years of fuzzy multiple criteria decision-making methods such as Fuzzy-based DEMATEL.

For these reasons, it was employed fuzzy-based DEMATEL to analyze the data. Definitions and properties of the fuzzy set and the fuzzy-based DEMATEL method are detailed in next item. The essence of the process is that it is intended to reflect the practical rationality and action of the actors involved, in their own preferred terms. This stage will therefore entail presenting the resulting causal diagram and factor ranking, taking into consideration the three major stakeholder perspectives which give rise to the inputting practical rationalities. These are: (i) 'Dry port entities' (DPEs), (ii) 'Customers', and (iii) 'Federal Revenue Superintendence' (FRS). We now discuss the principles of the fuzzy -based DEMATEL method.

6.2.1.1 Fuzzy sets

A fuzzy set A in a universe of discourse X is characterized by a membership function $f_A(x)$ that maps each element of x in X to a real number in an interval between 0 and 1. A triangular fuzzy number, which is one of the most popular fuzzy set representations due to its conceptual and computational simplicity, can be represented as a triple $A = (a, b, c)$. Here, the parameters $\mathrm{a, b, c}$ denote the smallest, most promising and largest promising values that describe a fuzzy event.

Definition 1: A triangular membership function of the fuzzy number $f_A(x)$ is defined as:

Equation 1

$$f_A(x) = \begin{cases} \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & x < a, x > c \end{cases}$$

Definition 2: Let $A = (a_1, b_1, c_1)$ and $B = (a_2, b_2, c_2)$ be two triangular fuzzy numbers, the main operations are expressed as follows:

Equation 2

$$A(+)B = (a_1, b_1, c_1)(+)(a_2, b_2, c_2) = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$$

Equation 3

$$A(-)B = (a_1, b_1, c_1)(-)(a_2, b_2, c_2) = (a_1 - c_2, b_1 - b_2, c_1 - a_2)$$

Equation 4

$$A(\times)B = (a_1, b_1, c_1)(\times)(a_2, b_2, c_2) = (a_1 \times a_2, b_1 \times b_2, c_1 \times c_2)$$

Equation 5

$$A(\div)B = (a_1, b_1, c_1)(\div)(a_2, b_2, c_2) = (a_1 \div a_2, b_1 \div b_2, c_1 \div c_2)$$

Equation 6

$$\alpha(\times)A = (\alpha \times a_1, \alpha \times b_1, \alpha \times c_1), \text{ where } \alpha \text{ is a constant}$$

Definition 3: Assume that a decision group has K decision makers $(k = 1,2, \dots, K)$, can be represented as a triangular fuzzy number $R_k = (1,2, \dots, K)$ with membership function $f_{R_k}(x)$. The aggregated fuzzy rating can be determined as:

$$R = (a, b, c), k = 1,2, \dots, K$$

Where:

Equation 7

$$a = min_k\{a_k\},\ b = 1/k \sum_{k=1}^{K} b_k,\ c = max_k\{c_k\}$$

Fuzzy set theory describes terms of linguistic variables, which should be converted from the influence score of DEMATEL to fuzzy numbers. This chapter assumes that the membership functions have a triangular shape, following the scale in Table 18 (KHOMPATRAPORN; SOMBOONWIWAT, 2017; MANGLA et al., 2018).

Table 18 – Fuzzy linguistic scale

Linguistic description	**Influence score**	**Triangular fuzzy numbers**
No influence	0	(0, 0, 0.25)
Low influence	1	(0, 0.25, 0.5)
Medium influence	2	(0.25, 0.5, 0.75)
High influence	3	(0.5, 0.75, 1)
Very high influence	4	(0.75, 1, 1)

Source: (KHOMPATRAPORN; SOMBOONWIWAT, 2017; MANGLA et al. 2018).

6.2.1.2 Fuzzy-based DEMATEL

This chapter employs a fuzzy -based DEMATEL analysis, phased by Si et al. (2018) as follows:

Phase 1: Evaluate the relationships between factors using a fuzzy linguistic scale. In this step it is presented the respondents, divided by expert stakeholder category, with a linguistic judgments survey. They were asked to evaluate the degree at which factor i is likely to affect factor j. The resulting influence scores were then converted into fuzzy linguistic values through the triangular fuzzy numbers shown in Table 18.

Phase 2: Establish the group direct-influence fuzzy matrix $\tilde{Z} = [\tilde{z}_{ij}]_{nxn}$. Through the linguistic judgments, converted into fuzzy values, it was constructed a fuzzy pair-wise comparison matrix $\tilde{Z}_k$ for each expert. After constructing the individual matrices $\tilde{Z}_k = (k = 1,2,\dots,l)$, it was calculated the group direct-influence fuzzy matrix $\tilde{Z} = [\tilde{z}_{ij}]_{n\times n}$ by aggregating all the experts' judgments. To produce the matrix, $\tilde{z}_{ii}$ is given as a triangular fuzzy number in the form $(0,0,0)$, and $\tilde{z}_{ij}$ is derived as follows:

Equation 8

$$\tilde{z}_{ij} = (\tilde{z}_{ij1}, \tilde{z}_{ij2}, \tilde{z}_{ij3}) = \frac{1}{l}\sum_{k=1}^{l} \tilde{z}_{ij}^{k} = \left(\frac{1}{l}\sum_{k=1}^{l} \tilde{z}_{ij1}^{k}, \frac{1}{l}\sum_{k=1}^{l} \tilde{z}_{ij2}^{k}, \frac{1}{l}\sum_{k=1}^{l} \tilde{z}_{ij3}^{k}\right)$$

Phase 3: Generate the normalized direct-influence fuzzy matrix $\tilde{X}$ by:

Equation 9

$$\tilde{X} = \frac{\tilde{Z}}{r}$$

Where:

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & x_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \tilde{x}_{nn} \end{bmatrix},$$

Equation 10

$$r = \max_{i,j}\left[\max_{1\le i\le n}\left(\sum_{j=1}^{n} z_{ij3}\right), \max_{1\le j\le n}\left(\sum_{i=1}^{n} z_{ij3}\right)\right]$$

Phase 4: Obtain the total-influence fuzzy matrix $\tilde{T} = [\tilde{t}_{ij}]_{n\times n}$ by:

Equation 11

$$\tilde{T} = \lim_{h\to\infty}(\tilde{X}^1 + \tilde{X}^2 + \cdots + \tilde{X}^h) = \tilde{X}\,(1 - \tilde{X})^{-1}$$

When:

$$\lim_{h\to\infty} \tilde{X}^h = 0$$

Here:

Equation 12

$$\tilde{t}_{ij} = (\tilde{t}_{ij1}, \tilde{t}_{ij2}, \tilde{t}_{ij3}) \text{ and,}$$

Equation 13

$$T_1 = [\tilde{t}_{ij1}]_{n\times n} = X_1(I - X_1)^{-1}$$

Equation 14

$$T_2 = [\tilde{t}_{ij2}]_{n\times n} = X_2(I - X_2)^{-1}$$

Equation 15

$$T_3 = [\tilde{t}_{ij2}]_{n\times n} = X_3(I - X_3)^{-1}$$

In which $X_1 = [x_{ij1}]_{n\times n}$, $X_2 = [x_{ij2}]_{n\times n}$, $X_3 = [x_{ij3}]_{n\times n}$, and I is an identity matrix. The elements of triangular fuzzy numbers in the matrix $\tilde{T}$ are divided into T_1, T_2, and T_3, and $T_1 \prec T_2 \prec T_3$, when $x_{ij1} < x_{ij2} < x_{ij3}$ for any $i, j \in \{1,2,\dots,n\}$.

Phase 5: Produce the Influential Relation Map (IRM). After obtaining the total-influence matrix $\tilde{T}$, the $\tilde{R}_i + \tilde{C}_i$ and $\tilde{R}_i - \tilde{C}_i$ variables were calculated, where $\tilde{R}_i$ and $\tilde{C}_i$are the sum of rows and the sum of columns, respectively, within the matrix, $\tilde{T}$. Then, the fuzzy numbers of $\tilde{R}_i + \tilde{C}_i$ and $\tilde{R}_i - \tilde{C}_i$ were converted into crispy values using a defuzzification method CFCS below (OPRICOVIC; TZENG, 2003).

Equation 16

$$\gamma_i = L + \Delta \times \frac{(m_i - L) \times (\Delta + u_i - m_i)^2 \times (R - l_i) + (u_i - L)^2 \times (\Delta + m_i - l_i)^2}{(\Delta + m_i - l_i) \times (\Delta + u_i - m_i)^2 \times (R - l_i) + (u_i - L) \times (\Delta + m_i - l_i)^2 \times (\Delta + u_i - m_i)}$$

Where y_i denotes the defuzzified value of the fuzzy number $\tilde{y}_i = (l_i, m_i, u_i)$, $L = min\, l_i$, $R = max\, u_i$, $\Delta = R - L$. To complete the fuzzy-based DEMATEL, the Influential Relation Map (IRM) was drawn by mapping the ordered pairs of $(\tilde{R}_i + \tilde{C}_i)^{def}$as a horizontal axis vector named ‘Prominence’, and $(\tilde{R}_i - \tilde{C}_i)^{def}$as a vertical axis vector named ‘Relation’.

6.3 RESULTS

Based on the 77 survey responses, the data was processed and analyzed using fuzzy-based DEMATEL as follows. Tables 19 to 22 show total effects for factors, as ordered by: (i) 'Dry port entities' (DPEs), (ii) 'Customers', (iii) 'Federal Revenue Superintendence' (FRS) and (iv) Aggregated result. Once this total-influence fuzzy matrix $\tilde{T}$ was obtained, the results were interpreted from the $\tilde{R}$ and $\tilde{C}$ sums of rows and columns within the total-influence matrix. More specifically, the fuzzy 'prominence' degree $\tilde{R} + \tilde{C}$, was taken to express the strength of influences that are given and received for every factor in the system. Similarly, the 'relation' degree $\tilde{R} - \tilde{C}$, was taken to express the net effect that each factor exerts upon the system. Then, the fuzzy numbers were converted into crisp values $R + C$ and $R - C$ by the defuzzification method detailed above. If $R - C$ is positive, then this means the factor has a net influence on the other factors and can therefore be entered into a 'cause' group; by the same token, if $R - C$ is negative, then this means the factor is being influenced by the other factors on the whole and should therefore be entered into an 'effect' group instead (SI et al., 2018).

Table 19 – Total effects by factors for FRS external stakeholders

Factor	Code	Fuzzy				Crispy		Role
		R	C	R+C	R-C	R+C	R-C	
Cost	F1	(0,52; 1,35; 6,99)	(0,64; 1,57; 7,42)	(1,16; 2,92; 14,41)	(-6,89; -0,21; 6,35)	4,80	-0,22	Effect
Location	F2	(0,38; 1,16; 6,48)	(0,47; 1,30; 6,80)	(0,86; 2,47; 13,28)	(-6,41; -0,14; 6,00)	4,28	-0,16	Effect
Infrastructural	F3	(0,58; 1,44; 7,15)	(0,54; 1,40; 7,09)	(1,12; 2,84; 14,24)	(-6,50; 0,04; 6,61)	4,72	0,01	Cause
Accessibility	F4	(0,42; 1,20; 6,43)	(0,47; 1,30; 6,85)	(0,90; 2,51; 13,28)	(-6,42; -0,10; 5,95)	4,32	-0,15	Effect
Operational	F5	(0,51; 1,34; 6,88)	(0,53; 1,39; 7,11)	(1,05; 2,73; 14,00)	(-6,60; -0,05; 6,34)	4,60	-0,09	Effect
Economic	F6	(0,38; 1,13; 6,27)	(0,28; 0,99; 5,99)	(0,66; 2,12; 12,26)	(-5,60; 0,14; 5,99)	3,86	0,12	Cause
Political and Social	F7	(0,26; 1,01; 6,02)	(0,09; 0,67; 4,97)	(0,36; 1,68; 10,99)	(-4,70; 0,33; 5,92)	3,30	0,36	Cause
Environment	F8	(0,10; 0,70; 5,08)	(0,13; 0,70; 5,07)	(0,23; 1,41; 10,16)	(-4,97; 0,00; 4,95)	2,94	-0,02	Effect

Source: This thesis (2022).

Table 20 – Total effects by factors for 'Customer' external stakeholders

Factor	Code	Fuzzy				Crisp		Role
		R	C	R+C	R-C	R+C	R-C	
Cost	F1	(0,87; 2,50; 12,93)	(1,06; 2,86; 13,78)	(1,93; 5,37; 26,71)	(-12,9; -0,35; 11,86)	8,86	-0,40	Effect
Location	F2	(0,85; 2,47; 12,91)	(0,94; 2,64; 13,45)	(1,80; 5,12; 26,37)	(-12,6; -0,16; 11,96)	8,61	-0,24	Effect
Infrastructural	F3	(0,84; 2,46; 12,82)	(0,91; 2,59; 13,41)	(1,76; 5,06; 26,24)	(-12,5; -0,12; 11,90)	8,55	-0,22	Effect
Accessibility	F4	(0,84; 2,45; 12,93)	(0,83; 2,43; 12,89)	(1,68; 4,88; 25,82)	(-12,0; 0,02; 12,10)	8,35	-0,03	Effect
Operational	F5	(0,87; 2,51; 13,11)	(0,88; 2,54; 13,24)	(1,76; 5,05; 26,36)	(-12,3; -0,03; 12,22)	8,56	-0,09	Effect
Economic	F6	(0,84; 2,45; 12,94)	(0,83; 2,44; 13,01)	(1,67; 4,89; 25,95)	(-12,1; 0,01; 12,11)	8,38	-0,06	Effect
Political and Social	F7	(0,76; 2,31; 12,54)	(0,57; 1,94; 11,49)	(1,34; 4,25; 24,03)	(-10,7; 0,36; 11,97)	7,59	0,34	Cause
Environment	F8	(0,75; 2,26; 12,49)	(0,61; 1,99; 11,38)	(1,36; 4,25; 23,88)	(-10,6; 0,27; 11,88)	7,58	0,29	Cause

Source: This thesis (2022).

Table 21 – Total effects by factors for DPEs internal stakeholders

Factor	Code	Fuzzy				Crisp		Role
		R	C	R+C	R-C	R+C	R-C	
Cost	F1	(0,83; 2,24; 9,74)	(0,99; 2,52; 10,26)	(1,83; 4,76; 20,01)	(-9,43; -0,28; 8,74)	7,19	-0,31	Effect
Location	F2	(0,80; 2,19; 9,54)	(0,85; 2,26; 9,78)	(1,66; 4,45; 19,33)	(-8,97; -0,07; 8,69)	6,86	-0,14	Effect
Infrastructural	F3	(0,82; 2,21; 9,61)	(0,85; 2,27; 9,77)	(1,67; 4,48; 19,38)	(-8,95; -0,05; 8,76)	6,89	-0,11	Effect
Accessibility	F4	(0,76; 2,10; 9,32)	(0,76; 2,11; 9,49)	(1,53; 4,21; 18,81)	(-8,72; -0,01; 8,55)	6,61	-0,08	Effect
Operational	F5	(0,75; 2,07; 9,23)	(0,82; 2,23; 9,65)	(1,58; 4,30; 18,88)	(-8,89; -0,15; 8,40)	6,68	-0,21	Effect
Economic	F6	(0,79; 2,15; 9,47)	(0,71; 2,03; 9,24)	(1,51; 4,18; 18,72)	(-8,44; 0,12; 8,76)	6,57	0,06	Cause
Political and Social	F7	(0,61; 1,83; 8,80)	(0,49; 1,62; 8,23)	(1,11; 3,46; 17,04)	(-7,61; 0,21; 8,31)	5,76	0,17	Cause
Environment	F8	(0,61; 1,85; 8,86)	(0,49; 1,60; 8,17)	(1,10; 3,45; 17,03)	(-7,55; 0,24; 8,36)	5,75	0,21	Cause

Source: This thesis (2022).

Table 22 – Total effects by factors of all stakeholders ‘Aggregated’

Factor	Code	Fuzzy				Crispy		Role
		R	C	R+C	R-C	R+C	R-C	
Cost	F1	(0,74; 2,03; 9,91)	(0,89; 2,31; 10,51)	(1,64; 4,34; 20,42)	(-9,76; -0,28; 9,01)	6,95	-0,31	Effect
Location	F2	(0,68; 1,94; 9,67)	(0,75; 2,06; 10,02)	(1,43; 4,00; 19,70)	(-9,34; -0,12; 8,91)	6,59	-0,18	Effect
Infrastructural	F3	(0,75; 2,04; 9,89)	(0,76; 2,08; 10,10)	(1,51; 4,12; 19,99)	(-9,35; -0,04; 9,12)	6,72	-0,11	Effect
Accessibility	F4	(0,67; 1,91; 9,58)	(0,68; 1,94; 9,75)	(1,36; 3,86; 19,34)	(-9,08; -0,02; 8,89)	6,42	-0,09	Effect
Operational	F5	(0,71; 1,97; 9,76)	(0,75; 2,05; 10,03)	(1,46; 4,02; 19,79)	(-9,31; -0,08; 9,01)	6,62	-0,14	Effect
Economic	F6	(0,67; 1,91; 9,59)	(0,61; 1,81; 9,43)	(1,28; 3,73; 19,02)	(-8,76; 0,09; 8,97)	6,28	0,03	Cause
Political and Social	F7	(0,54; 1,70; 9,13)	(0,38; 1,41; 8,24)	(0,93; 3,11; 17,37)	(-7,69; 0,29; 8,74)	5,54	0,28	Cause
Environment	F8	(0,48; 1,59; 8,81)	(0,41; 1,43; 8,24)	(0,89; 3,03; 17,06)	(-7,76; 0,16; 8,40)	5,43	0,14	Cause

Source: This thesis (2022).

The total effect from the ‘Federal Revenue Superintendence’ (FRS) perspective shown in Table 19, shows that F1, F3, F5 and F4 are the most prominent effect factors associated with dry ports. On the other hand, factors F6 and F7 are the most prominent cause factors. From the ‘Customers’ perspective in Table 20, the most prominent effects factors are F1, F2, F5 and F4, while F7 and F8 emerged as cause factors. Similarly, in Table 21, F1, F3, F2 and F5 were the most prominent effect factors and F6, F7 and F8 were the most prominent cause factors, considered from the Dry ports view. Summarizing the results for all three stakeholders, the total-influence fuzzy matrix $\tilde{T}$ was aggregated to produce Table 22. These aggregated results highlight F1, F3, F5 and F2 are the most important effect factors for assessing the success of the dry ports. However, those factors are also affected by F6, F7 and F8, classified as the key cause factors.

These results summarize the overall cause-effect relations for the various factors, considered from across the full range of stakeholder perspectives. However, to further evaluate the overall strength of influence for each factor on another, the net influence process described by Wang et al. (2012) was also followed, resulting in Figure 17. Its matrices, produced for each stakeholder group, show influences of factors listed by row relative to those of factors listed by column.

Figure 17 – Net influence matrices, by stakeholder group

Factor	FRS								Customer							
	F1	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*F8*	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*F8*
F1	-								-							
F2	0,010	-							0,024	-						
F3	0,028	0,020	-						0,030	0,008	-					
F4	-0,003	0,007	-0,020	-					0,050	0,030	0,032	-				
F5	0,025	0,023	-0,006	-0,002	-				0,049	0,023	0,024	-0,003	-			
F6	0,059	0,045	0,021	0,032	0,037	-			0,054	0,027	0,025	0,001	0,014	-		
F7	0,086	0,081	0,029	0,061	0,058	0,044	-		0,098	0,078	0,075	0,052	0,058	0,057	-	
F8	0,018	-0,005	-0,005	0,026	0,011	0,004	-0,039	-	0,089	0,071	0,066	0,050	0,053	0,048	0,000	-

Factor	Dry port entities								Aggregated							
	F1	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*F8*	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*F8*
F1	-								-							
F2	0,024	-							0,020	-						
F3	0,031	0,012	-						0,030	0,013	-					
F4	0,027	0,012	0,004	-					0,025	0,017	0,006	-				
F5	0,021	-0,008	-0,004	-0,019	-				0,031	0,012	0,004	-0,009	-			
F6	0,053	0,028	0,033	0,021	0,038	-			0,054	0,032	0,025	0,017	0,030	-		
F7	0,064	0,037	0,036	0,035	0,049	0,021	-		0,081	0,064	0,046	0,048	0,054	0,039	-	
F8	0,067	0,051	0,047	0,043	0,055	0,023	0,000	-	0,056	0,037	0,034	0,037	0,039	0,024	-0,013	-

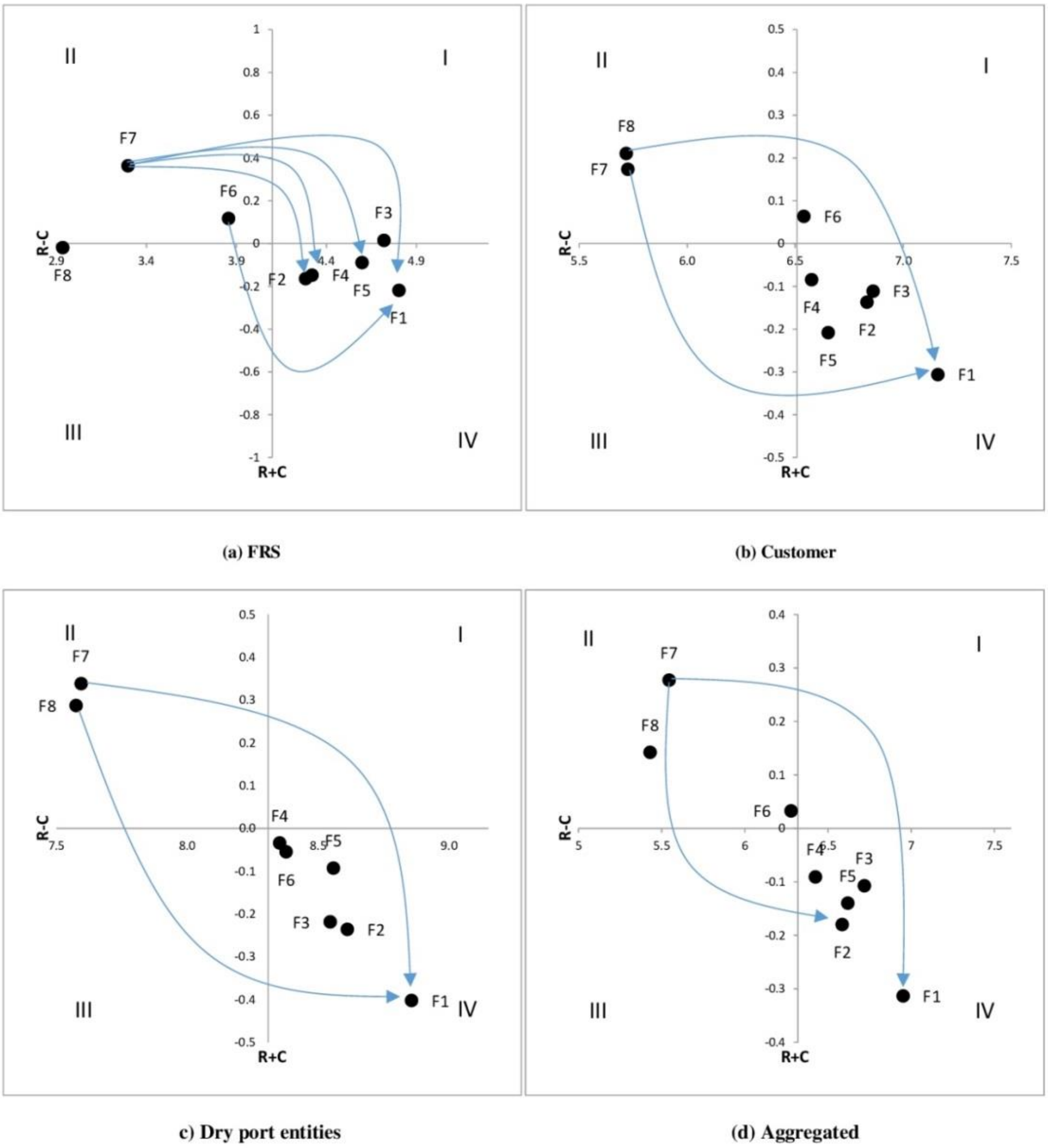
Source: This thesis (2022).

Positive values indicate influences of row factors on column factors; negative factors indicate influences running in the reverse direction. For further convenience of interpretation, the grey highlighted values in Figure 17 indicate influences above the net influence value averages (which for ‘Dry port entities’ is 0.031, for ‘Customers’ is 0.042, for ‘Federal Revenue Superintendence’ is 0.029 and for ‘Aggregated result’ is 0.032).

Finally, an Influential Relation Map (IRM) was designed by mapping the dataset of $(R + C, R - C)$. This resulted in a more practical instant visualization reference tool for decision makers who aspire to troubleshoot risk interconnection issues on dry port projects in a stakeholder-sensitive manner. Figures 18 (a), (b), (c), and (d) present the IRMs of all stakeholders, dividing the graph in four quadrants by the mean of $R + C$.

The factors in quadrant ‘I’ are identifiable as core factors, since they have high prominence and relationship significance; the factors in quadrant ‘II’ are identifiable as driving factors because they have low prominence but high relationship significance; the factors in quadrant ‘III’ are low in both prominence and relationship significance and are therefore relatively disconnected from the mapped system; the factors in quadrant 'IV' have high prominence but low relationship significance, which means they are impacted by relatively heterogeneous factors and therefore cannot be directly improved through specific and focused managerial interventions (SI et al., 2018).

Figure 18 – Influential Relation Map



Source: This thesis (2022).

To draw the net influence on the Influential Relation Map (IRM), represented by the blue arrows, we used the value 'twice-the-average' as the threshold for each net influence matrix, recognizing that the same threshold was used by (KHOMPATRAPORN;

SOMBOONWIWAT, 2017). This representation aim enriches the IRM visualization by highlighting the factor that most affects others on the net. This is intended to represent what should weigh most on the minds of practitioners. Accordingly, Figure 18 summarizes the prominence and relationship levels, as well the most important net influences, for the various factors. The intention, here, is to influence the minds of risk management participants on dry port projects to explore risk interconnectedness within risk identification contexts that frame how risk should be perceived and set within risk discourse, and hence broader management discourse, so as to optimize stakeholder interest and participation.

6.4 DISCUSSION

Results reveal a stakeholder congruence which regards 'Cost' (F1) as the most important risk factor for dry port success. This finding is in line with the extant literature, see for example Lirn and Wong (2013). Unsurprisingly, 'Cost' (F1) was also found to be the risk factor most affected by the others; and in the present study it was found to be particularly impacted by 'Economic' (F6), 'Political and Social' (F7) and 'Environment' (F8) risk factors. This finding has direct implications for how financial managers involved from various stakeholder perspectives on dry port projects should make prioritization-with-limited-resources decisions that shape their risk management participation within such projects.

Comparing the Influential Relation Maps (IRM), we see that from the 'Federal Revenue Superintendence' (FRS) perspective, the 'Political and Social' factor (F7) is the risk factor that most affect other risk factors, especially 'Cost' (F1), 'Location' (F2), 'Accessibility' (F4) and 'Operational' (F5) factors. Arguably, this makes good sense in terms of heterogeneous regulatory compliance imperatives for dry ports. More specifically, though, it is perhaps significant that the 'Federal Revenue Superintendence' (FRS) is the government agency that manages the stakeholder concessions, and, with considerable relevance to decision-making under that role remit, adherence to customs rules (RODRIGUES et al., 2021).

Also significant is that risk factors in quadrant IV of Aggregated IRM, specifically the 'Location' (F2), 'Infrastructural' (F3), 'Accessibility' (F4) and 'Operational' (F5) factors, can be interpreted together as being of particular importance through their dependency on others within the network. An important practical management conclusion, then, is that in order to achieve success in dry port 'project' to 'operations' phase transitions, these risk factors should not be considered discretely but rather synergistically and within longer tail risk context; more practically speaking, to improve performance on any one of these risk factors, it appears necessary to seek improvements on the others also. To further illustrate this point about the need to co-manage risk factors, and also to draw this research to final summary conclusions, Table 23 provides ranking orders (differentiated by stakeholder group) for prominence and relationship factors.

Table 23 – Factors rank

Factor		**R+C**								**R-C**							
		FRS		**Customer**		**DPE**		**Rank**		**FRS**		**Customer**		**DPE**		**Rank**	
Cost	F1	4,80	1	8,86	1	7,19	1	6,95	1	-0,22	8	-0,40	8	-0,31	8	-0,31	8
Location	F2	4,28	5	8,61	2	6,86	3	6,59	4	-0,16	7	-0,24	7	-0,14	6	-0,18	7
Infrastructural	F3	4,72	2	8,55	3	6,89	2	6,72	2	0,01	3	-0,22	6	-0,11	5	-0,11	5
Accessibility	F4	4,32	4	8,35	6	6,61	5	6,42	5	-0,15	6	-0,03	3	-0,08	4	-0,09	4
Operational	F5	4,60	3	8,56	4	6,68	4	6,62	3	-0,09	5	-0,09	5	-0,21	7	-0,14	6
Economic	F6	3,86	6	8,38	5	6,57	6	6,28	6	0,12	2	-0,06	4	0,06	3	0,03	3
Political and Social	F7	3,30	7	7,59	7	5,76	8	5,54	7	0,36	1	0,34	1	0,17	2	0,28	1
Environment	F8	2,94	8	7,58	8	5,75	7	5,43	8	-0,02	4	0,29	2	0,21	1	0,14	2

Source: This thesis (2022).

As summarized in Table 23, the importance of each risk factor varies by stakeholder. This in itself constitutes an important practical management finding because its mappings permit incongruent stakeholder risk perceptions and communications to be explored within broadly collaborative project risk management meetings that bring the relevant stakeholders together. However, also significant within these management contexts is that ‘Cost’ (F1), ‘Location’ (F2), ‘Infrastructural’ (F3) and ‘Operational’ (F5) factors were clearly considered the most important overall, thereby creating a clear common focus for project risk management effort. These factors are also the ones which ‘Dry port entities’ (DPEs) and ‘Customers’ are most able to exert significant influence upon, within their decision making. Correspondingly, then, it makes sense to centralize these decisions as focal points for broadly collaborative project risk management discussions.

It is also notable that ‘Dry port entities’ (DPEs), ‘Customers’ and the ‘Federal Revenue Superintendence’ (FRS), by contrast, have no control of the ‘Economic’ factor (F6), whose management can also fundamentally be considered a prerogative of the national governments that empower this and other regulators. This has subtler implications for where collaborative project risk management can productively focus. Clearly, economic effects must be anticipated and controlled, and scope for political lobbying, pushed collaboratively by stakeholders from across Brazil's dry ports, can be regarded as potentially useful for shaping the overall economic risk environment for dry port operations.

One interesting point to note, in that regard, is that the 'Economic' factor (F6) had a particularly significant impact on 'Customers', these being the stakeholders who were most likely to experience the impact of exchange rate fluctuations on import cargo. The question might be asked, then, of whether these relatively dis-united stakeholders might utilize dry port stakeholder management collaboration opportunities more effectively, in order to better present their cases to government.

Similarly, 'Dry port entities' (DPEs) and 'Customers' had no influence on 'Political and Social' risk factors, which are generally driven by customs rules and bureaucratic processes under the purview of the 'Federal Revenue Superintendence' (FRS). This suggests that these agencies might be valued more, within collaborative project risk management on dry ports, as conduits for engaging with government.

Finally, the 'Environment' factor (F8) emerged as least important overall to the success of dry ports. This suggests that there were limited concerns surrounding matters such as pollution reduction when considering 'project' to 'operations' phase transitions. Perhaps there is a framing or complacency issue here: the dry port projects appear to be regarded as providing environmental solutions, far more than they are regarded as facilitators of an ever larger and more polluting global economy. An obvious recommendation arising is that broadly collaborative dry port project risk management arguably requires a more careful focus on leveraging political, economic and cultural capital through its green logistics roles, and in support of these roles.

6.5 REMARKS

Citing the economic importance of dry ports, but concerned about the high rate of phase transition failures of dry port infrastructure projects, it was set out in this chapter to explore not only the most commonly engaged risk factors impacting upon the failure of phase transition from 'project' to 'operations' of dry port, but also the nature of their interdependence. Recognizing the need for constructively simplified project risk management narratives based on clear and explicit risk categories, it was identified from literature eight major risk factors to assess dry port phase transition success. From the stakeholder survey, it was found 'Cost' to be the most important risk factor likely to impact upon successful phase transitions of dry ports. 'Location', 'Accessibility', 'Infrastructural' and 'Operational' were however identified as the highest-ranked risk factors. The interrelationships between these risk factors were also discussed, so as to orient broadly collaborative project risk management to explore risk systemicity as a critical and reflective management practice which engages with risk systemicity-associated perceptual problems of stakeholder incongruence.

