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Container Port Selection in the ASEAN Region: Korean Shipping Companies' Perspective

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UNIVERSITY OF PLYMOUTH

CONTAINER PORT SELECTION IN THE ASEAN REGION:

KOREAN SHIPPING COMPANIES' PERSPECTIVE

by

INHYEOK YEO

A thesis submitted to the University of Plymouth
in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

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AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

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ABSTRACT

Inhyeok Yeo

Container Port Selection in the ASEAN Region: Korean Shipping Companies' Perspective

Ports are crucial platforms that connect the sea and inland transportation to foster logistics and transfer of goods and information. Thus, selection of the most optimal ports is ever crucial for decision makers. However, the increasing globalisation and international trade add to the already competitive and saturated market for marine container cargo shipping. Consequently, it may be of best interest to shift focus and find niche market, such as trading to the Southeast Asia, to increase profitability. In near proximity to Southeast Asia, South Korean multinational corporations' investment and interest in the Southeast Asian countries are significant. South Korea maintains a high position in the maritime transport business in the world and is one of the largest economies as well. Additionally, the topic of container port selection from South Korean shipping companies in the Southeast Asian region is under-researched. Therefore, this calls for an investigation into finding the most important port selection factors for Korean shipping companies that provide services to Southeast Asian countries and determining which ports are most optimal. This study focuses on container cargo shipping specifically and aims to enhance the understanding of port selection and port attractiveness.

In order to identify the driving port selection factors, port selection studies published between 1985 and 2022 were obtained from Systematic Literature Review (SLR) and analysed. Next, the identified factors have been verified and refined after pilot test and interviews with academic scholars and industrial experts of container port selection. Then, to determine the weight of importance of these factors as well as to choose the optimal ports of targeted

alternatives, two-step Analytic Hierarchy Process - Technique for Order of Preference by Similarity to Ideal Solution (AHP-TOPSIS) is used.

Following such process, this study has identified 4 main factors encompassing 14 sub-factors on container port selection through SLR. After series of revisions on these factors through pilot test and interviews, the study was able to refine the container port selection factors to 4 main factors encompassing 12 sub-factors. Then, using the two step AHP-TOPSIS, weights of the aforementioned factors have been determined, and the rankings of optimal ports, based on the initially chosen 6 Southeast Asian ports, have been calculated. The last portion of this study performed sensitivity analysis to test the robustness of the AHP-TOPSIS model and produced multiple hypothetical scenarios to instigate changes in the obtained rankings of ports.

Theoretical and practical contributions arising from this study include enhancing the understanding of container port selection and port attractiveness especially in the Southeast Asian region from Korean shipping companies' perspectives. This particular topic is under-researched; therefore, this study's investigation will contribute by filling in the gap in port selection literature. Additionally, weights of factors as well as rankings of targeted ports can provide crucial pieces of information for decision makers of port-related stakeholders since these results specify the degree of importance of such factors and the optimal order of ranking of ports. Furthermore, the multiple constructed scenarios provide various reference points to which port-related stakeholders can use when devising plans to improve port attractiveness.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABBREVIATIONS	FULL WORDS
AFTA	ASEAN Free Trade Area
AHP	Analytic Hierarchy Process
ASEAN	Association of South East Asian Nations
CAGR	Compound Annual Growth Rate
$\boldsymbol{C_i}$	Relative closeness to ideal solution
CI	Consistency Index
CR	Consistency Ratio
FDI	Foreign Direct Investment
FMCDMM	Fuzzy Multiple Criteria Decision-Making Method
GCMPH	Gross Crane Moves Per Hour
GDP	Gross Domestic Product
JICT	Jakarta International Container Terminal
KMTC	Korea Marine Transport Co.
LOLO	Lift-On / Lift-Off
MCDM	Multi-Criteria Decision-Making
MNC	Multinational Corporation
NIS	Negative Ideal Solution
NRT	Net Registered Tonnes
OOCL	Orient Overseas Container Line
PIS	Positive Ideal Solution
PLSCI	Port Liner Shipping Connectivity Index
RI	Random Index
RORO	Roll-On / Roll-Off
SLR	Systematic Literature Review
SSS	Short Sea Shipping
TCCL	Tan Cang - Cat Lai
TEU	Twenty Equipment Unit
THC	Terminal Handling Charge

TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UNCTAD	United Nations Conference on Trade And Development
UNSD	United Nations Statistics Division

CHAPTER 1: INTRODUCTION

1.1 Chapter introduction

This chapter gives an overview of this study, "Container Port Selection in the ASEAN Region: Korean Shipping Companies' Perspective." The chapter begins with a general research background regarding container port selection with specific focus on Southeast Asian region for South Korean shipping companies' perspectives. Then, research aims and objectives, as well as justification of this research are presented. Finally, the structure of the thesis is provided to give brief description of each chapter.

1.2 Research background

In terms of volume, nearly 90% of the world's trade is transported by maritime shipping (Li et al., 2015; Kosowska-Stamirowska et al., 2016), and maritime transport is considered to be the backbone of global trade. Ports provide important platforms to connect the sea and inland transportation; serve as integral points to foster logistics, transfer of goods, and information; and influence greatly on the development of their hinterland (Lam and Yap, 2011). Further, in ocean shipping, since its inception in 1951, containerisation has helped to unitise general cargo that were traded around the world and to substantially enhance many economies around the world (Slack, 1985).

With globalisation and increase in world trade, competition among ports is fierce. Therefore, determining which port is the most optimal for container vessels to call is crucial to port-related stakeholders. Port selection process is complex and challenging as numerous influencing factors have to be considered. Just some examples of these influencing factors, or port selection factors, include the following: port location, hinterland economy, port physical, cost, and other conditions (Chou, 2010a). The other conditions here refer to electronic data interchange (EDI) computer system, free trade zone and port future development plan. The factors listed from Chou (2010a) are, in fact, the main criteria and selection factors are further divided into sub-criteria. It should be noted that these provide a glimpse of just a few port selection factors and do not represent all of the multitude of port selection factors considered when choosing a port. Studies handling port selection use various sets of port selection factors based on their approach and their region of focus (Slack, 1985; Murphy et al., 1992; Malchow and Kanafani, 2001; Tongzon, 2009; Yeo et al., 2014; Pamucar and Gorcun, 2022).

There is a need to select the best port for the decision makers of port-related stakeholders because once a decision is made regarding port choice, it takes a lot of capital investment to make changes to the cargoes flowing through the route and port operations and maintenance (Yeo et al., 2014). Further, it is crucial for shipping companies to choose the most optimal port of call in order to reduce the total transportation cost as well (Chou, 2010b). Additionally, according to UNCTAD (2021), carriers have two options to cater the growing demand: a) offer more services and direct connections or b) deploy larger vessels. The combination of these options is also possible, but data shows that carriers have tended to use the second option (using larger ships) over the last two decades (UNCTAD, 2021). Hence, the decision to select the most optimal port is ever-important.

According to Chen et al., (2018), there have been three major relocations of global manufacturing in the modern history. Rapid development of manufacturing in the early 20th Century in the United States came to replace the United Kingdom as the global manufacturing hub. From the 1970s, Japan followed a similar path as that of the United States. From 1980 to 2010, China stood to be the most recent world's manufacturing hub. However, since 2011, Chinese manufacturing began to decline as various capital and labour costs have increased over these 30 years and the cost advantage is waning. Following this, Chen et al., (2018) suggest that next new global manufacturing hub is of hot topic since related logistics, shipping, and port companies will also move to the new manufacturing hub as they have done so in the past.

Taking a look at the global economy in 2019, many disturbances caused damage and played a part in depressing global business confidence. Majorly, there was friction between China and the U.S. from their trade war. There were other situations around the world where trade was made unstable; such include political hot spots in the Middle East raising concern and threat to the price and supply of oil. Another includes the potential happening of Brexit and its impact on the European economies. There were other more sector-specific situations that caused for the trade growth around the world to slow. However, economies in the Southeast Asia showed resilience. Although when compared to 2018, the economic growth had indeed decelerated, Southeast Asia's economic activities did not slow down as much as it had been expected. Also, in 2019, United States dollar (USD) became stronger and China experienced currency weakness. In contrast, the currencies in the Southeast Asian countries did not suffer too badly and especially so when compared to the previous global financial market hardship in mid-2013 (Bhaskaran, 2020). The trade war between China and the U.S. affected the firms whose products were influenced by the tariffs. These firms and many others threw-in to the reconfiguration of their supply chains, and relocation of production facilities were seen. With the continuous improvement in economic foundations in the Southeast Asian countries and trade war tension between the U.S. and China, relocation of production facilities sparked and has been accelerating to the Southeast Asia (Bhaskaran, 2020).

The Association of South East Asian Nations (ASEAN) region that this study is focusing on is a dynamic economic bloc that first formed in the 1960s by the first five countries, which were Indonesia, Malaysia, Philippines, Singapore, and Thailand. Later by 1999, the

ASEAN members grew to include the rest of the five countries which are Brunei, Cambodia, Laos, Myanmar, and Vietnam. In present day, the ASEAN consists of ten-member countries that have been recorded to exceed USD 2.77 trillion in 2017 in their combined gross domestic product (GDP) (Lai et al., 2019). Also, before further continuing into this research, it should be noted that this current research followed the composition of world's geographical regions assigned by the United Nation to define the exact area and group of countries that this research is referring to when mentioning the "Southeast Asian region." According to the United Nations Statistics Division (UNSD), South Eastern Asia is defined as the above mentioned ten countries along with Timor-Leste, which is currently not a part of the ASEAN.

Briefly glancing into the ASEAN's trade agreements, ASEAN free trade area (AFTA) agreement of 1992 reduced or eliminated tariff for intra-ASEAN countries trade in products like manufactured agricultural goods, manufactures, and capital goods in order to enhance the ASEAN's strength as production base in the global market (Lai et al., 2019). Tariff reduction has been successful, and to catch up with the demands of international trade, several measures had been taken to better facilitate transport logistic services as well. In 2007, *Roadmap for the Integration of Transport logistics Services* had been endorsed, and it brought about the following results: reduction of export time by 6.2 days on average from 2007 to 2014; increase in container port traffic by 31.3 million Twenty Equipment Unit (TEU) from 2007 to 2016 in the ASEAN member countries (Lai et al., 2019). Other intra-ASEAN multilateral trade agreements like ASEAN Trade in Goods Agreement (ATIGA) helped to grow Southeast Asia's merchandise exports by 10.1% from 2017 to 2021 and increased merchandise imports by 10% nominally each year on average from 2017 to 2021 (DPWorld, 2024).

The ASEAN is looking ahead to expand its economic intake through its coordination with other countries like China, Japan, and South Korea through free trade agreement such as ASEAN+3 or through further negotiations (Lai et al., 2019). Such further moves from the ASEAN part to sign and continue with regional trade liberalisation will facilitate cargo trade within the region, which will naturally foster trade with the outside region and to the rest of the world as well.

There is a positive and promising regional trade development for the ASEAN region as, over the past decade, measures have been taken to reduce tariff and promote more trade. With marine transportation playing a crucial role in the international trade, promotion of trade naturally leads to an increase in container volume and handling, as also analysed by Lai et al., (2019), in the ASEAN region.

As mentioned above, the ASEAN region is a very attractive location for multinational corporations (MNC) to move their production base to since institutional quality and free trade agreement promote Foreign Direct Investment (FDI) inflow into the region. Namely, Samsung Electronics and LG Electronics from South Korea have demonstrated such FDI by investing major capital in Vietnam (Nguyen and Pham, 2020).

Meanwhile, in close proximity to the ASEAN region, South Korea is a major participant in the maritime transport business. As of 2020, South Korea ranked as the 4th highest country in annual container port throughput measured in TEU (UNCTADSTAT, 2022). According to UNCTAD (2021), South Korea ranked as the third most connected economy in terms of maritime transport per Liner Shipping Connectivity Index, which generally indicates a country’s access to overseas market to be more competitive. Moreover, South Korea, along with China and Japan, dominate the shipbuilding market with their combined world market share of 93% in 2020; Their deliveries of newbuildings indicate their influence: China (40%), South Korea (31%), and Japan (22%), (UNCTAD, 2021). South Korea is also a major economic power in the world with its GDP reaching 1.637 trillion USD in 2020, making it a country with the 10th highest GDP in the world (World Bank, 2022). Thus, South Korea's scale of economy in the world and its high position within the maritime transport business make it worthwhile to further investigate port selection and port of call from South Korea to the emerging hotspots of the ASEAN region.

As explained above, ports are crucial platforms to connect the sea and inland transportation to foster logistic and transfer of goods and information. Therefore, selection of the most optimal ports is ever crucial for decision makers. The increasing globalisation and international trade add to the already competitive and saturated market for marine container cargo shipping. Park and Min (2017) also have written on the case of highly competitive shipping markets in the Asia-Pacific region. There is much research that analyse and evaluate best ways to provide decision makers attain a more competitive edge (Liu et al., 2016; Wan et al., 2021; Vukić and Cerbán, 2022). However, in addition to this, it may also be of best interest to shift focus and find niche market, such as trading to the Southeast Asia, to increase profitability. Also, it appears that the production ground is shifting towards Southeast Asian countries. Considering South Korean MNCs' investment and interest in the Southeast Asian countries as well as South Korea's high position in the maritime transport business in the world, investigation is needed into finding the most important selection factors for Korean shipping companies dealing marine transport with Southeast Asian countries. Additionally, determining which ports are the most optimal for Korean shipping companies is needed. This study aims to enhance the understanding of port selection and port attractiveness. Further, it aims to contribute to identifying and evaluating the extent of influence to which port selection factors have; this way, readers can understand how shipping companies make their final decisions in their port selection in the presence of port selection factors and multiple alternative ports (Yeo et al., 2014; Park and Min, 2011).

1.3 Research aims

There are numerous studies in the literature on port selection that evaluates the most important port selection factors. Each study focuses on a specific region from the perspective of the chosen port-related stakeholders (carrier, port authority / port operator, and shipper / freight forwarder). However, research on investigating driving container port selection factors from Korean carriers' perspectives in choosing ports in the ASEAN region is relatively under examined. The overarching research aim of this study is to explore port selection for container ports by providing and implementing empirical evidence to determine attractive port selection factors and optimal ports. In order to break down this overarching research aim and delve into more particular topics whilst addressing this overarching research aim, the three further major research aims of this research would be to:

1. Investigate selection factors that influence container port selection from the perspective of shipping company.
2. Analyse Korean shipping companies' focus on targeting the growing markets in the ASEAN region.
3. Find optimal ports in the ASEAN region for Korean shipping companies and present advantage and disadvantage of these container ports for related industrial stakeholders.

1.4 Research objectives

In order to achieve the research aims, the following research objectives will be addressed:

1. Identify the driving port selection factors within container port selection literature.

2. Develop a hierarchical model of factors that influence Korean shipping companies' container port selection.
3. Examine South Korea's growing maritime transport activities with the ASEAN region and its target container ports in the ASEAN region.
4. Investigate South Korean shipping companies' involvement in maritime trade with the ASEAN region and their widely used container terminals.
5. Evaluate the weight of importance of container port selection factors.
6. Evaluate the ranking of the most optimal ports in the ASEAN region to the Korean shipping companies.

These 6 research objectives were formed in order to help achieve the aforementioned research aims. Research objective 1 seeks to first establish what the key port selection factors are in container port selection literature. Research objective 2 follows up on the review of literature that will have been conducted in the first objective and seeks to develop a hierarchical model of port selection factors, particularly for Korean shipping companies' perspectives. The first two objectives will address the first research aim and are critical to this study as the objectives will help to narrow down the scope of stakeholder perspective and region since port selection literature encompasses numerous amounts of studies that focus on different stakeholder perspectives, region of study, or a combination of both.