As practical contribution, this chapter provides risk category design leadership for management of discrete risks that are set within deeper (i.e. systemic) risk contexts for complex multi-stakeholder infrastructure dry port projects. Recognizing the paucity of literature on risk categories for dry port projects, we conclude that the findings provide a practical management guideline on key risk factors requiring collaborative project management prioritisation during 'project' to 'operations' transitions of dry port projects, not only in Brazil, but also in other countries.

The theoretical contribution, however, is more nuanced. It pertains to how project risk management, seeking practical management simplifications, can achieve such simplification by viewing risk categories more specifically as 'readiness' categories pertaining to phase transitions. At these points of transition, we would contend, risk issues begin to crystallize, extending to include stakeholder-collaborative risk discussions and control options. To link the above benefits of a readiness focus back to the present findings, this chapter concludes that DEMATEL analysis can provide a viable practical means for drawing attention to basic readiness categories; that is, for offering a sensitizing conceptual framework for exploring the complex interdependence that are likely to matter most amidst transitions to operations.

7 SEAPORT-HINTERLAND DECISION MAKING: A CONTAINER SHIPPING COST OPTIMIZATION

A reviewed version of the papers:

RODRIGUES, T.; MOTA, C.; PINTO, D.; ARAÚJO, A. Identifying the factors engaged in customers' choice to operate through dry port or seaport. In *International Joint Conference on Industrial Engineering and Operations Management (IJCIEOM),* Rio de Janeiro – Brazil, February 22-24, 2021.

RODRIGUES, T.; MOTA, C.; OJIAKO, U. Container shipping cost optimization: a jointly seaport-hinterland network decision. Under Review.

7.1 CONTEXTUALIZATION

This chapter focus on the seaport-hinterland from the perspective of customers (shippers and consignees), which are currently looking for the entire supply-chain in order to choose the service providers that best fulfill their requirements in terms of cost and service level. As stated in the Introduction section, the seaport-hinterland network is responsible for 40% to 80% of the total logistic cost, value that could be reduced by one third with appropriate regionalization strategies (NOTTEBOOM; RODRIGUE, 2005). Such strategies regard a wide range of options that customer's should considerer jointly to reduce the total logistic cost.

Since the container is discharged in the seaport yard, looking from the import side, customers should decide to have their customs clearance process in the seaport or dry port, if it was through a dry port, which one is the cost efficient option, besides to choice the delivery route and the transportation mode (road or multimodal). These decisions, which from here is defined as 'jointly seaport-hinterland network decision', vary according to many factors as the value and type of cargo (consolidated or deconsolidated), the distance of the delivery route, the kind of transportation mode, the dwell-time of the container stored, the amount of additional-services required, and so on. Furthermore, this decision varies according to specificities of each customer as the location, infrastructure to store and handle containers and the urgency to get the cargo.

As highlighted in Theoretical Backgrounds section, some researchers have previously developed models that minimize the logistic cost through the seaport-hinterland network as Henttu, Lattila and Hilmola (2011) that estimated the quantity of dry ports which optimizes the transportation network in Finland context through simulation and Lättilä, Hunttu and Hilmola (2013), that analyzed the option to deliver the cargo directly to a seaport compared to using a dry port reducing the transportation cost and CO2 emission. Important insights for the dry port-seaport network decision came from Tran, Haasis and Buer (2017), which proposed a model to optimize container flows between two continents minimizing total costs. Going beyond, the model proposed by Iannone (2012) and Iannone and Thore (2010) have focused in demonstrates how the competitiveness of the regional container seaport cluster can be boosted by a dry port based with customs facilities and railway connections in Italy. Despite the relevant results of these studies, they have looked to seaport-hinterland choice from a holistic perspective, not focusing in offer to importers and exporters a flexible tool to aid the seaport-hinterland decision making, reducing the total logistic cost.

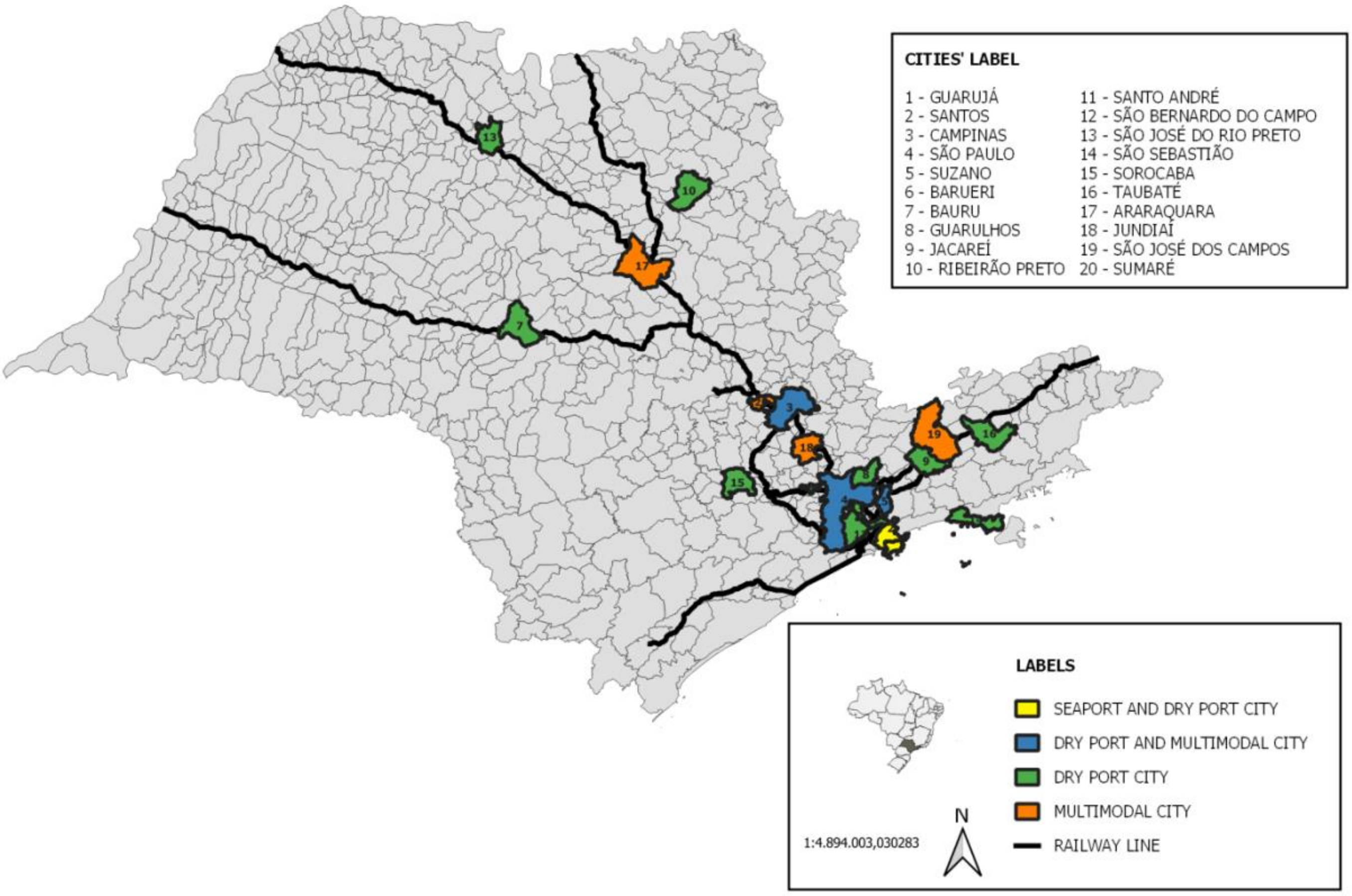
Taking into account the literature gap, the limitations in previous studies and the relevance of a flexible cost model aiding importers and exporters to chart the best seaport-hinterland network is required. With this in mind, this chapter aim to answer the seventh and eighth research questions, identifying the most important ‘cost’ factors, building a flexible model to aid customer’s jointly seaport-hinterland network decision. Looking for managerial contributions, simulations considering seaports, dry ports and multimodal transportation mode were carried in a case study in Brazil. Sensibility analysis also brought insights contributing to the literature of seaport-hinterland network.

7.2 STUDY CONTEXT

The context of this chapter is a case study in Brazil, specifically in São Paulo state. São Paulo state is the industrial and economical center of Brazil responsible for 32% of the national GDP (US$ 603 billion) and where the main logistic infrastructures are located (SEADE, 2020). Covering an area of 248.219 Km², São Paulo has approximately 46 million people allocated in 645 cities. Just São Paulo occupies the 21ª position in the largest economies in the world and the third economy in South America (IBGE, 2021; SÃO PAULO, 2021). Exporting US$51 billion and importing US$59 billion in 2019, São Paulo has the largest airport (Guarulhos) and seaport (Santos and Guarujá seaport) in Latin America (SÃO

PAULO, 2021). In terms of hinterland infrastructure, São Paulo has 24 dry ports located in 16 cities and 7 container rail facilities as follows in Figure 19.

Figure 19 – Seaport-hinterland network of São Paulo state



Source: This thesis (2022).

Despite the dry port definition, dry ports in São Paulo do not operate through railway, even when they are directly connected with the seaport, making contestable the real benefits of dry port for customers in terms of cost. Furthermore, dry ports in Brazil face bureaucratic customs process, lack of legislation, poor intermodal infrastructure and a competitive environment between seaports and dry ports (RODRIGUES et al., 2021). For those reasons, a flexible cost model applied in Brazilian context will bring insights for customers, policy makers and scholars about the jointly seaport-hinterland network decision in terms of total logistic cost.

7.3 MATERIALS AND METHODS

In order to answer the seventh research question, it was applied the same methodology of Chapter 3, a literature review based on the steps described by Tranfield, Denyer and Smart (2003). From a set of 72 papers, 11 cost factors related to the seaport-hinterland were found as follows in Table 24. These factors influences the inland leg operation, making possible to customers compares seaports and dry ports from cost perspective. Specific details concerning the systematic review are described in Rodrigues et al. (2020).

Table 24 – Set of cost factors

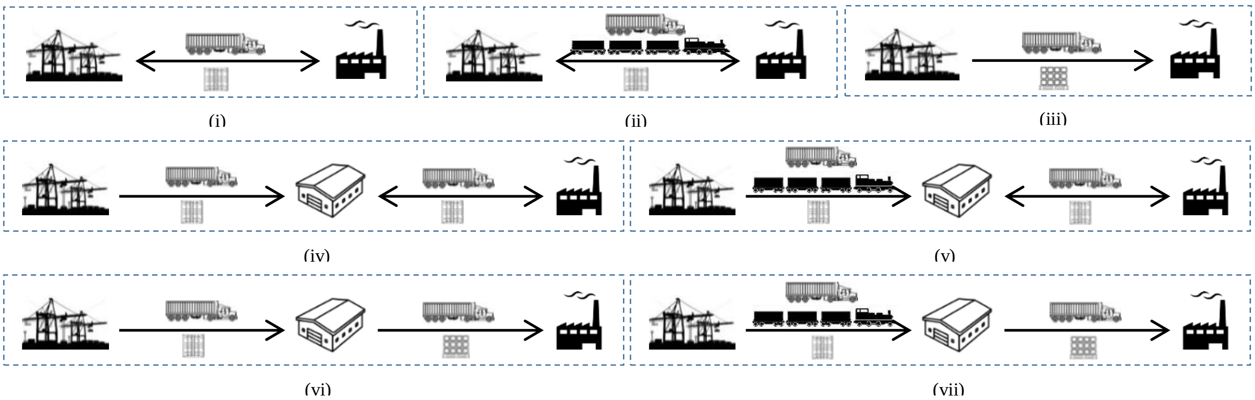
Cost factors	Authors
Congestion cost	(SLACK, 1985; TONGZON, 2009; TANG; LOW; LAM, 2011; STEVEN; CORSI, 2012; LEE; HU, 2012; BROOKS; SCHELLINCK, 2013; YEO et al., 2014; MOYA; VALERO, 2016; TSAO; LINH, 2018; BAERT; REYNAERTS, 2020; VALLS et al., 2020).
Cost of handling containers	(JANIC, 2007; IANNONE, 2012; CRAINIC et al., 2015; TRAN; HAASIS; BUER, 2017; TSAO; LINH, 2018; VAGGELAS, 2019).
Custom clearance cost	(IANNONE, 2012; CRAINIC et al., 2015).
Demurrage and detention cost	(TONGZON, 2009; YEO et al., 2014; CRAINIC et al., 2015; OEY; SETIAWAN, 2017; REZAEI et al., 2019; HSU; LIAN; HUANG, 2020).
Dry port and seaport inland charge cost	(BROOKS; SCHELLINCK, 2013; CRAINIC et al., 2015; BUTTON; CHIN; KRAMBERGER, 2015; TRAN; HAASIS; BUER, 2017).
Emissions cost	(LÄTTILÄ; HENTTU; HILMOLA, 2013; TRAN; HAASIS; BUER, 2017; TSAO; LINH, 2018).
Import and export charges in inland	(CASTELEIN; GEERLINGS; VAN DUIN, 2019; BAERT; REYNAERTS, 2020).
Inventory holding cost	(JANIC, 2007; IANNONE, 2012; TRAN; HAASIS; BUER, 2017; KAPETANIS; PSARAFTIS; SPYROU, 2016; OEY; SETIAWAN, 2017; TSAO; LINH, 2018).
Storage cost	(IANNONE, 2012; BROOKS; SCHELLINCK, 2013; QIU; LAM; HUANG, 2015; CRAINIC et al., 2015; OEY; SETIAWAN, 2017; QIU; LAM, 2018; TSAO; LINH, 2018; VAGGELAS, 2019).
Transportation cost	(SLACK, 1985; JANIC, 2007; TONGZON, 2009; IANNONE; THORE, 2010; IANNONE, 2012; BROOKS; SCHELLINCK, 2013; YEO et al., 2014; CRAINIC et al., 2015; QIU; LAM; HUANG, 2015; LARRANAGA; ARELLANA; SENNA, 2016; NUGROHO; WHITEING; JONG, 2016; TRAN; HAASIS; BUER, 2017; OEY; SETIAWAN, 2017; QIU; LAM, 2018; TSAO; LINH, 2018; MOYA; VALERO, 2016; REZAEI et al., 2019; HSU; LIAN; HUANG, 2020; JIANG et al., 2020).
Value-added services cost	(JANIC, 2007; MONIOS, 2011; BASK et al., 2014; CRAINIC et al., 2015; JEEVAN; CHEN; CAHOON, 2018).

Source: (RODRIGUES et al. 2020).

Towards building the cost model, the strategy in this chapter was the same of Iannone (2012), Janic (2007), Lättilä, Henttu and Hilmola (2013), and Tran, Haasis and Buer (2017), simulating delivery routes to aid customers' decision-making. In this way, three questions are considered jointly in the model: (i) the decision to perform all logistic services in seaport or in dry port (in this case, which dry port is the best option); (ii) the decision to transport the cargo by road of by multimodal transportation (rail); and (iii) to delivery/receive the cargo consolidated or deconsolidated.

For the simulations, a discrete system with seven delivery routes (*dr*) were tested based on Fazi and Roodbergen (2018) and Jeevan (2017): (i) *dr=1* when the container is directly delivery to the customer by truck from the seaport then returns empty to the same seaport $\left(i \overset{t}{\rightarrow} k_{con}; k \overset{t}{\rightarrow} i_{empt}\right)$; (ii) *dr=2* when the container is directly delivery to the customer by multimodal transport (rail and truck) from the seaport then returns empty through the same route $\left(i \overset{r,t}{\rightarrow} k_{con}; k \overset{t,r}{\rightarrow} i_{empt}\right)$; (iii) *dr=3* when the container is deconsolidated in the seaport and delivery directly by truck to the customer from the seaport $\left(i \overset{t}{\rightarrow} k_{deco}\right)$; (iv) *dr=4* when the container is delivery from a seaport to a dry port by truck, delivery to the customer also by truck and then returns empty to the same dry port $\left(i \overset{t}{\rightarrow} j_{con}; j \overset{t}{\rightarrow} k_{con}; k \overset{t}{\rightarrow} j_{empt}\right)$; (v) *dr=5* when the container is delivery from a seaport to a dry port by multimodal transport (rail and truck), delivery to the customer by truck and then returns empty to the same dry port $\left(i \overset{r,t}{\rightarrow} j_{con}; j \overset{t}{\rightarrow} k_{con}; k \overset{t}{\rightarrow} j_{empt}\right)$; (vi) *dr=6* when the container is delivery from a seaport to a dry port by truck and then be deconsolidated and delivery to the customer by truck $\left(i \overset{t}{\rightarrow} j_{con}; j \overset{t}{\rightarrow} k_{deco}\right)$; and (vii) *dr=7* when the container is delivery from a seaport to a dry port by multimodal transport (rail and truck), be deconsolidated and then delivery to the customer by truck $\left(i \overset{r,t}{\rightarrow} j_{con}; j \overset{t}{\rightarrow} k_{deco}\right)$. In Figure 20 follows a scheme of the simulated scenarios.

Figure 20 – Scenarios of simulations



Source: This thesis (2022).

Considering the seven delivery routes, ten cost factors related to seaport-hinterland network were considered based on previous models described above and in the literature review in chapter 7 as follows: terminal handling cost (*HC*), storage cost (*SC*), value-added service cost (*VA*), customs clearance cost (*CC*), inventory cost (*IC*), demurrage and detention costs (*DDC*), container leasing cost (*CLC*), delivery cost (*DEC*), back empty container cost (*BECC*), and emission cost (*EMC*). The cost model is applicable to import and export process, however, as dry ports in Brazil are characterized to operates import cargo the case study is limited to the import process (RODRIGUES et al., 2021).

The cost database was obtained from multiple agents. Related to road cost, we got data from the National Association of Cargo Transport and Logistics (NTC, 2021), from the resolution 5.867 of National Agency of Ground Transport (ANTT, 2021) and from the study of Araújo, Bandeira and Campos (2014). The rail fees were based on the average charged by the 2 rail carriers which transport container in São Paulo state. Dry ports fees were based on the services average charge of 7 companies responsible for manage 11 dry ports in São Paulo. In the same way, it was considered the average rate of the 3 most important seaports located in Santos hub seaport and 6 line operators/ship-owners. The road distances considered in the model was assessed by Google Maps, the simulations and data analysis ran in Microsoft Excel (2010) and the sensibility analysis of the delivery routes was built in QGIS 3.16 from January to April, 2021. The variables of the model are detailed in Appendix C.

7.3.1 Service cost (*SC*)

7.3.1.1 Terminal handling cost (*HC*)

Terminal handling cost vary based on the number of boxes loaded/unloaded at the dry port or seaport ($box_{i,j}$) , the terminal handling charges ($thc_{i,j}$), and the quantity of handling moves in each delivery route ($qhm_{i,j,dr}$) (CRAINIC et al., 2015; TRAN; HAASIS; BUER, 2017). After discharged from the vessel, the container is positioned in the seaport's yard and each handling after that should be charged. If the customer decide to receive the container directly from the seaport, 1 handling would be necessary to load the container on the truck. However, if the customer decides to import through a dry port, at least 3 handlings would be necessary, one to load the container on the truck or rail, another one to discharge the container in the dry port's yard, and the last one to load the container on the truck to be delivered to the customer. Any other container handling required by the customer or customs agents, as the positioning to inspection or deconsolidation, is considered an additional service and is fulfilled in other steps of the model.

Equation 17

$$HC_{dr} = \sum_{\substack{i \in SEA \\ j \in DRY \\ dr \in DRS}} thc_{i,j} \times box_{i,j} \times qhm_{i,j,dr}$$

7.3.1.2 Storage Cost (*SC*)

The storage cost is referenced to the charges paid by customer for storage their cargo inside the seaport or dry port facility. It is proportional to the storage charge per box ($scc_{i,j}$) or ($scd_{i,j}$) and the dwell-time of the cargo in the seaport or dry port facility ($doc_{i,j}$) (QIU; LAM; HUANG, 2015; TSAO; LINH, 2018). In order to avoid low operations efficiency, a seaport only provides a temporary storage space for containers by charging storage fees if containers' dwell time is longer than a free-time-limit. A dry port, however, charges a lower storage fee than that in the seaport container yard. Hence, the dry port seems to be more attractive for relatively long-term storage (KIM; KIM, 2007; QIU; LAM; HUANG, 2015).

The model simulates the storage cost of consolidated cargo (*con*) in the yard (when $dr = 1, 2, 4\ or\ 5$) and deconsolidated cargo (*deco*) in the warehouse (when $dr = 3, 6, or\ 7$). Some assumptions of the model are that no storage free-time in the seaport's and dry port's yard or warehouse is considered. Furthermore, a minimum rate of storage charge ($msrc_{i,j}$) or ($msrd_{i,j}$) is considered, applicable when the $scc_{i,j}$ or $scd_{i,j}$ is less than the $msrc_{i,j}$ or $msrd_{i,j}$ due the cargo value (cv) or the minimum time rate ($tmc_{i,j}$) for storage. The $scc_{i,j}$ and $scd_{i,j}$ can be assessed proportionally to the cargo value (cv), when a percentage of the cargo value is charged per day of storage ($src_{i,j}$) and ($srd_{i,j}$). In this model the cargo value (*cv*) is assessed through a relation among the CIF (Cost, Insurance and Freight) rate (*cifr*), the cargo weight (*cw*) and the dollar rate (*dor*). Additionally, if the cargo is deconsolidated, it must be stored and delivered as a whole, not partially.

Related to the dwell-time of the cargo in the seaport or dry port facility ($doc_{i,j}$), it vary according to the transit time from seaport to customer ($ttsc_{t,r}$), the transit time from seaport to dry port ($ttsd_{t,r}$), the transit time from dry port to the customer ($ttdc_t$), the documentation time to liberate the cargo at seaport (dtd_i) and how long the customer require it until receive the cargo in their facility (ttd). In this way, the storage cost is assessed as follows.

Equation 18

$$cv = cifr \times cw \times dor$$

Equation 19

$$doc_{i,j} = ttd - \sum_{\substack{t,r\in TM \\ i\in SEA}} ttsd_{t,r} - ttsc_{t,r} - ttdc_t - dtd_i$$

If $dr = 1, 2, 4\ or\ 5$:

Equation 20

$$scc_{i,j} = cv \times src_{i,j}$$

Equation 21

$$SC_{dr} = \sum_{\substack{i\in SEA \\ j\in DRY}} scc_{i,j} \times doc_{i,j} \times box_{i,j}$$

If $dr = 3, 6, or\ 7$:

Equation 22

$$scd_{i,j} = cv \times srd_{i,j}$$

Equation 23

$$SC_{dr} = \sum_{\substack{i\in SEA \\ j\in DRY}} scd_{i,j} \times doc_{i,j} \times box_{i,j}$$

7.3.1.3 Value-added service cost (*VA*)

More than handle and store container cargo, seaports and dry ports are becoming specialized in offer additional services to meet customers’ needs (RODRIGUES et al., 2021). These functions vary depending on the type of facility, ranging from basic logistics services to a variety of customer-oriented services including cargo consolidation and deconsolidation, maintenance and repair, track and trace, custom clearance, information processing and forwarding (JEEVAN; CHEN; CAHOON, 2018; KHASLAVSKAYA; ROSO, 2020). As pointed by Jeevan et al. (2017), specially dry ports are anticipating various value added services such as assorting, mixing, blending, packaging and repackaging, labeling and relabeling, offering tailored services beyond the standard offer.

Considering the congestion in seaport's facilities, value-added activities are likely to be less cost-intensive in dry ports (BASK et al., 2014). As the range of services available vary among the seaports and dry ports, the model will considerer every kind of value-added charge, except those related with customs clearance activities and container handling per delivery route. In this way, it is necessary from the decision-maker define the set of additional services required ($SAS = kas_1, kas_2, \ldots, kas_N$) and the respective charges (cas_{i,j,kas_q}). For instance, if the decision-maker decides to deconsolidate the cargo in the seaport, at least the positioning, consolidation/deconsolidation, and weighting is required and should be considered in the model.

Equation 24

$$VA_{dr} = \sum_{\substack{i \in SEA \\ j \in DRY \\ kas_q \in SAS}} \sum_{q=1}^{N} \left(cas_{i,j,kas_q} \right) \times box_{i,j}$$

7.3.1.4 Customs clearance cost (*CC*)

Customs clearance is the most anticipated service provided by dry ports, assisting seaport to ease the import and export procedure, reducing significantly container dwelling times and congestion in seaports (BASK et al., 2014; JEEVAN et al., 2017). Bringing customs and commercial release closer to the customer, they can collect their goods closer to the inland destination in a more flexible way (SHERAFATIPOUR et al., 2018). Essentially, there are four different customs control types: (1) automated computerized control, (2) documentary control, (3) physical inspection, and (4) X-ray scanner control. With this in mind, customs cost could be assessed taking into consideration direct costs and indirect costs.

Direct costs include terminal handling costs, storage costs, and customs operation costs in the case of physical inspection and x-ray scanner control. Instead, indirect costs consist of opportunity costs and economic-technical depreciation costs for the containerized goods during the time needed for the releasing operations (IANNONE; THORE, 2010). As major customs clearance costs are covered in the other steps of this model, only the positioning for physical inspection cost ($pic_{i,j}$), x-ray scanner control cost ($xsc_{i,j}$) and the transshipment customs cost (tcc_j) for transfer containers from seaport to dry ports were considered. As customs charges for automated computerized control and documentary control are the same for all custom office, it was not considered in the model.

Equation 25

$$CC_{dr} = \sum_{\substack{i \in SEA \\ j \in DRY}} \left(pic_{i,j} + xsc_{i,j} + tcc_{i,j}\right) \times box_{i,j}$$

7.3.2 Time cost (*TIC*)

Time is one of the most important factors in every logistic decision, where customers usually require their cargo as fast as possible. However, it can't be generalized (BASK et al., 2014). Many customers don't have storage capacity either specialized equipment to handle containers, requiring these services from logistic operators. As money change value along the time, many kinds of costs emerge from delivery time variance such 'inventory cost', that aggregates the opportunity and depreciation costs (TALLEY; NG, 2017; TRAN; HAASIS; BUER, 2017); 'demurrage and detention costs' (FAZI; ROODBERGEN, 2018); 'container leasing cost' (IANNONE, 2012); as well the 'storage cost' mentioned above. In this way, to assess the 'time cost' is necessary to measure the Total Logistic Time (TLT) first, which is the time expended for the cargo in each step of the import/export flow considering the return of the empty container, when applicable, and is defined as: (i) the dwell-time of the cargo at seaports' or dry ports' facility ($doc_{i,j}$); (ii) the documentation time to liberate the cargo at seaport (dtd_i); (iii) the transit time from the seaport to the customer's facility ($ttsc_{t,r,dr}$), from the dry port to the customer's facility ($ttdc_{t,dr}$) and from the seaport to the dry port ($ttsd_{t,r,dr}$); (iv) the transit time to return the empty container ($ttre_{t,r,dr}$).

It is important to highlight that the TLT starts to count since the container is discharged into the seaport's yard until the customer receive their cargo and considerate the returns of the empty container when the cargo is delivered consolidated. If the cargo is deconsolidated in the seaport or dry port, the $ttre_{t,r,dr}$ is not considered, since those facilities works as depots to receive the empty container. In this way, TLT is assessed considering the transit time until the customer receive their cargo (ttd), that should be defined by the customer (TRAN; HAASIS; BUER, 2017), plus the $ttre_{t,r,dr}$ when applicable. The ttd aggregate the storage time and the transit time, that can be estimated multiplying the distance per delivery route of each transportation mode ($dd_{dr,TM}$) and the average speed of the truck or rail ($as_{t,r}$) (KAPETANIS; PSARAFTIS; SPYROU, 2016; LARRANAGA; ARELLANA; SENNA, 2016). Moreover, the transit time should consider the time for rest and stops prescribed by the countries' regulations (IANNONE; THORE, 2010). Hence, the TLT_{dr} is assessed as follows.

Equation 26

$$ttd = \sum_{\substack{i \in SEA \\ j \in DRY \\ dr \in DRS \\ t,r \in TM}} doc_{i,j} + dtd_i + ttsd_{t,r,dr} + ttsc_{t,r,dr} + ttdc_{t,dr}$$

Equation 27

$$TLT_{dr} = \sum_{t,r \in TM} ttd + ttre_{t,r,dr}$$

7.3.2.1 Inventory cost (*IC*)

It may be expressed aggregating opportunity and depreciation costs, which are the inventory in transit holding costs depending on the cargo value (*cv*), the interest rate (opportunity and depreciation rates per day), and the transit time until the customer receive their cargo (ttd) (IANNONE; THORE, 2010; JANIC, 2007; TALLEY; NG, 2017).

Equation 28

$$IC = ttd \times cv \times (or + der)$$

7.3.2.2 Demurrage and detention costs (*DDC*)

In general, a container is said to be in demurrage for the time it is positioned at a seaport. Each container is usually granted a free demurrage period, after which additional days at the seaport are penalized with a daily demurrage fee (FAZI; ROODBERGEN, 2018). On the other hand, a container is said to be in detention once it has left the seaport and is in the hinterland for a period of time longer than the detention free-time, until the empty container had returned to the shipping line's depot, dry port or to an agreed seaport terminal (FAZI; ROODBERGEN, 2018). Despite the above concept, the ship-owners usually charge a unique rate that aggregates demurrage and detention charges, according to the transit time of the container (ttc_{dr}), that is the time since the container is discharged in the seaport and returns empty to the seaport or dry port, varying with the delivery route. Additionally, this rate is progressive, starting to charge a demurrage and detention fee 1 ($ddf1$) after the ttc_{dr} surpass the demurrage and detention free-time ($ddft$). After the ttc_{dr} surpass the double of ddft, a demurrage and detention fee 2 ($ddf2$) starts to be charged until the empty container returns. A general assumption is that if the cargo is deconsolidated in the seaport, no *DDC* is charged. In this way, the *DDC* is assessed as follows.

If $ttc_{dr} \leq ddft, DDC_{dr} = 0$

If $ddft < ttc_{dr} \leq (2 \times ddft)$:

Equation 29

$$DDC_{dr} = ttc_{dr} \times ddf1$$

If $ttc_{dr} > (2 \times ddft)$:

Equation 30

$$DDC_{dr} = (ddft \times ddf1) + \{[ttc_{dr} - (2 \times ddft)] \times ddf2\}$$

7.3.2.3 Container leasing cost (*CLC*)

Container leasing cost is assessed as function of a container leasing charge (lcd) and the container transit time (ttc_{dr}), since it is discharged from the vessel (full) and should return to the ship-owner through a seaports or a dry port (IANNONE, 2012). This dimension is measured in days of leasing and is formulated as follows.

Equation 31

$$CLC_{dr} = ttc_{dr} \times lcd$$

7.3.3 Transportation cost (*TRC*)

The transportation network is in the center of logistic decisions. Regarding dry port context, a direct and high capacity connection between dry ports and seaports, as railway and barge, is a characteristic of dry ports infrastructures (ROSO; WOXENIUS; LUMSDEN, 2009). Looking for increase container flow in a reliable and security way, optimizing the scale economies through direct connections, dry ports emerges as an option to reduce the transportation costs. However, in many developing economies, majority of the freight transport is undertaken by road based vehicles while rail and water based services remain either largely unutilized or highly disorganized in their functioning and coordination (BHATTACHARYA et al., 2014), which makes the benefits for using dry ports in terms of cost contestable from the customers perspective (RODRIGUES et al., 2021). Considering the relevance of assessing transportation cost as information to customers' decision-making, this model highlights and calculates three major transportation costs: delivery cost (CRAINIC et al., 2015; IANNONE, 2012; JANIC, 2007; LATTILA; HENTTU; HILMOLA, 2013; TRAN; HAASIS; BUER, 2017), back empty container cost (FAZI; ROODBERGEN, 2018; IANNONE, 2012; SONG; DONG, 2012), and emission cost (LATTILA; HENTTU; HILMOLA, 2013; ROSO, 2007; TRAN; HAASIS; BUER, 2017).

7.3.3.1 Delivery cost (*DEC*)

Delivery cost is the charge paid by customers to receive their cargo from dry port or seaport and usually is based on commercial deals between those actors and rail or truck carriers. However, as commercial deals vary among each customer, this model measures the delivery cost based on the quantity of boxes delivered ($box_{i,j}$), the modal charge ($mc_{t_{con,deco},r_{con}}$), varying by truck, rail, and the cargo type, and the delivery distance ($dd_{dr,t,r}$), which vary depending on the delivery route (*dr*) and the transportation mode (LÄTTILÄ; HENTTU; HILMOLA, 2013). A fixed delivery rate ($fdr_{t_{con,deco},r_{con}}$) is charged, fulfilling the fixed transportation cost for the carriers. An additional delivery cost (adc_{dr}) is also charged representing the transportation under customs control rate.

For the simulations, if the dry port is not direct connected with the seaport through railway, a multimodal transportation mode may be used, carrying the cargo by rail until some point, and then finishing the transport by truck; in this case, an operational transshipment rate (otr_{dr}) is charged to transfer the container from the train to the truck. Some assumptions are that the container is transported under merchant haulage, when the shipping line is only responsible for the sea transport; typically, the shipper appoints a local carrier for the inland transport (FAZI; ROODBERGEN, 2018). The distances of the delivery route vary according to the route and the location of each facility; the tolls charged in each delivery route are not considered in this model. Hence, the delivery cost (DEC_{dr}) is assessed as (LÄTTILÄ; HENTTU; HILMOLA, 2013; TRAN; HAASIS; BUER, 2017):

Equation 32

$$DEC_{dr} = \sum_{\substack{i \in SEA \\ j \in DRY \\ t,r \in TM \\ con,deco \in CT \\ dr \in DRS}} \left(box_{i,j} \times dd_{dr,t,r} \times mc_{t_{con,deco}, r_{con,deco}}\right) + fdr_{t_{con,deco}, r_{con}} + adc_{dr} + otr_{dr}$$

7.3.3.2 Back empty container cost (*BECC*)

Shipping companies are usually responsible for providing required empty container to their customers (SONG; DONG, 2012). When a customer asks to export freight, a truck will carry an empty container from a depot (dry port or seaport) and deliver it to the customer location in order to consolidate the cargo. In the same way, since the consignee received their import cargo and deconsolidate it, the empty container should return to a depot in order to avoid additional detention and leasing charges (SONG; DONG, 2012; WANG; YUN, 2013). Hence, here the transportation cost to return the empty container is assessed as follows below. Some assumptions are that the empty container should back to the same facility which it was delivered through road or rail transportation mode, for instance if the container was delivered through a seaport it should back to the same seaport and through the same transportation mode. In this way, ($dd_{dr,t,r}$) is the same distance in the route to deliver the cargo from the customer (k) to the dry port (j) or seaport (i). Additionally, if the cargo is deconsolidated in the seaport or dry port, no *BECC* is charged.

Equation 33

$$BECC_{dr} = \sum_{\substack{i \in SEA \\ j \in DRY \\ empt \in CT \\ t,r \in TM \\ dr \in DRS}} \left(box_{i,j} \times dd_{dr,t,r} \times mc_{t_{empt}, r_{empt}}\right) + fdr_{t_{empt}, r_{empt}} + otr_{dr}$$

7.3.3.3 Emission cost (*EMC*)

A well designed dry port can benefit ecologically the environment and the quality of life by shifting flows from road to rail (ROSO, 2007). In this model, emission cost is considered as an opportunity cost, where the government offers financial incentives to reduce the CO2 emission, changing the transportation mode from road to rail. In this way, the *EMC* is a carbon credit for shippers and consignees which choice to import/export through dry ports, using the railway network (*dr = 2, 5, 7*) compared to the other options of delivery routes by road.

The emission cost depend heavily on the delivery distance per delivery route (dd_{dr}), the weight of the truck with the cargo (w_t) and weight of the wagon with the cargo (w_r), varying through a marginal emission parameter ($me_{t,r}$), which depends on the transportation mode (truck or rail) (LÄTTILÄ; HENTTU; HILMOLA, 2013). As carbon credit, this opportunity cost is applicable only when the customer uses multimodal transport. In this way, the dd_{dr} using multimodal is compared with a direct delivery route option by truck (ddd_{dr_t}) to identify how much carbon was saved through the railway connection. Hence, the total carbon credit saved is converted into financial benefits through a carbon price (cp) as follows.

Equation 34

$$EMC = \sum_{\substack{dr=2,5,7 \\ t,r \in TM}} cp \times \left[\left(ddd_{dr_t} \times me_t \times w_t \right) - \left(dd_{dr_r} \times me_r \times w_r \right) - \left(dd_{dr_t} \times me_t \times w_t \right) \right]$$

7.3.4 Total Logistic Cost (*TLC*)

The Total Logistic Cost (TLC_{dr}) per delivery route function is assessed aggregating the Service Cost (*SEC*), Time Cost (*TIC*) and the Transportation Cost (*TRC*) as follows.

Equation 35

$$TLC_{dr} = HC_{dr} + SC_{dr} + VA_{dr} + CC_{dr} + IC + DDC_{dr} + CLC_{dr} + DEC_{dr} + BECC_{dr} + EMC_{dr}$$

From equation (35), the seaport-hinterland network costs for the 7 delivery routes defined as the discrete system may be assessed. When the seaport-hinterland network decision from the customer's perspective is made only in terms of cost, they should decide for the delivery route with the fewer cost. Applying the cost model in the Brazilian case with sensibility analysis in terms of the distance, time, cargo type, cargo value, transportation mode and emissions have brought political and managerial insights, with theoretical and practical implications.

7.3.5 Simulations' assumptions

Some assumptions were required to the simulations in São Paulo. In terms of services cost, to assess the handling cost, each delivery route was analyzed in order to identify the quantity of handling moves required. For instance in *dr=1* and *dr=2*, only one handle is required to load the container under the truck or rail to be delivered; on the other hand, in *dr=3* the container is deconsolidated in the seaports' warehouse, and the positioning is considered as an additional service, then no handling cost is charged; for *dr=4* and *dr=5* was considered one handling in the seaport and two handlings in the dry port; lastly, for *dr=6* and *dr=7* was considered one handling in seaport and one handling in dry port. For the storage cost was considered a minimum rate charge of storage that vary according to the cargo value and the dwell-time of storage, charging the highest rate, based on the average rate of the dry ports and seaports of São Paulo state. Furthermore, the time of some activities along the import process was considered as: the time to deconsolidate the cargo was not considered, so, in *dr=3, 6, 7,* the container is deconsolidated in the same day of it arrives in seaport or dry port facility; if the cargo is stored in the seaport less than 2 days, it is charged in the model, however, if the container was schedule to be delivered to the dry port, those 2 days is not charged; if the container does a gate-in and gate-out in the same day, no storage cost is charged. In resume, the simulations charged the storage cost in seaport just for *dr=1, 2, 3,* and in dry port just for *dr=4, 5, 6, 7*, even requiring using the seaport's facility for a short period of custom liberation.

Still related to services cost, as the set of additional services vary according to the customers' necessities, for the simulations it was considered only the required additional services for each delivery route as positioning, deconsolidation, consolidation and weighting. In terms of customs process, as it is the same in dry ports and seaport, the charges related to the process was not considered in the model. It was considerer 2 days as the documentation time to liberate the cargo through Customs Transit Declaration (DTA) (BFR, 2019). Furthermore, the transshipment customs cost (tcc_j) is only charged in delivery routes which use dry port, charged by the seaport to liberates the DTA and by dry ports receive it (NG; PADILHA; PALLIS, 2013).

Some assumptions were also made to assess the time cost (*TIC*). First, all the road and rail distances among customer's cities, dry ports' cities and seaports' city were measured through Google Maps, making possible estimate the transit-times. Second, the transit-time also considered the 8 working hours allowed by the Brazilian Legislation (TST, 2021), in this way, if a transit time to deliver a container exceed 8 hours, another day of transit was considered. Moreover, a unique transportation mode should be operated per day (truck or rail in the same day). Third, the operational time of load and discharge, as well the consolidation and deconsolidation of the cargo is not considered in the model. Lastly, is assumed that the customer returns the empty container to the dry port or seaport in the same day that it receives the container. Related to demurrage and detention cost, for $dr = 1,2,4,5$, ttc_{dr} is equal to TLT_{dr}. However, for $dr = 3$, where the container is deconsolidated in the seaport, $DDC_{dr=3} = 0$. For $dr = 6, 7$, where the container is deconsolidated in the dry port, the transit time from the seaport until the container reach the dry port was considered to identify if it doesn't surpass the ddft for each customer's city, and, after be deconsolidated in the dry port, the empty container remains in the dry port.

For the simulations was considered one 40 foot container box, and a road carrier profit of 10% (ARAÚJO; BANDEIRA; CAMPOS, 2014). The transportation cost was assessed for all options of routes available in São Paulo state. In this case, the transportation cost from Santos seaport for all customers' cities deliver directly were assessed, as well the cost from the seaport to all dry ports' cities, selecting the route that resulted the fewer transportation cost per delivery route. As in São Paulo there is no operational dry port direct connected with the seaport, we have considered the multimodal transport only for consolidated cargo. In this case, the container goes to a multimodal facility, is discharged from a train and loaded in a truck to then be delivered to a dry port or to the customer. For deliveries in the same city or neighbor cities of dry ports and seaports with less than 10km of distance, the fixed delivery rate ($fdr_{t_{con,deco,empt}, r_{con,empt}}$) plus 10km of distance for modal charge ($mc_{t_{con,deco,empt}, r_{con,empt}}$) were considered. Related to the return of empty container, it was considered as 92% of the variable cost to deliver a full container (ANTT, 2021). The container should return to the same facility that it came. In this way, for *dr=3, 6, 7*, there is no *BECC* since the container is deconsolidated in the seaport or dry port. Lastly, as there is no carbon credit policy in Brazil to stimulate shippers and consignees to use railways instead of roadways connections, we have simulated a scenario considering a carbon credit policy to understand if it's an option to policy makers in Brazil. For the simulations it was considered a carbon price of R$280.00 per tons of CO2 saved (EDF, 2020).

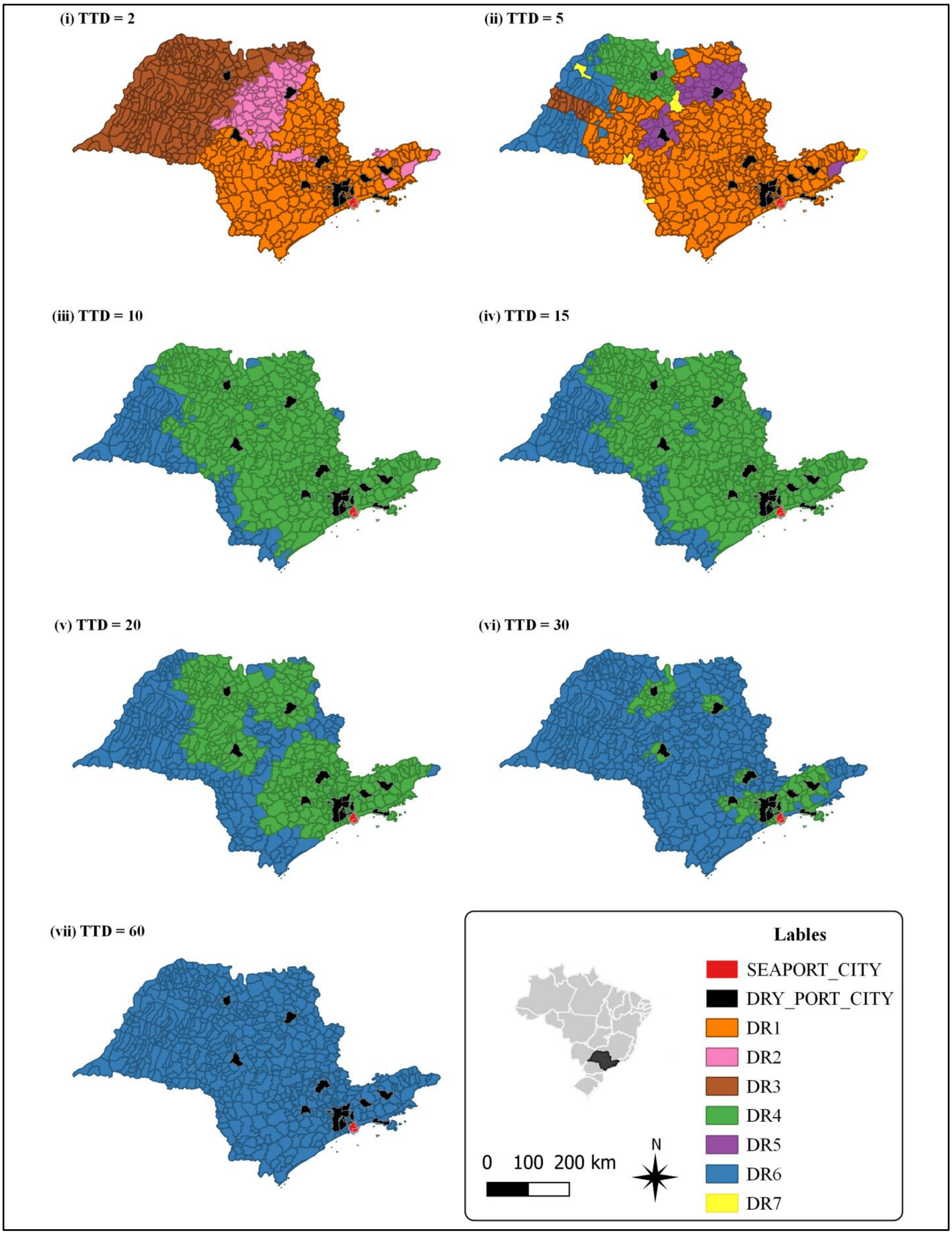
7.4 RESULTS

The results from the simulations looks to answer the proposed research question identifying how customers' specificities drive the jointly seaport-hinterland network decision in terms of cost varying factors as location, time, transportation mode and cargo type and cargo value. The first simulation (SIM1) has run the cost model considering the cargo value as R$415,580.00 (approximately US$74,000.00) (LÄTTILÄ; HENTTU; HILMOLA, 2013; ZHANG; SCHRAMM, 2020) and has varied the total time until the customer receive the cargo (ttd) from 2 days until 60 days, looking for identify the impact of those variables in the seven delivery routes available as options for consignee's to import their cargo. Figure 21 presents the result of seven simulations highlighting the cost efficient delivery route for each city in São Paulo state.

In cases when the consignee needs their imported cargo as fast as possible, as represented in the simulation by *TTD=2*, the cost efficient delivery routes are DR1, DR2 and DR3 as follows in Fig. 21(i), when the cargo is directly delivered to the customer from the seaport. This result demonstrates that in cities near from Santos seaport, delivery the container consolidated and returning the empty is the cost efficient option (DR1). However, as the distance from the seaport increases, deconsolidate the cargo in seaport and deliver become the cost efficient option (DR3). Lastly, using multimodal transportation mode is cost efficient for some cities, especially the ones near the Araraquara's multimodal facility. When *TTD=5*, especially due delays in customs process, DR1 keeps as the cost efficient option for most cities in São Paulo Fig. 21(ii). However, DR4 emerges as an option for cities near the dry port of São José do Rio Preto and DR5 as an option for cities near the dry ports of Ribeirão Preto and Bauru using the multimodal facility of Sumaré. Lastly, DR6 starts to become cost efficient for some cities, using a dry port to deconsolidate the cargo and deliver to the customer.

As the *TTD* increases for 10 and 15 days, import cargo through dry port is the cost efficient option for all São Paulo's cities, specifically through DR4. For *TTD=20*, deconsolidate the cargo in the dry ports starts to highlight as a cost efficient option especially for cities far from dry port's facilities. For *TTD=30*, DR4 keeps as the cost efficient option especially for cities near dry port's facilities while DR6 assumes as the best option for the other cities. Lastly, as the *TTD* increases toward 60 days, DR6 becomes the best option for all cities, delivering the cargo deconsolidated to the customer through a dry port.

Figure 21 – Results of simulation 1



Source: This thesis (2022).

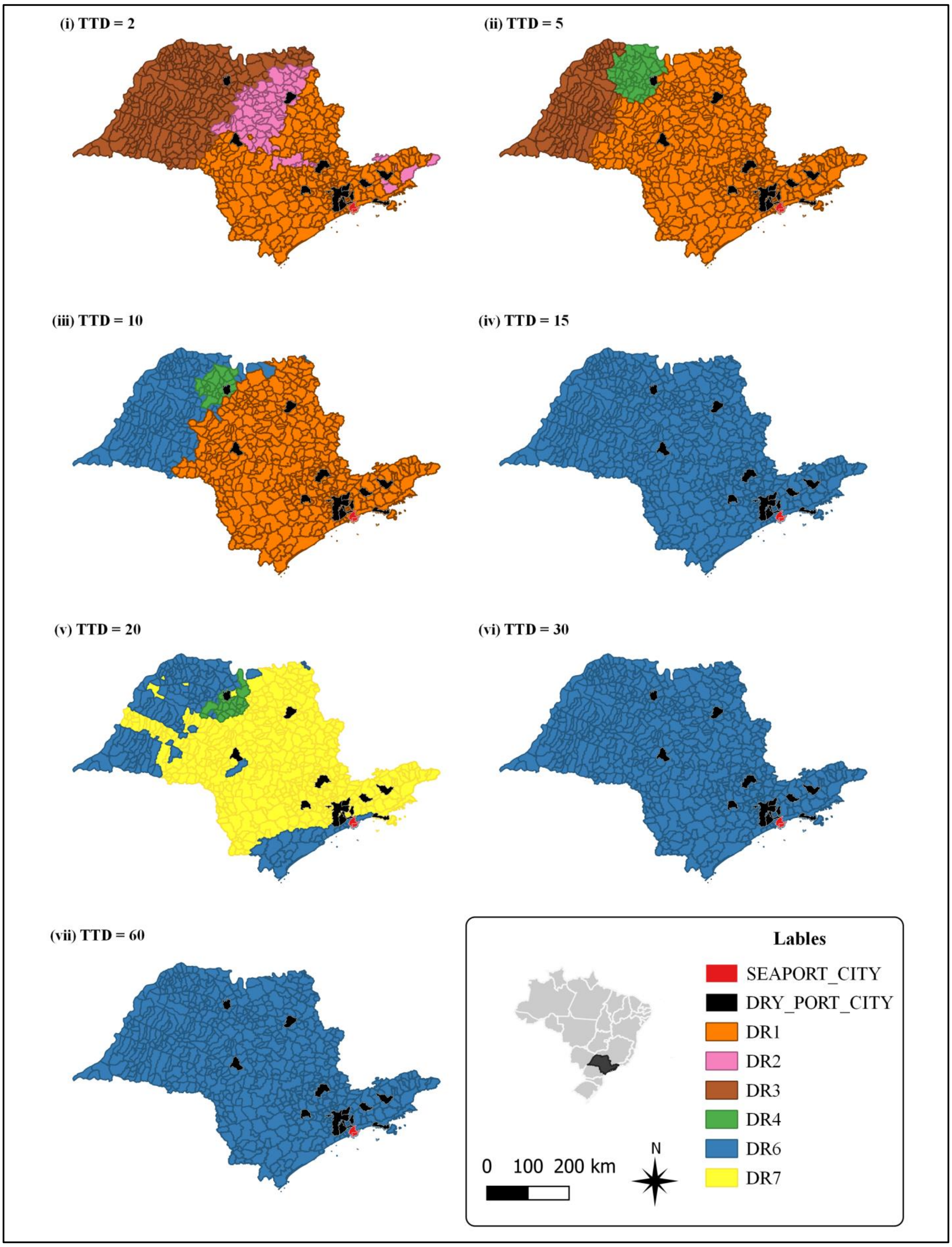
The second simulation (SIM2) has run the cost model varying total time until the customer receive the cargo from 2 days until 60 days and reducing the cargo value to R$45,000.00 (approximately US$8,040.00) (DP WORLD, 2021; ZHANG; SCHRAMM, 2020). The objective here was understand the impact of the cargo value in the total logistic cost, taking into account the storage cost is based on the cargo value and considering a minimum storage fees as rule when applicable. The results follow in Figure 22.

For *TTD=5* the results are close to the SIM1, with DR1, DR2 and DR3 as the cost efficient options to deliver the cargo to the customer, all of them going directly from the seaport facility. However, when *TTD=5* the scenario changes with DR1 as the cost efficient option for the most cities, DR3 as the best option for cities far from dry port's facilities and DR4 for cities near São José do Rio Preto's dry port. For *TTD=10* the differences between SIM1 and SIM2 become more evidence. While in SIM1 the cost efficient for all cities were through dry ports, in SIM2 DR1 keeps as the best option for most cities, delivering the cargo directly from seaports. This fact highlight that seaports remain as cost efficient option for a longer time for cargos with low value.

As *TTD* increases for 15 days, the DR6 becomes the cost efficient option for all cities, with the cargo passing through a dry port. However, for *TTD=20*, the DR7 emerges as a cost efficient option for most cities. It happened due the fact that a multimodal transportation mode takes more time to deliver the cargo until the dry port's facility, reducing in one day the storage time. As the cargo has a low value, the minimum storage fee is charged in the dry ports for each 15 days of storage; this additional storage day for delivery routes which use truck as transportation mode makes in some specific times, as for *TTD=20* and multiples of 15 days, the DR7 be cost efficient than DR6, however for a low average difference of R$193.86 (approximately US$35.00). After that, for *TTD* equal to 30, 60 and so on, the DR6 highlights as the cost efficient delivery route.

In Brazil there is no policy to reduce the CO2 emission and the road traffic. To simulate the impact of an environment policy, stimulating the use of multimodal transportation, two scenarios were tested. The simulation 3 (SIM3) has the same characteristics and inputs of SIM1 while simulation 4 (SIM4) has the same characteristics and inputs of SIM2, adding in both cases the emission cost factor. The results have shown an impact in customers' choice for 61 cities, changing the transportation mode from road to rail specifically for the direct cargo deliver from seaport to the customer facility when *TTD=2*, comparing SIM1 with SIM3 and SIM2 with SIM4 as presents Table 25. For *TTD=5*, only 7 cities have changed to rail for high cargo values (SIM1 compared with SIM3), including transferring the services from the seaport to dry ports. However, as the *TTD* increases, the *EMC* has no impact in customer's choice in terms of cost.

Figure 22 – Results of simulation 2



Source: This thesis (2022).

Table 25 – Cities fulfilled considering emission cost factor

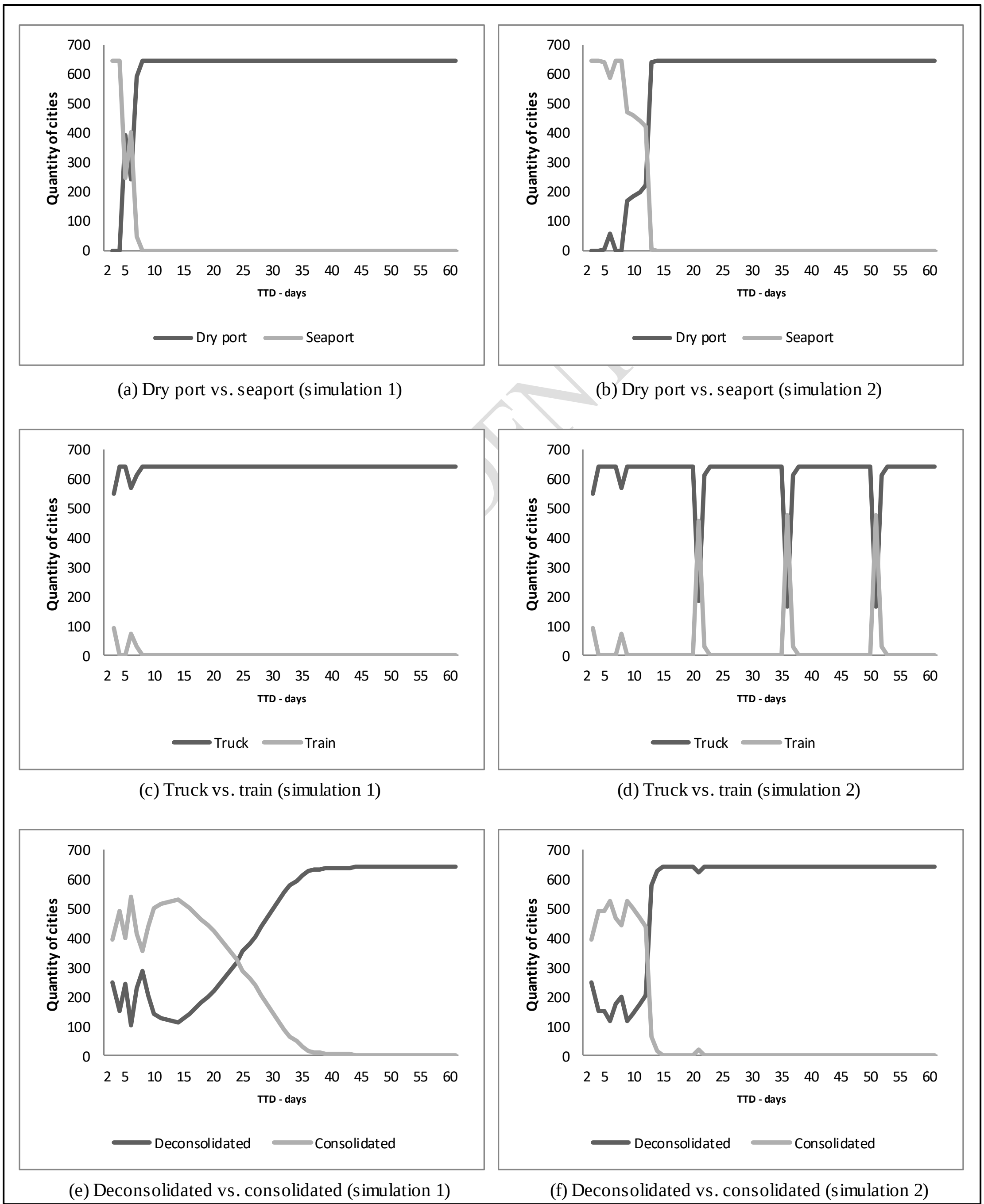
	Simulation	Quantity of cities fulfilled in the cost efficient delivery route						
		TTD = 2	**TTD = 5**	**TTD = 10**	**TTD = 15**	**TTD = 20**	**TTD = 30**	**TTD = 60**
Dry port	SIM1	-	**241**	645	645	645	645	645
	SIM2	-	56	200	645	645	645	645
	SIM3	-	**248**	645	645	645	645	645
	SIM4	-	56	200	645	645	645	645
Seaport	SIM1	645	**404**	-	-	-	-	-
	SIM2	645	589	445	-	-	-	-
	SIM3	645	**397**	-	-	-	-	-
	SIM4	645	589	445	-	-	-	-
Truck	SIM1	549	**570**	645	645	645	645	645
	SIM2	549	645	645	645	**187**	645	645
	SIM3	488	**563**	645	645	645	645	645
	SIM4	488	645	645	645	**174**	645	645
Train	SIM1	**96**	**75**	-	-	-	-	-
	SIM2	**96**	-	-	-	**458**	-	-
	SIM3	**157**	**82**	-	-	-	-	-
	SIM4	**157**	-	-	-	**471**	-	-
Consolidated	SIM1	393	541	516	504	398	119	-
	SIM2	393	525	470	-	22	-	-
	SIM3	393	541	516	504	398	119	-
	SIM4	393	525	470	-	22	-	-
Deconsolidated	SIM1	252	104	129	141	247	526	645
	SIM2	252	120	175	645	623	645	645
	SIM3	252	104	129	141	247	526	645
	SIM4	252	120	175	645	623	645	645

Source: This thesis (2022).

From another perspective, the graphs in Figure 23 present a comparison between simulations 1 and 2 in terms of the cost efficient option per city for each analysis: the kind of logistic operator (dry port or seaport), the transportation mode used (road or rail) and the cargo type (consolidated or deconsolidated). The result in Fig. 23a demonstrates that for a high cargo value, import through dry port is cost efficient for most cities in São Paulo when the customer request their cargo after 6 days; less than that, operate through a seaport is recommended in terms of cost. However, for a low cargo value (Fig. 23b), operates through dry ports becomes cheaper for most cities only after 12 days. In this way, as the cargo value and the storage time increases, operates through dry ports become cost efficient.

Related to the transportation mode, Fig. 23 (c) and (d) shows that deliver the cargo by truck is the cost efficient option for most cities. This result is due the fact that there is no dry port direct connected with the seaport, making necessary to use a multimodal transportation mode to the cargo reach a dry port facility (train and truck), increasing the total logistic cost; some exceptions appears for low cargo value in Fig.23 (d) for *TTD=20* and multiples of 15 days as mentioned above. Moreover, for a high cargo value in Fig.23 (e), delivery the cargo consolidated is cost efficient until 24 days for most cities in São Paulo. However, this inflection point reduces for 12 days for few cargo value Fig.23 (f), influenced by the demurrage and detention charges and the empty returns, which surpass the deconsolidated storage cost and the additional service of deconsolidation in a short time, compared with a high cargo value.

Figure 23 – Comparison between SIM1 and SIM2



(a) Dry port vs. seaport (simulation 1) (b) Dry port vs. seaport (simulation 2)

(c) Truck vs. train (simulation 1) (d) Truck vs. train (simulation 2)

(e) Deconsolidated vs. consolidated (simulation 1) (f) Deconsolidated vs. consolidated (simulation 2)

Source: This thesis (2022).

The simulations also have revealed the dry ports and multimodal facilities recommended attending most cities in São Paulo. It's important to highlight that the results are based in a fixed set of charges which could vary according to each logistic operation or commercial deals. In Table 26 follows the results with the quantity of cities fulfilled per each dry port and multimodal facility. Furthermore, a ranking rate follows in parenthesis considering the population of each city attended by the dry ports and multimodal facilities; in this case, a dry port that is cost efficient to attend São Paulo city, with more than 12 million habitants, has a higher weight (IBGE, 2021).

Table 26 – Dry port cities and multimodal cities recommended

Simulation	**Dry port (DP) and Multimodal (MM) used**	**TTD = 2**	**TTD = 5**	**TTD = 10**	**TTD = 15**	**TTD = 20**	**TTD = 30**	**TTD = 60**
Simulation 1	DP_Barueri	-	52	93	96	119	173	171
	DP_Bauru	-	22	101	99	79	36	32
	DP_Campinas	-	3	78	78	54	7	1
	DP_Guarujá	-	1	29	29	29	32	39
	DP_Santos	-	-	-	-	-	-	-
	DP_Jacareí	-	-	8	8	8	9	1
	DP_Rribeirão Preto	-	41	75	75	61	9	3
	DP_Santo André	-	2	6	6	8	15	18
	DP_Guarulhos	-	-	16	16	16	2	-
	DP_São Bernardo do Campo	-	25	31	36	107	277	327
	DP_São José do Rio Preto	-	92	107	103	77	32	8
	DP_São Paulo	-	-	12	12	12	6	4
	DP_São Sebastião	-	-	4	4	4	4	3
	DP_Sorocaba	-	-	47	45	33	6	-
	DP_Suzano	-	-	10	10	11	25	36
	DP_Taubaté	-	3	28	28	27	12	2
Simulation 1	MM_Araraquara	75	1	-	-	-	-	-
	MM_Sumaré	14	63	-	-	-	-	-
	MM_Campinas	-	-	-	-	-	-	-
	MM_Jundiaí	-	3	-	-	-	-	-
	MM_São Paulo	-	5	-	-	-	-	-
	MM_Suzano	-	-	-	-	-	-	-
	MM_São José dos Campos	7	3	-	-	-	-	-
Simulation 2	DP_Barueri	-	-	68	171	161	171	171
	DP_Bauru	-	-	29	32	57	32	32
	DP_Campinas	-	-	1	1	171	1	1
	DP_Guarujá	-	-	-	39	26	39	39
	DP_Santos	-	-	-	-	-	-	-
	DP_Jacareí	-	-	-	1	10	1	1
	DP_Rribeirão Preto	-	-	-	3	7	3	3
	DP_Santo André	-	-	4	18	6	18	18
	DP_Guarulhos	-	-	-	-	14	-	-
	DP_São Bernardo do Campo	-	-	67	327	82	327	327
	DP_São José do Rio Preto	-	56	29	8	30	8	8
	DP_São Paulo	-	-	1	4	28	4	4
	DP_São Sebastião	-	-	-	3	1	3	3
	DP_Sorocaba	-	-	-	-	9	-	-
	DP_Suzano	-	-	-	36	15	36	36
	DP_Taubaté	-	-	1	2	28	2	2
Simulation 2	MM_Araraquara	75	-	-	-	-	-	-
	MM_Sumaré	14	-	-	-	64	-	-
	MM_Campinas	-	-	-	-	-	-	-
	MM_Jundiaí	-	-	-	-	171	-	-
	MM_São Paulo	-	-	-	-	169	-	-
	MM_Suzano	-	-	-	-	16	-	-
	MM_São José dos Campos	7	-	-	-	38	-	-

Source: This thesis (2022).