Following the interest of this research on Korean shipping companies and the ASEAN region, it is important to further provide evidence on South Korea's growing maritime transport activities with the ASEAN region in detail. Therefore, Research objective 3 seeks to provide further investigation as well as identify major port of call in the region from the Korean shipping companies' interests. Following the third objective, Research objective 4 seeks to further hone in on specific container terminal that South Korean shipping companies most frequently use from the identified port of calls. At ports, there are numerous terminals that a shipping company would use so it is necessary to investigate specific terminals for the targeted ports in order to establish a concrete target for this research. It should be noted that the third and fourth research objectives both adhere to addressing the second research aim.

Taking the driving port selection factors identified through the first and second objectives, the purpose of Research objective 5 is to assess how much importance each factor has over another. Finally, Research objective 6 seeks to investigate which ASEAN container port is most optimal for Korean shipping companies to call to. The fifth and sixth research objectives both adhere to addressing the third research aim and these objectives contribute to the development of practical implications arising from this research in terms of container port selection in the ASEAN region.

1.5 Method

There are many studies that examine and present hierarchical structure of selection factors in the port selection literature. Additionally, studies in port selection literature predominantly also investigate finding the most optimal port in their research's region of focus. Since studies on port selection deal with ranking and selecting the best port under multiple criteria, these studies typically have incorporated MCDM methods.

This research has employed a mixed-methods of qualitative and quantitative methodologies. The research first goes through a preliminary review of literature as well as systematic literature review (SLR) to form a theoretical model of port selection factors which is then modified and verified by academic and industrial experts. Subsequently, quantitative methodologies have been employed using the theoretical model obtained previously. This research took on position of pragmatism to address this study's topic of interest as this research incorporates both subjectivism (using expert opinions to determine key port selection factors) and objectivism (using MCDM methods that incorporate hard data) to solve the practical problems in the real world (Saunders et al., 2019).

A comprehensive review of the literature as well as the use of SLR were used to provide background information on port selection and to form the initial theoretical hierarchical model of port selection factors. This was followed by using qualitative method through interviews where the initial hierarchical model underwent changes according to suggestions made by Korean academic and industrial experts in port selection. The interviews resulted in the final formation of the hierarchical model of port selection factors as well as gathering of crucial information on Korean shipping activities in the ASEAN region. The developed hierarchical model of port selection was then used as a key component to carry out further quantitative MCDM methods incorporated in this study. This quantitative part of the research used questionnaire data as well as reliable secondary data from shipping companies to compute for the importance of each factors within the hierarchical model as well as the ranking of optimal ports.

1.6 Justification of this research

Relocation of global manufacturing in the modern history is a hot topic since related logistics, shipping, and port companies will also move to the new manufacturing hub as they have done throughout the past three major global manufacturing relocations (Chen et al., 2018). It seems that since 2011, the most widely known hub, China, is seeing its cost advantage wane and with the recent trade war between the U.S. and China, relocation of production facilities have been sparked and have been accelerating in the Southeast Asian countries (Bhaskaran, 2020). South Korea is in close proximity to the Southeast Asian countries and is a major participant in the maritime transport business. According to UNCTADSTAT (2022), Korea ranked as the 4th highest country in terms of annual container port throughput measured in TEU of 2020. Korea’s GDP as of 2020 is 1.637 trillion USD and puts Korea as the 10th country with the highest GDP in the world (World Bank, 2022). Further, in terms of shipbuilding, three countries in Asia dominate the market with their combined market share as 93% of the world as of 2020. These three countries are China, Korea, and Japan and their percentage of deliveries of newbuildings are 40%, 31%, and 22% respectively

(UNCTAD, 2021). With Korea's scale of economy in the world and its high position within the maritime transport business, it is of great worth to further investigate into this topic of selecting the most optimal ports for Korean shipping companies that are providing shipping services to the newly emerging hotspots of Southeast Asian countries.

Additionally, currently in the port selection literature, numerous other studies have explored port selection of Asian regions and non-Asian regions and also from different perspectives such those of shipping companies or freight forwarder (Wiegmans et al., 2008; Saeed and Aaby, 2013; Yeo et al., 2014; Sun and Zheng, 2016; Notteboom et al., 2017; Kavirathna et al., 2018; Park et al., 2019; Subramanian and Thill, 2019; Fadda et al., 2020). Above mentioned research and many more have provided crucial analysis and insights on specific countries for both inside and outside of the ASEAN region. However, study on container port selection in the ASEAN region from Korean shipping companies' perspective has not been fully explored in the port selection literature. This study will address the current gap in the port selection literature where there is a scant of research to evaluate the important port selection factors and optimal container ports in the region of ASEAN from Korean shipping companies' perspective.

Accordingly, contribution to knowledge from this research project will be as follows:

- Update of important factors that influence the selection of container port from the perspective of shipping company.
- Suggestion of the actual picture of calling port activities in the targeted ASEAN region.
- Calculation of weights of factors of container port selection in the ASEAN region as well as the optimal ranking of targeted container ports in the ASEAN region.

1.7 Structure of the thesis

The thesis is organised into nine chapters excluding references and appendices. Figure 1.1 provides a visual representation of the organisation and flow of the thesis.

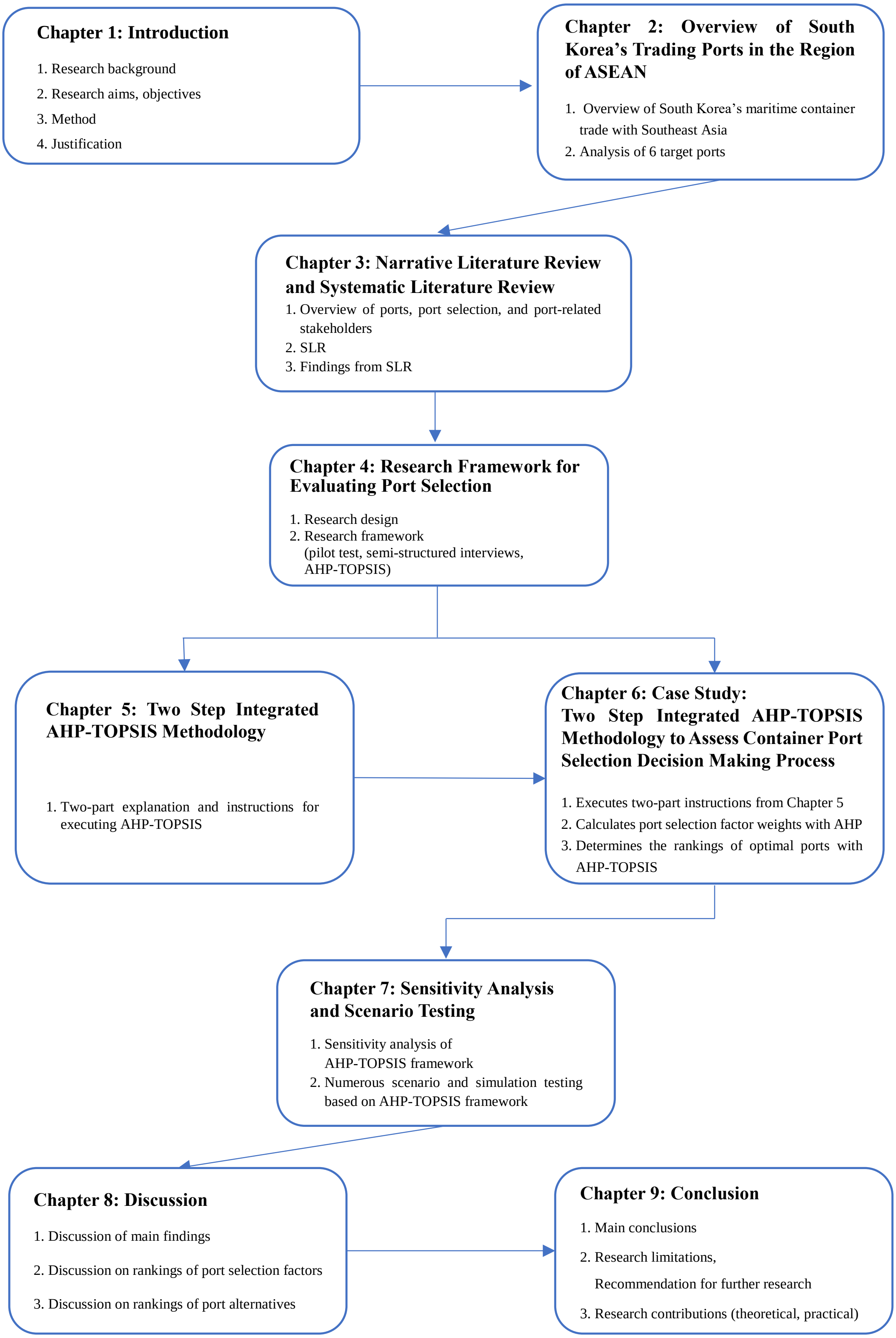

Figure 1.1 Thesis structure

Chapter two outlines container cargo volumes that are shipped from South Korea to the ASEAN region and highlights the six container ports in the ASEAN region that rank the highest in terms of their trade volume with South Korea. Additionally, overview of terminals of the six mentioned targeted ports are presented.

Chapter three presents a review of relevant literature on ports, port selection, and pattern of port selection based on geographical regions and various perspectives of port-related stakeholders to set a base of knowledge for the research. Further, process of Systematic Literature Review (SLR) is outlined, and analyses (descriptive and thematic) are carried out to present the findings. Based on these reviews and findings, research gap is identified and the chapter presents the under-researched area for further research to address the gap.

Chapter four explains the research framework used in order to achieve and address the research objectives and aims of this research. Research methodologies, research design, philosophy, approach, and research ethics pertaining to this research are discussed.

Chapter five explains in more detail the two-step integrated AHP-TOPSIS methodology that has been chosen in the previous chapter. This chapter gives explanation and instructions in multiple steps on how to apply this AHP-TOPSIS methodology.

Chapter six identifies the most optimal container port in the ASEAN region from Korean shipping companies' perspective and applies AHP-TOPSIS methodology. This chapter takes on the same format of the steps explained in the previous chapter, and provides details as well as calculation process on how each step was executed with the application of the case study.

Chapter seven tests the sensitivity of the results obtained from using AHP-TOPSIS framework. Additionally, numerous scenario tests and simulations are run using the AHP-TOPSIS framework by changing the performance values.

Chapter eight discusses the main findings obtained throughout the thesis. Also, it presents discussion on the rankings of the 12 port selection factors obtained through AHP and the rankings of the 6 alternative ports obtained through AHP-TOPSIS. This chapter discusses possible reasons for such display of results.

Chapter nine concludes the thesis by outlining the main findings obtained across all stages of the research, noting the limitations as well as recommendation for further research, and finally reporting theoretical contributions and practical implications of this research.

CHAPTER 2: OVERVIEW OF SOUTH KOREA'S TRADING PORTS IN THE REGION OF ASEAN

2.1 Chapter introduction

In this chapter, firstly, a review of short sea shipping (SSS) is given. Then, an overview of South Korea's trading ports in the ASEAN region is given to provide a better picture of the maritime cargo shipping activities between South Korea and countries in the Southeast Asia. The statistics presented in this chapter indicate South Korea's growing container cargo trading activities and interest in the countries of the ASEAN region. This chapter also presents a table that details the top trading ports with South Korea. The information in this table helps to identify the target alternative ports for this research, and these ports will be evaluated for their rankings in the later chapters of this study. Afterwards, details on specific terminals within these chosen ports are outlined. These terminals are the most frequently used terminals in the targeted ports for Korean shipping companies, and this selection of terminals has been obtained through semi-structured interviews with senior-level experts in the industry. It should be noted that the information as well as tables and statistics retrieved for sections 2.3 and 2.4 have been acquired from the Committee of Shipowners for Asian Liner Services annual report (2022) that is not publicly available. This report has been arranged by Committee of Shipowners for Asian Liner Services, which is an association for Korean small and medium-sized shipping companies engaging in short sea shipping (SSS) in the Southeast Asia.

2.2 Review of Short Sea Shipping

Before further continuing into this research, it should be noted that defining SSS is a difficult task that has not yet reached an academic agreement (Douet and Cappuccilli, 2011). Hence, there is no single definition to SSS that is universally agreed upon; rather, there are a number of definitions to SSS (Casaca and Marlow, 2007; Medda and Trujillo, 2010; Van den Bos and Wiegmans, 2018). In this current research, the author takes on the meaning of SSS defined by Van den Bos and Wiegmans (2018 p. 1) as "*maritime transport of goods over relatively short distances, as opposed to the intercontinental cross-ocean deep sea shipping.*" Therefore, this would include sea transport between South Korea and the ASEAN region as both locations are geographically within the same continent in the Pacific Ocean as opposed to the East–West intercontinental shipping between South Korea and Europe. Deep sea shipping such as the East–West route refers to maritime transportation of goods on intercontinental routes that cross oceans (Eurostat, 2023).

2.3 Export container cargo volumes from South Korea to ASEAN

Most of Korea's import and export cargo depend on sea transport and are carried out through several large ports. As of 2020, Korea's maritime transportation accounted for 99.7 percent of the total transportation (Lee et al., 2024). Among them, the three major ports of Korea (Busan, Incheon and Gwangyang) account for 93.8 percent, in terms of container cargo handled.

East Asia is not only a region with a high proportion of Korea's exports and imports, but also a region with higher growth rate than other regions. This is due the following facts: East Asia is geographically close to Korea; the economic development of East Asia's countries is prominent; and the industrial structure maintains complementary relations. Also, in terms of logistics, Korea's shipping and logistics companies' entry into the ASEAN region is also significant, as exports and imports to the ASEAN region are on the rise. More importantly, it should be noted that these regions have high potential for future growth.

South Korea's import and export container volume increased by about 13 percent from 25.4 million TEU in 2015 to 28.8 million TEU in 2020 (World Bank, 2024). The ASEAN member countries account for a growing share of Korea's overall exports as their economic growth rate is relatively high compared to other regions. In particular, the proportion of containers in Vietnam, Malaysia, and Thailand have increased rapidly in recent years. Table 2.1 below displays the increasing export cargo volumes from South Korea to ASEAN between 2010 and 2020. It should be noted that CAGR stands for Compound Annual Growth Rate.

Table 2.1 Export container cargo volumes from South Korea to ASEAN (Top 5)

(Units: Thousand TEUs)

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**CAGR (%)**
Vietnam	253	265	266	324	361	432	516	561	598	612	579	8.6%
Thailand	174	192	222	225	208	196	228	258	257	263	237	3.2%
Malaysia	123	127	168	215	223	203	217	235	258	249	255	7.5%
Indonesia	158	175	179	175	175	162	189	209	219	203	180	1.4%
Singapore	110	107	166	257	251	200	194	170	167	155	151	3.2%

Source: Statistics Korea (2021)

Due to the continued growth of trade activities in Southeast Asia, not only are the ship owners operating in Southeast Asia attracted to the market, but also are the global shipping companies suffering from worsening profitability due to oversupply attracted just the same. The recent relocation of production bases to Vietnam, Indonesia and Thailand by electronics, textiles and manufacturing plants that require low-wage and low-cost land prices also gives expectations of a significant increase in marine shipments.

South Korea's exports to Southeast Asia have generally been on a steady rise since the sharp drop in shipments caused by the global economic crisis in the late 2007. The country with the most marked growth is Vietnam. South Korea's investment in the Vietnamese market began after 1992. After establishing diplomatic relations with Vietnam, investment in clothing and textiles (labour-intensive industries using low labour force) was the main focus until the mid-2000s. However, since the mid-2000s, it has spread to the development of capital-intensive industries such as real estate, steel, and metal (Committee of Shipowners for Asian Liner Services, 2022).

South Korea's exports to Vietnam showed a high growth rate, with Vietnam growing rapidly as one of Korea's top three export markets after China and the United States as of January to May 2015. Particularly, Samsung Electronics' investment in Vietnam is estimated to be about 5 billion US dollars, but LG Electronics has also started operating its mobile phone and home appliance plants in Haiphong (Committee of Shipowners for Asian Liner Services, 2022).

On the other hand, in the case of routes from Busan to Southeast Asia, the number of route service did decrease by 1 from 2016 to 2020 but remained in similar share when compared with the top route share country, Japan, which experienced a drop in route service within the same years (according to Table 2.2). The ratio of services departing from Korea to Southeast Asia is 18.6% of the entire sea route, indicating that the second largest number of services are concentrated on Southeast Asian routes (Busan Port Authority, 2020).