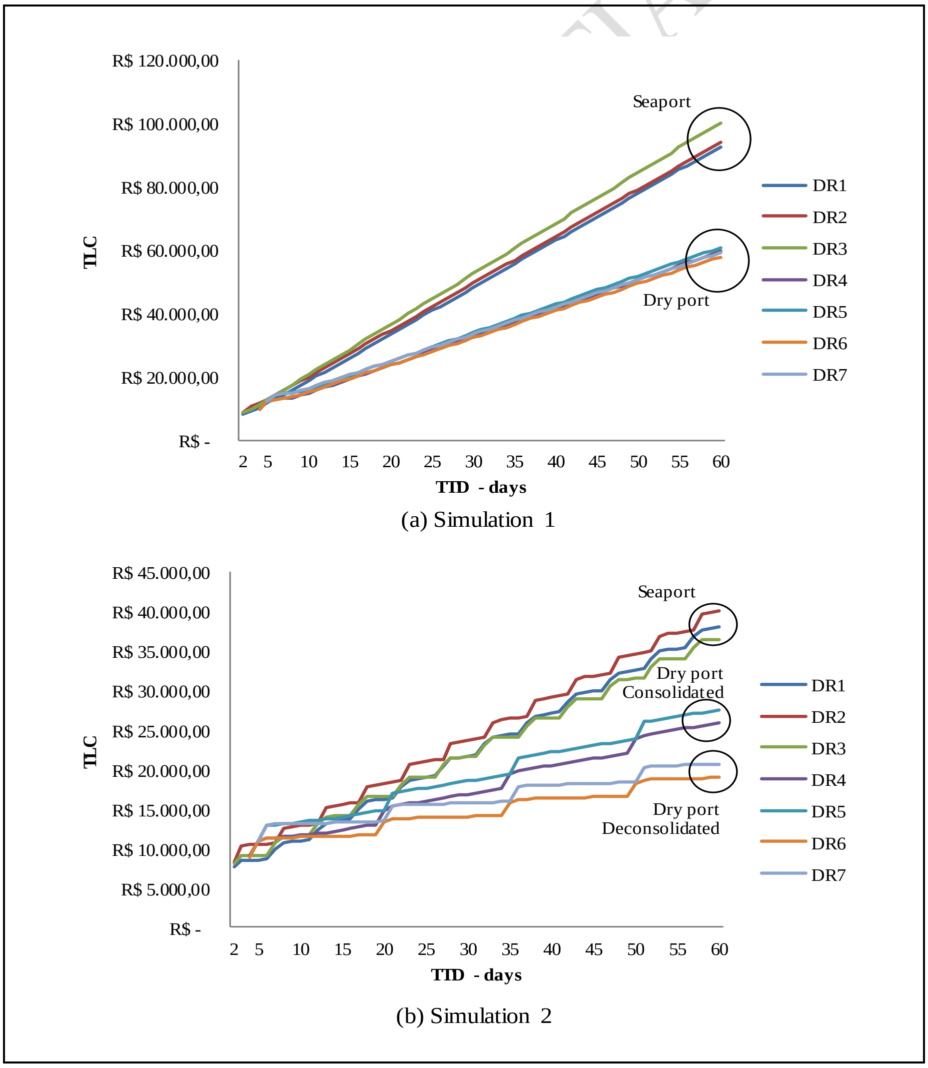
From here, 'DP' and 'MM' are the codes for dry port and multimodal facility respectively. For SIM1, DP_Barueri e DP_São Bernardo do Campo highlights as the most important to serve the most populations zones in São Paulo state. The difference of the most important facility through the quantity of cities and through the population is shown for DP_Campinas and DP_São José do Rio Preto in *TTD=10* and *TTD=15*, where those dry ports serve more cities than DP_Barueri and DP_São Bernardo do Campo, but cities with a few population. It's important to mention that the metropolitan zone surrounding São Paulo's capital (São Paulo city) is composed by 39 cities (CETESB, 2021), aggregating more than 21 million habitants, which represents almost 50% of the São Paulo's state population; as the cost model is sensible to the distances between the customer's city and the logistic facilities, selecting the fewer cost, the cost for use a dry port in that region (as DP_São Paulo, DP_Guarulhos, DP_Barueri, DP_São Bernardo do Campo, DP_Santo André) is almost similar, which doesn't disqualify some dry port that are not highlighted in Table 26. Also in SIM1, the multimodal facilities most used was MM_Araraquara for *TTD=2* and MM_Sumaré for *TTD=5*.

The results for SIM2 also ranks DP_Barueri and DP_São Bernardo do Campo as cost efficient. Some exceptions emerges when *TTD=20* for cargo with low value, when DR7 becomes the cost efficient delivery route as mentioned above. In this case, DP_Campinas, DP_Barueri and DP_São Paulo are top ranked for using multimodal transportation; this result evidence the relevance for a dry port to serve São Paulo city. According to the multimodal, MM_Araraquara highlights for *TTD=2*. For *TTD=20* and multiples of 15 days, MM_São Paulo, MM_Jundiaí and MM_Sumaré are ranked as cost most used.

Summarizing the results from the simulations, Figure 24 presents the variation of the total logistic cost according to the transit time until delivery and the delivery route for SIM1 (Fig. 24a) and SIM2 (Fig.24b). The graphs have shown that for high cargo value dry ports becomes cost efficient as the TTD increase. Another insight is the fact that the total logistic cost for all options of delivery routes increase linearly in a rate of R$1,473.00/day (US$263.00/day) for DR1 and 2; R$1,590.00/day (US$284.00/day) for DR3; R$886.00/day (US$158.00/day) for DR4 and 5; and R$850.00/day (US$152.00/day) for DR6 and 7.

In contrast, for cargos with low value as in SIM2, the variability of the total logistic cost segregates three groups of delivery routes: DR1,2,3 which use seaport to delivery directly, starting as the cost efficient options and becoming the most expensive options as *TTD* increases; DR4,5 which use dry port and deliver the cargo consolidated, returning the empty container; Hence, DR6,7 are cost efficient delivery routes as *TTD* increase, going through dry ports and delivering the cargo deconsolidated. The difference of variation between Fig.24(a) and (b) is caused because in (a) the storage cost for high cargo value surpass the minimum of storage fee, which doesn't happen in (b), making the total logistic cost vary according to the minimum storage time, which is 5 days for seaports and 15 days for dry ports. Furthermore, the impact of demurrage and detention fee and the return of the empty container make the option to deliver the cargo consolidated more expensive. The variability of total logistic cost in SIM2 is approximately R$539.00/day (US$96.00/day) for DR1 and 2; R$495.00/day (US$88.00/day) for DR3; R$295.00/day (US$52.00/day) for DR4 and 5; and R$163.00/day (US$29.00/day) for DR6 and 7.

Figure 24 – Variation of the total logistic cost



(a) Simulation 1

(b) Simulation 2

Source: This thesis (2022).

7.5 DISCUSSION

As relates to addressing research question (RQ: How do customer’s specificities drive the joint seaport-hinterland network decisions in terms of total container shipping cost?), the outcome of the simulations suggests that (i) cargo value, (ii) cargo type, (iii) transportation mode, (iv) delivery distance and (v) the time until the customer received their cargo impact the seaport-hinterland network decision. The first outcome of the simulations suggests that for a short storage time, cargo delivery directly from the seaport is cost efficient, especially for low cargo value and for delivery to locations (cities) next to seaports. These findings are aligned to earlier findings by Tsao and Linh (2018). Furthermore, this finding also suggests that as storage time increases, use of dry ports become the cost efficient option. However, as seaports charge a higher storage fee, dry ports appear more attractive for relatively long-term storage (KIM; KIM, 2007; QIU; LAM; HUANG, 2015).

The second outcome has shown that the road transportation is very cost efficient (for most cities in São Paulo state). As dry ports are not directly connected with seaports, an additional charge to transfer the cargo from rail to road is required in order to use multimodal in the flow of goods. By adding emission cost into the model in SIM3 and SIM4, for a short period of storage, multimodal transportation became the cost efficient option for 157 cities, this is especially for cities far from seaports and near to multimodal facilities. This result evidence that multimodal transportation may be improved in Brazil, mainly connecting dry ports to multimodal facilities, reducing the total logistic cost for customers and achieving the best benefit of scale economies in dry ports’ operation (KHASLAVSKAYA; ROSO, 2020).

Despite the short set of additional services considered for the simulations, the third outcome have shown that container deconsolidation and the dry ports’ function of depot of empty containers have impacted the results of jointly seaport-hinterland choice. Some insights are that for customers far from dry ports and seaports facility, deconsolidation charge is compensated for avoid the return of the empty container. Furthermore, the demurrage and detention charges stood out as a driver for customer decision to deconsolidate the cargo in dry ports, mainly for low cargo value.

Lastly, the average cost of each delivery route in Figure 24 has resumed the difference of total logistics cost by each delivery strategy, bringing light for importers/exporters in

Brazil. Hence, the cost model proved to be a flexible tool to assess the total logistics cost of seaport-hinterland network, bringing relevant insights for importers/exporters, policy makers and service providers. Despite the simulations offer recommendations of best route, each decision maker should take into account their specificities, logistics capacity, service level required and preferences to choice the seaport-hinterland network that best fit their necessities, going beyond the cost analysis. However, as the cost is one of the most important criteria for all logistics decision, the insights from the simulations may short the alternatives for customers' decision making.

7.6 REMARKS

Being able to offer a wide range of service options to a range of customer stakeholder groups in a manner that also ensures a reduction in total cost involved in international logistics is a complex decision depending on multiple criteria. There is substantial research focused on dry port and seaport choice and also intermodal connection decisions and network optimization. However, there still remains a paucity in terms of research focused on seaport-hinterland network choice. In order to attend the fourth specific objective, the results presented in this chapter from the simulation have shown that the proposed cost model works in a flexible manner and may be applicable in different countries and contexts once adjusted to customer's specificities. What the outcome of the simulation tells us is that using dry ports is a cost efficient mechanism in many cases, mainly for a long storage time. This finding has a major implication in that it takes away concerns among Brazilians' shippers and consignees that as an additional 'node' to contend with within the supply chain, dry ports are likely to be associated with additional costs.

The study makes both practical and theoretical contributions to joint decision-making in container shipping. In terms of practical contributions, the proposed cost model that emerges from the study serves as a flexible tool that may be applicable in diverse scenarios and countries; such application being possible by changes to specific parameters of the model. In terms of theoretical contributions, the study not only offered valuable insight into the intricacies of joint decision-making, but also contributed to the literature on seaport-hinterland logistics.

8 SEAPORT-HINTERLAND COMPETITION IN TERMS OF ‘COST’ AND ‘TIME’

A reviewed version of the paper:

RODRIGUES, T.; MOTA, C.; OJIAKO, U. Competitiveness throughout the seaport-hinterland: a container shipping cost analysis. Under Review.

8.1 CONTEXTUALIZATION

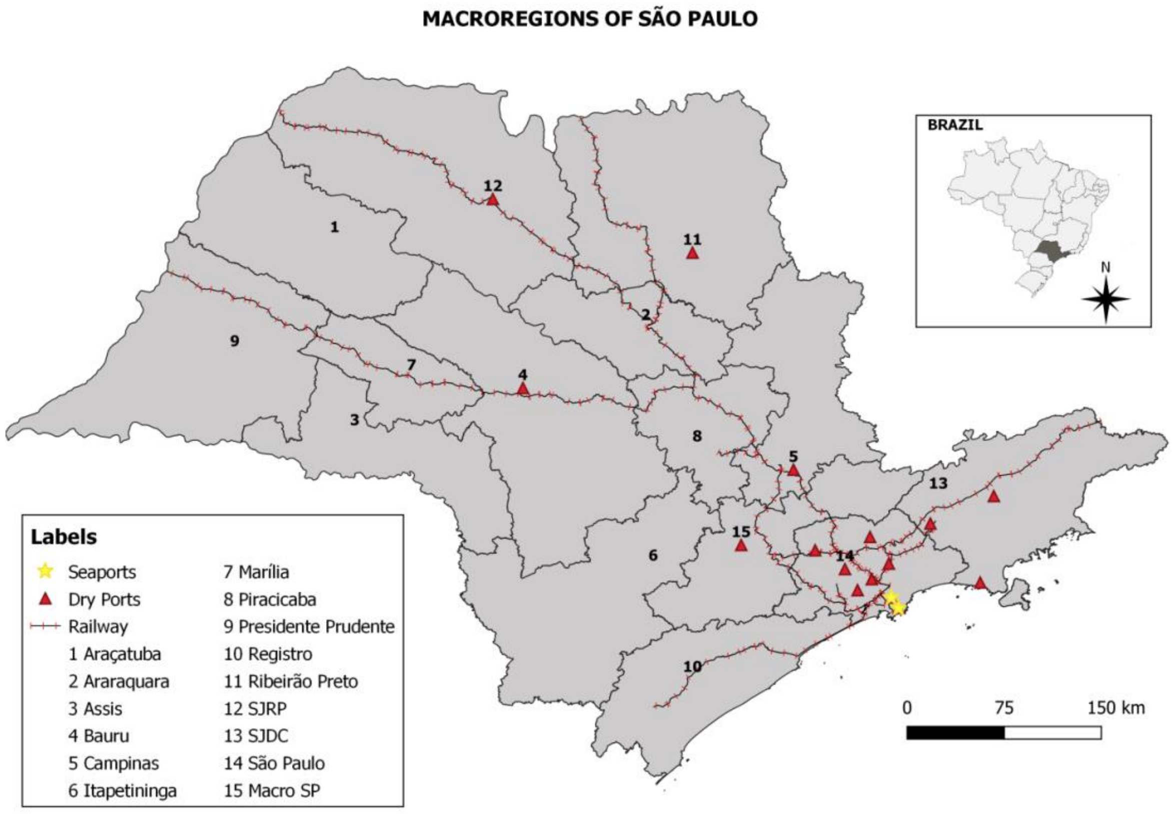
Shippers and logistics scholars have recently begun to focus on the entire process of containerized import/export of goods from a door-to-door approach. This new perspective have been driven by the intense development of international trade market allowing mass production and lower cost of maritime transport by economy of scale, which has improved the international competitiveness (HARALAMBIDES, 2019). Such environment makes the competition advance between ‘company against company’ to ‘supply chain against supply chain’, with customers looking for the highest level of services and reduction of cost (SAMSON; GLOET, 2018). Two key issues arising within this literature are how customers’ select their service providers and how seaport-hinterland actors interact and compete within the same hinterland (intra competition) and among different ones (inter competition). This chapter contributes to this literature exploring such competition by the customer seaport-hinterland choice in terms of ‘time’ and ‘cost’, two traditional logistic decision drivers (DURUGBO et al., 2021).

As pointed in Chapter 7, while studies of seaport choice have been strongly discussed in maritime cargo transportation literature, the seaport-hinterland has remained neglected. To contextualize this problem, none of the models to aid seaport-hinterland optimization detailed in theoretical background has focused specifically the choice among the main seaport-hinterland actors, taken into consideration a large set of logistic costs, the current transport infrastructure (delivery routes) and the customs process time. Furthermore, none of previous studies have considered the import/export process time and discussed the intra and inter competition among the main actors of the seaport-hinterland.

Considering the complexity among seaport-hinterland actors/functions, the range of cost factors related to import/export process, as well the variable customs and process time affecting the seaport-hinterland, it is imperative to further explore these issues in order to aid customers to choose their logistic operators. With this in mind, the aim of this chapter is not only assess the costs evolved throughout the seaport-hinterland and the customs process time of each step (documental and operational), but also to understand the impact of these factors among the main actors, discussing the competitiveness in light of the literature, bringing relevant insights to aid customers' choice. Thus, the ninth research question is answered, fulfilling the fourth specific objective of the thesis.

To address the research question, this chapter focuses on logistics infrastructure in Brazil as case study for the seaport-hinterland analysis in terms of 'cost' and 'time', more specifically in State of São Paulo. From a different approach compared to Chapter 7, this chapter simplifies the cost model proposed, simulating stochastically the import cost for 15 macro regions in São Paulo, as presents Figure 25.

Figure 25 – Macro regions of São Paulo state



Source: This thesis (2022).

8.2 HYPOTHESIS PROPOSITIONS

As stated by Roso, Woxenius, and Lumsden (2009), dry port can serve as an inland clearance depot which may greatly improve customs clearance efficiency of multimodal transport. Customs clearance were perceived as one of the most important factors for Malaysian dry port stakeholders (JEEVAN; CHEN; CAHOON, 2018). Reinforcing that, Jiang et al. (2020) identified that customs clearance time have significant impact on shippers hinterland transport chain choice behavior. With the import process described above in mind, the customs clearance time could be assessed to compare the efficiency of dry ports and seaports. Considering the high volume of customs process in seaports, causing congestion as evidenced by Witte, Wiegmans, and Ng (2019) and Ng, Padilha, and Pallis (2013), it is stated the fifth hypothesis of the thesis.

- Hypothesis 5. The customs clearance process is faster in dry ports.

In order to avoid low operations efficiency, a seaport only provides a temporary storage space for containers by charging storage fees if containers' dwell time is longer than a free-time-limit. A dry port, however, usually charges a lower storage fee than that charged by the seaport container yard. Hence, the customers takes more time operating through dry port, since it is more attractive for relatively long-term storage in terms of cost (KIM; KIM, 2007; QIU; LAM; HUANG, 2015). In order to test this literature in the Brazilian case, it is defined the sixth, seventh and eight hypothesis.

- Hypothesis 6. The customer takes more time to begin the customs process in dry port.
- Hypothesis 7. The customer takes more time to remove the container from the dry port.
- Hypothesis 8. The total import process is longer for customers that use dry ports.

As the portion of inland costs is significant in the total container shipping costs, the interest of shippers and consignees about the hinterland transport chain has been increased (NOTTEBOOM; RODRIGUE, 2005). In this context, dry ports emerge as an option that could bring significant benefits to stakeholders involved in hinterland transport operations by improving distribution systems and reducing direct and indirect logistics costs (KHASLAVSKAYA; ROSO, 2020). As the outputs of the cost simulations in Chapter 7 highlighted, dry ports seems to be the cost efficient option mainly for customers that require a long storage time. With this in mind, identify, the behavior of the shipping cost in function of the storage time should bring relevant insights and information for customer's decision-making. Hence, it is stated the ninth hypothesis.

- Hypothesis 9. How the shipping cost varies in terms of the storage time?

Previous literature reinforce the fact that the intermodal transport is the way to reduce transportation cost through scale economy, making dry ports attractive to shippers and consignees (JEEVAN; CHEN; CAHOON, 2019; RODRIGUES et al., 2020). Some issues emerge concerning the real economy of scale for customers using dry ports when they are not direct connected with the seaport, as the case of Brazil (RODRIGUES et al., 2021). By contrast, despite Brazil be a continental country, the main industrial and consumption zone, located in São Paulo state, are near to the seaport, such as happen in the Republic of Korea and those of Southeast Asia countries, with distances between trade origins or destinations ranging of 100-300 km, putting in check the advantage of scale economy of multimodal transport (UNESCAP, 2015). Going beyond to this issue, we simulated a hypothetical scenario where the studied dry ports were direct connected with the seaport through railway, comparing the results with the current context and testing the tenth hypothesis.

- Hypothesis 10. Dry ports directly connected through multimodal transport with seaport are cost efficient.

8.3 MATERIAL AND METHODS

The study concentrates on the seaport-hinterland network decision from customers' perspective and the competitiveness among the main actors in terms of time and cost. Regarding 'time', it were compared statistically the import process through seaports, dry ports and extended gates based on historical data. In terms of 'cost', we have applied the cost model approach stated in Chapter 7 to assess the import cost since vessel berthing until the container cargo reaches the customers' door. Then, we simulated the cost model stochastically through Monte Carlo method in a case study in Brazil. As dry ports in Brazil are characterized to operates mostly import cargo, enabling the analysis, the case study is limited to the import process (RODRIGUES et al., 2021).

The methodology used in this chapter was based in the Monte Carlo simulation, which is a representative method of the stochastic approach through random numbers that has been extensively applied in the literature (SAMSON; GLOET, 2018). Some examples were the study of Pattanayak, Prakash, and Mohanty (2019), which was designed to estimate the cost of quality in the supply chain from a risk perspective, and the study of Samson and Gloet (2018), which proposed an approach to integrate performance and risk elements of the supply chain based on Monte Carlo simulation. Other examples follows in Jung et al. (2020) and Luz et al. (2020). With that in mind, the next topic describes the methodology applied for this chapter in four steps and then the adapted cost model is detailed.

8.3.1 Step 1 – Import process description

Until the imported cargo reaches the customer/consignee, it goes through the documental customs process in order to nationalize the cargo, and physical operations, as the handling, storage and transport of the container. In terms of process time, it may be generalized in 4 steps (BRAZILIAN FEDERAL REVENUE, 2021; FAZI; ROODBERGEN, 2018; SARMADI et al., 2020). The ‘Step 1’ is the time between the vessel berthing and the cargo manifest, when the seaport declares that the container is located on the yard. As for dry ports the cargo should be transported from the seaport by road or multimodal transportation under customs control, ‘Step 1’ is broken in ‘Step 1.1’ for the time between the vessel berthing and the Declaration of Customs Transit (DTA), when the container is released to be delivered to dry port, and ‘Step 1.2’ for the time between the DTA and the cargo manifest already in the dry port. Then, ‘Step 2’ is the time between the cargo manifest in the seaport/dry port and the import declaration record, when the customer/consignee formalizes the cargo information for the customs authority and begins the import clearance process.

‘Step 3’ is effectively the clearance process time where the cargo is parameterized in three different channels: (i) green channel, whereby the clearance of the cargo occurs automatically; (ii) yellow channel, requiring a documentary examination; and (iii) red channel, whereby the cargo is only cleared after the documentary examination and physical inspection. After that, we stated the ‘Step 4’ as the time between the goods is nationalized and delivered for the customer. Aggregating the above steps, we define as ‘Full Process’ all the time expended since the vessel berthing until the cargo leave the seaport/dry port facility. Lastly, the import process for extended gate is stated as the same of seaports.

8.3.2 Step 2 – Data and tools

Looking for answer the stated hypothesis, comparing the import process time of each step for seaport, dry port and extended gate, we got data of the customs clearance movement and times from the database of Brazilian Federal Revenue (BFR, 2021). The database aggregates the process time of containerized import of goods through all logistics operators in São Paulo state in the year 2019, parameterized in the three different customs channels. After clean the missing values, a total of 23,099 imports register through seaports, 8,602 through dry ports and 8,305 through extended gates were considered for the statistical analysis and for the Monte Carlo simulation.

In order to run the stochastic cost model, the parameters were obtained from multiple sources. Related to road cost, we obtained data from the National Association of Cargo Transport and Logistics (NTC, 2021), from resolution 5.867 of National Agency of Ground Transport (ANTT, 2021) and from the study of Araújo, Bandeira and Campos (2014). The rail fees were based on the average charged by the 2 rail carriers operating transport containers in São Paulo state. Dry ports fees were based on the services average charges of 7 companies responsible for the management of 11 dry ports in São Paulo. In the same way, we considered the average rate of the 3 most important container terminals located in the Santos seaport and 6 line operators/ship-owners. The road distances considered in the model was assessed by Google Maps, the simulations and statistical analysis were coded in Python 3.8.5, using especially Pandas, Numpy, Statistics, Scipy and Fitter libraries. Lastly, to display the results in a map format, we used QGIS 3.16.

8.3.3 Step 3 – Statistical results and analysis

Step 3 starts the data analysis, answering hypothesis 5 to 10. First, a descriptive analysis was performed to identify the mean, median, and standard deviation of the sample. Second, the outliers of the dataset were dropped considering 3 standard deviations as reference. To define which statistical test apply to compare the import process time among the logistic operators, a Shapiro-Wilk test was run, confirming that no sample in any step of the process followed a normal distribution (rejecting the null hypothesis), requiring a non-parametric test for the sample comparisons. In this way, the Mann-Whitney tests (‘U’ test) were paired performed to identify if there are statistical differences of import process time among seaport, dry port and extended gate. The significance level for all tests was 0.05 in the bi-tailed tests.

8.3.4 Step 4 – Cost model simulation

For the cost simulations, we have concentrated on the current logistic infrastructure of São Paulo state. It were considered 4 dry ports' locations as options for the simulations based on the dry port classification (ROSO; WOXENIUS; LUMSDEN, 2009): Santos dry port/extended gate, 10 km far from the seaport (close); Campinas dry port, 163 km far from the seaport (midrange); São José do Rio Preto (SJRP) dry port, 518 km far from the seaport (long distance); and São Paulo dry port, located in the capital of the state, 72 km far from the seaport (close). The seaport city is Santos and the transportation mode is the road, since there is no dry port directly connected with the seaport in São Paulo state. The simulations were divided in two parts: (i) according to the current logistic infrastructure in São Paulo state, comparing the import cost for each actor; (ii), according to a hypothetical scenario, estimating the cost impact for the customers if dry ports were directly connected with the seaport through railway.

For the Monte-Carlo simulations, we focused on the data distribution of import cargo through dry ports. The objective here was to identify if the customers that are using dry ports in Brazil are making the cost efficient option and what is the inflection point of import process time when dry ports becomes more cost competitive. It took us to some issues regarding using statistical tests with a large amount of data. A particular advantage of large datasets is that they can cover a number of underlying subpopulations with particular features, which enable investigations of the stability of conclusions across different groups (COX; KARTSONAKI; KEOGH, 2018). On the other hand, in statistical inference as for the case of using the Kolmogorov-Smirnov test to compare a sample with a reference probability distribution, having a large dataset in connection with goodness-of-fit makes small differences between two datasets indicate statistically significant differences, rejecting the null hypothesis (LAZARIV; LEHMANN, 2018). This aspect refers to the discriminatory power of test, which increases with an increasing sample size. Thus, results from statistical inference with a large sample may not reflect the practical relevance of an existing difference/distance between two distributions.

In many practical applications there might be no appropriate probability distribution model because of "unusual" distribution shapes that make it hard to apply some known distribution model. Hence, a utilization of the Empirical Cumulative Distribution Function (ECDF) directly is justified, because having a large amount of observations makes this ECDF a reliable reference (LAZARIV; LEHMANN, 2018). With that in mind, given the large database from Brazilian Federal Revenue (BFR, 2021), it was used the fit method of SciPy to extract the parameters of that distribution that best fit the data. This process was repeated for 80 available distributions. Finally, it was selected the distribution that best fitted the data based on the Sum Square Error (SSE), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Kullback–Leibler divergence (Kl_div) (PARDO; ORRO; ALONSO, 2020). The stochastic variables in the cost model were fitted through the Fitter library in Python.

For the Monte Carlo simulation, we got the distribution parameters for 'Full process' time, 'Step 1' time for dry ports (aggregating steps 1.1 and 1.2 of import process), and for the 'cargo value' , from 62,255 containerized import cargos registers in São Paulo state in the year 2019 (ECONOMY MINISTERY, 2021). The results of goodness of fit, the best distribution and the respective parameters used for the cost model simulation follow in Table 27.

Table 27 – Goodness of fit and distributions parameters

	Cargo value	**Full process (dry port)**	**Step 1 (dry port)**
Distribution	Betaprime	Wald	Loglaplace
SSE	6.07439E-13	0.000546	0.023425
AIC	3166.943367	1157.962754	869.362443
BIC	-2413009	-133096.6226	-103263.0483
Kl_div	0.002745	0.042313	0.048606
Parameters	(1.522; 1.915; -188.215, 58)	(0.144; 39.744)	(2.594; -0.044; 6.824)

Source: This thesis (2022).

8.3.5 Cost model approach

The cost model applied in this chapter follows the same structure of the model proposed in Chapter 7 with some simplifications. The main difference regards in process time and cargo value assessment, which was considered stochastically for the simulations. The variables and parameters used for the simulations in this chapter follows in Table 28.

Table 28 – Variables and parameters of the cost model simulation

	Description	Unit of measure	Assumptions	Based on
Indexes				
i	Set of seaports (i)			
j	Set of dry ports (j)			
k	Set of customers (k)			
Variables				
$ttsc_{t,r}$	Transit time from the seaport (i) to the customer's facility (k) by truck (t) or rail (r)	Days	Defined by the customer or assessed multiplying the Distance and the Average speed (adding stops and resting time).	(LARRANAGA; ARELLANA; SENNA, 2016)
$ttdc_t$	Transit time from the dry port (j) to the customer's facility (k) by truck	Days	Defined by the customer or assessed multiplying the Distance and the Average speed (adding stops and resting time).	(LARRANAGA; ARELLANA; SENNA, 2016)
$ttre_{t,r}$	Transit time to return the empty container by truck (t) or rail (r)	Days	Defined by the customer or assessed multiplying the Distance and the Average speed (adding stops and resting time).	(LARRANAGA; ARELLANA; SENNA, 2016)
$dd_{t,r}$	Delivery distance by truck (t) or rail (r)	Kilometers	Discrete	Google Maps
cv	Cargo value	US$	Stochastic	(ECONOMY MINISTERY, 2021)
$doc_{i,j}$	Dwell-time of the cargo stored at the seaport (i), dry port (j)	Days	Stochastic	(BFR, 2021)
tud	Time until deliver the cargo to the customer	Days	Stochastic	(BFR, 2021)
ttd	Total time until the customer receive the cargo	Days	Stochastic	(BFR, 2021)
tlt	Total logistic time	Days	Stochastic	(BFR, 2021)
HC	Terminal handling cost	US$	Discrete	(CRAINIC et al., 2015; TRAN; HAASIS; BUER, 2017)
SC	Storage cost	US$	Stochastic	(QIU; LAM; HUANG, 2015; TSAO; LINH, 2018)
CC	Customs clearance cost	US$	Discrete	(IANNONE; THORE, 2010; SHERAFATIPOUR et al., 2018)
IC	Inventory cost	US$	Stochastic	(IANNONE; THORE, 2010; JANIC, 2007; TALLEY; NG, 2017)
DDC	Demurrage and detention cost	US$	Stochastic	(FAZI; ROODBERGEN, 2018)
DEC	Delivery cost	US$	Discrete	(LATTILA; HENTTU; HILMOLA, 2013; TRAN; HAASIS; BUER, 2017)
REC	Return empty container cost	US$	Discrete	(SONG; DONG, 2012; WANG; YUN, 2013)
TLC	Total logistic cost	US$	Stochastic	
Parameters				
box	Quantity of boxes handled, stored or delivered through seaport (i) and dry port (j)	Quantity of containers	1 container 40 foot (2 TEUs)	Defined by the author
$thc_{i,j}$	Terminal handling charge per handle in seaport (i) and dry port (j)	US$/handle	$thc_i =$ US$110.85/handle $thc_j =$ US$54.47/handle	Average fee in seaports (i) and dry ports (j)
$qhm_{i,j}$	Quantity of handling moves in seaport (i) and dry port (j)	Quantity of handles	Delivering from seaport: $qhm_i = 1$ Delivering from dry port: $qhm_i = 1$; $qhm_j = 2$	Operational process required in each facility
$scc_{i,j}$	Storage charge per box at the seaport's (i) and dry port's (j) yard	% cv/day	$scc_i = src_i \times cv$ $scc_j = src_j \times cv$	Average rate in seaports (i) and dry ports (j)
$src_{i,j}$	Storage rate related to the cargo value (cv)	%	src_i =0.255% src_j =0.114%	Average rate in seaports (i) and dry ports (j)
$msrc_{i,j}$	Minimum storage rate in seaport (i) and dry port (j)	US$	$msrc_i =$ US$359.61 $msrc_j =$US$380.95	Average rate in seaports (i) and dry ports (j)
$tmc_{i,j}$	Time related to the minimum storage rate in seaport (i) and dry port (j)	Days	$tmc_i = 5$ days $tmc_j = 15$ days	Average rate in seaports (i) and dry ports (j)
$pic_{i,j}$	Physical inspection cost in seaport (i) and dry port (j)	US$/box	pic_i = US$100.70 pic_j = US$37.93	Average rate in seaports (i) and dry ports (j)
$xsc_{i,j}$	X-ray scanner cost in seaport (i) and dry port (j)	US$/box	xsc_i = US$88.12 xsc_j = US$63.42	Average rate in seaports (i) and dry ports (j)
$as_{t,r}$	Average speed of truck (t) and rail (r)	Km/hr	as_t= 60km/hr as_r= 40 km/hr	(LARRANAGA; ARELLANA; SENNA, 2016)
or	Opportunity cost rate	% of the cargo value/day	$or + der$ = 0.0685%	(TRAN; HAASIS; BUER, 2017)
der	Depreciation cost rate	% of the cargo value/day	$or + der$ =0.0685%	(TRAN; HAASIS; BUER, 2017)
$ddft$	Demurrage and detention free-time	Days	$ddft$ =7 days	Average rate among ship-owners
$ddf1$	Demurrage and detention fee 1	US$/day	$ddf1$ = US$13.84/day	Average rate among ship-owners
$ddf2$	Demurrage and detention fee 2	US$/day	$ddf2$ = US$24.22/day	Average rate among ship-owners

tcc	Transshipment customs cost to transfer the cargo from seaport (*i*) to dry port (*j*)	US$/box	tcc = US$340.00	Average rate in seaports (*i*) and dry ports (*j*)
$mc_{t,r}$	Modal charge per delivery distance by truck (*t*) and rail (*r*)	US$/(box*Km)	Container full: mc_t =US$0.783 mc_r =US$0.684 Container empty: mc_t =US$0.718 mc_r =US$0.326	(ANTT 2021; ARAÚJO; BANDEIRA; CAMPOS, 2014; NTC, 2021; TRAN; HAASIS; BUER, 2017). Average rate among rail carriers
$fdr_{t,r}$	Fixed delivery rate per transportation by truck (*t*) and rail (*r*)	US$	Container full: fdr_t =US$149.62 fdr_r =US$116.05 Container empty: fdr_t =US$137.65 fdr_r =US$83.23	(ANTT 2021; ARAÚJO; BANDEIRA; CAMPOS, 2014; NTC, 2021). Average rate among rail carriers
adc	Additional delivery cost for transportation under customs control	US$	US$ 176.10	(NTC, 2021)

Source: This thesis (2022).

To assess the time cost, it is necessary to measure the total logistics time (tlt) which is the time expended for the cargo in each step of the import/export flow considering the return of the empty container, when applicable. Total logistics time (tlt) is defined as: (i) the time until deliver ($tud_{i,j}$) that is the difference between 'Step 4' and 'Step 1', stated as 'Full process time'; (ii) the transit time of the cargo from the seaport or dry port to the customer's facility respectively ($ttsc$), ($ttdc$); (iii) and then the transit time to return the empty container ($ttre$). Aggregating (i) and (ii) we stated the transit time that is expended until the customer receive their cargo as (ttd) (IANNONE; THORE, 2010; TALLEY; NG, 2017).

Some assumptions were considered in this chapter. First, just the current logistic infrastructure in São Paulo was considered for the simulations. In this case, the emission cost is not taking into account as well the delivery routes using multimodal transportation. Lastly, a hypothetical scenario where the studied dry ports are directly connected with the seaport is simulated in order to test the tenth hypothesis stated. Considering these assumptions, the total logistics cost (TLC) is assessed aggregating the handling cost ($HC_{i,j}$), storage cost ($SC_{i,j}$), customs cost ($CC_{i,j}$), inventory cost (IC), demurrage and detention cost (DDC), and the transportation cost to delivery ($DEC_{t,r,j}$) and return the empty container ($REC_{t,r}$) as follows.

Equation 36

$$TLC = \sum_{i,j} \sum_{t,r} HC_{i,j} + SC_{i,j} + CC_{i,j} + IC + DDC + DEC_{t,r,j} + REC_{t,r}$$

Where:

Equation 37

$$HC_{i,j} = \sum_{i,j} thc_{i,j} \times box \times qhm_{i,j}$$

Equation 38

$$SC_{i,j} = \sum_{i,j} scc_{i,j} \times doc_{i,j} \times box$$

Equation 39

$$CC_{i,j} = \sum_{i,j} \left(pic_{i,j} + xsc_{i,j} + tcc_{i,j}\right) \times box$$

Equation 40

$$IC = \sum ttd \times cv \times (or + der)$$

Equation 41

$$DDC = \sum(ddft \times ddf1) + \{[tlt - (2 \times ddft)] \times ddf2\}$$

Equation 42

$$DEC_{t,r,j} = \sum_{t,r} \sum_{j} \left(box \times dd_{t,r} \times mc_{t,r}\right) + fdr_{t,r} + adc_j + tcc_j$$

Equation 43

$$REC_{t,r} = \sum_{t,r} \left(box \times dd_{t,r} \times mc_{t,r}\right) + fdr_{t,r}$$

8.4 RESULTS

8.4.1 In terms of time

The first outcome of the study was the descriptive analysis for each step of the import process through seaport, dry port and extended gate. The results for ‘step 3’ and ‘full process’ were divided in green channel (GC) and yellow/red channels (YRC) and follows in Table 29.

Some discrepancies of the import process time among the actors are highlighted in grey. First, the mean and median time of the full process for GC and YRC presented a higher value in dry ports, mainly due the time expended in ‘step 2’. Second, the customs process for GC and YRC in ‘step 3’ highlighted the difference of the process time when the cargo should be documental or physically inspected. Lastly, the process time for step 1 is notably higher for dry ports, since the cargo should be liberated in the seaport (step 1.1) and then transported under customs control (step 1.2). The statistical tests for the highlighted steps follow below.

Table 29 – Process time in days of each step for import cargo

	Step 1	Step 1.1	Step 1.2	Step 2	Step 3 GC	Step 3 YRC	Step 4	Full process GC	Full process YRC
Seaport									
Full data	23099	-	-	23099	22769	330	23099	22769	330
Outliers (3 sd)	336	-	-	432	1222	6	434	449	4
Sample	22763	-	-	22667	21547	324	22665	22320	326
Mean time (days)	0.624	-	-	3.293	0.421	11.37	3.625	8.519	19.23
std	0.511	-	-	3.582	0.403	7.488	3.570	5.663	10.80
Min (days)	0.000	-	-	0.001	0	1.747	0.005	0.267	2.704
25% (days)	0.283	-	-	0.934	0	6.773	1.017	4.413	11.79
50% (days)	0.492	-	-	2.056	0.302	8.945	2.299	7.265	16.11
75% (days)	0.760	-	-	4.232	0.795	13.88	5.145	10.81	23.92
Max (days)	2.730	-	-	21.041	2.552	42.75	21.925	33.81	62.45
Dry port									
Full data	-	8602	8602	8602	8203	399	8602	8203	399
Outliers (3 sd)	-	115	148	173	6	5	130	139	10
Sample	-	8487	8454	8429	8197	394	8472	8064	389
Mean time (days)	-	3.614	3.851	25.581	0.622	5.041	3.738	39.68	37.37
std	-	3.268	2.074	30.918	0.776	5.411	5.206	33.51	31.82
Min (days)	-	0.000	0.710	0.000	0	0.087	0.008	1.910	4.857
25% (days)	-	1.460	2.210	2.005	0.142	1.231	0.654	14.54	17.92
50% (days)	-	3.160	3.230	11.897	0.267	3.141	1.838	27.79	26.20
75% (days)	-	4.340	5.120	40.806	0.767	6.771	4.818	54.51	41.48
Max (days)	-	21.820	12.290	134.605	3.068	29.21	34.613	154.0	150.5
Extended gate									
Full data	8305	-	-	8305	7938	367	8305	7938	367
Outliers (3 sd)	35	-	-	121	420	9	80	107	7
Sample	8270	-	-	8184	7518	358	8225	7831	360
Mean time (days)	1.411	-	-	3.932	0.493	10.03	3.606	9.813	19.41
std	0.580	-	-	3.904	0.511	6.678	3.676	5.842	10.80
Min (days)	0.028	-	-	0.006	0	1.244	0.004	1.253	5.545
25% (days)	0.978	-	-	1.463	0	6.019	1.017	6.022	12.85
50% (days)	1.331	-	-	2.822	0.325	7.872	2.232	8.300	15.83
75% (days)	1.788	-	-	4.952	0.805	12.00	4.967	11.81	22.82
Max (days)	3.428	-	-	24.730	2.795	42.67	21.824	37.89	70.53

Source: This thesis (2022).

In order to test the hypothesis 5, it was run a Mann-Whitney U test in the samples of GC and YRC and the results follows in Table 30.

The results have shown that there is no statistical evidence that the customs clearance process time (step 3) for the seaport, dry port and extended gate follows the same distribution, rejecting the null hypothesis. For the green channel, the median time for seaport (0.302 day), dry port (0.267 day) and extended gate (0.325 day) shows that the process time for dry port is faster. Operationally, the customs process in green channel in all logistic operators occurs in the same day. However, for yellow/red channels, the median customs process time in dry ports (3.141 days) is considerable faster compared to seaport (8.945 days) and extended gate (7.872), confirming the hypothesis 5.

Table 30 – Statistics tests for the import process

	Mann-Whitney U test		
	Statistic	**p-value**	**Result**
Step 2			
Seaport vs. dry port	51472082.5	0.000	Dry port and seaport have different distribution (reject H0)
Seaport vs. extended gate	77847829.0	0.000	Seaport and extended gate have different distribution (reject H0)
Dry port vs. extended gate	20725865.5	0.000	Dry port and extended gate have different distribution (reject H0)
Step 3			
Green channel			
Seaport vs. dry port	87098275.5	0.033	Dry port and seaport have different distribution (reject H0)
Seaport vs. extended gate	76575474.5	0.000	Seaport and extended gate have different distribution (reject H0)
Dry port vs. extended gate	28969036.5	0.000	Dry port and extended gate have different distribution (reject H0)
Yellow and red channels			
Seaport vs. dry port	22886.5	0.000	Dry port and seaport have different distribution (reject H0)
Seaport vs. extended gate	51342.0	0.005	Seaport and extended gate have different distribution (reject H0)
Dry port vs. extended gate	28940.0	0.000	Dry port and extended gate have different distribution (reject H0)
Step 4			
Seaport vs. dry port	83454354.0	0.000	Dry port and seaport have different distribution (reject H0)
Seaport vs. extended gate	92137500.5	0.061	Seaport and extended gate have the same distribution (fail to reject H0)
Dry port vs. extended gate	30509572.0	0.000	Dry port and extended gate have different distribution (reject H0)
Full process			
Green channel			
Seaport vs. dry port	17290094.0	0.000	Dry port and seaport have different distribution (reject H0)
Seaport vs. extended gate	72936071.0	0.000	Seaport and extended gate have different distribution (reject H0)
Dry port vs. extended gate	7394017.0	0.000	Dry port and extended gate have different distribution (reject H0)
Yellow and red channels			
Seaport vs. dry port	34437.0	0.000	Dry port and seaport have different distribution (reject H0)
Seaport vs. extended gate	57815.0	0.369	Seaport and extended gate have the same distribution (fail to reject H0)
Dry port vs. extended gate	37701.0	0.000	Dry port and extended gate have different distribution (reject H0)

Source: This thesis (2022).

Answering the hypothesis 6, the results from the Mann-Whitney U test for ‘step 2’ shows that there is no statistical evidence that the time to begin the customs process is the same for seaport, dry port and extended gate. The median time for step 2 were 2.056 days for seaport, 11.897 days for dry port, and 2.822 days for extended gate, which means that customers takes more time to begin the customs process in dry ports, confirming the hypothesis 6. For answer the hypothesis 7, the Mann-Whitney U test ran comparing dry port with seaport and extended gate for step 4. The results show that there is no statistical evidence that they follow the same distribution, rejecting the null hypothesis. However, the comparison between seaport and extended gate resulted in a $p>0.05$, failing to reject the null hypothesis.

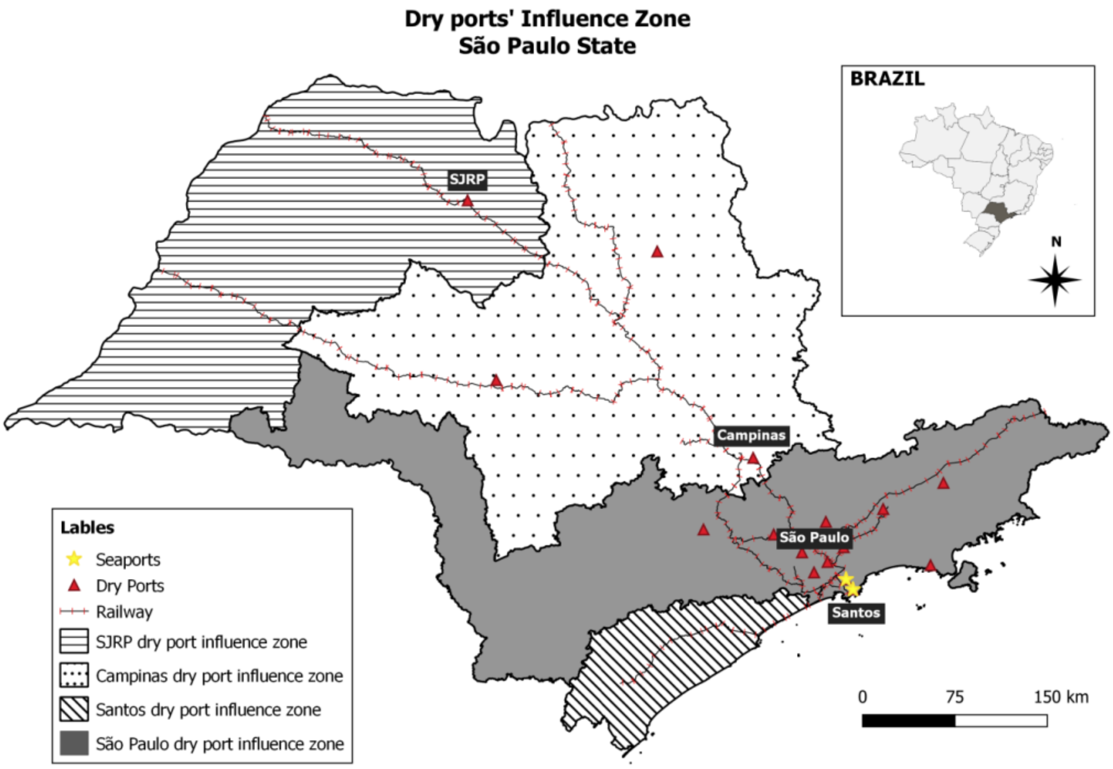
Considering this output, as the median time for step 4 in dry ports (1.838 days) is fewer than in seaport (2.299 days) and extended gate (2.232 days), we observe that the customer take more time to remove the container from the seaport, rejecting the hypothesis 7.

The last analysis in terms of time looked for the entire import process, since the vessel berthing until the costumer remove the cargo from the logistic operator. The objective here was answering the hypothesis 8, bringing insights about the characteristic of the customers that use each type of logistic operator. For the full process we divided the sample in (i) green channel and (ii) yellow/red channels. The Mann-Whitney U test rejected the null hypothesis for all comparisons in green channel, resulting that the import process for all logistic operators follows different distributions. On the other hand, for yellow/red channels, the test between seaport and extended gate failed to reject the null hypothesis, having insufficient evidence to conclude that the difference between medians is statistically significant. The data in Table 28 showed that the median time of the full process in dry ports for sample GC and YRC were 27.79 and 26.20 days respectively. This value is considerable higher compared to seaport (7.26 and 16.11 days) and extended gate (8.30 and 15.83 days), confirming the hypothesis 8 that the total import process is longer for customers that use dry ports. Going beyond into this result, the difference between the full process time in dry ports for green and yellow/red channels is not considerable, demonstrating that the cargo stays in the dry port for a longer time due a customer requirement, not because the customs process. On the other hand, the full process time in seaport and extended gate for green and yellow/red channels presented a high difference, especially due the customs process.

8.4.2 In terms of cost

The cost for import a containerized cargo varies stochastically according to many factors as the cargo value, the storage time, delivery distances and others that were aggregated in the cost model proposed. To compare the import cost through dry port and seaport we have applied the cost model using a Monte Carlo simulation with 10,000 tests for each macro region of São Paulo state (JUNG et al., 2020). For the comparisons, the full process time was based according to the distribution fitted from the database for the dry port users, considering that if the customer wants their cargo as soon as possible, they will remove the cargo directly from the seaport. Doing that, it was simulated the import process varying the cargo value and the import process time according to the distributions parameters stated before, and using the current logistic transportation infrastructure in Brazil (road transportation by truck). First the cost efficient dry port facility was assessed for each macro region of São Paulo, finding the influence zone of each dry port as follows in Figure 26. Campinas dry port was the cost efficient facility for most macro regions (6); SJRP serves the macro regions far from seaport, while the most populated and industrial zone of São Paulo is best served by dry ports located in São Paulo city. Since the cost parameters for the dry ports (operational costs) were considered the same, the results vary according to the delivery and return distance of the container.

Figure 26 – Influence zone of dry ports in São Paulo state



Source: This thesis (2022).

The statistical descriptive that follows in Table 31 shows the difference between the cost to import through seaport and the cheaper dry port for each macro region. Some highlights from this results is the fact that the mean and median difference cost for all cities are positive, which means that for customers that are importing containerized cargo with the characteristic of dry port's users (in terms of process time) are mostly choosing the cheaper option. However, as the minimum value from the simulations was negative, for some cases, seaport seams the best option in terms of cost. Taking into account the outputs of the simulation, the last column of Table 31 (column ‘P’) assess the probability of a containerized cargo that follows the process time of dry ports be cost efficient using seaport compared to dry port. This result shows that for around 22% of the simulations, seaport was cheaper than dry ports.

Table 31 – Cost difference between seaport and the best dry port option

City	Mean	Std	Min	0.25	0.5	0.75	Max	P
Aracatuba	$ 1573.27	$ 3397.99	$ -713.10	$ 344.88	$ 732.73	$ 2100.34	$ 195163.05	11%
Araraquara	$ 1438.85	$ 2720.20	$ -890.17	$ 223.17	$ 628.32	$ 1958.01	$ 72521.03	23%
Assis	$ 1298.78	$ 2613.28	$ -914.98	$ 142.56	$ 523.65	$ 1602.43	$ 80678.75	24%
Bauru	$ 1353.10	$ 2744.29	$ -1763.09	$ 174.98	$ 558.75	$ 1764.34	$ 82339.53	24%
Campinas	$ 1434.59	$ 3375.39	$ -863.10	$ 194.61	$ 580.20	$ 1950.00	$ 214861.14	24%
Itapetininga	$ 1419.54	$ 3389.08	$ -916.48	$ 141.09	$ 524.90	$ 1896.55	$ 137313.62	24%
Marília	$ 1446.83	$ 3522.87	$ -1717.94	$ 175.20	$ 572.16	$ 1909.50	$ 136105.13	23%
Piracicaba	$ 1436.86	$ 2883.15	$ -1575.43	$ 198.93	$ 583.28	$ 1954.39	$ 65688.76	24%
Presidente_Prudente	$ 1465.64	$ 2829.09	$ -834.79	$ 222.89	$ 628.64	$ 1994.53	$ 93148.36	24%
Registro	$ 1292.58	$ 3251.75	$ -1332.68	$ 84.46	$ 465.41	$ 1607.17	$ 140470.05	24%
Ribeirao_Preto	$ 1498.05	$ 6001.95	$ -1198.68	$ 218.65	$ 603.07	$ 1952.77	$ 517831.24	23%
SJRP	$ 1699.97	$ 3695.23	$ -1319.05	$ 450.24	$ 855.74	$ 2150.06	$ 145353.70	10%
SJDC	$ 1362.66	$ 4115.90	$ -1288.03	$ 129.04	$ 510.38	$ 1844.86	$ 211749.52	24%
São_Paulo	$ 1301.84	$ 2656.82	$ -928.51	$ 129.09	$ 510.54	$ 1863.21	$ 85752.73	24%
Sorocaba	$ 1473.46	$ 4298.71	$ -1417.85	$ 142.63	$ 524.26	$ 1814.80	$ 249999.24	23%

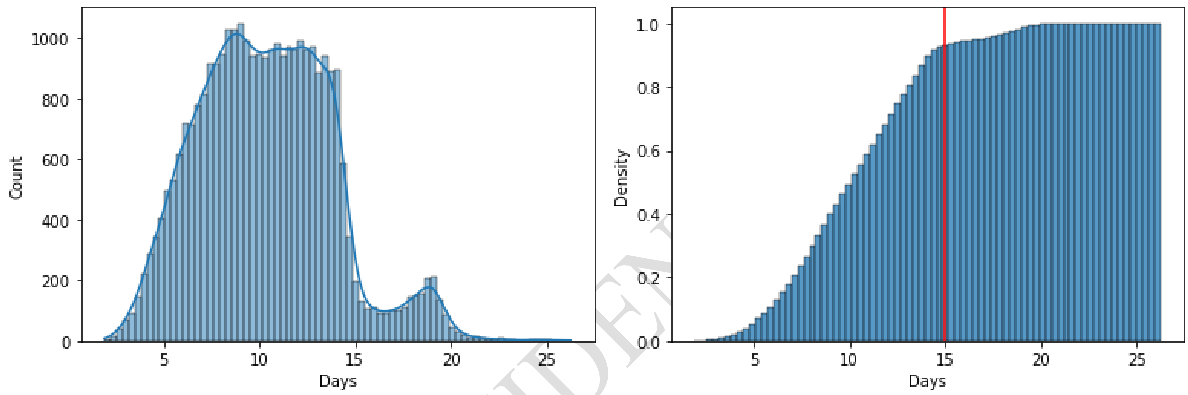
Source: This thesis (2022).

Considering that for some cases the import process through seaport were cost efficient, identify the inflection point in the full import process time that makes dry port more attractive is necessary to answer the hypothesis 9. With this in mind, all simulations where seaport was cost efficient for all cities were aggregated in the histogram in Figure 27(a). As the distributions for the Monte Carlo simulation represented the import time based on dry port users, few evidences with a short import process time (less than 10 days) ran in the simulations, and all results had seaport as the cheaper option. The Figure 27(b) shows the probability density function of the evidences of seaport been cost efficient varying in function of the import process time. The results show that 93% of the cases where seaports were cost efficient were for import process time less than 15 days. In this way, we stated 15 days of import process as the inflection point where dry ports becomes cost efficient, confirming the hypothesis 9 that import through dry ports is cheaper for a long storage time.

Going beyond the inflection point to measure the opportunity for dry port managers to enlarging the market share, competing in terms of cost, we have assessed the quantity of cases in the seaport users’ database of year 2019 where the import process took more than 15 days.

The results have shown that 13.76% (3125 cases) of the cases surpassed 15 days for green channel and 57.27% for yellow/red channels (189 cases), which demonstrate a great opportunity for dry ports to enlarge their market share, especially regarding the cargo that goes to physical inspection. Doing the same with the dry port users' database, it was observed that the opportunity for seaport to keep the cargo in their facility is proportionally higher for green channel, where 26.22% of the containerized cargo took less than 15 for the full import process using dry ports (2151 cases). For yellow/red channels, 14.28% of the import cargo through dry ports took less than 15 days (57 cases), meaning that seaport should be a cost efficient option for those cases.

Figure 27 – Evidences and density function per day of import process



(a) (b)

Source: This thesis (2022).

So far, the simulations have tested the import cost based on the current logistic infrastructure of São Paulo state, where there is no dry port directed connected with the seaport through multimodal transport. In order to identify if dry ports directly connected with seaports through railway would reduce logistic cost for the customers, it was simulated and compared this hypothetical scenario with the current one, keeping the other parameters as stated before. First it was compared the cost results from both scenarios through a Mann-Whitney U test, confirming that there is no statistical evidence that the cost by rail and by road using dry ports follows the same distribution (rejected null hypothesis). The median cost for all logistics operators had cheaper costs for the hypothetical scenario, confirming the hypothesis 10 that dry ports directly connected through multimodal transport with seaport are cost efficient. A synthesis of the total logistic cost for each logistic operator, aggregating the results for all cities considered in this study follows in Table 32.

Lastly, despite the transportation through railway be cheaper compared to road, the real relevance of that difference should be considered by the customer. The median cost differences from rail to road were $112.5, $50.5, $46.9 and $34.6 for SJRP, Campinas, São Paulo and Santos dry ports respectively. This result means that the transportation cost seems to reduce as the distance from the seaport increase.

Table 32 – Import cost using road and rail transportation for all logistic operators

	Direct from Seaport	SJRP	Campinas	São_Paulo	Santos
Road					
mean	$ 5,904.74	$ 4,953.40	$ 4,552.96	$ 4,537.35	$ 4,592.17
std	$ 8,809.42	$ 5,289.24	$ 5,285.56	$ 5,287.83	$ 5,289.14
min	$ 640.40	$ 2,333.04	$ 2,054.74	$ 1,983.30	$ 2,027.86
25%	$ 2,681.22	$ 3,131.65	$ 2,726.58	$ 2,732.51	$ 2,793.31
50%	$ 4,032.58	$ 3,849.27	$ 3,436.49	$ 3,433.59	$ 3,492.76
75%	$ 6,646.55	$ 5,299.14	$ 4,893.55	$ 4,884.62	$ 4,942.84
max	$ 1,369,007.43	$ 851,379.24	$ 851,176.19	$ 851,308.76	$ 851,414.10
Rail					
mean	-	$ 4,840.87	$ 4,502.46	$ 4,490.44	$ 4,557.60
std	-	$ 5,289.24	$ 5,285.56	$ 5,287.83	$ 5,289.14
min	-	$ 2,220.50	$ 2,004.25	$ 1,936.40	$ 1,993.29
25%	-	$ 3,019.11	$ 2,676.08	$ 2,685.60	$ 2,758.74
50%	-	$ 3,736.73	$ 3,386.00	$ 3,386.69	$ 3,458.19
75%	-	$ 5,186.60	$ 4,843.06	$ 4,837.71	$ 4,908.27
max	-	$ 851,266.86	$ 851,125.71	$ 851,261.71	$ 851,379.43

Source: This thesis (2022).

8.5 DISCUSSION

In this chapter it was investigated deeply the customers' choice in select their services providers in terms of time and cost. In this environment, seaports take advantage as the only player indispensable to import/export of goods, responsible for the vessel operation. As essentially customers requires their goods as fast as possible, especially regarding maritime transportation where the transport takes in some cases months, the majority of customers will begin the custom process and remove the container cargo directly from the seaport. Furthermore, import through dry ports or extended gate seems add another player into the supply chain, which may enhance the complexity. Despite these competitive advantages of seaports, customers are even more requiring personalized services and looking for reduce the entire logistic cost, services which in some cases, seaports cannot fulfill. Such issues enhance the competitiveness among the actors in the supply-chain and make more complex for customers to choice the logistic operator that best fit their requirements. With this in mind, this section discusses competitiveness based on the results from the data analysis and the Monte-Carlo simulations.

The first outcome confirmed that the customs process is faster in dry ports. As the cargo nationalization in green channel take place automatically by the Federal Revenue system, this process occurs in less than one day for all actors and do not impact the customers operationally. However, when the cargo is classified in yellow/red channels, it takes considerable much time in seaports and extended gate. One reason for that is the high volume of process in the seaport zone, which bring operational issues for positioning the container to physical inspection, requiring adequate infrastructure. The congestion problem in seaports also impacts other steps of the import process and the second outcome shows that since the cargo is already nationalized, the customers take more time to remove the cargo from the seaport and extended gate. It can happen due customer's will, or again due congestion issues, where customers face difficulties to schedule the removal of the cargo especially due gate availability (ALONSO; MONIOS; PINTO, 2017; JEEVAN; CHEN; CAHOON, 2019). These issues affect the competitiveness of seaports and should be considered by customers when deciding which logistic operator choice.

The results from hypothesis 6, 7 and 8 showed that the import process seems to be longer for customers that use dry ports as logistic operator. Taking into account the seaport-hinterland decision, customers that choice dry ports are distinguished for not require their cargo as soon as possible. It may happens when they not have logistic infrastructure to handle and store container or when the importers are willing to pay for additional services, stock of goods and predictability/availability of their cargo. Besides the long time to import goods through maritime transportation, recent events have touched the relevance of predictability and supply chains disruption as the Covid-19 pandemic and the blockade of the Suez' channel in Egypt in 2021, which brought import/export instabilities and shortages around the world (UNCTAD, 2021). In this context, dry ports seems to gain competitive advantage in Brazil for three main reasons: (i) the cargo can stay stored for 120 days, compared to 90 days in seaport; (ii) dry ports works in a modality of 'customs warehouse', where the cargo is stored under customs control without require the immediate collection of taxes levied on importation; (iii) dry ports permits the partial removal of the goods, with the payment of import taxes only on the part to be cleared (NG; PADILHA; PALLIS, 2013; RODRIGUES et al., 2021). Lastly, the results reinforced the relevance of dry ports in synchronizing the import cargoes with the customers' production lines due the geographic proximity. This fact influences the competitiveness of dry ports, enhancing the customers' reliability and avoiding supply chain disruptions.

In addition to competitiveness in terms of time, customers are struggling to reduce the total logistic cost choosing the best strategy in the seaport-hinterland network. The results have confirmed the competitive advanced of seaport as the cost efficient option for a short storage time in the hinterland, while dry ports works better for a long storage time. Simplifying the analysis and offering to the decision-maker a general insight, it was stated 15 days since the vessel berth and the customer receive their cargo as the inflection point, when after that, dry ports starts to become the cheapest option. Based on the database from year 2019, it was observed opportunities for enlarge the market-share for both sides, which is relevant for managers to gain the intra competition. As the fees charged may vary by contracts, dry ports and seaports managers' should consider the import cost through all seaport-hinterland network in order to be more competitive.

Looking from the hypothetical scenario, the results revealed that dry port direct connected with seaport through railway would be cost efficient for customers. However, this competitive advantage is operationally small, compared with the total logistic cost. As the cost benefit using railways is low, customers should compare the cost-benefit taking into account other factors as the rail schedules and the transport time. Lastly, the simulations have shown that the effectiveness of multimodal transport improve as the distance. However, despite Brazil been a continental country, the industrial zone remains near the coast, as the case of São Paulo's capital, less than 100 km far from the seaport. This fact justify that in Brazil the rail transportation is dedicated to transport commodities as iron ore and grains, representing 80% of total volume transported by rail, once the productive zones are located far from the seaports, in the middle of the country (ANTF, 2019).

As stated in the literature, choice the logistic operator in seaport-hinterland network is a complex decision and the objective of this research was simplify this process focusing on two of the most important factors. Therefore, this chapter brought useful insights for customers to balance cost and time as a first step in their decisions. Furthermore, the results have shown how dry ports and seaports managers may act in order to become more competitive and in which situation each logistic operator fulfills better the customers' requirements. Despite the competitive environment among the actors, the intra competition may strengthen the seaport-hinterland network, enlarging the influence zone of the seaport (inter competition).

8.6 REMARKS

The results from the simulations in the real case of Brazil have brought useful practical contributions to improve the competitiveness of the supply-chain as well contributed with the current literature of supply-chain choice. As managerial contributions, this chapter attests that seaports remain as the most competitive player in seaport-hinterland. However, we identified that dry ports also fulfill an important role, becoming more competitive when the import process takes more than 15 days. The results from the Monte-Carlo simulations brought insights for customers', aiding to choice the logistic operator and the delivery route with less information, as well for dry ports and seaports managers, highlighting the market-share opportunity and the strategic role that each logistic operator should fulfill. The results also suggested that multimodal transportation remains an option to reduce costs and optimize the seaport-hinterland network. However, such advantage should be investigated from multiple perspectives, since the real value in terms of cost for customers are relatively low.

In narrower terms of our more academic-theoretical contribution, this chapter strengthened the discussion about seaport-hinterland network choice, testing 6 hypothesis based on previous literature, looking specifically for the inland side since the container is discharged until reach the customers' door. Toward to attend the fourth specific objective, this chapter analyzed the import process in terms of time and cost, discussing the competitiveness among the main actors throughout the hinterland, bridging theory and practice.

9 CONCLUSIONS

Seaport-hinterland network has been highlighted as a critical step in international trade of goods. With economies around the world struggling for supply-chain optimization, new strategies to reduce the shipping cost, to enhance the reliability and predictability throughout the supply chain, to mitigate risks in new infrastructure projects, and to avoid instabilities and shortages in the international trade of goods are increasingly required. This chapter concludes the thesis by answering the stated research questions and emphasizing the main theoretical and practical contributions, the social, environmental and economic impact, the main limitations and directions for future researches.

9.1 CONCLUDING REMARKS AND MAIN FINDINGS

The thesis started focusing on the criticality of dry ports development as a problem that requires investigation. Answering the first research question, it was showed the evolution of publications about dry ports developments which evidenced that the research in this area is still in the initial phase with increasing importance. The results revealed a concentration of case studies on this subject in Asia and Europe, especially in China and India, while American and African countries had low representativeness. The main issues discussed by the selected papers were the dry port development, models to aid de decision making in dry port location and allocation, and the dry port concept.

Answering the second research question, the thesis highlighted the complexity of decision-making in dry ports developments, evolving multiple actors, within some cases conflicting objectives. Besides requiring huge investment in logistic infrastructure, decisions regarding dry ports developments may impact positively or negatively the stakeholders in the seaport-hinterland. With that in mind, the thesis has brought light to a set of 45 criteria which should be considered in dry ports developments decision, which can be useful for managers, governments and other players in a first analysis.

Looking for the Brazilian case and answering the third research question, it was identified that the main role of dry ports is offering to exporters and importers storage capacity and additional services in a customs area. The case studies in the northeast of Brazil have pointed that the fundamental objectives of dry ports were to meet customers' needs, to increase profitability, to expand market share and to fulfill the role as supply-chain player. In order to achieve such objectives, a framework with 27 attributes was proposed to assess and control the dry ports' objectives; this contribution has showed that the VFT approach is a valuable method that could aid dry ports' managers to drive decisions toward the strategic objective. For the fourth research question, the thesis have found that dry ports in Brazil are concentrated on the sea coast, which is also the most populated region, performing road transport to connect the logistics players. Lastly, it was identified the bureaucratic customs process, the lack of legislation, the competitive environment between seaport and dry ports besides the poor intermodal infrastructure as the main challenges faced in the Brazilian case.

Going beyond the complexity of dry ports developments, more specifically comparing the view of risk by multiple stakeholders related to the 8 major risk factors and the 40 sub-factors in order to avoid *disastrous openings*, it was identified a strong congruence for factor weighting and rankings, especially for dry ports operators and their customers, and to a lesser extent between dry ports operators and the regulators' agents. Furthermore, for Customer and dry ports operators, 'cost' was considered the most relevant factor, while 'political and social' as well 'environment' were considered the least important. For the regulators' agents, by contrast, 'infrastructure' was considered the most important factor, thus revealing the general focus of their regulatory effort. Considering the interrelationship among the risk factors, it was explored not only the most commonly engaged risk factors impacting upon the failure of phase transition from 'project' to 'operations' of dry port, but also the nature of their interdependence. Through the IRM map, it was possible to highlight the factors that most affects others on the net. The similarities and differences of perspective of risk and the implications that arise for stakeholder-collaborative project risk management were discussed in the thesis, answering the fifth and sixth research questions.