Meanwhile, the shipping service routes opening at Incheon Port, which is South Korea's second-largest container port, increased from 24 in 2016 to 30 in 2020 (according to Table 2.3). This is due to the increasing number of ships being deployed to improve the deficit on Southeast Asian routes (Incheon Port Authority, 2020).

Table 2.2 Number of shipping service routes from Busan port

	Number of service routes					Route Share (2020)
	2016	**2017**	**2018**	**2019**	**2020**	
Japan	77	73	67	73	68	25.3%
Southeast Asia	51	53	58	50	50	18.6%
China	41	35	42	46	47	17.5%
North America (West coast)	27	29	30	28	25	9.3%
North America (East coast)	13	12	13	13	17	6.3%
South America (West coast)	8	7	7	9	12	4.5%
Russia	8	9	8	8	12	4.5%
Mediterranean region	10	8	11	11	9	3.3%
Northern Europe	6	5	5	5	6	2.2%
Southwestern Asia	7	6	6	7	6	2.2%
Oceania region	7	7	6	7	6	2.2%
Africa	2	1	2	2	5	1.9%
Middle East	7	5	5	6	4	1.5%
South America (East coast)	4	3	3	3	2	0.7%
Sum	268	253	263	268	269	100.0%

Source: Busan Port Authority

Table 2.3 Number of shipping service routes from Incheon port

	Number of service routes					Route Share (2020)
	2016	**2017**	**2018**	**2019**	**2020**	
Southeast Asia	24	26	23	24	30	56.6%
China	14	15	17	18	16	30.2%
Japan	4	4	4	4	4	7.5%
Russia	1		1		1	1.9%
Africa	1	1	1	1	1	1.9%
North America (West coast)	1	1	1	1	1	1.9%
Middle East	1	1	-	-	-	-
Sum	46	48	47	48	53	100.0%

Source: Incheon Port Authority

Table 2.4 lists ASEAN member countries and ports, which are shown to have the fastest growth in trade volume with South Korea. Vietnam (Ho Chi Minh City) took the 6th place, which is the highest of the ASEAN member countries that are present in the top 30 trading ports with South Korea in terms of trade volume. Next, Vietnam (Haiphong) ranked 9th, Thailand (Laem Chabang) ranked 12th, Malaysia (Port Kelang) ranked 16th, Indonesia (Jakarta) ranked 17th, and Singapore ranked 21st (Port-MIS, 2020). It could be observed in Table 2.5 that five of the 6 most traded ASEAN ports are listed in the world's top 30 ports as well.

Table 2.4 Top trading container ports with Korea

	Top 30 trading ports with South Korea	
	Port	**Nation**
1	Qingdao	China
2	Shanghai	China
3	Tianjin	China
4	Ningbo-Zhoushan	China
5	Dalian	China
6	**Ho Chi Minh City**	**Vietnam**
7	LA/LB	US
8	Vancouver	Canada
9	**Haiphong**	**Vietnam**
10	Shekou	China
11	Hong Kong	China
12	**Laem Chabang**	**Thailand**
13	Savannah, GA	US
14	Vladivostok	Russia
15	Manzanillo	Mexico
16	**Port Kelang**	**Malaysia**
17	**Jakarta**	**Indonesia**
18	Kaohsiung	Taiwan
19	Hakata	Japan
20	Tokyo	Japan
21	**Singapore**	**Singapore**
22	Weihai	China
23	Yokohama	Japan
24	Seattle	US
25	NY/NJ	US
26	Xiamen	China
27	Ssaka	Japan
28	Vostochnyy	Russia
29	Oakland	US
30	Lianyungang	China

Source: Port-MIS (2020)

Table 2.5 World top 30 container ports

	World Top 30 ports	
	Port	**Nation**
1	Shanghai	China
2	**Singapore**	**Singapore**
3	Ningbo-Zhoushan	China
4	Shenzhen	China
5	Guangzhou	China
6	Qingdao	China
7	Busan	South Korea
8	Tianjin	China
9	Hong Kong	China
10	LA/LB	US
11	Rotterdam	Netherlands
12	Dubai	UAE
13	**Port Kelang**	**Malaysia**
14	Antwerp	Belgium
15	Xiamen	China
16	Tanjung Pelepas	Malaysia
17	Kaohsiung	Taiwan
18	Hamburg	Germany
19	NY/NJ	US
20	**Laem Chabang**	**Thailand**
21	**Ho Chi Minh City**	**Vietnam**
22	Colombo	Sri Lanka
23	**Jakarta**	**Indonesia**
24	Tanger Med	Morocco
25	Yingkou	China
26	Piraeus	Greece
27	Valencia	Spain
28	Dalian	China
29	Algeciras	Spain
30	Rizhao	China

Source: Alphaliner (2020)

This research aims to evaluate the attractiveness of these six calling ports in the ASEAN region by Korean shipping companies. Visual representation of this research's target area is shown in Figure 2.1.

Figure 2.1 Research target area

Source: Author

2.4 Analysis of the current status and overview of research target ports

While 6 targeted ports in Southeast Asia for this research have been chosen based on the data on the top trading ports by volume with South Korea, as indicated in Table 2.4, it should be noted that there are multiple terminals present at these ports. Therefore, it is useful to identify which specific container terminals of each of the 6 targeted ports that the Korean shipping companies frequently utilise to get more accurate information. In this research, setting target port and terminal are ultimately within the same context. Targeting a specific terminal for each of the 6 ports could be seen merely as an extension of the selection of the 6 ports. As Tongzon and Heng (2005) and Kadaifci et al., (2019) also demonstrate in their port-related studies, the terms container port and container terminal are used interchangeably as the studies set their targets. Information regarding the most frequently used container terminals for the 6 ports was collected and identified through semi-structured interviews with 3 senior-level experts in Korean shipping companies. This helps to keep the research focused on a specific target from which data could be collected for computation. The details regarding the interviews such as the reason for conducting semi-structured style of interview as well as the reason for choosing these 3 particular experts will be further explained in the subsequent chapter, which dives deeper into uses of methodologies for this research. This section outlines the 6 container terminals (1 for each targeted port) and gives a brief overview of each terminal to assist in giving a picture of the current specifications and status of the port terminals that are being researched in this study.

2.4.1 Tan Cang - Cat Lai (TCCL) terminal at Ho Chi Minh City

TCCL terminal is the largest and the most modern international container terminal in Vietnam. The terminal is situated on Dong Nai river in Ho Chi Minh city and is vital to the economy of the city. The terminal is well connected to key highways such as National Highway 1, Inner Ring Highway, Outer Ring Highway, highway that connects Ho Chi Minh city, Long Thanh, and Dau Giay by Interprovincial Road 25, and more. Through these highways, cargoes are able to be circulated with ease from the TCCL terminal to major economic zones of Binh Duong, Dong Nai, Long An, Ba Ria Vung Tau, and Mekong Delta provinces (Tan Cang Cai Mep Thi Vai Terminal, 2023).

Currently, TCCL terminal is operated by Operations Center - Saigon Newport Corporation. The terminal has 3 terminals (A, B, and C) that also has a separate area designated to handle reefer containers, barges, and the stuffing of rice cargoes. Additionally, since 2008, the terminal uses TOP-X modern container management and operation system of RBS (Australia) as well as TOPOVN and synchronous hardware system. These allow the terminal to manage real-time containers, reduce delivery time, and optimise port operation capacity (Shipnext, 2023). Table 2.6 shows the key statistics of the TCCL terminal.

Table 2.6 Tan Cang - Cat Lai terminal key statistics

Tan Cang - Cat Lai Terminal	
Port Code (UNLOCODE)	VNSGN
Berth length	2,040 metres
Number of berths	10
Port depth at berth	12 metres
Number of gantry cranes	26
Area of container yard	160 hectares

Source: Shipnext (2023); Internal data from shipping company

2.4.2 Green port terminal at Haiphong

Green port terminal is situated along the bank of Cam river in Hai Phong and has been operational since September of 2004. The terminal is currently operated by Viconship and offers 2 berths and 5 shore cranes, which have a lifting capacity of 45 tons (Greenport, 2023). It should be noted that Green port terminal is not to be mixed with VIP Green terminal. The two mentioned terminals are both operated by Viconship, but the latter of the two mentioned terminals (VIP Green terminal) is the newer of these two container terminals and is situated in a different location with a slightly deeper draft. Although VIP Green terminal has a better capacity than the Green port terminal, this research focuses on Green port terminal as it is found through in-depth interviews that Green port terminal is the most frequently used terminal for Korean shipping companies. Table 2.7 below shows the key statistics of Green port terminal.

Table 2.7 Green port terminal key statistics

Green port terminal	
Port Code (UNLOCODE)	VNHPH
Berth length	350 metres
Number of berths	2
Port depth at berth	7.8 metres
Number of gantry cranes	5
Area of container yard	20 hectares

Source: Greenport (2023); Internal data from shipping company

2.4.3 LCMT at Laem Chabang

LCMT is a part of LCB1 Group as its subsidiary since 2006. It should be noted that the LCB1 Group is a Thailand-based container terminal operator in Laem Chabang port, and consists of LCB1 (commenced operation in 1995) and LCMT (commenced operation in 2006). LCMT consists of 2 berths (Terminals A0 and B0 (A0s)) and LCB1 consists of 1 berth (Terminal B1). Currently, APM terminals, which is a part of A.P. Moller-Maersk, owns 35% share of the LCB1 Group as a joint venture, and the concession for LCMT is agreed to expire in 2034 (APM terminals, 2024). Table 2.8 below shows the key statistics of LCMT.

Table 2.8 LCMT key statistics

LCMT	
Port Code (UNLOCODE)	THLCH
Berth length	590 metres
Number of berths	2
Port depth at berth	14 metres
Number of gantry cranes	9
Area of container yard	19 hectares

Source: APM terminals (2024); Internal data from shipping company

2.4.4 North port terminal at Port Kelang

Northport is situated in Port Kelang, Malaysia and is a member of the MMC Group, which is a leading utilities and infrastructure group in Malaysia. As one of the largest multi-purpose ports in Malaysia, North port is equipped with facilities to handle various types of cargo including containers to cars, break bulk, as well as liquid and dry bulk cargoes. The facilities are located in two locations: Northport and Southpoint. State-of-the-art container and conventional cargo handling are carried out at Northport whereas conventional cargo handling is carried out at Southpoint (Northport, 2024).

Additionally, it is important to note that Northport has been undergoing redevelopment of the terminal that involved reinstatement of rubber-tyred gantry (RTG) block E that has a ground slots of 1,020 TEU's and 320,000 TEU's per annum. Also, construction of RTG block J had commenced in January 2022. Further, purchases of various equipment and cranes had been made like the following: 23 RTG's as replacement units, 11 e-RTG's for deployment at block J, and planned purchase of 10 quay cranes (KMTC, 2023). Such improvement and modernisation of the port will greatly affect the attractiveness of the port.

Table 2.9 below shows the key statistics of North port terminal.

Table 2.9 North port terminal key statistics

North port terminal	
Port Code (UNLOCODE)	MYPKG
Berth length	4,300 metres
Number of berths	13
Port depth at berth	13 metres
Number of gantry cranes	32
Area of container yard	93 hectares

Source: MMC Ports (2024); Internal data from shipping company

2.4.5 Koja terminal at Jakarta

Koja terminal has been operating since 1997, officially having been inaugurated in early 1998, and is the first private and modern container terminal in Indonesia. Currently, PT Pelabuhan Indonesia II (state-owned enterprise) owns 54.91% of the share and PT Hutchison Ports Indonesia (subsidiary of Hutchison Ports Holding) owns 45.09% of the share in their joint operation since 1998 (Namsung, 2023).

Koja terminal is situated next to Jakarta International Container Terminal (JICT) at the Port of Tanjung Priok, and was established to meet the steeply growing demand for container handling services that had been going through Tanjung Priok Port (Hutchison Ports, 2024). The main customers of Koja terminal include Korea Marine Transport Co., Ltd (KMTC), Orient Overseas Container Line (OOCL), Namsung, Sinokor, and Samudera Shipping Line (Namsung, 2023). Table 2.10 below shows the key statistics of Koja terminal.

Table 2.10 Koja terminal key statistics

Koja terminal	
Port Code (UNLOCODE)	IDJKT
Berth length	650 metres
Number of berths	2
Port depth at berth	13 metres
Number of gantry cranes	7
Area of container yard	26 hectares

Source: Internal data from shipping company

2.4.6 PSA terminals (Pasir Panjang terminal) at Singapore

PSA terminals, more specifically Pasir Panjang terminal, in Singapore is one of the leading ports in the world and ranks second in its volume of handling capacity at around 37 million TEU. The Pasir Panjang terminal holds 41 berths and the types of vessels that regularly call at this terminal are the following: container ship by 75%; vehicles carrier by 7%; oil products tanker by 6%; bunkering tanker by 5%; and general cargo by 1%. As of July of 2023, according to MarineTraffic (2023), 430 vessels had been docked at the terminal within the last 7 days and the turnaround time for the vessels was at 0.6 days.

Looking at the broader picture of the Singapore itself, PSA Singapore is mainly divided into 3 main terminals or areas: Tuas terminal; Pasir Panjang terminal; and Brani, Keppel, Tanjong Pagar. Although the first and the third terminal do not pertain directly to this research's focused terminal, which is Pasir Panjang terminal, since Singapore houses the second busiest port in the world, it is worth exploring the three main terminals that make up PSA Singapore.

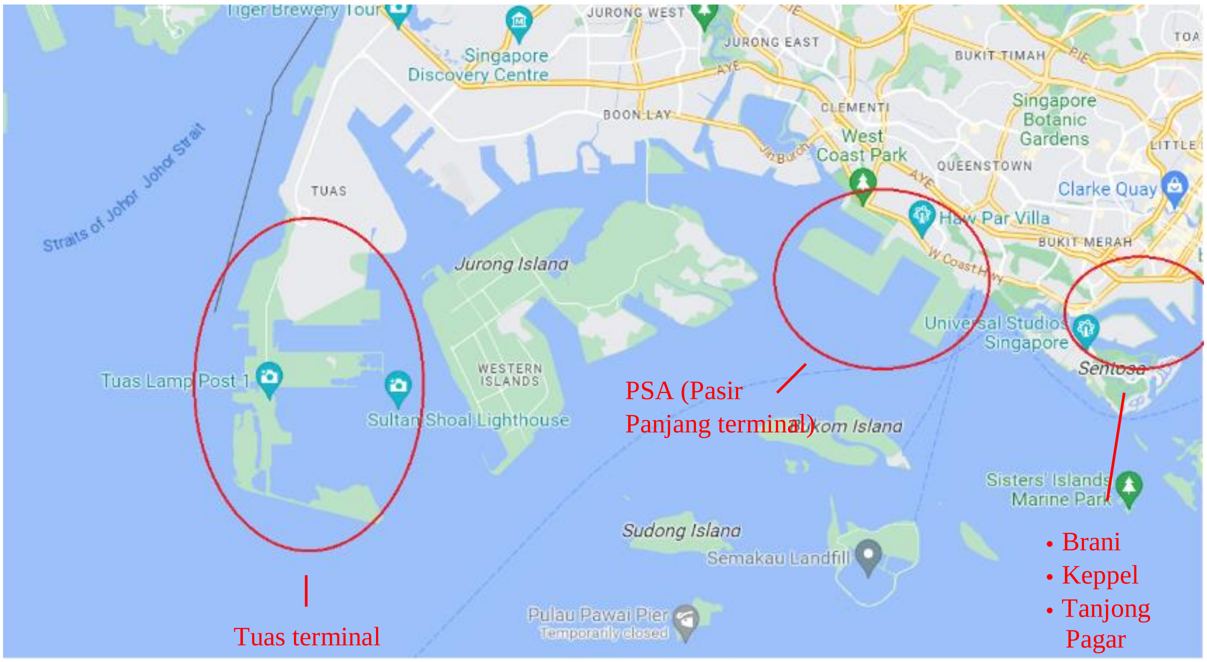

Figure 2.2 Picture of three main terminal areas under PSA Singapore operation.

Source: Google Maps (2023)

Figure 2.2 shows a map of the port area of Singapore, and the circled location on the farthest left is the Tuas terminal. This terminal is currently under development and construction. There are 4 phases to the completion of the Tuas terminal, and the terminal is currently in Phase 1 with a portion of the terminal operational. The circled location in the middle is the Pasir Panjang terminal, which is the focused terminal of this research. This terminal is currently the most active main terminal, and ocean-bound and coastal shipping companies all operate their businesses here. Finally, the circled location on the farthest right houses 3 terminals: Brani, Keppel, Tanjong Pagar. These are the oldest terminals and are rarely in use since they are now preparing for closure. Table 2.11 below shows the key statistics of PSA terminals (Pasir Panjang terminal).

Table 2.11 PSA terminals (Pasir Panjang terminal) key statistics

PSA terminals (Pasir Panjang terminal)	
Port Code (UNLOCODE)	SGSIN
Berth length	13,450 metres
Number of berths	41
Port depth at berth	18 metres
Number of gantry cranes	148
Area of container yard	550 hectares

Source: MarineTraffic (2023); Internal data from shipping company

2.5 Chapter summary

This chapter provided an overview of South Korea's trading ports in the ASEAN region to give a better picture of the maritime cargo shipping activities between South Korea and countries in Southeast Asia. Numerous tables of statistics suggest South Korea's growing interest and economic activities to Southeast Asian countries. Also, it is important to note the table that highlights top 30 trading ports with South Korea. Southeast Asian ports were selected from this list to be further used in the latter portion of this research as alternatives, which will be evaluated for their optimal rankings. Additionally, this chapter gave an overview of most frequently used terminal for each of the 6 chosen ports. Again, these terminals are the most frequently used terminals of their respective ports, and they have been determined whilst conducting semi-structured interviews with senior-level industrial experts. Further details of this semi-structured interviews will be discussed and mentioned in the upcoming chapter.

CHAPTER 3: NARRATIVE LITERATURE REVIEW AND SYSTEMATIC LITERATURE REVIEW

3.1 Chapter introduction

This chapter covers both a brief narrative literature review and also an extensive SLR of accessible peer-reviewed literature. A short narrative literature review gives an overview of the key terms, definitions, and background information to provide a knowledge base for this study's research area of port selection. This chapter will put more focus on the conducting of SLR because it uses transparent, replicable, and scientific process unlike the traditional narrative reviews (Tranfield et al., 2003). Petticrew (2001) also notes that systematic reviews are more efficient in summarising results of existing studies and for evaluating consistency as well among the previous studies. According to Fink (1998) and Hart (1998), narrative reviews have been criticised for the implicit bias in researchers selecting their reviewed literature. However, as Tranfield et al., (2003) notes, systematic approach to literature review reduces such bias by relying on its scientific process. After the narrative literature review, extensive SLR will be conducted following Denyer and Tranfield (2009)'s five steps in order to explore and narrow down major themes to help answer the research question or aim. According to Seuring and Müller (2008), patterns of conceptual content could be identified and further development of theory could be achieved with the use of SLR. This is ideal for this study as the major purpose of conducting SLR is to filter down the most relevant, quality articles and ultimately identify which port selection factors (theme) are deemed as key factors in port selection literature. The identification of such driving port selection factors as well as the construction of the hierarchical structure (main factors and sub-factors) of port selection variables are crucial results that are obtained from the SLR. These results contribute to providing a new analysis to the existing body of literature and also help to prepare an understanding of port selection for this current research before undertaking interviews with the experts in the industrial field.

3.2 Narrative Literature Review

3.2.1 Ports

Ports are integral part of transport logistics that serve as platforms for international trade to occur on a large scale. According to the Port Working Group of the European Commission (1977 p. 6), the definition of a port is as follows: "*an area of land and water [...] to permit, principally, the reception of ships, their loading and unloading, the storage of goods, the receipt and delivery of these goods by inland transport and can also include the activities of businesses linked to sea transport.*" Since, in principle, no single country could be self-sufficient, various kinds of goods and products are traded around the world either to be processed or consumed. For example, grain produced from the United States could be shipped to another country in the world to be processed and consumed elsewhere in the world (Nijdam and Horst, 2018). De Icaza and Parnell (2018) as well as Tongzon and Sawant (2007) state also that port's performance and efficiency can heavily influence the region's or the nation's global trade and growth of its regional economy.

Ports act as nodes within transport chains and are like other nodes in transport chain such as a train station or an airport, only that ports are focused more on receiving cargo. These cargoes include the following: bulk cargo, general cargo, container cargo, roll-on / roll-off cargo, and special project cargo. Whereas other inland transportation such as trucks are more suited for continental transport taking products to their final destination, ocean transportation is used for long-distance intercontinental transport bringing large quantities of goods to ports to then be interconnected to other modes of transportation bound inland. These ports are important not only in that they provide such platforms for receiving large quantities of products globally, but also in that they could act as a temporary storage for shortening the time for these products to reach the inland market to the end user (Nijdam and Horst, 2018).

Taking into account of such crucial role of ports in economies globally, it is vital to follow appropriate strategies to select the most optimal ports as regions compete to receive shares of seaborne trade (Aaby, 2012). Additionally, Moya and Valero (2017) mentions that since the 1990s when the process of relocation of production has started, optimal selection of ports has become ever-important for countries to act as trade facilitators. The relocation of productions in the 1990s refer to redistribution of production facilities more to emerging and developing countries such as China following the participation of a larger number of countries in the global economy since the 1980s (Miotti and Sachwald, 2008).

3.2.2 Port selection

In the current port selection literature, there is numerous research about the selection of ports, transshipment ports, bunkering ports, networks of multi-port and hub-and-spoke ports, and location of seaport. Additionally, there are also studies regarding shipping route selection, calling patterns of container shipping services, ports of call in relation to the changing organisational routines, and importance of relationship marketing for port business (Lam and Yap, 2011; Caliskan and Esmer, 2019; Park et al., 2019). As early as 1985, Slack (1985) explored the port selection criteria that exporters and freight-forwarders chose in their port selection process. Studies regarding port selection continued to be undertaken for various regions around the world and for different port-related stakeholders. Subsequent studies reflect the current literature regarding port selection.

Selecting the most optimal ports require a multi-criteria decision-making (MCDM) approach, and there is a copious amount of research in the current port selection literature that use various methodologies to conduct their research. Listing only a few, Chou (2007) has used Fuzzy Multiple Criteria Decision-Making Method (FMCDMM), Zavadskas et al., (2015) has used Analytic Hierarchy Process (AHP), and Wang et al., (2014) used a hybrid Fuzzy-Delphi-TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) approach.

Incorporating these methodologies and various research approach, there are research that aid players of port-related stakeholders in realising which criteria and factors are the most important for selecting ports. Chou (2007), for example, has proposed a method that allows port managers to realise what factors the shipping companies are looking for when selecting ports particularly through a Taiwanese case study. Similarly, in another region's context, Saeed and Aaby (2013) conducted their research by collecting data from shipping companies to find what the crucial port selection factors are in the European region. Alternatively, there is also a research that examined port development policies to determine factors of global logistics hub ports (Yang and Chen, 2016). While the studies above, as well as this current thesis, are focusing on container ports, there are also literature on other specific types of ports such as selection of bunkering ports demonstrated in Wang et al., (2014). Also, aside from investigating broader elements of port selection such as finding the most optimal port factors or ports, research regarding the optimal route selection have also been conducted, as such from Park et al., (2019) that investigated the optimal routing for Small and Medium Ports (SMP) in Korea.

3.2.3 Geographical regions (Asian region and non-Asian region)

Port selection literature consist of research from various regions of the world with data collected from the perspectives of different players of port-related stakeholders. They range from research on the European region (Lin and Wang, 2019; O'Connor et al., 2020) to the Asian region (Tang et al., 2011; Lam and Dai, 2012) to Northeast Asia (Park and Min, 2011; Veenstra and Notteboom, 2011; Kim, 2014; Yeo et al., 2014) to South Asia (Kavirathna et al., 2018; Subramanian and Thill, 2019; Park and Dossani, 2020) and to Southeast Asia (Tongzon and Sawant, 2007).

The choice of key port selection factors vary from region to region. For the European region, research indicate that congestion factor was of importance (O'Connor et al., 2020) as well as freight competitiveness and service capability (Lin and Wang, 2019). In the Asian region, it seemed that operations and cost were more of the focus. For the Northeast Asia, port's strategic location enabling connectivity and the cost factor were found to be important while service factor was found to be the least important (Park and Min, 2011; Yeo et al., 2014). In South Asia, port performance and operations factors were of more importance such as berth availability while liner's special preference and special contacts were of least importance (Veenstra and Notteboom, 2011; Kavirathna et al., 2018). Finally, as for Southeast Asia, efficiency, port charges, and connectivity were of the importance (Tongzon and Sawant, 2007). It seems that there is relatively little literature on the Southeast Asian region and especially fewer in number from Korean shipping companies' perspective.

3.2.4 Various perspectives from shipping companies (carriers), port authority / port operator, shipper / freight-forwarder

The research regarding the aforementioned important port selection factors from different regions of the world also are separated by from which player of port-related stakeholder the data is collected from and which perspective the research would like to focus on. There is also a research such as from Nazemzadeh and Vanelslander (2015) in which the study collects data relatively evenly from all three players of the port-related stakeholders. In port selection literature, it seems that studies are representatively carried out from the perspectives of the key port-related stakeholders as the following: shipping companies (Lam and Dai, 2012; Yeo et al., 2014; Zhu et al., 2021); port authority or port operator (Sanchez et al., 2011; Kim, 2014; Gonzalez-Lax et al., 2015); and shipper or freight-forwarder (Nir et al., 2003; Kolar and Rodrigue, 2018; Kramberger et al., 2018).

3.3 Systematic Literature Review (SLR)

This section includes SLR of container port selection. Ample amount of studies has conducted investigation on which structure (main factors and sub-factors) of port selection factors are suitable for their research. With each study's region of focus and the subject of data collection being different, this led to these studies producing structures of port selection that may be either drastically different or only slightly different from those of other port selection research. Similarly, in this current research, in order to narrow down, refine, and define particular port selection factors that will be specific to this study, semi-structured interviews were conducted with experts. However, prior to gaining the experts' insight, it was necessary to form a structure of port selection factors through careful analysis of current relevant secondary data that best represent this study following a more rigorous, transparent, and objective protocol. Thus, SLR method is used as it is an evidence-based approach to best identify the most relevant secondary data to provide in-depth understanding about what is known (Colicchia and Strozzi, 2012). This study will be following the five steps of SLR according to Denyer and Tranfield (2009). According to Denyer and Tranfield (2009), the SLR method is a tried and tested method that examines the bibliographic sources for a specific topic with the aim of delivering an organised outcome. Through its transparent and universally accepted structure, the SLR is not only replicable but also particular in that it categorises and analyses literature in a specific research area or topic. Additionally, the use of Denyer and Tranfield (2009)'s SLR method steps have already been effectively used in numerous studies in the logistics and supply chain field (Abbasi, 2017; Rafi-Ul-Shan et al., 2018; Tiwari, 2021). A visual representation of the five steps of SLR taken is shown in Figure 3.1.

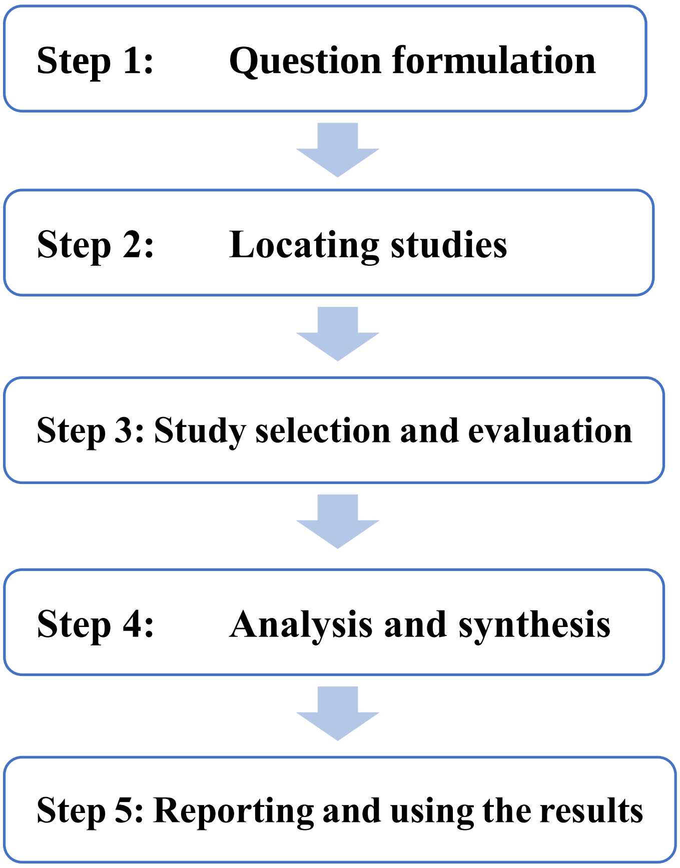

Figure 3.1 Representation of five-step Systematic Literature Review adapted from Denyer and Tranfield (2009)

3.3.1 Step 1: Question formulation

Establishing the right focus is crucial in preparing a review (Light and Pillemar, 1984). According to Counsell (1997), "*the question guides the review by defining which studies will be included, what the search strategy to identify the relevant primary studies should be, and which data need to be extracted from each study.*" Formulation of the review question in this step is crucial in helping the researcher to identify a specific research area to examine more in-depth within the broad topics the researcher is investigating in a review (Denyer and Tranfield, 2009).

According to Denyer and Tranfield (2009), there are mainly two systemic ways of formulating review question. The first way is to make use of an advisory group in forms of review panel which may be composed of scientists or specialists with academic or practical expertise in the research area. Another way is to make use of CIMO-logic to build a systemic review question. Denyer and Tranfield (2009) states that using the CIMO-logic approach is particularly advantageous when including different types of studies such as case studies. Thus, due to the objectives and focus of this study involving a case study into Korean shipping companies, using this analytical framework (CIMO-logic) approach in formulating review question is deemed to be the most appropriate. Below, more details and process of using the CIMO-logic will follow.