Looking for the shipping process, it was identified 11 cost factors that customers should consider in choosing the service provider in the seaport-hinterland network. The simulations revealed that for the case of São Paulo state, customers' specificities as the location, the additional-services required, and the urgency to receive the cargo may affect the decision-making to operate through dry port or seaport, to deliver the cargo consolidated or deconsolidated, and to select the transport mode and route, fulfilling the seventh and eighth research question.

For the last research question, it was identified how cost and time influence the seaport-hinterland customers' choice. First, it was confirmed that the customs process in dry ports are faster than in seaports and that customers take more time to start the process in dry ports. On the other hand, if the customers require removing their cargo from the facility, it's slightly faster in dry ports, mainly due the congestion in seaports and the gate schedule. Moreover, the analysis showed that indeed the import process is longer for customers who use dry ports, which was identified as a characteristic of dry ports' users. Second, in terms of shipping cost, it was defined the influence zone of 4 main dry ports in São Paulo, and the inflection point when dry ports starts to become the cost efficient option was defined as 15 days. Lastly, the competition and collaboration throughout the main actors in the seaport-hinterland was addressed in the thesis.

9.2 THEORETHICAL AND MANAGERIAL CONTRIBUTIONS

As managerial contribution, the first result of the thesis identified a set of 45 critical factors that should be considered in the decision processes of dry ports' developments. The results have shown the complexity of decisions in dry port processes due to a large number of criteria and decision-makers, bringing useful insights of the current context of dry ports studies for practitioners, policy-makers and others stakeholders in seaport-hinterland.

Evidenced as a research problem, more studies regarding dry ports developments in different contexts, especially in developing countries with poor logistic infrastructure were required. Such issue was defined as the second specific objective of the thesis, focusing in the case of dry ports in Brazil. As theoretical contributions, the dry ports in Brazil were classified based on the literature definitions, and the main role, challenges and opportunities for Brazilian case was discussed. As managerial contributions, it was proposed a framework to assess the achievement of the means-and and fundamental objectives of dry ports, working as a tool to drive managerial decision-making.

Looking for dry ports developments from the view of risk, the third specific objective aimed to assess the risk factors and their interdependence for dry port's transition from 'projects' to 'operations' from a multi-stakeholder perspective. Toward this objective, it was suggested a set of factors and sub-factors for assessing dry port risks in a unidimensional, reliable and replicable framework, derived using Exploratory Factor Analysis. The author suggested that the set of 8 main factors and 40 sub-factors could be applied in other countries to assess the risk of dry ports projects, while being careful to nuance variations for national conditions. Focusing on the interrelationship among the main risk factors in dry ports' project transition phase, it was developed a typology of interdependent risks for dry port 'project'-to-'operations' comprising eight interdependent risk factors, with 'Cost' emerging as the most important one. The thesis highlighted the risk factors which most matter from multiple stakeholders in seaport-hinterland, bringing relevant insights for dry ports' practitioners and policy-makers.

The last objective of the thesis was to provide to shippers and consignees a flexible tool to aid the choice among the services providers in the seaport-hinterland. As managerial contribution, a cost model was proposed, comparing the containerized import/export process cost by using dry ports or seaports. The results from the simulations in the Brazilian case suggested that cargo value, cargo type, transportation mode, delivery distance, storage time and emissions policy may affect the customer's choice. Moreover, dry ports seemed to be a cost efficient option where there is a need for a long duration of storage, despite they are not directly connected to seaports or multimodal facilities. Moreover, the cost model was simulated stochastically, discussing the outputs in light of the competitiveness literature. In terms of time, the findings indicated that dry ports have been operationally more efficient, with customs and delivery process faster than in seaports and extended gates. In terms of cost, the findings suggested that seaports remain cost efficient when seaport-hinterland import process time is less than 15 days.

As final conclusion, the author advocates that the thesis fulfilled all objectives proposed, contributing practically and theoretically with the discussion about the seaport-hinterland network, especially regarding the dry ports' subject. The results achieved have covered the two main topics of the thesis: (i) assessing the risk factors weighting and interdependences in dry ports' projects transition phase and (ii) proposing a flexible cost model to aid customer to select their services providers throughout the seaport-hinterland.

9.3 ECONOMIC IMPACTS

More specifically in terms of the economical insights, the thesis contributed bringing light for some issues which can aid decision-makers. First, the framework to assess the dry ports' objectives in Northeast of Brazil may work as a control tool to assess the means-end objectives toward the dry port strategy. This managerial contribution may bring economic benefits for dry ports practitioners, guiding the decisions toward the main role of the dry port, improving the services offered, making the dry port more competitive in the supply chain. Second, the discussion about the risk factors in dry ports' projects may aid government agents, customers and investors to collaborate to avoid disastrous openings. As stated in the thesis, a strong seaport-hinterland infrastructure may enhance the inter-competition position, attracting more customers and investors.

Focusing on customers' decision, it was highlighted that as the import time grows, dry port start to become the cost efficient option, mainly due the low storage cost. The inflection point between dry port and seaport for the case of São Paulo was around 5 days for high cargo value and around 15 days for low cargo value. Other contribution of the simulations was showing that the road transportation is cost efficient compared to railway in Brazil. This fact is an obstacle for using railways, since the customers don't have economic advantages in using such modal. Moreover, the results presented that for a short import time, deliver the container consolidated still remains the best option. Due demurrage and detention fees, as the import time increase, deconsolidate the cargo becomes the best option, requiring an additional service in seaport or in dry port facility.

Lastly, the thesis presented a discussion in terms of cost regarding the customer's decision-making in choose their service provider. Despite the results were focused in the Brazilian case, it brought useful economic and operational insight for decision-makers, working as a first step for other analysis. Hence, the author advocate that dry ports may be an option to achieve economic benefits for customer, even when it's not directly connected with the seaport, reducing the shipping cost, adding value to the supply-chain, and enhancing the competitiveness of the entire logistic system.

9.4 SOCIAL AND ENVIRONMENTAL IMPACTS

The literature discussed in the thesis highlighted the benefits of dry ports for the society and for the environment. Working as a hub in the inland side, dry ports may concentrate the cargo and deliver directly to the seaport by railway or barge, which generates less congestion in seaport zone, fewer accidents, lower road maintenance, and especially reduce the CO_2 emissions. Despite the relevance, the thesis evidenced that the environmental issues and political and social factors are not a priority for the Brazilian case. This fact was first showed in the project risk analysis, where environmental, political and social factors emerged as least important overall to the success of dry ports for all stakeholders. Second, in the cost simulations for the case of São Paulo, it was verified that there is no green policy to encourage customers to use railway transportation. Third, the results presented in the thesis revealed that using road transportation in Brazil is cost efficient compared to railway, mainly due the poor logistic infrastructure, where dry ports are not directly connected with the seaport. In order to achieve the best benefits of dry ports infrastructure, the author encourage the investments in the direct connections between dry ports and seaports, besides the incentives for reduce the CO2 emissions in developing countries; such issues may also be addressed in future researches.

The contribution of the thesis in terms of environmental and social impacts was limited to highlight and discuss such issues as part of the general context of seaport-hinterland. In this way, as the simulations in the thesis tried to emulate the real case of Brazil, for instance, the emission cost was not considered in the model. However, the thesis contributed showing how dry ports may work in order to improve the competitiveness of the seaport-hinterland, offering specialized services and reducing the total cost for the shippers and consignees. Such insights may impact the current dynamics in different ways. First, customers may be encouraged to use dry ports as an option to import and export goods; second, the collaboration among dry ports, seaports and carriers toward a more connected and effective supply-chain, sharing operations, information and risks, may enhance the efficiency of the seaport-hinterland. Lastly, such collaboration may result in policy changes, new regulations and environmental incentives. As discussed in the thesis, it’s not possible to change the logistic infrastructure of a country in a short time, requiring a long term project toward to achieve the real benefits of a more complete and structured seaport-hinterland. Such policies have already started in Asian and European countries, and the thesis has argued the urgency of such changes also in the Brazilian context.

9.5 THESIS LIMITATIONS

Some limitations were found achieving each specific objective of the thesis. First, the systematic review was limited to the research scope stated. In this way, the set of criteria to be considered in dry ports developments was a result from the 76 papers selected as research database. For the second specific objective the main obstacle was the lack of information about dry ports as well as the scarce or outdated data provided by regulatory government agencies in Brazil. About the limitations, despite the framework to assess the objectives of dry ports have brought relevant insights for dry ports' practitioners, it cannot be generalized as representing the set of objectives for all dry ports in Brazil.

The main obstacle in the third specific objective was the survey approach that required a high effort to get a sample size that represented statistically the view of risk of multiple stakeholders. The sample size achieved was not enough to apply the EFA approach through all factors and sub-factors in a unique way, requiring first to aggregate the sub-factors in major factors and then validating through the EFA. Lastly, despite the outputs from the risk assessment cannot be generalized, representing only the case of Brazil, it may be useful for other cases, especially for developing countries.

Regarding the last specific objective, a limitation of the cost model proposed was that the results worked only as recommendations of the cost efficient route, requiring from the decision-maker a refined analysis, or trade-off, concerning the cost difference among the delivery routes options. Furthermore, despite 'cost' be one of the most important factors in any logistic decision, the author advocates that a set of qualitative criteria must be considered by the customers in seaport-hinterland decision. Lastly, the basis of the model on the assessable cost parameters found in the literature is also a limitation. The simulations not considered specificities of logistic operators as the set of available additional services in each dry port/seaport as well the current taxes and operational charges of each actor in the studied seaport-hinterland. Moreover, the analysis focused on quantitative factors, remaining as opportunity for future researches to add qualitative factors as the service level, quality and flexibility perceived by the decision-maker, improving the decision model.

9.6 FUTURE RESEARCH DIRECTIONS

Some literature gaps were found from the systematic review of the thesis, working as suggestion for future research. First, a deep investigation concerning the development of dry ports in other countries outside Europe and Asia may bring relevant information for managers and policy-makers, comparing the best practices and challenges faced in different countries. This thesis started to address this issue with the Brazilian case. As second recommendation, the set of criteria to be considered in dry ports developments, as well the set of ‘cost’ factors identified could work as inputs for a seaport-hinterland decision analysis. Rationalizing qualitative and quantitative criteria through a common scale represent a challenge for future developments. Such issue may be applicable in multi-criteria decision models, bringing relevant information for seaport-hinterland practitioners’ and decision-making.

As third recommendation, the author here proposes that further studies should progress the global benchmarking agenda for dry ports by focusing in particular on defining measurement attributes for more pertinent risk (sub) factors. Therefore, the author advocates that future studies should look more carefully at risk systemicity analysis which recognizes a practical management needs to reduce complexity in ways that create viable conceptual frameworks for exploring complex risk interdependence. For this reason, the author argues that a research approach, similar to the applied in this thesis, should focus on designing and exploring risk category architectures, taking clarity efficiency for very specific temporal contexts as their primary goal. These may be narrowed for specific phase transitions. What matters is that they should offer managerial value within some clearly defined risk management context that is challenged by the opacity and complex interdependence of risk.

Fulfilling some limitations of the thesis, the author also recommends considering other facilities in the cost model as hub warehouses in not customs areas as option for shippers and consignees. Furthermore, simulations of hypothetical dry ports directly connected through railway with multimodal facilities may offer valuable information for policy makers and practitioners in Brazil. Accordingly, as last recommendation, the author suggests to improve the proposed cost model to a more holistic perspective, considering the containerized import of goods from a ‘door to door’ view, covering all steps in the international trade of goods. Furthermore, the author advocate to future studies using Discrete Choice models toward to understand customers’ behavior in supply-chain decisions, strengthen the discussion about intra competition and inter competition on seaport-hinterland.

REFERENCES

AL-MAZROUIE, J.; OJIAKO, U.; WILLIAMS, T.; CHIPULU, M.; MARSHALL, A. An operations readiness typology for mitigating against transitional 'disastrous openings' of airport infrastructure projects. *Production Planning and Control*, v. 32, n. 4, p. 283-302, 2021. DOI: https://doi.org/10.1080/09537287.2020.1730997.

ALAM, J. Role of effective planning process in boosting dry port effectiveness: a case study of central Pakistan. *International Journal of Supply Chain Management*, v. 5, n. 3, p. 153-164, 2016.

ALENCAR, L.; MOTA, M.; ALENCAR, M. The problem of disposing of plaster waste from building sites: problem structuring based on value focus thinking methodology. *Waste Management*, v. 31, n. 12, p. 2512-2521, 2011. DOI: https://doi.org/10.1016/j.wasman.2011.06.015.

ALONSO, L.; MONIOS, J.; PINTO, J. Port competition through hinterland accessibility: the case of Spain. *Maritime Economics and Logistics*, v. 21, n. 2, p. 258-277, 2017. DOI: https://doi.org/10.1057/s41278-017-0085-5.

ANTAQ. *Statistical database from national waterway transport agency*. 2021. Disponível em: http://web.antaq.gov.br/ANUARIO/. Acesso em: 04 Mai. 2021.

ANTF. *The brazilian rail freight sector*. 2019. Disponível em: https://www.antf.org.br/informacoes-gerais/. Acesso em: 15 Jun. 2019.

ANTT. *Assessing the freight cost*. 2021. Disponível em: https://portal.antt.gov.br/como-calcular-o-piso-minimo. Acesso em: 15 Fev. 2021.

ARAÚJO, M.; BANDEIRA, R.; CAMPOS, V. Custos e fretes praticados no transporte rodoviário de cargas: uma análise comparativa entre autônomos e empresas. *Journal of Transport Literature*, v. 8, n. 4, p. 187-226, 2014. DOI: https://doi.org/10.1590/2238-1031.jtl.v8n4a8.

ARORA, A.; ARORA, A.; SIVAKUMAR, K. Relationships among supply chain strategies, organizational performance, and technological and market turbulences. *International Journal of Logistics Management*, v. 27, n. 1, p. 206-232, 2016. DOI: https://doi.org/10.1108/IJLM-09-2013-0103.

BAERT, L.; REYNAERTS, J. An examination of the determinants of inter-port competition for U.S. imports. *Case Studies on Transport Policy*, v. 8, n. 2, p. 281-292, 2020. DOI: https://doi.org/10.1016/j.cstp.2020.01.008.

BASK, A.; ROSO, V.; ANDERSSON, D.; HAMALAINEN, E. Development of seaport-dry port dyads: two cases from Northern Europe. *Journal of Transport Geography*, v. 39, p. 85-95, 2014. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2014.06.014.

BENTALEB, F.; MABROUKI, C.; SEMMA, A. A multi-criteria approach for risk assessment of dry port-seaport system. *Supply Chain Forum*, v. 16, n. 4, p. 32–49, 2015. DOI: https://doi.org/10.1080/16258312.2015.11728692 .

BERESFORD, A.; PETTIT, S.; XU, Q.; WILLIAMS, S. A study of dry port development in China. *Maritime Economics and Logistics*, v. 14, n. 1, p. 73-98, 2012. DOI: https://doi.org/10.1057/mel.2011.17.

BEZERRA, B.; SANTOS, A.; DELMONICO, D. Unfolding barriers for urban mobility plan in small and medium municipalities – a case study in Brazil. *Transportation Research Part A: Policy and Practice*, v. 132, p. 808-822, 2020. DOI: http://dx.doi.org/10.1016/j.tra.2019.12.006.

BHATTACHARYA, A.; KUMAR, S.; TIWARI, M.; TALLURI, S. An intermodal freight transport system for optimal supply chain logistics. *Transportation Research Part C: Emerging Technologies*, v. 38, p. 73-84, 2014. DOI: http://dx.doi.org/10.1016/j.trc.2013.10.012.

BLACK, J.; ROSO, V.; MARUSIC, E.; BRNJAC, N. Issues in dry port location and implementation in metropolitan areas: the case of Sydney, Australia. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, v. 6, n. 1, p. 952–958, 2018. DOI: https://doi.org/10.7225/toms.v07.n01.004.

BOSSCHE, M.; GUJAR, G. Competition, excess capacity and pricing of dry ports in India: some policy implications. *International Journal of Shipping and Transport Logistics*, v. 2, n. 2, p. 151-167, 2010. DOI: https://doi.org/10.1504/IJSTL.2010.030864

BRADY, T.; DAVIES, A. From hero to hubris: reconsidering the project management of Heathrow's Terminal 5. *International Journal of Project Management*, v. 28, p. 151-157, 2010. DOI: https://doi.org/10.1016/j.ijproman.2009.11.011.

BRAZILIAN FEDERAL REVENUE. *Import process in Brazil*. 2021. Disponível em: https://www.gov.br/receitafederal/pt-br/acesso-a-informacao/dados-abertos/resultados/aduana/estudo-modal-maritimo/apresentacao-do-fluxo. Acesso em: 09 Mai. 2021.

BRAZILIAN SUPPLIERS. *Brazilian Directory of Exporting Commercials*. 2020. Disponível em: http://www.braziliansuppliers.com.br/busca. Acesso em: 09 Jun. 2020.

BFR. *Brazilian customs report*. 2019. Disponível em: file:///C:/Users/Dell/Downloads/BalanoAduaneiroAno2019COANA%20(5).pdf. Acesso em: 15 Feb. 2021.

BFR. *Customs clearance movement and times*. 2021. Disponível em: https://www.gov.br/receitafederal/pt-br/acesso-a-informacao/dados-abertos/resultados/aduana. Acesso em: 09 Jan. 2021.

BROOKS, M.; SCHELLINCK, T. Measuring port effectiveness in user service delivery: what really determines users' evaluations of port service delivery? *Research in Transportation Business and Management*, v. 8, p. 87-96, 2013. DOI: http://dx.doi.org/10.1016/j.rtbm.2013.04.001.

BUTTON, K.; CHIN, A.; KRAMBERGER, T. Incorporating subjective elements into liners' seaport choice assessments. *Transport Policy*, v. 44, p. 125-133, 2015. DOI:

https://doi.org/10.1016/j.tranpol.2015.07.006.

CARBONI, A.; DEFLORIO, F. Performance indicators and automatic identification systems in inland freight terminals for intermodal transport. *IET Intelligent Transport Systems*, v. 12, n. 4, p. 309-318, 2018. DOI: http://dx.doi.org/10.1049/iet-its.2017.0349

CARIS, A.; MACHARIS, C.; JANSSENS, G. K. Decision support in intermodal transport: a new research agenda. *Computers in Industry*, v. 64, n. 2, p. 105-112, 2013. DOI: http://dx.doi.org/10.1016/j.compind.2012.12.001.

CASTELEIN, R. B.; GEERLINGS, H.; VAN DUIN, J. H. Divergent effects of container port choice incentives on users' behavior. *Transport Policy*, v. 84, p. 82-93, 2019. DOI: https://doi.org/10.1016/j.tranpol.2019.04.010.

CATVE. *Judge decides to close CODAPAR dry port.* 2020. Disponível em: https://catve.com/noticia/4/286107/desembargador-decide-pelo-fechamento-do-porto-secoem-cascavel. Acesso em: 28 Nov. 2020.

CAVONE, G.; DOTOLI, M.; SEATZU, C. Management of intermodal freight terminals by first-order hybrid petri nets. *IEEE Robotics and Automation Letters*, v. 1, p. 2-9, 2016. DOI: http://dx.doi.org/10.1109/lra.2015.2502905.

CETESB. *Metropolitan cities of São Paulo*. 2021. Disponível em: https://cetesb.sp.gov.br/licenciamentoambiental/licenca-previa-documentacao-nescessaria/municipios-que-fazem-parte-regiao-metropolitana-de-sao-paulo/. Acesso em: 15 Fev. 2021.

CHAPMAN, C.; WARD, S. *Project risk management*. 2. ed. West Sussex, UK: John Wiley & Sons, 2003.

CHANG, Z.; NOTTEBOOM, T.; LU, J. A two-phase model for dry port location with an application to the port of Dalian in China. *Transportation Planning and Technology*, v. 38, n. 4, p. 442-464, 2015. DOI: http://dx.doi.org/10.1080/03081060.2015.1026103.

CHEN, J.; FEI, Y.; ZHANG, F.; JING, C. Evaluating correlations between a seaport and its dry ports: case study of Xiamen port in China. *Discrete Dynamics in Nature and Society*, v. 2018, p. 1-16, 2018. DOI: https://doi.org/10.1155/2018/6831302.

CHEON, S. H.; SONG, D. W.; PARK, S. Does more competition result in better port performance? *Maritime Economics and Logistics*, v. 20, n. 3, p. 433-455, 2018. DOI: https://doi.org/10.1057/s41278-017-0066-8.

CHIPULU, M.; OJIAKO, U.; GARDINER, P.; WILLIAMS, T.; MOTA, C.; MAGUIRE, S.; SHOU, Y.; STAMATI, T.; MARSHALL, A. Exploring the impact of cultural values on project performance. *International Journal of Operations & Production Management*, v. 34, n. 3, p. 364-389, 2014. DOI: https://doi.org/10.1108/IJOPM-04-2012-0156.

CHIPULU, M.; OJIAKO, U.; MARSHALL, A.; WILLIAMS, T.; BITITCI, U.; MOTA, C.; SHOU, Y.; THOMAS, A.; DIRANI, A.; MAGUIRE, S.; STAMATI, T. A dimensional analysis of stakeholder assessment of project outcomes. *Production Planning and Control*, v.

30, n. 13, p. 1072-1090, 2019. DOI: https://doi.org/10.1080/09537287.2019.1567859.

CIB. *Catalog of Brazilian Importers*. 2016. Disponível em: https://cib.dpr.gov.br/. Acesso em: 05 Fev. 2020.

CNT. *Transportation Yearbook.* 2017. Disponível em: http://anuariodotransporte.cnt.org.br/2018/Rodoviario/1-3-1-1-1-/Malha-rodovi%C3%A1ria-total. Acesso em: 05 Ago. 2019.

COSTA SPERB, L.; MARASHALL, A. The risk radar and the view of risk: a centre for risk research discussion booklet. 2020. Disponível em: https://eprints.soton.ac.uk/438543/. Acesso em 22 Fev. 2021.

COX, D.; KARTSONAKI, C.; KEOGH, R. Big data: some statistical issues. *Statistics and Probability Letters.* v. 136, p. 111-115, 2018.

CRAINIC, T.; DELL'OLMO, P.; RICCIARDI, N.; SGALAMBRO, A. Modeling dry-port-based freight distribution planning. *Transportation Research Part C: Emerging Technologies*, v. 55, p. 518-534, 2015. DOI: http://dx.doi.org/10.1016/j.trc.2015.03.026.

CULLINANE, K.; BERGQVIST, R.; WILMSMEIER, G. The dry port concept - theory and practice. *Maritime Economics and Logistics*, v. 14, n. 1, p. 1-13, 2012. DOI: https://doi.org/10.1057/mel.2011.14.

DADVAR, E.; GANJI, S. R. S.; TANZIFI, M. Feasibility of establishment of “dry ports” in the developing countries-the case of Iran. *Journal of Transportation Security*, v. 4, n. 1, p. 19–33, 2011.

DO, N.; NAM, K.; LE, Q. A consideration for developing a dry port system in Indochina area. *Maritime Policy and Management*, v. 38, n. 1, p. 1-9, 2011. DOI: https://doi.org/10.1080/03088839.2010.533712.

DOOMS, M.; HAEZENDONCK, E.; VALAERT, T. Dynamic green portfolio analysis for inland ports: an empirical analysis on Western Europe. *Research in Transportation Business and Management*, v. 8, p. 171-185, 2013. DOI: http://dx.doi.org/10.1016/j.rtbm.2013.07.006.

DOROSTKAR, E.; SHAHBAZI, S.; NAEINI, S. The effect of forming dry port in spatial and regional planning system in Yazd Province. *Journal of Engineering and Applied Sciences*, v. 11, p. 145-152, 2016.

DOTOLI, M.; EPICOCO, N.; FALAGARIO, M.; CAVONE, G. A timed petri nets model for performance evaluation of intermodal freight transport terminals. *IEEE Transactions on Automation Science and Engineering*, v. 13, n. 2, p. 842-857, 2016. DOI: https://doi.org/10.1109/TASE.2015.2404438.

DP WORLD. *Public price list and services.* 2021. Disponível em: https://www.dpworld.com/pt-br/santos/services/list-of-prices-and-services. Acesso em: 22 Fev. 2020.

DU, Y. W.; ZHOU, W. New improved DEMATEL method based on both subjective experience and objective data. *Engineering Applications of Artificial Intelligence*, v. 83, p. 57-71, 2019.

DURUGBO, C.; ANOUZE, A.; AMOUDI, O.; AL-BALUSHI, Z. Competitive priorities for regional operations: a Delphi study. *Production Planning and Control*, v. 32, n. 15, p. 1295-1312, 2021. DOI: https://doi.org/10.1080/09537287.2020.1805809.

ECONOMY MINISTERY. *Dry ports economy*. 2020. Disponível em: http://receita.economia.gov.br/ orientacao/aduaneira/importacao-e-exportacao/recinto-alfandegados/portos-secos. Acesso em: 09 Mai. 2020.

ECONOMY MINIESTERY. *Foreign Trade Statistics in Open Data*. 2021. Disponível em: https://www.gov.br/produtividade-e-comercio-exterior/pt-br/assuntos/comercio-exterior/estatisticas/base-de-dados-bruta. Acesso em:09 Jan. 2021.

EDF. *The true cost of carbon pollution*. 2020. Disponível em: http://encurtador.com.br/bvMX8. Acesso em: 22 Fev. 2020.

EISENHARDT, K.M. Building theories from case study research. *Academy of Management Review*, v. 14, n. 4, p. 532-550, 1989.

EXAME. *Dry ports between Brazil and Argentina are left without owner*. 2017. Disponível em: https://exame.abril.com.br/economia/porto-seco-entre-brasil-e-argentinafica-sem-dono/. Acesso em: 03 Ago. 2019.

FABRIGAR, L.; WEGENER, D.; MACCALLUM, R.; STRAHAN, E. Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods*, v. 4, n. 3, p. 272-299, 1999. DOI: https://doi.org/10.1037/1082-989X.4.3.272.

FAZI, S.; ROODBERGEN, K. J. Effects of demurrage and detention regimes on dry-port-based inland container transport. *Transportation Research Part C: Emerging Technologies*, v. 89, p. 1-18, 2018. DOI: https://doi.org/10.1016/j.trc.2018.01.012.

FENG, X.; ZHANG, Y.; LI, Y.; WANG, W. A location-allocation model for seaport-dry port system optimization. *Discrete Dynamics in Nature and Society*, v. 2013, p. 1-9, 2013. DOI: https://doi.org/10.1155/2013/309585.

FERRANDO, P.; LORENZO-SEVA, U. Program FACTOR at 10: origins, development and future directions. *Psicothema*, v. 29, n. 2, p. 236-241, 2017.

FIELD, A. *Discovering Statistics Using IBM SPSS Statistics*. 4 ed. London: Sage Publications, 2011.

FLYNN, B.; SAKAKIBARA, S.; SCHROEDER, R.; BATES, K.; FLYNN, E. Empirical research methods in operations management. *Journal of Operations Management*, v. 9, n. 2, p. 250-284, 1990.

FONTELA, E.; GABUS, A. *The DEMATEL observe*. Geneva: Battelle Institute, Geneva Research Center, 1976.

FORZA, C. Survey research in operations management: a process-based perspective. *International Journal of Operations & Production Management*, v. 22, n. 2, p. 152-194, 2002. DOI: https://doi.org/10.1108/01443570210414310.

GOVERNMENT OF BRAZIL. *Essential for foreign trade, maritime transport advances in Brazil:Waterways*. 2017. Disponível em: http://www.brazil.gov.br/about-brazil/news/2017/11/essential-for-foreign-trademaritime-transport-advances-in-brazil. Acesso em: 08 Jun. 2020.

GONZÁLES, E.; BLANCA, J.; MELLADO, F. Impacto del puerto seco de Antequera en el sistema logistico Andaluz. *Revista de Estudios Regionales*, v. 95, p. 149-174, 2012.

GRABHER, G. Temporary architectures of learning: Knowledge governance in project ecologies. *Organization studies*, v. 25, n. 9, p. 1491-1514, 2004.

HA, M.; AHN, K. Measurement of port service quality in container transport logistics using importance–performance analysis: a case of Busan port. *Journal of Korean Navigation and Port Reserch*, v. 41, n. 5, p. 353-358, 2017. DOI: https://doi.org/10.5394/KINPR.2017.41.5.353.

HA, M.; YANG, Z.; NOTTEBOOM, T.; NG, A.; HEO, M. Revisiting port performance measurement: a hybrid multi-stakeholder framework for the modelling of port performance indicators. *Transportation Research Part E: Logistics and Transportation Review*, v. 103, p. 1-16, 2017. DOI: http://dx.doi.org/10.1016/j.tre.2017.04.008.

HAIR, J.; BLACK, W.; BABIN, B.; ANDERSON, R.; TATHAM, R. *Multivariate data analysis*. 7 ed. London, UK: Pearson Education, 2014.

HANAOKA, S.; REGMI, M. B. Promoting intermodal freight transport through the development of dry ports in Asia: an environmental perspective. *IATSS Research*, v. 35, n. 1, p. 16-23, 2011. DOI: http://dx.doi.org/10.1016/j.iatssr.2011.06.001.

HANCOCK, G.; MUELLER, R. Rethinking construct reliability within latent variable systems. In DUTOIT, S.; CUDECK, R.; SORBOM, D. *Structural equation modeling: present and future*. Lincolnwood, IL: Scientific Software, 2000, p. 195-216.

HARALAMBIDES, H. Gigantism in container shipping, ports and global logistics: a time-lapse into the future. *Maritime Economics and Logistics*, v. 21, p. 1-60, 2019. DOI: https://doi.org/10.1057/s41278-018-00116-0

HARALAMBIDES, H.; GUJAR, G. The Indian dry ports sector, pricing policies and opportunities for public-private partnerships. *Research in Transportation Economics*, v. 33, n. 1, p. 51-58, 2011. DOI: http://dx.doi.org/10.1016/j.retrec.2011.08.006.

HARALAMBIDES, H.; GUJAR, G. On balancing supply chain efficiency and environmental impacts: an eco-DEA model applied to the dry port sector of India. *Maritime Economics and Logistics*, v. 14, n. 1, p. 122-137, 2012. DOI: https://doi.org/10.1057/mel.2011.19.

HASSAN, L. Modeling framework for intermodal dry port based hinterland logistics system. *Journal of Theoretical and Applied Information Technology*, v. 94, n. 1, p. 197-206, 2016.

HENTTU, V.; HILMOLA, O. P. Financial and environmental impacts of hypothetical Finnish dry port structure. *Research in Transportation Economics*, v. 33, p. 35-41, 2011. DOI: https://doi.org/10.1016/J.RETREC.2011.08.004.

HENTTU, V.; LÄTTILÄ, L.; HILMOLA, O. P. Optimization of relative transport costs of a hypothetical dry port structure. *Transport and Telecommunication*, v. 12, n. 2, p. 12-19, 2011.

HÖFER, T.; MADLENER, R. A participatory stakeholder process for evaluating sustainable energy transition scenarios. *Energy Policy*, In press, 2020. DOI: https://doi.org/10.1016/j.enpol.2020.111277.

HSU, W. K.; LIAN, S. J.; HUANG, S. H. An assessment model based on a hybrid MCDM approach for the port choice of liner carriers. *Research in Transportation Business and Management*, v. 34, p. 1-8, 2020. DOI: https://doi.org/10.1016/j.rtbm.2019.100426.

HUTCHESON, G.; SOFRONIOU, N. *The multivariate social scientist: introductory statistics using generalized linear models*. Thousand Oaks, CA: Sage, 1999.

HWANG, B.; ZHAO, X.; YU, G. Risk identification and allocation in underground rail construction joint ventures: contractors' perspective. *Journal of Civil Engineering and Management*, v. 22, n. 6, p. 758-767, 2016. DOI:https://doi.org/10.3846/13923730.2014.914095.

IANNONE, F. A model optimizing the port-hinterland logistics of containers: the case of the Campania region in Southern Italy. *Maritime Economics and Logistics*, v. 14, n. 1, p. 33-72, 2012.

IANNONE, F.; THORE, S. An economic logistics model for the multimodal inland distribution of maritime containers. *International Journal of Transport Economics*, v. 37, n. 3, p. 281-326, 2010.

IBGE. *Projections of the population in Brazil*. 2020. Disponível em: https://www.ibge.gov.br/apps/populacao/projecao/. Acesso em: 28 Jun. 2020.

IBGE. *General information of São Paulo state from National Institute of Geography and Statistics*. 2021. Disponível em: https://cidades.ibge.gov.br/brasil/sp/panorama. Acesso em: 28 Jun. 2021.