The analytical framework of CIMO-logic helps to determine the scope of the literature review and contains the following elements: context (C), intervention (I), generative mechanism (M), and the outcome (O). Many literature in the supply chain management and logistics have already implemented CIMO-logic for SLR's as it provides clear analytical framework (Pilbeam et al., 2012; Nurmala et al., 2017; Colicchia et al., 2019; Balan, 2020). Rafi-Ul-Shan et al., (2018), which applied CIMO-logic for their research on sustainability and risk management in supply chains, give simpler explanation of the elements of CIMO-logic according to Denyer and Tranfield (2009) as depicted in Figure 3.2:

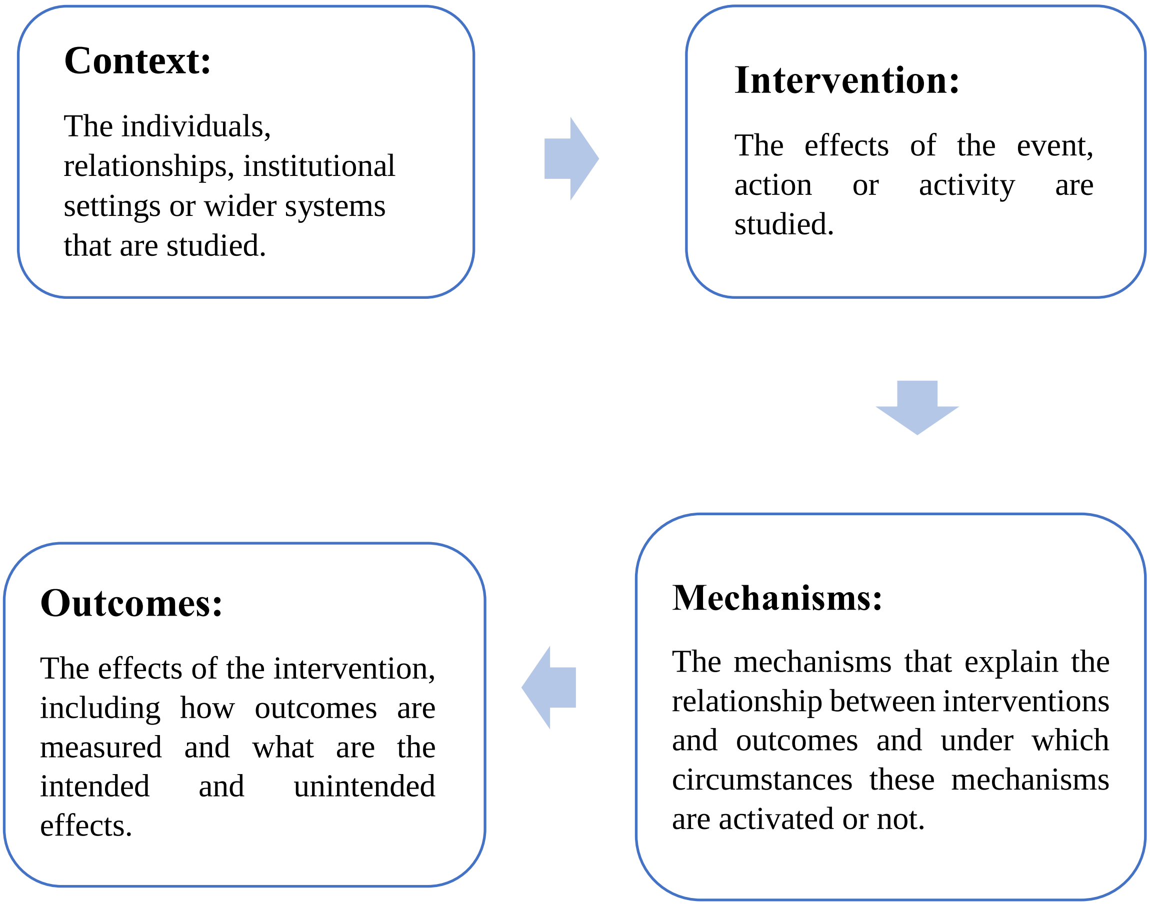

Figure 3.2 Components of Denyer and Tranfield (2009)'s CIMO-logic according to Rafi-Ul-Shan et al., (2018)

3.3.1.1 Context:

This particular element of CIMO-logic covers which institutional settings, problems, or system is being studied (Colicchia and Strozzi, 2012). The context in this study is container port selection. Relocation of global manufacturing is occurring as cost advantage in China is starting to wane and the relocation of production facilities in the Southeast Asian countries is growing and accelerating (Bhaskaran, 2020). This relocation has close ties with container port selection because related logistics, shipping, and port companies will also follow the new manufacturing hub (Chen et. al, 2018). With Korea's high economic stance in the world and its reputation and involvement in its marine transportation business, it is worthwhile to explore aspects of container port selection for Korean shipping companies with the aim to identify driving factors considered in choosing ports and ultimately finding the ranking of optimal Southeast Asian ports.

3.3.1.2 Intervention:

This element covers the effects of the event or action (Colicchia and Strozzi, 2012). The intervention in this study is the Korean shipping companies' perspective on port selection factors in the ASEAN region. In order to find out the perspectives of Korean shipping companies that are involved with maritime transportation trade with countries in the Southeast Asia, it is important to investigate categories, elements, and factors that appeal to them. Therefore, semi-structured interviews will be used as the means to identify these factors as numerous other container port selection literature such as Yang et al., (2016) and Kavirathna et al., (2018) have demonstrated.

3.3.1.3 Mechanism:

The mechanism element explains the relationship between the intervention and the outcome. In other words, the mechanism explains the process of why a certain intervention will lead to a particular outcome (Colicchia and Strozzi, 2012). The mechanism for this SLR is composed of developing the structure of port selection factors that would fit this study's specific topic of focus through semi-structured interviews. The Korean shipping experts' input will be invaluable on the validation or changes to the port selection structure that will be obtained after SLR.

3.3.1.4 Outcome:

The outcome element covers the effects or the results obtained from the intervention element through the use of a specific mechanism (Colicchia and Strozzi, 2012). By compiling and analysing the responses from the experts in the semi-structured interviews, this SLR presents the following outcome: composition of main factors and sub-factors of port selection in the ASEAN region from the Korean shipping companies' perspective.

3.3.1.5 Research Review question

Based on the CIMO-logic as described above, and in line with the first and second research objectives stated in Chapter 1, this study proposes the review question within this systematic literature section as the following:

In the context of container port selection, what is the structure of the factors that would best represent Korean shipping companies that deal with maritime trade in the ASEAN region?

3.3.2 Step 2: Locating studies

According to Denyer and Tranfield (2009), it is critical for the systematic review to locate, select, and appraise as much relevant literature as possible that is related to the research question. The main purpose of this step is to classify articles that address the finding of port selection factors in container ports from various port-related stakeholders – be it from carrier, shipper/freight-forwarder, or port authority/port operators. In order to identify such articles, sets of keywords have been carefully chosen to draw in as much relevant and accurate studies possible.

3.3.2.1 Database selection

Two prominent databases were used to identify studies: Scopus and Web of Science. These databases were chosen because they provide access to vast selection of publications and peer-reviewed articles that are of high-quality research literature in this study's relevant domains (Balan, 2020; Tiwari, 2021). Additionally, in order to pull as much needed articles as possible, searching options for the mentioned databases have been set to cover as much content as possible. Web of Science has been fixed with "All Fields" option for the searching option. Scopus has been added with "TITLE-ABS" field codes for one of the search strings and relevant subject areas such as the following: Engineering; Social Sciences; Environmental Science; Business, Management and Accounting; Computer Science; Decision Sciences; Mathematics; Economics, Econometrics and Finance (excluding other subject areas like Medicine; Earth and Planetary Sciences; Agricultural and Biological Sciences). Further, all the searched documents were sorted based on relevance.

3.3.2.2 Time horizon used for searching

There is an abundance of literature on port selection and numerous literature such as Cantillo et al., (2022) and Moya and Valero (2022) list the study done by Slack (1985) as their furthest and oldest port selection literature within their literature review chapters. This indicates that significance of port selection literature and its related areas began being published at this period.

However, note that in the initial searching process of this study, limit to the starting year of the searches to the year 1985 has not been specified but is later incorporated as inclusion & exclusion criteria for study selection and evaluation. The search was performed in September 2022, so the search covers published articles up until September 2022.

3.3.2.3 Implementation of search string, grouping of keywords, and Boolean operators

In order to obtain articles suitable to assist the development of port selection factors for this current study, multiple search terms were formed. As the focus of this study is on selection factors for container ports, the following initial search terms were chosen: container port, choice, selection. After this initial formation of crucial set of keywords, searches were conducted using the following search strings: container port selection; container port choice. These yielded ample results, however, in order to also search for possible articles that may have been left out from these initial searches, a search string in combination with Boolean operators and wildcard (asterisk) has been constructed as the following: (container* OR lift*) AND (port* OR terminal*) AND (select* OR choice* OR determin*) AND (fact* OR criteri*) NOT (efficien* OR rout* OR dry* OR inland*). By connecting synonymous key terms by "OR," and adding wildcard (asterisk) at the end of each possible formation of words, the new extensive search string pulled as much articles as possible that may be relevant to this current study. Additionally, the extensive search string's "NOT" operator helped to exclude articles that have slightly different focus. The search terms were designed wide enough to be able to pull in as much references as possible, but, at the same time, eliminate unnecessary material to avoid information overload (Duff, 1996). Search terms and search strings (with Boolean operators and wildcard) that have been used are represented in Table 3.1.

Table 3.1 Search terms and strings used for SLR

	First term	Second term	Third term	Fourth term	Fifth term
Boolean operators		AND	AND	AND	NOT
Search terms	Container* Lift*	Port* Terminal*	Select* Choice* Determin*	Fact* Criteri*	Efficien* Rout* Dry* Inland*
Search strings	container port selection container port choice (container* OR lift*) AND (port* OR terminal*) AND (select* OR choice* OR determin*) AND (fact* OR criteri*) NOT (efficien* OR rout* OR dry* OR inland*)				

Source: Author

3.3.3 Step 3: Study selection and evaluation

3.3.3.1 Inclusion and exclusion criteria

A set of inclusion and exclusion criteria has been set in order to select the most relevant articles to ultimately address the systematic literature study's research question. During the search stage, there were numerous literature regarding maritime port, however, vast amount also focused on a different kind of selection such as dry-port selection, site selection, or cruise port selection. There was more literature that did not pertain to the focus of this current study, therefore the inclusion and exclusion criteria outlined in Table 3.2 helped to eliminate irrelevant articles.

Table 3.2 Inclusion and exclusion criteria applied for SLR

Aspect	Inclusion criteria	Exclusion criteria	Rationale
Language	All articles that are in English	Any other articles that are not in English	To account for language capability of the author
Document type	Peer-reviewed journal articles	All else documents such as conference papers, chapters, thesis, etc.	To access quality published documents
Subject	Identifiable port selection / choice factors, container port (LOLO)	Articles that focus on the following: efficiency, competition, hinterland, dry-port, inland port, RORO port, cruise port, tank container, routing selection, site / yard / terminal location selection	To narrow the focus of found documents to this study's specific container cargo port selection and avoid extracting information irrelevant to this study
Year	All published articles from 1985 to the present	Any other possible published articles before 1985	From numerous sources in port selection literature, the furthest article of port selection literature dates back to 1985
Relevant subject areas (fields)	Following subjects: Engineering; Social Sciences; Environmental Science; Business, Management and Accounting; Computer Science; Decision Sciences; Mathematics; Economics, Econometrics and Finance	Other subjects such as: Medicine; Earth and Planetary Sciences; Agricultural and Biological Sciences	To narrow down the search to the discipline of study (business) and other social science disciplines

3.3.3.2 Study selection

It is also important to note that within the searched articles that have passed the inclusion & exclusion criteria, the “References” have been used to identify further studies that are relevant to this SLR (Balan, 2020). Additionally, discovery of influential authors in the port selection literature and the examination of their publications have yielded further studies (Habib et al., 2015). Table 3.3 represents synoptic view of the number of articles identified and selected from each database and also shows the total number of articles after applying the inclusion & exclusion criteria.

Table 3.3 Breakdown of search results

Details by search string		Databases: Web of Science	Databases: Scopus
1. container port selection			
Total number of results identified		262	5,215
1.1.	Number of results after including only articles	203	3,706
1.2.	Number of results after applying subject filter for Scopus	-	3,479
1.3.	Number of results after applying inclusion & exclusion criteria	27	79
1.4.	Total number of results after duplicate elimination	83*	
2. container port choice			
Total number of results identified		258	3,874
2.1.	Number of results after including only articles	217	2,736
2.2.	Number of results after applying subject filter for Scopus	-	2,629
2.3.	Number of results after applying inclusion & exclusion criteria	30	64
2.4.	Total number of results after duplicate elimination	67*	
3. (container* OR lift*) AND (port* OR terminal*) AND (select* OR choice* OR determin*) AND (fact* OR criteri*) NOT (efficien* OR rout* OR dry* OR inland*)			
Total number of results identified		513	514
3.1.	Number of results after including only articles	399	310
3.2.	Number of results after applying inclusion & exclusion criteria	19	18
3.3.	Total number of results after duplicate elimination	23*	
a)	Total number of articles from each database after duplicate elimination from all-above search strings	43	86
b)	Total number of articles from both database after duplicate elimination from all-above search strings	91	
c)	Total number of articles added from “References” and influential authors in the field.	4	
d)	Total number of articles for further review	95**	

Notes:
*These numbers are obtained after duplicates from 2 databases are taken out for each of the search strings from 1 to 3. It should be noted also that due to similar key words, duplicates are present between these 3 numbers too, which then are taken out in step b).

**This number is accounted for after duplicate elimination from the final results of search strings 1, 2, and 3.

Figure 3.3 below represents a schematic diagram that visualises process and action taken and the number of articles that resulted from each phase of steps 2 and 3 of Denyer and Tranfield (2009)'s 5 steps SLR.

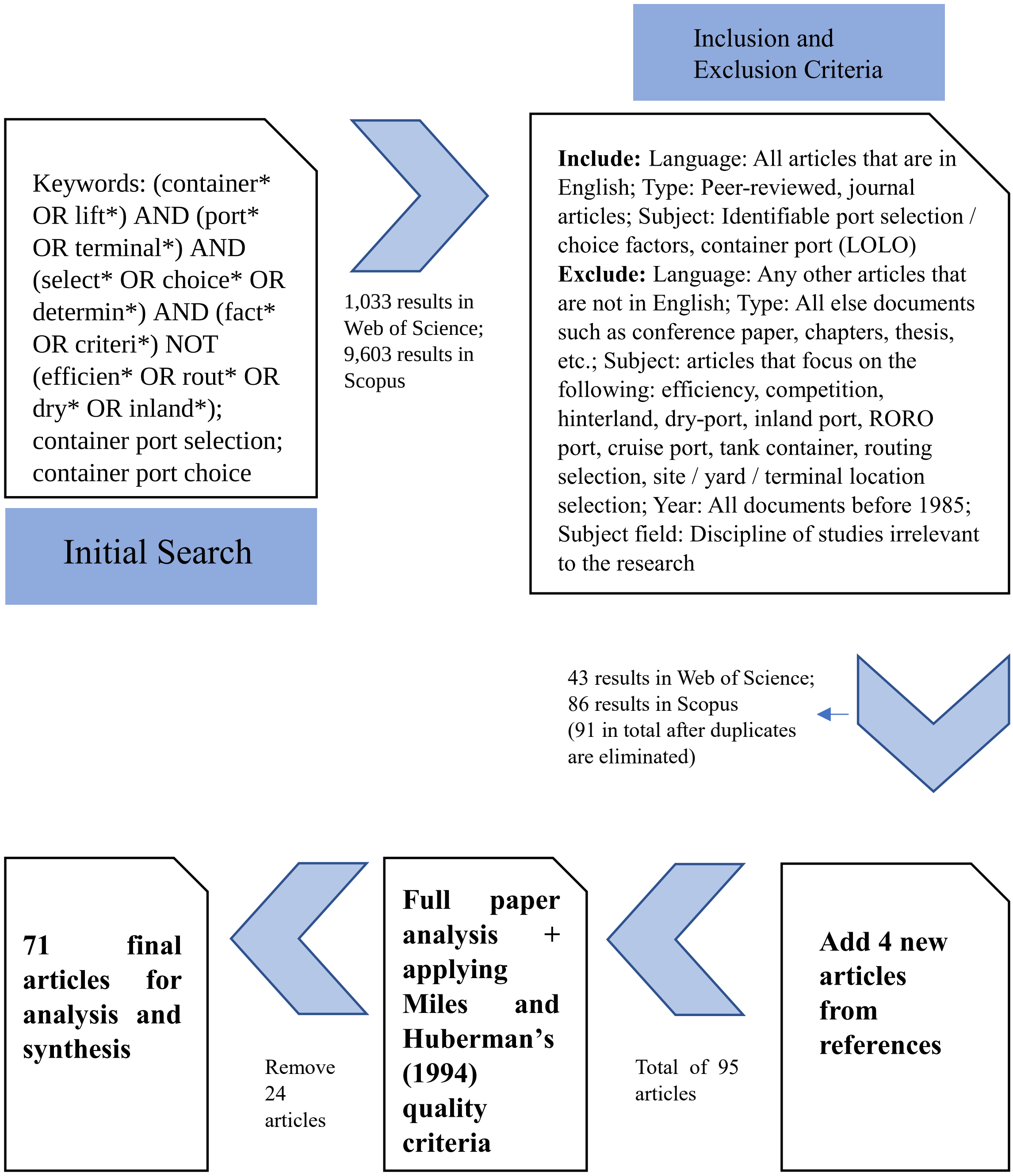

Figure 3.3 Schematic diagram of steps 2 & 3 of Denyer and Tranfield (2009)'s 5 steps

Ultimately, articles most relevant to determining port selection factors were selected after using specific inclusion and exclusion criteria and also using quality criteria covering alignment between research questions, chosen methods and execution of research, methodological rigour (Miles and Huberman, 1994). Quality of the articles were made sure to be critically assessed according to their rationale in relation to their topic, methodology, findings, and significance. Previous literature in supply chain have used such pre-determined quality criteria as well from Miles and Huberman, 1994 whilst conducting SLR (Pilbeam et al., 2012; Wong et al., 2012; Habib et al., 2015; Ali et al., 2017; Wijewickrama et al., 2021). Selection of appropriate articles were carried out by firstly scanning the titles, abstract and then the content of the articles in respective order to examine if the articles were fit after against the set inclusion and exclusion criteria. After further in-depth examination of the articles, 24 articles were rejected mainly due to their focus leaning towards competition or being on a site selection. Additionally, four more articles were identified from a previous study on a related topic (Murphy et al., 1988; Murphy et al., 1989; Murphy et al., 1992; Murphy and Daley, 1994). This yielded in a total of 71 articles which were then further analysed.

3.3.4 Step 4: Analysis and synthesis

The fourth stage of Denyer and Tranfield (2009)'s SLR includes analysing and synthesising of the selected and evaluated 71 studies from the previous stage into descriptive analysis that is more deductive in nature and into thematic analysis that is more inductive in nature. It should be noted that Appendix A lists references to these 71 studies. Table 3.4 shows what sorts of descriptive information was extracted from the 71 studies. Further results of descriptive analysis will be outlined in the subsequent section in detail.

Table 3.4 Categories used to analyse and synthesise data in the systematic review

Category	Information
Journal	Identifies from which journal of ranking the study is published from
Years studies present	Categorises from which time periods the study is published (1985-2000; 2001-2010; 2011-2022)
Geographical coverage of the study	Locates which region of the world the study is focusing on
Perspective of the study	States from which port-related stakeholder's perspective the study is based on

Next, the selected and evaluated 71 studies were analysed and synthesised according to particular themes. Four major dimensions were identified from the studies per port selection literature and these dimensions ultimately represent the major factors that were used in port selection literature. For the purpose of clarification and to prevent confusion, it should be noted that in the author's research, the term "major factor" is expressed as "main factor." There are numerous additional factors or sub-factors that are applied and discussed in port selection literature. However, these sub-factors fall within the main four factors that were identified from analysing the 71 studies. It is crucial that the number of factors be not too extreme in number. Further each of the names of dimensions or main factors are carefully chosen to best represent the sub-factors that they cover and help the decision makers comprehend the situation better when undertaking interviews or questionnaires (Onut et al., 2011). The four main factors are defined below and sub-factors are also shown below:

1) Port location is a factor that is identified across the majority of port selection literature. In the literature, some studies consider this factor as a geographical location of the port and regard parts of its component to be, according to Lirn et al., (2004), proximity to

the main navigation routes, proximity to feeder ports, and proximity to import and export centres. Other studies link the port's location more with the port's association with its hinterland. After reviewing the literature, sub-factors determined for the port location main factor are the following: the sub-factors include the following: proximity to feeder ports; proximity to main navigation routes; proximity to the markets (demand); distance of shippers from the port (supply).

2) Port charge is another important factor in port selection literature. The review of port selection literature suggest that port charges are more importantly considered by shipping companies as well as shippers / freight forwarders. Port charges between ports vary in their structure and levels, so this research has used the argument that Tongzon (2009) stated in his research that there are two types of port charges: ship-based type and cargo-based type. It seems that the sub-factors listed in Tongzon (2009) also comprehensively covers various port costs mentioned in the literature. Thus, the sub-factors include the following: port charges (port dues, pilot cost, towage, etc.); handling & storage cost of containers; Inland transport cost.

3) Port hinterland is another main factor identified that includes elements such as cargo volume, frequency of port of calls, and intermodal links. Port hinterland also encompasses various sub-factors across port selection literature. Hinterlands could be commodity-specific (Malchow and Kanafani, 2004) and intermodal connectivity is a determinant for market share of a port in certain hinterland regions (Caballé Valls et al., 2020). There are numerous studies that indicate the importance of port hinterland as the

main factor of selecting a port. According to Chou (2007), the decision maker considers first the hinterland economy (cargo volume) and cost. Thus, the sub-factors include the following: total container cargo volume (import/export & transshipment containers); frequency of port of call; intermodal links.

4) Port efficiency is the last of the main factors identified and has sub-factors such as port infrastructure and port depth. There are studies that note the port efficiency factor as one of the major aspects of port choice decisions (Steven and Corsi, 2012; Cantillo et al., 2022). Port productivity, efficiency (Steven and Corsi, 2012) and port performance (Cantello et al., 2022) are indicated to be important factors when deciding on port choice. Additional factors listed throughout port selection literature such as port physical or infrastructure ultimately contribute to the port's efficiency. Thus, the sub-factors include the following: port infrastructure; container handling efficiency; container yard efficiency; customs efficiency.

In terms of studies dealing with port choice from the perspective of shipping companies, Steven and Corsi (2012) also categorises the literature into similar main factors as the following: port location; port charges; port efficiency, berth availability and size; and general infrastructure. Similarly, study from Nazemzadeh and Vanelslander (2015) identified numerous sub-factors and classified them into main five factors which are the following: geographical location, port costs, hinterland connection, port productivity, and port capacity. Port productivity and port capacity mentioned in this study indicates such attributes like available berths, cranes, storage, customs efficiency, and container yard efficiency which are attributes that is categorised as port efficiency in this current research. Further results of thematic analysis will be outlined in the subsequent section in detail. Table 3.5 below shows a visual representation of the four identified factors as well as their detailed sub-factors as per the classification levels.

Table 3.5 Display of port selection factors according to the literature

Goal	Main factors	Sub (detailed) factors
Container port selection factors	Port location	Proximity to feeder ports
		Proximity to main navigation routes
		Proximity to the markets (demand)
		Distance of shippers from port (supply)
	Port charge	Port charges (port dues, pilot cost, towage, etc.)
		Handling & storage cost of containers
		Inland transport cost
	Port hinterland	Total container cargo volume (import/export & transshipment containers)
		Frequency of port of call
		Intermodal links
	Port efficiency	Port infrastructure
		Container handling efficiency
		Container yard efficiency
		Customs efficiency

3.3.5 Step 5: Reporting and using the results

In this section, results are presented regarding the research review question that has been formed at the beginning of this chapter following the CIMO-logic according to Denyer and Tranfield (2009): in the context of container port selection, what is the structure of the factors that would best represent Korean shipping companies that deal with maritime trade in the ASEAN region? In order to answer this question, taking the frequency of port selection factors from the 71 papers obtained through SLR provides the most precise representation of key port selection factors that may be used as reference to represent Korean maritime shipping companies' perspectives in the ASEAN region. The mentioned 71 papers have been obtained through rigorous process of filtering within the port selection literature.

The port selection factors used in the finally-screened 71 articles from step 3 have been counted for their frequency of appearance to determine the importance of port selection factors. Table 3.6 outlines the top 10 port selection factors in their order of frequency obtained from these 71 articles. The author chose to focus on top 10 most frequently mentioned factors because they represent a significant portion of port selection factors of all the factors reviewed within the scope of this research in 71 articles; they contain key comprehensive main factors that could be used to further encompass sub-factors; and 10 is tractable number for the construction of a table to track the frequency of appearance of factors. As it can be seen below, port location is the number one most frequently mentioned factor amongst these 71 articles. It is important to note that the frequency of appearance for Table 3.6 has been counted regardless of which perspective the articles focus or which region the articles conducted their research on.

Table 3.6 Order of port selection factors by frequency of appearance regardless of perspective or region

	Port selection factor	Frequency of appearance
1	Port location	29
2	Port charge	25
3	Frequency of port of call	22
4	Port hinterland	20
5	Port efficiency	20
6	Port infrastructure	16
7	Port depth	13
8	Port connectivity	13
9	Intermodal link	10
10	Cargo volume	9

This research will proceed with the structure of factors presented in the above Table 3.6 to be further used in interviews and questionnaire with the Korean shipping companies.

Next, the subsequent sections will give descriptive analysis of the identified articles. Then, thematic analysis of the four main factors (port location, port charge, port hinterland, port efficiency) generated for the identified articles will be carried out.

3.4 Research gap

There is a copious amount of port selection literature focusing on the Asian region or non-Asian region and also from perspectives of various port-related stakeholder such as shipping company or shipper / freight forwarder (Wiegmans et al., 2008; Saeed and Aaby, 2013; Yeo et al., 2014; Sun and Zheng, 2016; Notteboom et al., 2017; Kavirathna et al., 2018; Park et al., 2019; Subramanian and Thill, 2019; Fadda et al., 2020). Above research have provided crucial analysis and insights for specific countries for both inside and outside of the ASEAN region. Although there are many research that have focused on the Asian region from shipping company's perspective, research focusing on Southeast Asia from shipping company's perspective for the case study of Korea have been relatively under-examined in the literature. Research into this topic could help to identify port selection factors from the perspectives of Korean shipping companies. As there is indication that Korean trade with Southeast countries have been increasing, seen from the increase in shipping service routes and export container cargo volume into Southeast Asian region, research into finding what the driving port selection factors are from Korean shipping companies' perspectives as well as the order of importance in calling ports in the Southeast Asia is necessary.

3.5 Descriptive analysis

This section covers the descriptive findings from the screened and filtered 71 studies obtained from stage 3 of Denyer and Tranfield (2009)'s SLR. As briefly mentioned in stage 4 of the SLR, 71 studies are analysed with respect to their descriptive area (publication years; geographical coverage of the study; perspective of the study). In this section, there are majorly three components of descriptive area in which studies are allocated to provide descriptive analysis. Table 3.7 and Table 3.8 will provide the analysis of the three components mentioned above.

Although there exists several literature regarding ports before the designated time horizon of 1985 to present, the previous literature do not adhere to the specific focus of port selection and rather on general analysis of ports of focus. The earliest article that handle the topic of port selection is a study done by Brian Slack in 1985. Subsequent literature that followed also list the study by Slack (1985) as the oldest port selection study according to their literature review section (Cantillo et al., 2022; Martínez-Moya and Feo-Valero, 2022). Thus, it is concluded that port selection literature along with its related areas began to be published at this period. It is also important to note that during the initial searching stage, this study has not limited the starting year of the searches in order to account for the possible likelihood of finding literature related to port selection published before 1985. However, as demonstrated in earlier in this chapter, any studies prior to 1985 have been deemed to be excluded according to the inclusion & exclusion criteria that this study applied for the SLR.

As shown in Figure 3.4, of the 71 articles published after 1985, only 8% of them were published up until 2003. Approximately half of the articles were published from 2014 onwards. The figure indicates the increased presence of port selection articles from 2003 onwards. Further, the trend shows a fluctuating, yet gradual increase in published articles regarding port selection with the year 2019 having the highest number of published articles in the entire time horizon.
Table 3.7 presents the distribution of articles according to their descriptive categories which are by the following: years published; geographical focus / coverage of the study; and the perspective (port-related stakeholders) of the study. As also visually represented in Figure 3.4, vast majority of port selection literature found are heavily concentrated in the third group of time period of 2011-2022 by accounting for around 66% of the total collected studies (71). Moving onto the next descriptive category of geographical coverage of the studies, it can be seen that articles focusing on the Asian region was the most dominant by taking up around 46% of the collected articles (71). Finally, according to the descriptive category of the perspective of the studies, it can be seen that articles focusing on the carrier's perspective were the most prevalent by accounting for around 46% of the collected articles (71). These descriptive categories indicate the following: regarding port selection literature, there is an increasing

amount and the greatest number of articles in the recent time period (2011-2022) that are of Asian region-of-focus from carrier's perspective.

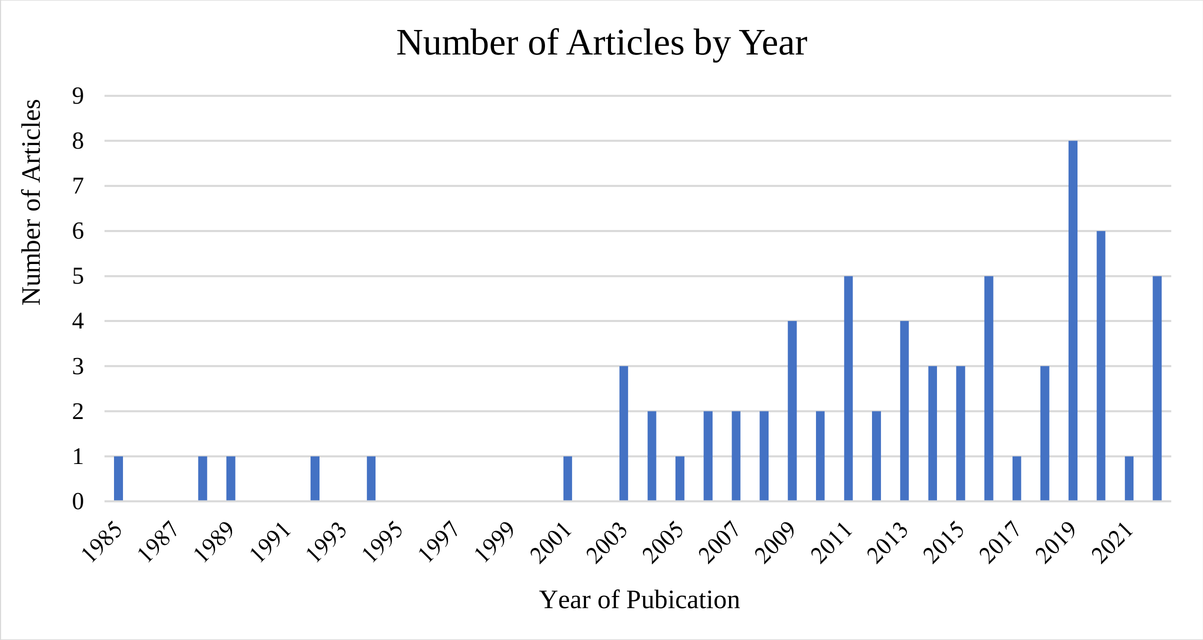

Figure 3.4 Distribution of articles by year

Table 3.7 Number of papers assigned to each category

Category	Information	Number of articles
Years studies present (1985-2000; 2001-2010; 2011-2022)	1985-2000	5
	2001-2010	19
	2011-2022	47
	Total	**71**
Geographical coverage of the study (Asia, Europe, United States, South America, Africa, global)	Asia	33
	Europe	18
	United States	8
	South America	4
	Africa	3
	Global	5
	Total	**71**

Perspective of the study (carrier; shipper / freight-forwarder; port authority / port operator; none in particular	Carrier	33
	Shipper / freight-forwarder	14
	Port authority / port operator	4
	None in particular	20
	Total	**71**

The articles were published in 35 different journals. The first part of Table 3.8 represents the distribution of articles into their respective published journals according to the Association of Business School (ABS) Academic Journal Guide (AJG) 2021. 45 papers have been identified to be from the journals of ABS AJG 2021, and around 53% of these papers are from *Maritime Economics and Logistics* and *Maritime Policy and Management* journals. As it is widely known, it should be noted that the ABS journal quality guide has high levels of external and internal reliability and is considered to be a fair means of ranking journals (Morris et al., 2009). The second part of Table 3.8 represents the distribution of 26 articles into their respective journals that are not included in the ABS AJG 2021. These articles were still collected from the same two prominent databases (Scopus and Web of Science) that are of high-quality research literature. Thus, these articles are valuable and aid to this current research. Around 23% of the articles are from *The Asian Journal of Shipping and Logistics* and *Transportation Journal*.