JADHAV, A.; ORR, S.; MALIK, M. The role of supply chain orientation in achieving supply chain sustainability. *International Journal of Production Economics*, v. 217, p. 112-125, 2019. DOI: https://doi.org/10.1016/j.ijpe.2018.07.031.

JANIC, M. Modelling the full costs of an intermodal and road freight transport network. *Transportation Research Part D: Transport and Environment*, v. 12, n. 1, p. 33-44, 2007.

JARZEMSKIS, A.; VASILIAUSKAS, A. Research on dry port concept as intermodal node. *Transport*, v. 22, n. 3, p. 207-213, 2007. DOI: https://doi.org/10.1080/16484142.2007.9638126.

JEEVAN, J. *The role of malaysian dry ports in the container seaport system*. Tasmania, 2016. 443 f. Thesis (Maritime and Logistics Management) - Department of Maritime and Logistics Management, University of Tasmania, Tasmania, 2016.

JEEVAN, J.; SALLEH, N.; LOKE, K.; SAHARUDDIN, A. Preparation of dry ports for a competitive environment in the container seaport system: a process benchmarking approach. *International Journal of e-Navigation and Maritime Economy*, v. 7, p. 19-33, 2017. DOI: http://linkinghub.elsevier.com/retrieve/pii/S2405535217300189.

JEEVAN, J.; CHEN, S.; CAHOON, S. Determining the influential factors of dry port operations: worldwide experiences and empirical evidence from Malaysia. *Maritime Economics & Logistics*, v. 20, n. 3, p. 476-494, 2018. DOI: https://doi.org/10.1057/s41278-017-0063-y.

JEEVAN, J.; CHEN, S.; CAHOON, S. The impact of dry port operations on container seaports competitiveness. *Maritime Policy and Management*, v. 46, n. 1, p. 4-23, 2019. DOI: https://doi.org/10.1080/03088839.2018.1505054.

JEEVAN, J.; CHEN, S.; LEE, E. The challenges of Malaysian dry ports development. *Asian Journal of Shipping and Logistics*, v. 31, p. 109-134, 2015. DOI: http://dx.doi.org/10.1016/j.ajsl.2015.03.005.

JIANG, X.; FAN, H.; LUO, M.; XU, Z. Strategic port competition in multimodal network development considering shippers' choice. *Transport Policy*, v. 90, p. 68-89, 2020. DOI: https://doi.org/10.1016/j.tranpol.2020.02.002.

JUNG, W.; KIM, H.; PARK, Y.; LEE, J.; SUH, E. Real-time data-driven discrete-event simulation for garment production lines. *Production Planning and Control*, In press, 2020. DOI: https://doi.org/10.1080/09537287.2020.183019.

KA, B. Application of fuzzy AHP and ELECTRE to China dry port location selection. *Asian Journal of Shipping and Logistics*, v. 27, n. 2, p. 331-354, 2011. DOI: https://doi.org/10.1016/S2092-5212(11)80015-5.

KAPETANIS, G. N.; PSARAFTIS, H. N.; SPYROU, D. A simple synchro - modal decision support tool for the Piraeus container terminal. *Transportation Research Procedia*, v. 14, p. 2860-2869, 2016. DOI: https://doi.org/10.1016/j.trpro.2016.05.403.

KEENEY, R. L. Modeling values for telecommunications management. *IEEE Transactions on Engineering Management*, v. 48, n. 3, p. 370-379, 2001. DOI: https://doi.org/10.1109/17.946536.

KEENEY, R. L. *Value-focused Thinking: a Path to Creative Decision-making*. London: Harvard University Press, 1992.

KEENEY, R. L. Value-focused thinking: identifying decision opportunities and creating alternatives. *European Journal of Operational Research*, v. 92, n. 3, p. 537-549, 1996.

KHASLAVSKAYA, A.; ROSO, V. Dry ports: research outcomes, trends, and future implications. *Maritime Economics and Logistics*, v. 22, p. 265–292, 2020. DOI:

https://doi.org/10.1057/s41278-020-00152-9.

KHOMPATRAPORN, C.; SOMBOONWIWAT, T. Causal factor relations of supply chain competitiveness via fuzzy DEMATEL method for Thai automotive industry. *Production Planning & Control*, v. 28, p. 538-551, 2017. DOI: https://doi.org/10.1080/09537287.2017.1309713.

KIM, K. H.; KIM, K. Y. Optimal price schedules for storage of inbound containers. *Transportation Research Part B: Methodological*, v. 41, n. 8, p. 892-905, 2007.

KOMCHORNRIT, K. The selection of dry port location by a Hybrid CFA-MACBETH-PROMETHEE method: a case study of southern Thailand. *Asian Journal of Shipping and Logistics*, v. 33, n. 3, p. 141-153, 2017. DOI: http://dx.doi.org/10.1016/j.ajsl.2017.09.004.

KOROVYAKOVSKY, E.; PANOVA, Y. Dynamics of Russian dry ports. *Research in Transportation Economics*, v. 33, n. 1, p. 25-34, 2011. DOI: http://dx.doi.org/10.1016/j.retrec.2011.08.008.

KRAMBERGER, T.; MONIOS, J.; STRUBELJ, G.; RUPNIK, B. Using dry ports for port co-opetition: the case of Adriatic ports. *International Journal of Shipping and Transport Logistics*, v. 10, n. 1, p. 18-44, 2018.

KWATENG, K.; DONKOH, A.; MUNTAKA, A. Evaluation of dry port implementation in Ghana. Maritime Business Review, v. 2, n. 3, p. 261-278, 2017. DOI: https://doi.org/10.1108/MABR-01-2017-0005.

LARRANAGA, A.; ARELLANA, J.; SENNA, L. Encouraging intermodality: a stated preference analysis of freight mode choice in Rio Grande do Sul. *Transportation Research Part A: Policy and Practice*, v. 102, p. 202-211, 2016. DOI: http://dx.doi.org/10.1016/j.tra.2016.10.028.

LÄTTILÄ, L.; HENTTU, V.; HILMOLA, O. P. Hinterland operations of sea ports do matter: dry port usage effects on transportation costs and CO2 emissions. *Transportation Research Part E: Logistics and Transportation Review*, v. 55, n. 2013, p. 23-42, 2013. DOI: http://dx.doi.org/10.1016/j.tre.2013.03.007.

LAZARIV, T.; LEHMANN, C. *Goodness-of-fit tests for large datasets*. 2018. Disponível em: https://doi.org/10.48550/arXiv.1810.09753. Acesso em: em 21 Mar. 2022.

LEE, P.; HU, K. Evaluation of the service quality of container ports by importance-performance analysis. *International Journal of Shipping and Transport Logistics*, v. 4, n. 3, p. 197-211, 2012.

LI, J.; JIANG, B. Cooperation performance evaluation between seaport and dry port: case of Qingdao port and Xi'an port. *International Journal of e-Navigation and Maritime Economy*, v. 1, p. 99-109, 2014. DOI: http://dx.doi.org/10.1016/j.enavi.2014.12.009.

LI, Y.; DONG, Q.; SUN, S. Dry port development in China: current status and future strategic directions. *Journal of Coastal Research*, v. 73, p. 641-646, 2015. DOI: http://www.bioone.org/doi/10.2112/SI73-111.1.

LIMA, E. *Engineering asset management: problem-solving models to support asset-intensive organisations in the regulatory and business performance contexts.* Recife, 2020. 142 f. Tese (Engenharia de Produção) - Programa de Pós-Graduação em Engenharia de Produção, Universidade Federal de Pernambuco, Recife, 2020.

LIRN, T. C.; WONG, R. Determinants of grain shippers and importers freight transport choice behaviour. *Production Planning and Control*, v. 24, n. 7, p. 575-588, 2013. DOI: https://doi.org/10.1080/09537287.2012.659868.

LUTHRA, S.; MANGLA, S.; SHANKAR, R.; GARG, C.; JAKHAR, S. Modelling critical success factors for sustainability initiatives in supply chains in Indian context using Grey-DEMATEL. *Production Planning & Control*, v. 29, n. 9, p. 705-728, 2018. DOI: https://doi.org/10.1080/09537287.2018.1448126.

LUZ, G.; TORTORELLA, G.; BOUZON, M.; REYES, J.; GAIARDELLI, P. Proposition of a method for stochastic analysis of value streams. *Production Planning and Control*, In press, 2020. DOI: https://doi.org/10.1080/09537287.2020.1833377.

MANGLA, S.; LUTHRA, S.; JAKHAR, S.; TYAGI, M.; NARKHEDE, B. Benchmarking the logistics management implementation using Delphi and fuzzy DEMATEL. *Benchmarking: An International Journal*, v. 25, n. 6, p. 1795-1828, 2018. DOI: https://doi.org/10.1108/BIJ-01-2017-0006.

MARINGAPOST. *Maringa dry port is definitely closed.* 2018. Disponível em: https://maringapost.com.br/negocios/2018/10/30/porto-seco-de-maringa-estadefinitivamente-fechado-receita-federal-encerra-processo-de-desalfandegamento-do-centrologistico-industrial-e-aduaneiro/. Acesso em: 28 Nov. 2020.

MARSHALL, A.; OJIAKO, U.; WANG, V.; LIN, F.; CHIPULU, M. Forecasting unknown-unknowns by boosting the risk radar within the risk intelligent organization. *International Journal of Forecasting*, v. 35, n. 2, p. 644-658, 2019. DOI: https://doi.org/10.1016/j.ijforecast.2018.07.015.

MARSHALL, A.; OJIAKO, U.; WILLIAMS, T.; AL-MAZROOIE, J.; LIN, F.; CHIPULU, M. Risk management as knowledge production: application to fast-tracked complex multi-stakeholder airport projects, In WEBB, H.; AL-NUMAIRY, H., ed. *Entrepreneurial Innovation and Economic Development in Dubai and Comparisons to Its Sister Cities*. Hershey: IGI Global, 2020. cap 3, p. 33-66.

PARDO, A.; ORRO, A.; ALONSO, L. Analysis of port choice: a methodological proposal adjusted with public data. *Transportation Research Part A: Policy and Practice*, v. 136, p. 178-193, 2020. DOI: https://doi.org/10.1016/j.tra.2020.03.031.

MASKEY, R.; FEI, J.; NGUYEN, H. O. Critical factors affecting information sharing in supply chains. *Production Planning and Control,* 2020. v. 31, n. 7, p. 557-574, 2014. DOI: https://doi.org/10.1080/09537287.2019.1660925.

MAYLOR, H.; MEREDITH, J.; SODERLUND, J.; BROWNING, T. Old theories, new contexts: extending operations management theories to projects. *International Journal of Operations & Production Management*, v. 38, n. 6, p. 1274-1288, 2018. DOI:

https://doi.org/10.1108/IJOPM-06-2018-781.

MCGIVERN, G.; DOPSON, S.; FERLIE, E.; FISCHER, M.; FITZGERALD, L.; LEDGER, J.; BENNETT, C. The silent politics of temporal work: a case study of a management consultancy project to redesign public health care. *Organization Studies*, v. 39, n. 8, p. 1007-1030, 2018. DOI: https://doi.org/10.1177/0170840617708004.

MDIC. *Import and export general data*. 2021. Dispoível em: http://comexstat.mdic.gov.br/pt/geral. Accesso em: 04 Mai. 2021.

MOHER, D.; LIBERATI, A.; TETZLAFF, J.; ALTMAN, D. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Medicine*, v. 6, n. 7, 2009. DOI: https://doi.org/10.1371/journal.pmed.1000097.

MONIOS, J. The role of inland terminal development in the hinterland access strategies of Spanish ports. *Research in Transportation Economics*, v. 33, n. 1, p. 59-66, 2011. DOI: http://dx.doi.org/10.1016/j.retrec.2011.08.007.

MONIOS, J.; WANG, Y. Spatial and institutional characteristics of inland port development in China. *GeoJournal*, v. 78, n. 5, p. 897-913, 2013. DOI: https://doi.org/10.1007/s10708-013-9473-2.

MONTE, M.; MORAIS, D. A decision model for identifying and solving problems in an urban water supply system. *Water Resources Management*, v. 33, n. 14, p. 4835-4848, 2109. DOI: https://doi.org/10.1007/s11269-019-02401-w.

MOURA, T. G. Z.; ALONSO, L.; OLMEDO, M. H. Delimiting the scope of the hinterland of ports: proposal and case study. *Journal of Transport Geography*, v. 65, p. 35-43, 2017. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2017.09.012.

MOYA, J. M.; VALERO, M. F. Port choice in container market: a literature review. *Transport Reviews*, v. 37, n. 3, p. 300-321, 2016. DOI: http://dx.doi.org/10.1080/01441647.2016.1231233.

MURAVEV, D.; RAKHMANGULOV, A. Environmental factors' consideration at industrial transportation organization in the seaport-dry port system. *Open Engineering*, v. 6, n. 1, p. 476–484, 2016. DOI: https://doi.org/10.1515/eng-2016-0070.

NG, A.; CETIN, I. Locational characteristics of dry ports in developing economies: some lessons from Northern India. *Regional Studie***s**, v. 46, n. 6, p. 757-773, 2012. DOI: https://doi.org/10.1080/00343404.2010.532117.

NG, A.; GUJAR, G. C. Government policies, efficiency and competitiveness: the case of dry ports in India. *Transport Policy*, v. 16, n. 5, p. 232-239, 2009.

NG, A.; LOOSEMORE, M. Risk allocation in the private provision of public Infrastructure. *International Journal of Project Management*, v. 25, n. 1, p. 66-76, 2007.

NG, A.; TONGZON, J. L. The transportation sector of India's economy: dry ports as catalysts for regional development. *Eurasian Geography and Economics*, v. 51, n. 5, p. 669-682, 2010.

DOI: https://doi.org/10.2747/1539-7216.51.5.669.

NG, A.; PADILHA, F.; PALLIS, A. Institutions, bureaucratic and logistical roles of dry ports: the Brazilian experiences. *Journal of Transport Geography*,v. 27, p. 46-55, 2013. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2012.05.003.

NGUYEN, L. C.; NOTTEBOOM, T. A multi-criteria approach to dry port location in developing economies with application to Vietnam. *Asian Journal of Shipping and Logistics*, v. 32, n. 1, p. 23-32, 2016. DOI: https://doi.org/10.1016/j.ajsl.2016.03.003.

NGUYEN, L. C.; NOTTEBOOM, T. Public-private partnership model selection for dry port development: an application to Vietnam. *World Review of Intermodal Transportation Research*, v. 6, n. 3, p. 229-250, 2017. DOI: https://doi.org/10.1504/WRITR.2017.086208.

NGUYEN, L. C.; NOTTEBOOM, T. The relations between dry port characteristics and regional port-hinterland settings: findings for a global sample of dry ports. *Maritime Policy and Management*, v. 46, n. 1, p. 24–42, 2019. DOI: https://doi.org/10.1080/03088839.2018.1448478.

NGUYEN, N. H.; SKITMORE, M.; WONG, J. K. W. Stakeholder impact analysis of infrastructure project management in developing countries: A study of perception of project managers in state-owned engineering firms in Vietnam. *Construction Management and Economics*, v. 27, n. 11, p. 1129-1140, 2009.

NILSSON, F. A complexity perspective on logistics management. *The International Journal of Logistics Management*, v. 30, n. 3, p. 681-698, 2019. DOI: https://doi.org/10.1108/ijlm-06-2019-0168.

NOTTEBOOM, T. E.; RODRIGUE, J. P. Port regionalization: towards a new phase in port development. *Maritime Policy and Management*, v. 32, n. 3, p. 297–313, 2005. DOI: https://doi.org/10.1080/03088830500139885.

NOTTEBOOM, T.; RODRIGUE, J. Inland terminals within North American and European supply chains. *Transport and Communications Bulletin*, n. 78, p. 1-39, 2009.

NTC. *Container freight cost in Brazil*. 2021. Disponível em: https://www.portalntc.org.br/wp-content/uploads/emailmkt/planilhas/arquivos/20/090eo9omma/conteiner.pdf. Acesso em: 15 Fev. 2021.

NUGROHO, M. T.; WHITEING, A.; JONG, G. Port and inland mode choice from the exporters’ and forwarders’ perspectives: case study - Java, Indonesia. *Research in Transportation Business and Management*, v. 19, p. 73-82, 2016. DOI: http://dx.doi.org/10.1016/j.rtbm.2016.03.010.

NÚÑEZ, S.; CANCELAS, N.; FLORES, F.; ORIVE, A. A methodology for measuring sustainability of dry ports location based on bayesian networks and multi-criteria decision analysis. *Transportation Research Procedia*, v. 13, p. 124-133, 2016. DOI: http://dx.doi.org/10.1016/j.trpro.2016.05.013.

NÚÑEZ, S.; CANCELAS, N.; ORIVE, A. Establecimiento de los factores a considerar para determinar la zona de ubicación de un puerto seco y de sus jerarquías a través de un panel DELPHI. *Transporte y Territorio*, v. 13, p. 100-121, 2015. DOI: https://doi.org/10.34096/rtt.i13.1879.

OEY, E.; SETIAWAN, V. Evaluating import cargo performance through Tanjung Priok sea port vs. Cikarang dry port - a case study in a FMCG company in Indonesia. *International Journal of Logistics Systems and Management*, v. 26, n. 3, p. 379-401, 2017. DOI: https://doi.org/10.1504/IJLSM.2017.081966.

OJIAKO, U.; PAPADOPOULOS, T.; STAMATI, T.; ANAGNOSTOPOULOS, D.; MARSHALL, A. Collaborative governance in Greek infrastructure projects. *Proceedings of the Institution of Civil Engineers: Management, Procurement and Law*, v. 168, n. 3, p. 135-145, 2015a. DOI: https://doi.org/10.1680/mpal.1400037.

OJIAKO, U.; CHIPULU, M.; MARSHALL, A.; ASHLEIGH, M.; MAGUIRE, S. WILLIAMS, T.; OBOKOH, L. Heterogeneity and perception congruence of project outcomes. *Production Planning & Control*, v. 26, n. 11, p. 858-873, 2015b. DOI: https://doi.org/10.1080/09537287.2014.994684.

OJIAKO, U.; MANVILLE, G.; ZOUK, N.; CHIPULU, M. Social cohesion and interpersonal conflicts in projects. *Proceedings of the Institution of Civil Engineers: Management, Procurement and Law*, v. 169, n. 2, p. 77-84, 2016. DOI: https://doi.org/10.1680/jmapl.14.00038.

OLÁH, J.; NESTLER, S.; NOVEL, T.; RÁKOS, M.; POPP, J. Development of dry ports in Europe. *International Journal of Applied Management Science*, v. 10, n. 4, p. 269–289, 2018a.

OLÁH, J.; NESTLER, S.; NOVEL, T.; POPP, J. Ranking of dry ports in Europe-benchmarking. *Periodica Polytechnica Transportation Engineering*, v. 46, n. 2, p. 95-100, 2018b.

OLIVEIRA, G.; CARIOU, P. The impact of competition on container port (in)efficiency. *Transportation Research Part A: Policy and Practice*, v. 78, p. 124-133, 2015. DOI: http://dx.doi.org/10.1016/j.tra.2015.04.034.

ONWUEGBUCHUNAM, D.; EKWENNA, D. Analysing the determinants of dry port selection by shippers in Nigeria. *Journal of Research in National Development*, v. 6, n. 1, p. 15-25, 2008.

OPRICOVIC, S.; TZENG, G. H. Defuzzification within a multicriteria decision model. *International Journal of Uncertainty, Fuzziness and Knowlege-Based Systems*, v. 11, n. 5, p. 635-652, 2003.

PADILHA, F.; NG, A. K. Y. The spatial evolution of dry ports in developing economies: the Brazilian experience. *Maritime Economics and Logistics*, v. 14, n. 1, p. 99-121, 2012.

PANOVA, Y.; HILMOLA, O. P. Justification and evaluation of dry port investments in Russia. *Research in Transportation Economics*, v. 51, p. 61-70, 2015. DOI:

https://doi.org/10.1016/j.retrec.2015.07.008.

PARREIRAS, R.; KOKSHENEV, I.; CARVALHO, M.; WILLER, A.; DELLEZZOPOLLES, C.; NACIF, D.; SANTANA, J. A flexible multicriteria decision-making methodology to support the strategic management of acience, technology and innovation research funding programs. *European Journal of Operational Research*, v. 272, n. 2, p. 725-739, 2019. DOI: https://doi.org/10.1016/j.ejor.2018.06.050.

PATTANAYAK, A.; PRAKASH, A.; MOHANTY, R. Risk analysis of estimates for cost of quality in supply chain: a case study. *Production Planning and Control*, v. 30, n. 4, p. 299-314, 2019. DOI: https://doi.org/10.1080/09537287.2018.1541488.

QIU, X.; LAM, J. The value of sharing inland transportation services in a dry port system. *Transportation Science*, v. 52, n. 4, p. 835-849, 2018. DOI: https://doi.org/10.1287/trsc.2017.0755.

QIU, X.; LAM, J.; HUANG, G. A bilevel storage pricing model for outbound containers in a dry port system. *Transportation Research Part E: Logistics and Transportation Review*, v. 73, p. 65-83, 2015. DOI: http://dx.doi.org/10.1016/j.tre.2014.10.009.

RAHIMI, M.; ASEF-VAZIRI, A.; HARRISON, R. An inland port location-allocation model for a regional intermodal goods novement system. *Maritime Economics and Logistics*, v. 10, n. 4, p. 362-379, 2008. DOI: https://doi.org/10.1057/mel.2008.17.

RASOULI, M. R.; KUSTERS, R.; TRIENEKENS, J.; GREFEN, P. Service orientation in business networking: a demand-supply chain perspective. *Production Planning and Control*, v. 30, n. 1, p. 2–19, 2019. DOI: https://doi.org/10.1080/09537287.2018.1519730.

RATHNAYAKE, J.; JING, L.; ERANDI, D. Truck turnaround time problem at the port of Colombo and a solution through inland ports. *International Journal of Logistics Systems and Management*, v. 21, n. 4, p. 413-441, 2015. DOI: https://doi.org/ 10.1504/IJLSM.2015.070208.

RATHNAYAKE, J.; JING, L.; WIJERATNE, A. Dry ports: a lacuna in Sri Lanka. *International Journal of Process Management and Benchmarking*, v. 3, n. 4, p. 441-466, 2013. DOI: https://doi.org/10.1504/IJPMB.2013.058269.

REZAEI, J.; PALTHE, L.; TAVASSZY, L.; WIEGMANS, B.; LAAN, F. Port performance measurement in the context of port choice: an MCDA approach. *Management Decision*, v. 57, n. 2, p. 396-417, 2019. DOI: https://doi.org/10.1108/MD-04-2018-0482.

RODRIGUE, J.; DEBRIE, J.; FREMONT, A.; GOUVERNAL, E. Functions and actors of inland ports: European and North American dynamics. *Journal of Transport Geography*, v. 18, n. 4, p. 519-529, 2010. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2010.03.008.

RODRIGUE, J.; NOTTEBOOM, T. Dry ports in European and North American intermodal rail systems: two of a kind? *Research in Transportation Business and Management*, v. 5, p. 4-15, 2012. DOI: http://dx.doi.org/10.1016/j.rtbm.2012.10.003.

RODRIGUES, T.; MOTA, C.; OJIAKO, U. (2020). Exploratory evaluation of dry ports in Northeast of Brazil. *International Conference on Industrial Engineering and Operations Management (IEOM)*, Dubai, United Arab Emirates, 10-12 March 2020.

RODRIGUES, T.; MOTA, C.; OJIAKO, U.; DWEIRI, F. Assessing the objectives of dry ports: main issues, challenges and opportunities in Brazil. *International Journal of Logistics Management*, v. 32, n. 1, p. 237-261, 2021. DOI: https://doi.org/10.1108/IJLM-10-2020-0386.

RODRIGUES, T.; MOTA, C.; PINTO, D.; ARAÚJO, A. (2020) Identifying the factors engaged in customers' choice to operate through dry port or seaport. *International Joint Conference on Industrial Engineering and Operations Management (IJCIEOM)*, Rio de Janeiro, Brazil, 22-24 February 2021.

RODRIGUES, T.; MOTA, C.; SANTOS, I. Determining dry port criteria that support decision making. *Research in Transportation Economics*,v. 88, p. 1-10, 2021. DOI: https://doi.org/10.1016/j.retrec.2020.100994.

ROSO, V. Evaluation of the dry port concept from an environmental perspective: a note. *Transportation Research Part D: Transport and Environment*, v. 12, n. 7, p. 523–527, 2007. DOI: https://doi.org/10.1016/j.trd.2007.07.001.

ROSO, V. Factors influencing implementation of a dry port. *International Journal of Physical Distribution and Logistics Management*, v. 30, n. 10, p. 782-798, 2008. DOI: https://doi.org/10.1108/09600030810926493.

ROSO, V. Emergence and significance of dry ports: the case of the port of Goteborg. *World Review of Intermodal Transportation Research*, v. 2, n. 4, p. 296-310, 2009.

ROSO, V.Sustainable intermodal transport via dry ports - importance of directional development. *World Review of Intermodal Transportation Research*, v. 4, p. 140-156, 2013.

ROSO, V.; LUMSDEN, K. A review of dry ports. *Maritime Economics and Logistics*, v. 12, p. 196–213, 2010. DOI: https://doi.org/10.1057/mel.2010.5.

ROSO, V.; WOXENIUS, J.; LUMSDEN, K. The dry port concept: connecting container seaports with hinterland. *Journal of Transport Geography*, v. 17, n. 4, p. 338–345, 2009. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2008.10.008.

ROUCOLLE, C.; SEREGINA, T.; URDANOZ, M. Measuring the development of airline networks: comprehensive indicators. *Transportation Research Part A: Policy and Practice*, v. 133, p. 303-324, 2020. DOI: https://doi.org/10.1016/j.tra.2019.12.010.

ROTHENGATTER, W. Megaprojects in transportation networks. *Transport Policy*, v. 5, p. 1-15, 2019. DOI: https://doi.org/10.1016/j.tranpol.2018.08.002.
SÃO PAULO. *São Paulo's economic rank*. 2020. Disponível em: https://encurtador.com.br/moqOW. Acesso em: 04 Mai. 2021.

SAMSON, D.; GLOET, M. Integrating performance and risk aspects of supply chain design processes. *Production Planning and Control*, v. 29, n. 15, p. 1238–1257, 2018. DOI: https://doi.org/10.1080/09537287.2018.1520314.

SARMADI, K.; AMIRI-AREF, M.; DONG, J.; HICKS, C. Integrated strategic and operational planning of dry port container networks in a stochastic environment. *Transportation Research Part B: Methodological*, v. 139, p. 132–164, 2020. DOI: https://doi.org/10.1016/j.trb.2020.06.002.

SEADE. *São Paulo highlights among the highests economies in the world*. 2020. Disponível em: https://encurtador.com.br/gxQT3. Acesso em: 04 Mai. 2021.

SELEEM, S.; ATTIA, E.; EL-ASSAL, A. Managing performance improvement initiatives using DEMATEL method with application case study. *Production Planning and Control*, v. 27, p. 637-649, 2016. DOI: https://doi.org/10.1080/09537287.2016.1165301.

SHAW, S.; GRANT, D.; MANGAN, J. A supply chain practice-based view of enablers, inhibitors and benefits for environmental supply chain performance measurement. *Production Planning & Control*, v. 32, n. 5, p. 382-396, 2021. DOI: https://doi.org/10.1080/09537287.2020.1737977.

SHERAFATIPOUR, S.; SAFFARZADEH, M.; TAVASSZY, L.; ARDESTANI, S. Predicting the competitive position of extended gates: The case of inland customs zones. *European Journal of Transport and Infrastructure Research*, v. 18, n. 4, p. 433-456, 2018.

SHUKLA, S.; MOHANTY, B. K.; KUMAR, A. Strategizing sustainability in e-commerce channels for additive manufacturing using value-focused thinking and fuzzy cognitive maps. *Industrial Management and Data Systems*, v. 118, n. 2, p. 390-411, 2018. DOI: https://doi.org/10.1108/IMDS-03-2017-0122.

SI, S.; YOU, X.; LIU, H.; ZHANG, P. DEMATEL technique: a systematic review of the state-of-the-art literature on methodologies and applications. *Mathematical Problems in Engineering*, v. 2018, p. 1-33, 2018. DOI: https://doi.org/10.1155/2018/3696457.

SIMON, H. *Sciences of the artificial*. 2. ed. Cambridge, MA: MIT Press, 1982.

SIMONI, M.; SCHIAVONE, F.; RISITANO, M.; LEONE, D.; CHEN, J. Group-specific business process improvements via a port community system: the case of Rotterdam. *Production Planning and Control*, In press, p. 1–15, 2020. DOI: https://doi.org/10.1080/09537287.2020.1824029.

SLACK, B. Containerization, inter-port competition and port selection. *Maritime Policy & Management*, v. 12, n. 4, p. 293-303, 1985.

SMITH, T. On the validity of inferences from non-random samples. *Journal of the Royal Statistical Society: Series A*, v. 146, n. 4, p. 394-403, 1983.

SONG, D. P.; DONG, J. X. Cargo routing and empty container repositioning in multiple shipping service routes. *Transportation Research Part B: Methodological*, v. 46, n. 10, p. 1556–1575, 2012. DOI: https://doi.org/10.1016/j.trb.2012.08.003.

SONI, G.; KODALI, R. Evaluating reliability and validity of lean, agile and leagile supply-chain constructs in Indian manufacturing industry. *Production Planning & Control*, v. 23, p. 864-884, 2012. DOI: https://doi.org/10.1080/09537287.2011.642207.

SOUZA, R.; LARA, J.; SILVA, S. Os portos secos como canais de comércio exterior. Espacios, v. 38, n. 21, p. 1-16, 2017.

STEVEN, A. B.; CORSI, T. M. Choosing a port: an analysis of containerized imports into the US. *Transportation Research Part E: Logistics and Transportation Review*, v. 48, n. 4, p. 881-895, 2012. DOI: http://dx.doi.org/10.1016/j.tre.2012.02.003.

TABACHNICK, B.; FIDELL, L. *Using multivariate statistics*. 5 ed. Boston, MA: Pearson Education, 2007.

TALLEY, W. K. Determinants of cargo port choice by port service providers. *Transportation Research Part E: Logistics and Transportation Review*, v. 132, p. 48-50, 2019. DOI: https://doi.org/10.1016/j.tre.2019.10.010.

TALLEY, W. K.; NG, M. Maritime transport chain choice by carriers, ports and shippers. *International Journal of Production Economics*, v. 142, n. 2, p. 311-316, 2013. DOI: http://dx.doi.org/10.1016/j.ijpe.2012.11.013.

TALLEY, W. K.; NG, M. Hinterland transport chains: determinant effects on chain choice. *International Journal of Production Economics*, v. 185, p. 175-179, 2017. DOI: http://dx.doi.org/10.1016/j.ijpe.2016.12.026.

TALLEY, W. K.; NG, M. Hinterland transport chains: a behavioral examination approach. *Transportation Research Part E: Logistics and Transportation Review*, v. 113, p. 94-98, 2018. DOI: https://doi.org/10.1016/j.tre.2018.03.001.

TANG, L.; LOW, J.; LAM, S. Understanding port choice behavior: a network perspective. *Networks and Spatial Economics*, v. 11, n. 1, p. 65-82, 2011.

TESTORELLI, R.; LIMA, P.; VERBANO, C. Fostering project risk management in SMEs: an emergent framework from a literature review. *Production Planning & Control*, In press, 2020. DOI: https://doi.org/10.1080/09537287.2020.1859633.

TIMMERMAN, M.; LORENZO-SEVA, U. Dimensionality assessment of ordered polytomous items with parallel analysis. *Psychological Methods*, v. 16, n. 2, p. 209-220, 2011.

TONGZON, J. L. Port choice and freight forwarders. *Transportation Research Part E: Logistics and Transportation Review*, v. 45, n. 1, p. 186-195, 2009. DOI: http://dx.doi.org/10.1016/j.tre.2008.02.004.

TRAN, N. K.; HAASIS, H. D.; BUER, T. Container shipping route design incorporating the costs of shipping, inland/feeder transport, inventory and CO2 emission. *Maritime Economics and Logistics*, v. 19, n. 4, p. 667-694, 2017. DOI: https://doi.org/10.1057/mel.2016.11.

TRANFIELD, D.; DENYER, D.; SMART, P. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, v. 14, p. 207-222, 2003. DOI: https://doi.org/10.1111/1467-8551.00375.

TSAO, Y. C.; LINH, V. T. Seaport- dry port network design considering multimodal transport and carbon emissions. *Journal of Cleaner Production*, v. 199, p. 481–492, 2018. DOI: https://doi.org/10.1016/j.jclepro.2018.07.137.

TSHERING, G.; GAO, S. Understanding security in the government's use of blockchain technology with value focused thinking approach. *Journal of Enterprise Information Management*, v. 33, n. 3, p. 519-540, 2020. DOI: https://doi.org/10.1108/JEIM-06-2018-0138.

TST. *Brazilian Legislation: work hours day*. 2021. Disponível em: https://www.tst.jus.br/jornada-de-trabalho. Acesso em: 15 Fev. 2021.

UNCTAD. Multimodal transport and containerisation. In: *Ports and Container Depots, United Nations Conference on Trade and Development.* Geneva. United Nations Publications, 1982.

UNCTAD. *Review of maritime transport*. New York: United Nations Publications, 2019. Disponível em: https://unctad.org/en/Pages/Publications/Review-of-Maritime-Transport-(Series).aspx. Acesso em: 07 Jun. 2020.

UNCTAD. *Review of maritime transport*. New York: United Nations Publications, 2020. Disponível em: https://unctad.org/system/files/official-document/rmt2020_en.pdf. Acesso em: 02 Out. 2021.

UNCTAD. *The complex factors behind the unprecedented shortage of containers hampering trade's recovery and how to avoid a similar situation in the future*. 2021. Disponível em: https://unctad.org/es/node/32834. Acessado em: 04 Oct. 2021.

UNESCAP. *Planning, development and operation of dry ports of international importance*. 2015. Disponível em: https://www.unescap.org/resources/study-planning-developmentand-operation-dry-ports-international-importance. Acesso em: 13 Jun. 2019.

VAGGELAS, G. Measurement of port performance from users' perspective. *Maritime Business Review*, v. 4, n. 2, p. 130-150, 2019. DOI: https://doi.org/10.1108/MABR-08-2018-0024.

VALLS, J.; LANGEN, P.; ALONSO, L.; PINTO, T. Understanding port choice determinants and port hinterlands: findings from an empirical analysis of Spain. *Maritime Economics and Logistics*, v. 22, n. 1, p. 53-67, 2020. DOI: https://doi.org/10.1057/s41278-019-00138-2.

VAN MARREWIJK, A.; YBENA, S.; SMITS, K.; CLEGG, S.; PITSIS, T. Clash of the titans: temporal organizing and collaborative dynamics in the Panama Canal megaproject. *Organization Studies*, v. 37, n. 12, p. 1745-1769, 2016. DOI: https://doi.org/10.1177/0170840616655489.

VEENSTRA, A.; ZUIDWIJK, R.; VAN ASPEREN, E. The extended gate concept for container terminals: Expanding the notion of dry ports. *Maritime Economics and Logistics*, v. 14, n. 1, p. 14-32, 2012. DOI: https://doi.org/10.1057/mel.2011.15.

VEJVAR, M.; LAI, K.; LO, C.; FURST, E. Strategic responses to institutional forces pressuring sustainability practice adoption: case-based evidence from inland port operations.

Transportation Research Part D: Transport and Environment, v. 61, p. 274-288, 2018. DOI: https://doi.org/10.1016/j.trd.2017.08.014.

VOSS, C.; TSIKRIKTSIS, N.; FROHLICH, M. Case research in operations management. *International Journal of Operations and Production Management*, v. 22, n. 2, p. 195-219, 2002. DOI: https://doi.org/10.1108/01443570210414329.

WALTER, C.; POIST, R. Desired attributes of an inland port: Shipper vs. carrier perspectives. *Transportation Journal*, v. 42, n. 5, p. 42-55, 2003.

WALTER, C.; POIST, R. North American inland port development: international vs domestic shipper preferences. *International Journal of Physical Distribution and Logistics Management*, v. 34, n. 7, p. 579-597, 2004. DOI: https://doi.org/10.1108/09600030410552267.

WANG, C.; CHEN, Q.; HUANG, R. Locating dry ports on a network : a case study on Tianjin port. *Maritime Policy & Management*, v. 45, n. 1, p. 71-88, 2018. DOI: https://doi.org/10.1080/03088839.2017.1330558.

WAN, Y.; YUEN, A.; ZHANG, A. Effects of hinterland accessibility on US container port efficiency. *International Journal of Shipping and Transport Logistics*, v. 6, n. 4, p. 422-440, 2014. DOI: http://dx.doi.org/10.1504/IJSTL.2014.062908.

WANG, W.; LIN, Y.; LIN, C.; CHUNG, C.; LEE, M. DEMATEL-based model to improve the performance in a matrix organization. *Expert Systems with Applications*, v. 39, n. 5, p. 4978-4986, 2012.

WANG, W. F.; YUN, W. Y. Scheduling for inland container truck and train transportation. International Journal of Production Economics, 2013. v. 143, n. 2, p. 349–356.

WAKEMAN, T. *Marine Transportation of International Freight for the Northeast Corridor*. 2008. Disponível em: https://udspace.udel.edu/bitstream/handle/19716/3809/NECorridorLinkagesPapers.pdf?isAllowed=y&sequence=1. Acesso em: 04 Mai. 2019.

WARFIELD, J. *Societal systems, planning, policy and complexity*. New York: John Wiley and Sons, 1976.

WEI, H.; SHENG, Z. Dry ports-seaports sustainable logistics network optimization: considering the environment constraints and the concession cooperation relationships. *Polish Maritime Research*, v. 24, n. S3, p. 143-151, 2017.

WEI, H.; SHENG, Z.; LEE, P. The role of dry port in hub-and-spoke network under belt and road initiative. *Maritime Policy & Management*, v. 45, n. 3, p. 370-387, 2018. DOI: https://doi.org/10.1080/03088839.2017.1396505.

WILLIAMS, T. The nature of risk in complex projects. *Project Management Journal*, v. 48, n. 4, p. 55-66, 2017. DOI: https://doi.org/10.1177/875697281704800405.

WITTE, P.; WIEGMANS, B.; NG, A. K. Y. A critical review on the evolution and development of inland port research. *Journal of Transport Geography*, v. 74, p. 53-61, 2019. DOI: https://doi.org/10.1016/j.jtrangeo.2018.11.001.

WITTE, P.; WIEGMANS, B.; VAN OORT, F.; SPIT, T. Governing inland ports: a multi-dimensional approach to addressing inland port-city challenges in European transport corridors. *Journal of Transport Geography*, v. 36, p. 42-52, 2014. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2014.02.011.

WHYTE, J.; NUSSBAUM, T. Transition and temporalities: spanning temporal boundaries as projects end and operations begin. *Project Management Journal*, v. 51, n. 5, p. 505-521, 2020. DOI: https://doi.org/10.1177/8756972820919002.

WINTER, J.; DODOU, D.; WIERINGA, P. Exploratory factor analysis with small sample sizes. *Multivariate Behavioral Research*, v. 44, n. 2, p. 147-181, 2009. DOI: https://doi.org/10.1080/00273170902794206.

WORLD BANK. Current GDP. 2020. Disponúvel em: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?most_recent_value_desc=true. Acesso em: 04 Mai. 2021.

WRIGHT, J. Risk management: a behavioural perspective. *Journal of Risk Research*, v. 21, n. 6, p. 710-724, 2018. DOI: https://doi.org/10.1080/13669877.2016.1235605.

WU, H.; LEUNG, S. Can likert scales be treated as interval scales? A simulation study. *Journal of Social Service Research*, v. 43, n. 4, p. 527-532, 2017.

XU, X.; FAN, C. Autonomous vehicles, risk perceptions and insurance demand: An individual survey in China. *Transportation Research Part A: Policy and Practice*, v. 124, p. 549-556, 2019. DOI: https://doi.org/10.1016/j.tra.2018.04.009.

YAP, J.; ABDUL-RAHMAN, H.; WANG, C.; SKITMORE, M. Exploring the underlying factors inducing design changes during building production. *Production Planning & Control*, v. 29, n. 7, p. 586-601, 2018. DOI: https://doi.org/10.1080/09537287.2018.1448127.

YEO, G.; NG, A.; LEE, P.; YANG, Z. Modelling port choice in an uncertain environment. *Maritime Policy and Management*, v. 41, n. 3, p. 251-267, 2014. DOI: http://dx.doi.org/10.1080/03088839.2013.839515.

YEO, G.T.; THAI, V. V.; ROH, S. Y. An analysis of port service quality and customer satisfaction: the case of korean container ports. *Asian Journal of Shipping and Logistics*, v. 31, n. 4, p. 437–447, 2015. DOI: http://dx.doi.org/10.1016/j.ajsl.2015.08.008.

ZHANG, X.; SCHRAMM, H. Assessing the market niche of Eurasian rail freight in the belt and road era. *International Journal of Logistics Management*, v. 31, n. 4, p. 729-751, 2020. DOI: https://doi.org/10.1108/IJLM-12-2019-0351.

ZENG, Q.; MALONI, M.; PAUL, J.; YANG, Z. Dry port development in China: motivations, challenges, and ppportunities. *Transportation Journal*, v. 52, n. 2, p. 234-263, 2013.

APPENDIX A – SURVEY QUESTIONNAIRE

Risk factors of dry ports infrastructure projects in Brazil

Dear Specialist,

We invite you to share your experience with us expressing your vision about the risk factors engaged in dry ports infrastructure projects. This questionnaire is part of the Strategic Decision Making project in Service Systems of the Research Group in Development and Project Management (PMD) of the Federal University of Pernambuco (UFPE), in collaboration with the University of Sharjah of the United Arab Emirates, financed by the Foundation for the Support of Science and Technology of the State of Pernambuco (FACEPE) and Coordination for the Improvement of Higher Education Personnel (CAPES).

This project aims to identify your perception about the risk factors engaged in dry ports infrastructure projects in Brazil, according to the view of the main stakeholders and specialists in the logistics chain. The results will be aggregated, making possible to identify similarities and conflicts from the multi-stakeholder perspective. We expect that the managerial and theoretical results of this project provides useful information to dry port's managers, shippers, consignees and government agents, assisting in future decision-making processes.

The questionnaire consists of 2 steps:

• Step 1: Identification of the specialist;
• Step 2: Evaluation of the importance level of the main risk factors of dry ports infrastructure projects.

Filling out the questionnaire will take about 20 minutes. We emphasize that the information provided here is of an academic nature and will be used as a database for this research project.

We thank you in advance for your collaboration, which is extremely important for the development of this research.

Step 1 – Identification of the specialist

At this step the specialist will be asked about personal information, so that we can know the characteristics of our sample. This step is important for the statistical treatment of the responses obtained.

Age	
	Less than or 20 years old
	Between 21 – 30 years old
	Between 31 – 40 years old
	Between 41 – 50 years old
	More than or 51 years old

Work experience	
	Less than or 5 years
	Between 6-10 years
	Between 11-14 years
	Between 15-19 years
	More than or 20 years

Gender	
	Male
	Female

Company that you work	
	Dry port
	Export/Import company
	Government agencies

Educational level	
	Post Graduated
	Graduated
	Other

Work position	
	Owner
	CEO/Director
	Superintendent
	Top Manager
	Top Specialist

Actuation zone	
	North
	Northeast
	Middle west
	South
	Southeast

Step 2 – Assessing the risk factors engaged in dry ports projects

At this stage, you will assess, according to your perception and personnel experience, the degree of importance of each risk factor of dry ports projects. Keep in mind that the importance scale should represent your vision when considering all factors. In this case, if one factor has the same importance as another, it must present the same score on the scale.

Another point to be considered is that the distance between the scale values is equivalent; therefore, the difference between a criterion with importance '1' and another with importance '2' is similar to the difference between a criterion with importance '3' and another with importance '4' (1 point difference on the scale).

The question to be asked when answering the questionnaire is: **'How important is the risk factor "A" to consider in dry port projects?'**

Note: The questions refer to the level of absolute importance of a risk factor. We are not considering the importance of changing one factor more or less (Ex: reduction in cost, reduction in transportation time, and increase in environmental actions). Please, find below the scale of importance considered in this study and further the questions to be evaluated.

Scale of importance evaluation

0	**1**	**2**	**3**	**4**
Very Low Importance	**Low Importance**	**Medium Importance**	**High Importance**	**Very High Importance**

Cost Factors					
Sub-factor / Importance	**0**	**1**	**2**	**3**	**4**
Facility cost					
Transportation cost					
Storage cost					
Additional services cost					
Cost caused by road congestion					

Location Factors					
Sub-factor / Importance	**0**	**1**	**2**	**3**	**4**
Demand for DP's services					
Distance between DP and customers					
Distance between DP and Seaport					
Proximity with other logistic facilities					
Size of hinterland population					
Cargo transportation time					

Infrastructure Factors					
Sub-factor / Importance	**0**	**1**	**2**	**3**	**4**
Dry ports' total area					
Dry ports' yard capacity					
Dry ports' warehouse capacity					
Dry ports' expansion capacity					
Multimodal infrastructure					
Equipment infrastructure					

Accessibility Factors					
Sub-factor / Importance	**0**	**1**	**2**	**3**	**4**
Accessibility to airports					
Accessibility to seaports					
Accessibility to railways					
Accessibility to highways					
Accessibility to other facilities					
Accessibility to customers					
Transportation capacity between DP and Seaport					
Quality of network transportation infrastructure					

Operational Factors					
Sub-factor / Importance	**0**	**1**	**2**	**3**	**4**
Set of operational services offered					
Container handling capacity (per day)					
Information and technology system					
Operational execution time					
Cargo security and monitoring					
DP's occupation (yard and warehouse)					

Economic Factors					
Sub-factor / Importance	**0**	**1**	**2**	**3**	**4**
Gross Domestic Product (GDP) rate					
Dollar rate					
Trade market (export and import)					
Purchasing power of hinterland population					

Political and Social Factors					
Sub-factor / Importance	**0**	**1**	**2**	**3**	**4**
Customs' rules					
Job creation					
Government financial incentive					
Political and business environment					
Bureaucracy for opening new companies and dry ports					

Environmental Factors					
Sub-factor / Importance	**0**	**1**	**2**	**3**	**4**
Urban and environmental impact due DP facility					
Noise reduction and visual impact in seaport cities					
Environmental politics					
Reduction of congestion and CO_2 emission					

Major Factors

Factor / Importance	0	1	2	3	4
Cost					
Location					
Infrastructure					
Accessibility					
Operational					
Economic					
Political and Social					
Environmental					

Would you like to add any relevant factors that were not addressed in the questions above? If so, what is its scale of importance?

____

Please, inform a valid e-mail: ______________________________

APPENDIX B – RESULTS OF TESTS FOR H2.a, H3 AND H4

	Comparison between stakeholders		Comparison between DPOs by distance		Comparison between DPOs by transportation mode	
Factors	p-value	Decision	p-value	Decision	p-value	Decision
F1	0,001	Reject null hypothesis	0,392	Support null hypothesis	0,880	Support null hypothesis
SF1	0,119	Support null hypothesis	0,353	Support null hypothesis	0,651	Support null hypothesis
SF2	0,061	Support null hypothesis	0,548	Support null hypothesis	0,846	Support null hypothesis
SF3	0,028	Reject null hypothesis	0,372	Support null hypothesis	0,846	Support null hypothesis
SF4	0,023	Reject null hypothesis	0,281	Support null hypothesis	0,503	Support null hypothesis
SF5	0,644	Support null hypothesis	0,298	Support null hypothesis	0,780	Support null hypothesis
F2	0,717	Support null hypothesis	0,703	Support null hypothesis	0,476	Support null hypothesis
SF7	0,851	Support null hypothesis	0,265	Support null hypothesis	0,983	Support null hypothesis
SF8	0,617	Support null hypothesis	0,598	Support null hypothesis	0,074	Support null hypothesis
SF9	0,022	Reject null hypothesis	0,316	Support null hypothesis	0,560	Support null hypothesis
SF11	0,157	Support null hypothesis	0,928	Support null hypothesis	0,143	Support null hypothesis
F3	0,715	Support null hypothesis	0,524	Support null hypothesis	0,682	Support null hypothesis
SF12	0,319	Support null hypothesis	0,573	Support null hypothesis	0,476	Support null hypothesis
SF13	0,804	Support null hypothesis	0,928	Support null hypothesis	0,813	Support null hypothesis
SF14	0,610	Support null hypothesis	0,478	Support null hypothesis	0,352	Support null hypothesis
SF15	0,177	Support null hypothesis	0,456	Support null hypothesis	0,268	Support null hypothesis
F4	0,214	Support null hypothesis	0,334	Support null hypothesis	0,590	Support null hypothesis
SF18	0,096	Support null hypothesis	0,434	Support null hypothesis	0,747	Support null hypothesis
SF19	0,159	Support null hypothesis	0,068	Support null hypothesis	0,846	Support null hypothesis
SF20	0,040	Reject null hypothesis	0,986	Support null hypothesis	0,914	Support null hypothesis
SF21	0,011	Reject null hypothesis	0,048	Reject null hypothesis	0,714	Support null hypothesis
SF22	0,021	Reject null hypothesis	0,207	Support null hypothesis	0,620	Support null hypothesis
SF23	0,204	Support null hypothesis	0,758	Support null hypothesis	0,714	Support null hypothesis
SF24	0,316	Support null hypothesis	0,281	Support null hypothesis	0,780	Support null hypothesis
SF25	0,185	Support null hypothesis	0,094	Support null hypothesis	0,813	Support null hypothesis
F5	0,848	Support null hypothesis	0,478	Support null hypothesis	0,682	Support null hypothesis
SF26	0,234	Support null hypothesis	0,080	Support null hypothesis	1,000	Support null hypothesis
SF27	0,483	Support null hypothesis	0,334	Support null hypothesis	0,747	Support null hypothesis
SF28	0,618	Support null hypothesis	0,598	Support null hypothesis	0,560	Support null hypothesis
SF29	0,597	Support null hypothesis	0,524	Support null hypothesis	0,560	Support null hypothesis
SF30	0,546	Support null hypothesis	0,501	Support null hypothesis	0,232	Support null hypothesis
SF31	0,303	Support null hypothesis	0,957	Support null hypothesis	0,651	Support null hypothesis
F6	0,433	Support null hypothesis	0,221	Support null hypothesis	0,476	Support null hypothesis
SF32	0,000	Reject null hypothesis	0,813	Support null hypothesis	0,813	Support null hypothesis
SF33	0,156	Support null hypothesis	0,758	Support null hypothesis	0,308	Support null hypothesis
SF34	0,036	Reject null hypothesis	0,524	Support null hypothesis	0,590	Support null hypothesis
SF35	0,008	Reject null hypothesis	0,087	Support null hypothesis	0,249	Support null hypothesis
F7	0,426	Support null hypothesis	0,899	Support null hypothesis	0,846	Support null hypothesis
SF36	0,483	Support null hypothesis	0,334	Support null hypothesis	0,651	Support null hypothesis
SF37	0,399	Support null hypothesis	0,785	Support null hypothesis	0,560	Support null hypothesis
SF38	0,149	Support null hypothesis	0,899	Support null hypothesis	0,780	Support null hypothesis
SF39	0,776	Support null hypothesis	0,478	Support null hypothesis	0,183	Support null hypothesis
SF40	0,626	Support null hypothesis	0,676	Support null hypothesis	0,503	Support null hypothesis
F8	0,278	Support null hypothesis	0,128	Support null hypothesis	0,288	Support null hypothesis
SF41	0,919	Support null hypothesis	0,048	Reject null hypothesis	0,215	Support null hypothesis
SF42	0,081	Support null hypothesis	0,169	Support null hypothesis	0,914	Support null hypothesis
SF43	0,104	Support null hypothesis	0,413	Support null hypothesis	0,914	Support null hypothesis
SF44	0,031	Reject null hypothesis	0,372	Support null hypothesis	0,450	Support null hypothesis

APPENDIX C – VARIABLES AND PARAMETERS OF THE MODEL

	Description	Unit of measure	Assumptions	Based on
Indexes				
SEA	Set of seaports (i)		i – seaport	
DRY	Set of dry ports (j)		j – dry port	
CUS	Set of customers (k)		k – customer	
TM	Set of transportation mode		t – truck r – rail	
DRS	Set of delivery route (dr) simulations, dr=1,2…,7		$if \begin{cases} dr = 1 & \left(i \xrightarrow{t} k_{con}; k \xrightarrow{t} i_{empt}\right) \\ dr = 2 & \left(i \xrightarrow{r,t} k_{con}; k \xrightarrow{t,r} i_{empt}\right) \\ dr = 3 & \left(i \xrightarrow{t} k_{deco}\right) \\ dr = 4 & \left(i \xrightarrow{t} j_{con}; j \xrightarrow{t} k_{con}; k \xrightarrow{t} j_{empt}\right) \\ dr = 5 & \left(i \xrightarrow{r,t} j_{con}; j \xrightarrow{t} k_{con}; k \xrightarrow{t} j_{empt}\right) \\ dr = 6 & \left(i \xrightarrow{t} j_{con}; j \xrightarrow{t} k_{deco}\right) \\ dr = 7 & \left(i \xrightarrow{r,t} j_{con}; j \xrightarrow{t} k_{deco}\right) \end{cases}$	(FAZI; ROODBERGEN, 2018)
CT	Set of cargo type		*con* – consolidated *deco* – deconsolidated *empt* – empty	
SAS	Set of additional services (kas_q) in seaports (i) and dry ports (j)		For the simulations, the authors have defined: kas_1 = positioning kas_2 = deconsolidation kas_3 = consolidation kas_4 = weighting	Activities required for delivery route's simulations
Variables				
$ttsc_{t,r,dr}$	Transit time from the seaport (i) to the customer's facility (k) by truck (t) or rail (r)	days	Defined by the customer or assessed multiplying the distance and the average speed	(LARRANAGA; ARELLANA; SENNA, 2016)
$ttdc_{t,dr}$	Transit time from the dry port (j) to the customer's facility (k) by truck	days	Defined by the customer or assessed multiplying the distance and the average speed	(LARRANAGA; ARELLANA; SENNA, 2016)
$ttsd_{t,r,dr}$	Transit time from the seaport (i) to the dry port (j) by truck (t) or rail (r)	days	Defined by the customer or assessed multiplying the distance and the average speed	(LARRANAGA; ARELLANA; SENNA, 2016)
$ttre_{t,r,dr}$	Transit time to return the empty container (*empt*) by truck (t) or rail (r)	days	$if \begin{cases} dr = 1, 2 & ttre_{t,r} = ttsc_{t,r} \\ dr = 4, 5 & ttre_{t} = ttdc_{t} \\ dr = 3, 6, 7 & ttre_{t,r} = 0 \end{cases}$	(LARRANAGA; ARELLANA; SENNA, 2016)
$dd_{dr,t,r}$	Delivery distance of the delivery route by transportation mode	Kilometers		Google Maps
cv	Cargo value	R$	$cv = cifr \times cw \times dor$ For simulation 1: R$415,580.00 (approximately US$74,000.00) For simulation 2: R$45,000.00 (approximately US$8,040.00)	(DP WORLD, 2021; LATTILA; HENTTU; HILMOLA, 2013; ZHANG; SCHRAMM, 2020)
$doc_{i,j}$	Dwell-time of the cargo stored at the seaport (i), dry port (j) consolidated or deconsolidated	days	Vary according to ttd, $ttsc_{t,r}$, and $ttsd_{t,r}$	Customer decision
HC_{dr}	Terminal handling cost in seaport (i) and dry port (j) per delivery route	R$		(CRAINIC et al., 2015; TRAN; HAASIS; BUER, 2017)
SC_{dr}	Storage cost in seaport (i) and dry port (j) per delivery route	R$		(QIU; LAM; HUANG, 2015; TSAO; LINH, 2018)
VA_{dr}	Value-added service cost in seaport (i) and dry port (j) per delivery route	R$		(JEEVAN et al., 2017;KHASLAVSKAYA; ROSO, 2020)
CC_{dr}	Customs clearance cost in seaport (i) and dry port (j) per delivery route	R$		(IANNONE; THORE, 2010)
TLT_{dr}	Total logistic time per delivery route (dr)	days		(FAZI; ROODBERGEN, 2018; IANNONE, 2012; TALLEY; NG, 2017; TRAN; HAASIS; BUER, 2017)
IC	Inventory cost	R$		(IANNONE; THORE,

				2010; JANIC, 2007; TALLEY; NG, 2017)
DDC_{dr}	Demurrage and detention cost per delivery route (*dr*)	R$		(FAZI; ROODBERGEN, 2018)
CLC_{dr}	Container leasing cost per delivery route (*dr*)	R$		(TRAN; HAASIS; BUER, 2017)
DEC_{dr}	Delivery cost per delivery route (*dr*)	R$		(LATTILA et al., 2013; TRAN; HAASIS; BUER, 2017)
$BECC_{dr}$	Back empty container cost per delivery route (*dr*)	R$		(SONG; DONG, 2012)
EMC_{dr}	Emission cost per delivery route (*dr*)	R$		(LATTILA et al., 2013)
TLC_{dr}	Total logistic cost per delivery route (*dr*)	R$		
Parameters				
$box_{i,j}$	Quantity of boxes handled, stored or delivered through seaport (*i*) and dry port (*j*)	Quantity of containers	1 container 40 foot (2 TEUs)	Defined by the authors
$thc_{i,j}$	Terminal handling charge per handle in seaport (*i*) and dry port (*j*)	R$/handle	thc_i = R$582.00/handle thc_j = R$286.00/handle	Average fee in seaports (*i*) and dry ports (*j*)
$qhm_{i,j,dr}$	Quantity of handling moves in seaport (*i*) and dry port (*j*) per delivery route (*dr*)	Quantity of handles	$if \begin{cases} dr = 1 & qhm_{i,j} = (1{,}0) \\ dr = 2 & qhm_{i,j} = (1{,}0) \\ dr = 3 & qhm_{i,j} = (0{,}0) \\ dr = 4 & qhm_{i,j} = (1{,}2) \\ dr = 5 & qhm_{i,j} = (1{,}2) \\ dr = 6 & qhm_{i,j} = (1{,}1) \\ dr = 7 & qhm_{i,j} = (1{,}1) \end{cases}$	Operational process of each delivery route
$scc_{i,j}$	Storage charge per consolidated box (*con*) at the seaport's (*i*) and dry port's (*j*) yard	% cv/day	$scc_i = src_i \times cv$ $scc_j = src_j \times cv$	Average rate in seaports (*i*) and dry ports (*j*)
$scd_{i,j}$	Storage charge per deconsolidated cargo (deco) at the seaport's (*i*) and dry port's (*j*) warehouse	% cv/day	$scd_i = srd_i \times cv$ $scd_j = srd_j \times cv$	Average rate in seaports (*i*) and dry ports (*j*)
$cifr$	CIF rate	US$/Kg	4,95	(ZHANG; SCHRAMM, 2020)
cw	Cargo weight	Kg	15000	(LATTILA et al., 2013)
dor	Dollar rate	R$ /US$	5,6	Dollar rate in February 27, 2021
$src_{i,j}$	Storage rate related to the cargo value (*cv*) consolidated	%	src_i = 0.255% src_j = 0.144%	Average rate in seaports (*i*) and dry ports (*j*)
$srd_{i,j}$	Storage rate related to the cargo value (*cv*) deconsolidated	%	srd_i = 0.314% srd_j = 0.137%	Average rate in seaports (*i*) and dry ports (*j*)
$msrc_{i,j}$	Minimum storage rate to consolidated cargo in seaport (*i*) and dry port (*j*)	R$	$msrc_i$ = R$1,888.00 $msrc_j$ = R$2,000.00	Average rate in seaports (*i*) and dry ports (*j*)
$msrd_{i,j}$	Minimum storage charge to deconsolidated cargo in seaport (*i*) and dry port (*j*)	R$	$msrd_i$ = R$2,329.00 $msrd_j$ = R$2,000.00	Average rate in seaports (*i*) and dry ports (*j*)
$tmc_{i,j}$	Time related to the minimum storage rate in seaport's (*i*) and dry port's (*j*) yard or warehouse	days	tmc_i = 5 days tmc_j = 15 days	Average rate in seaports (*i*) and dry ports (*j*)
ttd	Total time until the customer receive the cargo	days	Variable defined by the customer that determines the value of $doc_{i,j}$	Defined by the customer
dtd_i	Documentation time to liberate the cargo at seaport (*i*)	days	2 days	(BFR, 2019)
kas_q	Kind of additional services required per delivery route defined by the customer		$if \begin{cases} dr = 1 & kas_4\ is\ required \\ dr = 2 & kas_4\ is\ required \\ dr = 3 & kas_1, kas_2, kas_3, kas_4\ is\ required \\ dr = 4 & kas_4\ is\ required \\ dr = 5 & kas_4\ is\ required \\ dr = 6 & kas_1, kas_2, kas_3, kas_4\ is\ required \\ dr = 7 & kas_1, kas_2, kas_3, kas_4\ is\ required \end{cases}$	Activities required per delivery route
cas_{i,j,kas_q}	Charge per kind of additional service in seaport (*i*) and dry	R$/box	cas_{i,j,kas_1} = (R$528.67; R$225.71) cas_{i,j,kas_2} = (R$1,182.00; R$725.46)	Average rate in seaports (*i*) and dry ports (*j*)

	port (*j*)		cas_{i,j,kas_3} = (R$1,367.67; R$725.46) cas_{i,j,kas_4} = (R$108.33; 96.17)	
$pic_{i,j}$	Physical inspection cost in seaport (*i*) and dry port (*j*)	R$/box	pic_i = R$528.67 pic_j = R$199.14	Average rate in seaports (*i*) and dry ports (*j*)
$xsc_{i,j}$	X-ray scanner cost in seaport (*i*) and dry port (*j*)	R$/box	xsc_i = R$462.67 xsc_j = R$333.00	Average rate in seaports (*i*) and dry ports (*j*)
$tcc_{i,j}$	Transshipment customs cost to transfer the cargo from seaport (*i*) to dry port (*j*)	R$/box	$if\ dr = 4,5,6,7,$ $tcc_{i,j} = (R\$1{,}323.36, R\$176.00)$	Average rate in seaports (*i*) and dry ports (*j*)
$as_{t,r}$	Average speed of truck (*t*) and rail (*r*)	Km/hr	as_t= 60km/hr as_r= 40 km/hr	(LARRANAGA; ARELLANA; SENNA, 2016)
or	Opportunity cost rate	% of the cargo value/day	*or+der* = 0.0685%	(TRAN; HAASIS; BUER, 2017)
der	Depreciation cost rate	% of the cargo value/day	*or+der* = 0.0685%	(TRAN; HAASIS; BUER, 2017)
$ddft$	Demurrage and detention free-time	Days	*ddft* =7 days	Average rate among ship-owners
$ddf1$	Demurrage and detention fee 1	R$/day	*ddf1* = R$72.67/day	Average rate among ship-owners
$ddf2$	Demurrage and detention fee 2	R$/day	*ddf2* = R$127.17/day	Average rate among ship-owners
ttc_{dr}	Container transit time per delivery route (*dr*)	days	if $\begin{cases} dr = 1,2,4,5 & ttc_{dr} = TLT_{dr} \\ dr = 3 & ttc_{dr} = 0 \\ dr = 6,7 & ttc_{dr} = ttsd_{t,r} + dtd_i \end{cases}$	Operational process of each delivery route
lcd	Leasing charge per day	R$/day	R$8.96/day	(TRAN; HAASIS; BUER, 2017)
$mc_{t_{con,deco,empt}}, r_{con,empt}$	Modal charge, varying among truck, rail and the cargo type (*con*, *deco*, *empt*)	R$/box*Km	$mc_{t_{con}}$ = R$ 4.114 $mc_{t_{deco}}$ = R$ 4.114 $mc_{t_{empt}}$ = R$3.773 $mc_{r_{con}}$ = R$3.591 $mc_{r_{empt}}$ = R$1.716	(ANTT, 2021; ARAÚJO; BANDEIRA; CAMPOS, 2014; NTC, 2021; TRAN; HAASIS; BUER, 2017); average rate among rail carriers
$fdr_{t_{con,deco,empt}}, r_{con,empt}$	Fixed delivery rate per transportation mode (*TM*) and cargo type (*CT*)	R$	$fdr_{t_{con}}$ = R$785.51 $fdr_{t\ deco}$ = R$785.51 $fdr_{t\ empt}$ = R$722.70 $fdr_{r_{con}}$ = R$609.24 $fdr_{r_{empt}}$ = R$437.00	(ANTT, 2021; ARAÚJO; BANDEIRA; CAMPOS, 2014; NTC, 2021); average rate among rail carriers
adc_{dr}	Additional delivery cost for transportation under customs control per delivery route (*dr*)	R$	$If\ dr = 4,5,6,7 \quad adc_{t_{con},r_{con}}$ = R$924.57	(NTC, 2021)
otr_{dr}	Operational transshipment rate per delivery route (*dr*)	R$	$If\ dr = 2,4,7 \quad otr_{dr}$ = R$276.77	(ANTT, 2021)
cp	Carbon price	RS$/CO2tonn	R$280.00/CO2ton	(EDF, 2020)
$me_{t,r}$	Marginal emission	KgCO2/tonn.km	$me_t = 0.044$ KgCO2/t.km $me_r = 0.0067$ KgCO2/t.km	(LATTILA et al., 2013)
$w_{t,r}$	Weight of the cargo and the truck (*t*) or wagon (*r*)	tonnes	$w_t = 30$ t when $cw = 15$ t $w_r = 47.76$ t when $cw = 15$ t	(LATTILA et al., 2013)
ddd_{dr_t}	Direct delivery distance by truck	Km	Vary according to the customer city, dry port city and multimodal used.	Google Maps