Table 3.8 Number of papers according to journals and ABS category

ABS field	Journal	Number of articles
Sector studies (Code SECTOR)	Maritime Economics and Logistics	12
	Maritime Policy and Management	12
	Transport Policy	4
	Transport Reviews	1
	Transportation Research, Part A: Policy and Practice	1
	Transportation Research, Part E: Logistics and Transportation Review	4
	Marine Policy	1
Economics, Econometrics and Statistics (Code ECON)	Research in Transportation Economics	2
	Applied Economics	1
	Networks and Spatial Economics	1
Information Management (Code INFO MAN)	Expert Systems with Applications	1

Regional Studies, Planning and Environment	Growth and Change	1
Operations and Technology Management (Code OPS&TECH)	International Journal of Shipping and Transport Logistic	2
	International Journal of Logistics Research and Applications	1
	International Journal of Shipping and Transport Logistics	1
	Total	**45**
N/A	Applied Mathematics and Computation	1
	Case Studies on Transport Policy	2
	European Transport Research Review	1
	International Journal of Maritime Engineering	1
	International Journal of Physical Distribution & Materials Management	1
	International Journal of Transport Economics	1
	Journal of Marine Science and Technology	2

Logistics and Transportation Review	1
Marine Technology Society Journal	1
Mathematical and Computer Modelling	1
Mathematical Problems in Engineering	1
Naše more	1
Research in Transportation Business & Management	1
Tehnički vjesnik	1
The Asian Journal of Shipping and Logistics	3
Transportation Journal	3
Transportation Letters	1
Transportation Planning and Technology	1
Transportation Research Record: Journal of the Transportation Research Board	1
Uncertain Supply Chain Management	1
Total	**26**
Grand total	**71**

3.6 Thematic analysis

This section provides further explanations on the four main factors identified through the SLR. As briefly mentioned in stage 4 of the SLR, 71 studies were analysed and synthesised to yield the classification of themes or main factors regarding port selection factors mentioned in the literature. These main factors are the following: port location, port charge, port hinterland, and port efficiency. There were also numerous other factors that are seen as sub-factors in the literature. Majority of important sub-factors fall within the four classifications of main factors. Below, process of how the four main factors were selected and their further context with description of sub-factors within them will be covered.

First of all, Table 3.9 shows how frequently various port selection factors appeared in the 71 articles. Four main factors were chosen from the table as well as their sub-factors that they encompass. Port location and port charge were chosen to be main factors because they ranked as the top two most frequently used factors in the identified literature. Factor such as port connectivity could fall under port location as its sub-factor. Next, frequency of port of call ranks as the third most used factor; however, considering the lack of sub-factors it may entail amongst the multi-various port selection factors in the literature, this factor was not chosen to be represented as a main factor. Port hinterland and port efficiency were chosen to be main factors since they were the next two most frequently used factors and have the encompassing definitions to entail other sub-factors. Port hinterland, for example, could encompass factors such as frequency of port of call, intermodal link, and cargo volume. Port efficiency, for example, could encompass factors such as port infrastructure and port depth.

Table 3.9 Order of port selection factors by frequency of appearance regardless of perspective or region

	Port selection factor	Frequency of appearance
1	Port location	29
2	Port charge	25
3	Frequency of port of call	22
4	Port hinterland	20
5	Port efficiency	20
6	Port infrastructure	16
7	Port depth	13
8	Port connectivity	13
9	Intermodal link	10
10	Cargo volume	9

3.6.1 Port location

In vast majority of port selection literature, port location factor can be predominantly identified. Port location is outlined as the proximity to the following: import and export centres, corresponding feeder ports, and main navigation routes (Lirn et al., 2004). Another study outlines port location in regards to the following: main shipping lanes and immediate and extended hinterland (Wiegmans et al, 2008). Zhao et al., (2007 p. 3) defines location as the following: *"the natural condition of port and the distance from international line."*

Studies across the literature have slightly different definitions and elements that make up the factor of port location. Upon screening and analysis of articles that used port location as its main factors, the following have been mentioned the most: proximity to feeder ports; proximity to main navigation routes; proximity to the markets (demand); distance of shippers from the port (supply) (Lirn et al., 2004; Wiegmans et al., 2008; Onut et al., 2011; Nazemzadeh and Vanelslander, 2015).

3.6.2 Port charge

Port charge factor is also a crucial factor that heavily influences the decision-making in port selection. Although port charges vary between ports in their structure and levels, according to Tongzon (2009), port charge is levied on the basis of port visits and/or cargoes. There are many various kinds of cost-related factors in the literature. This current study uses Tongzon (2009)'s definition of two types of port charge which are ship-based type (includes navigation fees, berthage, berth hire, harbour dues and tonnage) and cargo-based type (includes wharfage and demurrage). Here, Tongzon (2009) notes that berthage and berth hire are levied as NRT and gross registered tonnes, respectively.

Therefore, after reviewing the literature, sub-factors selected for the main factor of port charge are the following: port charges (port dues, pilot cost, towage, etc.); handling & storage cost of containers; inland transport cost (Lirn et al., 2004; Wiegmans et al., 2008; Onut et al., 2011; Nazemzadeh and Vanelslander, 2015). With these sub-factors, majority of cost-related factors in decision making for port selection are adequately covered as the sub-factors mentioned above includes the ship-based, cargo-based, and other (inland transport cost) aspects of cost-incurring factors that occur when a vessel berths at a port for container shipping.

3.6.3 Port hinterland

Another main factor that embodies many sub-factors across port selection literature is the port hinterland. A study by Indriastiwi et al., (2021) provides an adequate definition of port hinterland. The study states that *"hinterland is an inland area of a port where most of its business activities originate from that area"* Indriastiwi et al., (2021 p. 5). Hinterlands could be commodity-specific (Malchow and Kanafani, 2004) and intermodal connectivity is a determinant for market share of a port in certain hinterland regions (Caballé Valls et al., 2020). There are numerous studies that indicate the importance of port hinterland as the main factor of selecting a port. According to Chou (2007), the decision maker considers first the hinterland economy (cargo volume) and cost.

This study has identified three sub-factors for port hinterland which are the following: total container cargo volume (import/export & transshipment containers); frequency of port of call; and intermodal links (Chou, 2007; Onut et al., 2011; Yeo et al., 2014; Nazemzadeh and Vanelslander, 2015).

3.6.4 Port efficiency

Lastly, the fourth main factor identified is port efficiency. There are studies that note the port efficiency factor as one of the major aspects of port choice decisions (Steven and Corsi, 2012; Cantillo et al., 2022). Port productivity, efficiency (Steven and Corsi, 2012) and port performance (Cantello et al., 2022) are indicated to be important factors when deciding on port choice. Numerous literature incorporate infrastructure factor for port selection evaluation and some have found the port's infrastructure to be one of the most important criterion in their studies (Aversa et al., 2005; Kim, 2014). As such, port choice factor of port physical or infrastructure has been considered and placed under port efficiency. Customs is regarded as one of the criteria that Ergin and Eker (2019) considered as well and the study indicates that customs that provides a straightforward and quick load handling would score a higher weight of importance. As efficient handling of customs would contribute to faster handling of loads, customs has been put under this main factor of port efficiency. In literature too, customs efficiency has been categorised under port efficiency (Gohomene et al., 2016) or under "time and cost" (Liu et al., 2020).

Thus, after reviewing port selection literature, sub-factors have been identified as the following: port infrastructure; container handling efficiency; container yard efficiency; customs efficiency (Chou, 2007; Wiegmans et al., 2008; Onut et al., 2011; Nazemzadeh and Vanelslander, 2015).

3.7 Chapter summary

In this chapter, a brief narrative literature review and extensive SLR of accessible peer-reviewed articles have been covered. The short narrative literature review was necessary to give an overview of key terms, definitions, and background information as these will serve as a base of knowledge for this study's research area of container port selection. Afterwards, SLR has been conducted to filter down the most relevant and quality article, which turned out to be 71 articles for this study. This study has used Denyer and Tranfield (2009)'s five steps of SLR since it uses transparent, replicable, and scientific process to reduce bias unlike the traditional narrative reviews (Tranfield et al., 2003).

The 71 obtained articles were further analysed to ultimately identify which port selection factors are deemed as key driving factors in port selection literature. 4 main factors encompassing 14 sub-factors were identified, and the following gives the list of obtained factors: port location (which encompassed sub-factors of proximity to feeder ports; proximity to main navigation routes; proximity to the markets (demand); distance of shippers from the port (supply)), port charge (which encompassed sub-factors of port charges (port dues, pilot cost, towage, etc.); handling & storage cost of containers; inland transport cost), port hinterland (which encompassed sub-factors of total container cargo volume (import/export & transshipment containers); frequency of port of call; and intermodal links), and port efficiency (which encompassed sub-factors of port infrastructure; container handling efficiency; container yard efficiency; customs efficiency). Table 3.10 below gives a visual representation of these driving port selection factors.

Table 3.10 Container port selection factors after conducting SLR

Goal	Main factors	Sub (detailed) factors after SLR
Container port selection factors	Port location	Proximity to feeder ports
		Proximity to main navigation routes
		Proximity to the markets (demand)
		Distance of shippers from port (supply)
	Port charge	Port charges (port dues, pilot cost, towage, etc.)
		Handling & storage cost of containers
		Inland transport cost
	Port hinterland	Total container cargo volume (import/export & transshipment containers)
		Frequency of port of call
		Intermodal links
	Port efficiency	Port infrastructure
		Container handling efficiency
		Container yard efficiency
		Customs efficiency

The identification of these driving port selection factors as well as the construction of the hierarchical structure (main factors and sub-factors) of port selection variables are crucial results that were obtained from SLR. It is worthwhile to note that this constructed hierarchical structure of factors will be used in pilot test in Chapter 4 to be refined by academic experts who are in Korean shipping field relevant to the topic of this study.

CHAPTER 4: RESEARCH FRAMEWORK FOR EVALUATING PORT SELECTION

4.1 Chapter introduction

This chapter discusses the research design and research framework of this study. Then the research ethics and sampling techniques are covered. It should be noted that the research framework in this chapter is divided into two major steps: first step pertaining to pilot test and semi-structured interviews, and the second step pertaining to the integrated AHP-TOPSIS methodology. In the first step, academic experts and industrial experts were invited to finalise the hierarchical structure of container port selection factors that had been constructed with SLR in Chapter 3. Then in the second step, the utilisation of AHP-TOPSIS to determine the weights of the port selection factors obtained in step 1, and to find the most optimal ports amongst the 6 Southeast Asian ports are presented. Further details on the second step will be covered in Chapters 5 and 6.

4.2 Research design

It is imperative for a researcher to adopt a research design that allows the researcher to optimally collect data in order to answer the established research objectives and ultimately the research's aims. A research design provides framework for collecting and analysing data, and also, the "*choice of research design reflects decisions about the priority being given to a range of dimensions of the research process*" (Bryman and Bell, 2011, p. 40). Since research design can be organised in many ways (Blaikie and Priest, 2019), the author's choice of research design reflects the best way to address objectives of this research. With this current study's objectives involving analysis of driving port selection factors and ultimately evaluation of top port selection factors as well as the most optimal calling ports, choice of appropriate methodology is crucial. Therefore, in order to accomplish this, subsequent sections detail the researcher's choice on philosophical position, approach, methodological choice, strategy, and time horizon.

4.2.1 Research philosophy

Research philosophy is a system of beliefs and assumptions about the development of knowledge (Bajpai, 2011; Saunders et al., 2019). Research philosophy influences the quality of management research; therefore, it is an important notion in research design (Easterby-Smith et al., 2012). At different stages of research, various assumptions are made whether they be regarding realities encountered during research, human knowledge, or ways in which the researcher's own values may influence the research process (Burrell and Morgan, 2016). A well-considered and consistent set of assumptions paves way to form a credible research philosophy and will ultimately help support decisions that the researcher makes as the researcher works through different stages to develop an effective methodology (Saunders et al., 2019).

The four philosophical positions according to Saunders et al., (2012) are positivism, realism, interpretivism, and pragmatism. This current study has taken the position of pragmatism due to the practical nature of this study. Pragmatists seek to overcome the subjectivism-objectivism dichotomies in their research. The subjectivism here *"incorporates assumptions of the arts and humanities, asserting that social reality is made from the perceptions and consequent actions of social actors (people)"* (Saunders et al., 2019, p. 137). As an example, Saunders et. al, (2019) gives an example to a case where managers attach their own individual meanings as to how a job should be performed as opposed to strictly adhering to objective guidelines on how management should be carried out. Subjectivism collects information through such acceptable knowledge like the following: opinions; written, spoken, and visual accounts; and individuals and contexts. Subjective studies are characterised to be exploratory, descriptive, and subjective in nature (Niglas, 2010). Objectivism on the other hand *"incorporates the assumptions of the natural sciences, arguing that the social reality that we research is external to us and others (referred to as social actors)"* (Saunders et al., 2019, p. 135). As an example, Saunders et. al, (2019) gives example to a case where a study of social phenomenon of management can be researched in objectivist ways under the assumption that there are manuals and specific job duty descriptions that managers are each assigned. Although several elements of such management duties may differ amongst various organisations, the fundamental essence of managerial functions are very much the same. Under objectivism, the researcher gathers information through such medium like facts, numbers, and observable phenomena. Objective studies are described to be confirmatory, objective, and comprehensive in nature (Niglas, 2010). In this current research, in order to solve port selection evaluation factors as well as obtain rankings of targeted ports, the researcher uses the pragmatic stance to overcome the subjectivism-objectivism dichotomies by incorporating both of these continua to solve for this research's aims and objectives. Incorporating both subjectivism (using expert opinions to find and determine key port selection factors) and objectivism (implementing MCDM calculation methods that incorporates hard data), this research seeks to solve the practical problems in the real world. Through this demonstration of continua, it can be seen that both subjective and objective viewpoints of social realities are offered based on personal value (Zha and Tu, 2016). This current research has a clear issue or a specific topic that it is trying to address regarding port selection. It aims to produce practical results that inform future practices. As stated in the research aims in Chapter 1, this research begins with identifying and investigating the hierarchical structure of driving container port selection factors. A subjective approach is taken by collecting and incorporating opinions of various experts to complete this hierarchical structure. Then, an objective approach is incorporated through the use of MCDM methodologies to use hard data to solve for this research's ultimate goal of evaluating importance of port selection factors and optimal ports. Accordingly, since this research *"strives to reconcile both objectivism and subjectivism, facts and values, accurate and rigorous knowledge and different contextualised experiences"* (Saunders et al., 2019, p. 151) in order to achieve and address this study's topic of interest, it is very suitable that this research takes on the pragmatic position.

4.2.2 Research approach

According to Saunders et al., (2019), there are three types of research approach, which are inductive approach, deductive approach, and abductive approach. In this study, abductive approach is taken.

Inductive approach is defined as progressing from specific to the general (Bryman and Bell, 2011). Typically, interpretivism philosophy involves inductive methods that use small samples, in-depth investigations, and incorporates qualitative methods of analysis (Saunders et al., 2019). An inductive approach usually entails the collection of data to investigate a phenomenon and follows with the creation of theory. Principles of deductive approach is a mirror to those of inductive approach. The deductive approach starts with a theory, and a research design is created to test the theory. Abductive approach moves back and forth between both the inductive and deductive approaches, effectively combining them (Suddaby, 2006). This current research befits abductive approach more due to the nature and flow of its investigation. Abductive approach involves firstly the collection of data to investigate a phenomenon and identify themes and patterns. This will create new theory or modify existing theory, which will be subsequently tested again through collection of additional data (Saunders et al., 2019). This is also in line with the literature from Hyde (2000), which describes that researchers may begin to gather information through literature first and develop theoretical concepts, which then can be taken into real world settings to be tested under deductive reasoning approach. Given the nature of this study's objectives (firstly analysing driving port selection factors, and then investigating optimal port selection in the ASEAN region from Korean shipping company's perspective), it is more suitable that this study uses the abductive approach since data collection in different stages of the research will alter the findings of different stages of the research framework.

4.2.3 Methodological choice

According to Nastasi et al., (2010), the nature of the research context as well as research question most likely determines the most suitable methodological choice for pragmatists. Additionally, both qualitative and quantitative research are valued and utilised by researchers with the stance of pragmatism (Saunders et al., 2019). Therefore, considering the nature of this current research, is was appropriate to incorporate mixed methods. This research first starts with reviewing and forming theoretical concepts (hierarchical structure of port selection factors) through literature review and SLR. After this has been obtained, the research required, firstly, qualitative methods to test and verify such theoretical concept (hierarchical structure) with experts in both academic and industrial fields. Therefore, interviews in the form of semi-structured interviews was selected as the main qualitative method for gathering such information. Then, in order to address the rest of the research aims and objectives, calculations incorporating hard data were needed to evaluate the weights of these factors in the structure as well as the ranking of optimal ports. Thus, quantitative MCDM methodologies such as AHP and TOPSIS have been selected as the main quantitative method to evaluate for the desired findings. The combination of both qualitative and quantitative methods ultimately allowed the researcher to seamlessly obtain the results to address the research aims and objectives. It should be noted that further specific explanation and reasoning of why these specific methodologies have been chosen are detailed in upcoming section 4.3, which describes research framework in detail.

4.2.4 Research strategy

Research strategy pertains to how the researcher will go about answering the research questions (Saunders et al., 2019). This strategy is described as a link that connects the chosen research philosophy and the subsequent choice of methods that the researcher will use to analyse and collect data (Denzin and Lincoln, 2018). The selection of the research strategy should be guided by the research questions and objectives that had been set, and the choice of research strategy should also take into consideration of the pragmatic concerns of the research that may include available resources, time, and existing knowledge on the matter of research. There are numerous research strategies to choose from. It should be noted, however, that each is not either superior or inferior to any other; nor is one mutually exclusive. According to Saunders et al., (2019), in general, the strategies are categorised by their principal characteristics of research design of either being qualitative or quantitative. The following lists this categorisation: experiment and survey being exclusively or principally quantitative research design; archival research and case study involving qualitative or quantitative research design; and ethnography, action research, and grounded theory being exclusively or principally qualitative research design.

For this research, case study has been chosen. Case study focuses on specific topic or phenomenon in real-life setting (Yin, 2018). Case study research may be challenging to take on due to its in-depth and intensive nature as well as the need to gain access to such chosen case study settings. However, using this research strategy leads to the potential of generating in-depth insights from real-life contexts that bring about rich empirical descriptions (Yin, 2018). Considering the benefits of using a case study as well as considering the nature of this research that delves into port selection of Korean shipping companies, choosing case study as research strategy has been most appropriate.

4.2.5 Time horizon

Saunders et al., (2019) describes the two types of time horizon for research: cross-sectional studies and longitudinal studies. Conducting cross-sectional studies is where the research takes a snapshot of the study's particular phenomenon at a particular time – limited to specific time-frame. On the other hand, conducting longitudinal studies is where the research takes a series of these snapshots to give representation of events over an extended period of time. This study has chosen to use cross-sectional approach. Although this may allow the researcher to collect and yield data that represents findings at a specific point in time, the wide coverage of possible sample size for this research's case study and the invitation of highly experienced experts adequately help to give a quality representation of such collected data.

4.3 Research framework

Container port selection is determined by both quantitative and qualitative factors and is a typical MCDM problem. The following is this research's order of used methodologies. Firstly, through SLR, articles that is most suited to this research topic (Asian region and carrier's perspective) are ultimately picked and port selection factors are reviewed. Secondly, using semi-structured interview, driving port selection factors are identified and structure of factors (main factors and sub-factors) are constructed. Thirdly, using AHP, weights of each driving factors are calculated. Fourthly, using TOPSIS, ranks of the alternatives (ports) are calculated, providing the ranks of the six Southeast Asian ports that Korean carriers find most optimal. Figure 4.2 visually represents order of used methodologies.

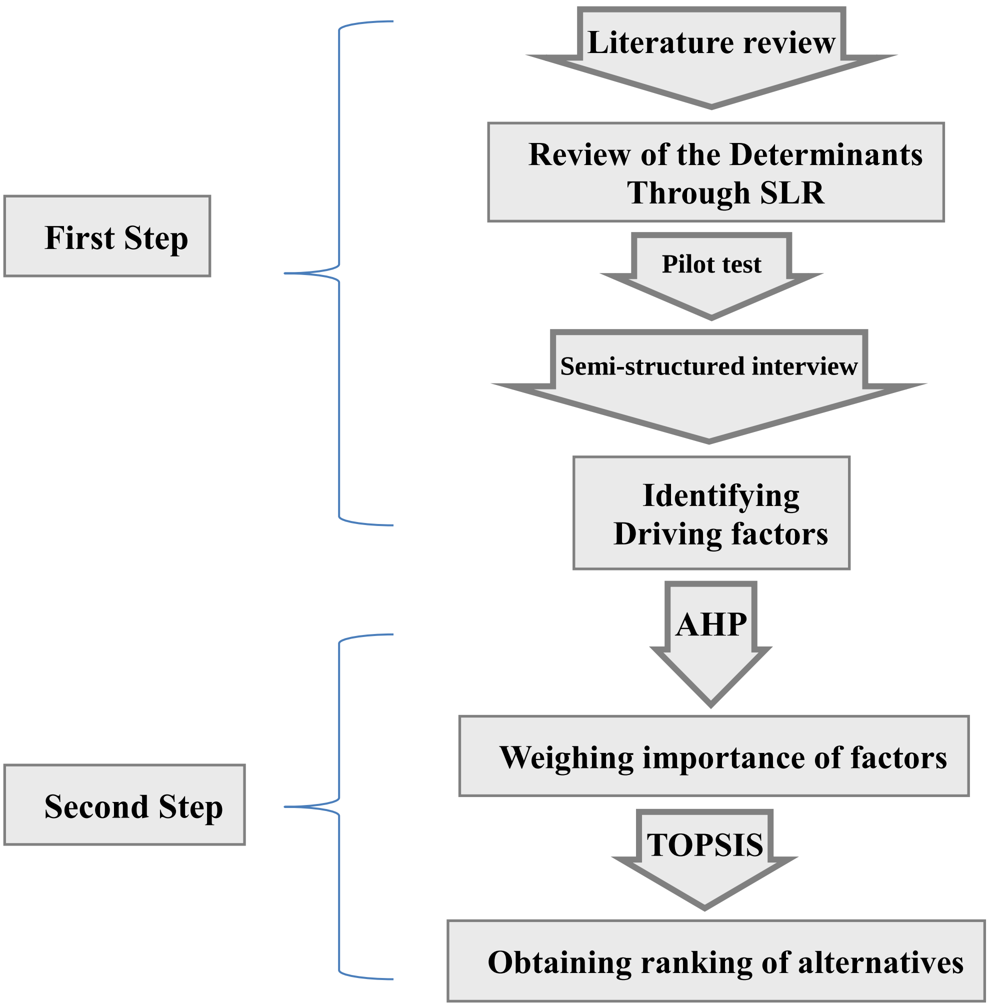

Figure 4.1 Research Methodology and Structure
Source: Author

4.3.1 First step (Semi-structured interview): Constructing hierarchical structure

There are three different forms of qualitative research interviews: structured, unstructured, and semi-structured. Each form has its own advantages and disadvantages, but semi-structured interviews formats are most widely used in human and social sciences. In short, structured interviews follow the same research logic as questionnaires in that preset questions are presented to the participants and the resulting responses compared and possibly quantified. An unstructured interview is on the opposite spectrum in that it has a very few preset structure. Sometimes, it is difficult to prepare questions and rather the focus should be to prepare on how to facilitate the telling of the interviewee's story. For example, it is difficult for the interviewer to compose number of questions when the topic is about the most important influences in the interviewee's life. The interviewer should rather focus on how best to draw out the answer by preparing for methods of adroit facilitation. Semi-structured interview is in the middle ground between structured and unstructured interview. The interviewer has greater control on focusing the conversation on topics of desire. At the same time, semi-structured interview allows for dialogues that enable the interviewees to follow up on a question in-depth (Leavy, 2014). Longhurst (2003) explains also that semi-structured interviews are conversational and informal in tone that the participants are able to voice their knowledge about set questions rather than giving just a "yes" or a "no" answer.

The advantages to using semi-structured interview are numerous According to Yin (2003), when a research objective is to understand complex elements as well as their intersection of elements such as perceptions or values, semi-structured interview is appropriate. Compared to other forms of interviews, a semi-structured interview allows the interviewer with standardised questions for guidance to prompt discussions while at the same time enabling the interviewer the flexibility to create spontaneous channel of in-depth information exchange that may also sometimes aid in providing unanticipated narrative to the research (Harrell and Bradley, 2009; Saunders et al., 2016). Easterby-Smith et al., (2012) and Butt (2022) also state the advantage of semi-structured interviews in that they allow the platform to provide open-ended questions in order to obtain crucial in-depth information on the author's targeted topic. Already existing literature in port selection such as Yang et al., (2016) and Kavirathna et al., (2018) also used semi-structured interviews to ultimately verify and identify key port selection factors after conducting literature review. Additionally, another port selection literature by Fahim et al., (2022) demonstrates the use of semi-structured interviews to establish a set of criteria. Fahim et al., (2022) also states that semi-structured format of the interview gives the experts direction while at the same time allowing them to express their opinions to the questions. Other literature in port selection such as one from Svindland et al., (2019) shows of the use of semi-structured interview to draw upon important port choice criteria as part of their results.

Semi-structured interviews are used to discuss and refine port selection factors both in their order of importance and in their composition (main factors and sub-factors) from the industry experts' input and point of view. This chosen form of research method allows for up-to-date data on specific topic such as what port selection factors the senior experts in Korean carrier companies consider when shipping containerised goods to Southeast Asian region. Port selection factors in this stage will be refined and will be hierarchised that help with accurate comparison of components involved in complicated decision-making process (Saaty, 1990). This stage is crucial because the hierarchised outcome will be used in further in research for questionnaires to determine the ranking of port selection factors through the use of AHP and to produce ranking of preferred ports (alternatives) from the Korean shipping companies' perspectives with the use of TOPSIS.

Below is the process of the semi-structured interview.

Step 1: SLR on port selection has been conducted to first draw out which port selection factors have been used most frequently in articles that deal with both the region (Asia) and the perspective (carrier shipping company) that this current research is focusing on. From the literature review of 71 articles on port selection, top 10 most frequently appeared port selection factors have been determined.

Step 2: Prior to conducting semi-structured interview with the interviewees, a pilot test was conducted with two academic experts in Korean shipping field in order to test and verify the appropriateness of the interview questions. The first expert is the managing editor of *The Journal of Shipping and Logistics*, which is published from the Korean Association of Shipping and Logistics, Inc. Seoul Korea. The first expert has experiences in using the AHP methodology along with Fuzzy TOPSIS methodology, and has studied calling port selection of South Korea by adopting fuzzy theory. The second expert is the managing editor of *The Asian Journal of Shipping and Logistics*, which publishes articles relating to Asian port selection and evaluation. As the managing editor in this journal, the expert possesses numerous experiences in port selection and evaluation. The expert especially has expertise in using AHP methodology and has published various articles using fuzzy methodologies to evaluate factors.

As indicated above, both of the experts hold managing editor positions in journals that publish numerous articles on Asian port selection and evaluation. Therefore, these experts' area of study as well as their previously used methodologies align with this current research's topic and chosen methodologies. Thus, receiving feedback based on their knowledge, skill and experience are invaluable in refining this research's interview questions as well as port selection framework. Further, other literature in the supply chain and port studies by Soliman (2017) and Shitu (2021) have also utilised recommendations from academics prior to conducting interviews and questionnaires. The adjustments to the interview questions and port selection structure further helped for better clarity of the questions and prevent any potential misinterpretation or confusion.

The following below are comments and feedback regarding adjustments to the interview questions and structure of port selection.

First academic scholar:

- Addition of questions below to inquire and confirm the place of demand and starting points of cargoes would be recommended.
    - What is the final place of demand (final destination) for the containers (cargo) for each of the below's ports?
    - What is the shipping cost per ton to transport cargos inland from each of the below's ports?
    - What are the shippers' locations (such as cargo's starting point or point of origin) for each of the below's ports?
- It is recommended that the sub-factor of "Proximity to feeder ports" under the port location main factor be deleted. This sub-factor would be better suited when determining and evaluating ports within East Asia's top 10 ports. Since most of the ports in the ASEAN are not high in their container port rankings, it is best that this sub-factor be removed from the port selection structure.

Second academic scholar:

- It would be most helpful to add a figure of port selection factor structure obtained from SLR for the interviewees' better understanding before proceeding with Part 2 questions (referring to Appendix B.1).

- Adjustments to sub-factors under the main factor of port efficiency are recommended.
    - "Port infrastructure" factor encompasses various elements. It is recommended to modify this sub-factor to "port depth."
    - "Container handling efficiency," "Container yard efficiency," and "Customs efficiency" all pertain to the concept of port superstructure. Therefore, it is recommended to adjust these factors like below:
        - Container handling efficiency → Number of gantry cranes / gantry crane handling capacity per hour.
        - Container yard efficiency → Area of container yard.
        - Deletion of customs efficiency as it is not a factor that contributes majorly in port selection in the research's region of focus. Recently important factor, port connectivity, was suggested to be used as it plays a crucial role in port selection. Additionally, according to the presented document, port connectivity factor was the 8th most frequently appearing factor within the 71 studies selected from SLR conducted in this research.
- Regarding Part 2 of the interview questions, below adjustments are recommended (referring to Appendix B.1):
    - Rewording of the 4 main questions to be clearer and more concise.
    - Reduce and compress the additional questions (2.1 - 2.3) that ask about specific port charges to a single question to inquire about the possibility of receiving data on port tariff for the research's targeted ports.

In summary, additional questions have been added to Part 1 of the interview, modifications have been made to a few of the sub-factors, and questions in Part 2 of the interview have been reworded and adjusted to allow for clearer understanding of the questions.

Step 3: Whilst arranging the interviews, a comprehensive e-mail containing information on the aim, objective as well as the copy of the interview questions was sent to the interviewees in order to draw out the best response during the interview (Butt, 2022). Interviews were carried out face-to-face with three professionals from each of the top Korean shipping companies such as KMTC, Sinokor, and Namsung shipping that operate SSS to ASEAN ports. As shown in Table 4.1, the interviewed shipping companies make up for 52% of the sum share (both import and export) of the SSS from South Korea to South East Asia. As these three companies make up over half of the total sum share, their responses are adequate in representing the prevailing consensus of knowledge regarding various questions asked in the interview. For each interviewee, the interview lasted an average of 45 minutes. Additionally, audios of all interviews have been recorded with the permission of the interviewees.

Step 4: Conducting semi-structured interview aided in identifying the categorisation of sub-factors into their respective main factors for port selection. The interview questions in the Appendix B.1 are preset questions in semi-structured interview format that have been conducted with senior experts in Korean shipping companies dealing with trade to Southeast Asian ports.

As a background information prior to viewing the responses from the three Korean shipping companies, Table 4.1 shows the current statistics on trade for the eight Korean shipping companies that operate SSS between Korea and Southeast Asia.

Table 4.1 Statistics on trade for shipping lines dealing with South East Asia

(Unit: TEU)

Year 2020	Category	TAIWAN	H.K(SPRC)	PHILIPPINES	THAILAND	SINGAPORE	INDONESIA	MALAYSIA	VIETNAM	Total	Share
Sinokor Merchant Marine	Export	786	23,950	6,821	23,557	5,509	24,848	15,675	73,821	174,967	13%
	Import	2,042	58,851	1,301	25,233	1,786	23,351	12,953	72,559	198,076	14%
	Sum	2,828	82,801	8,122	48,790	7,295	48,199	28,628	146,380	373,043	13%
Heunga line	Export	0	31,042	7,778	15,071	3,085	20,129	8,308	49,816	135,229	10%
	Import	0	45,185	561	23,831	1,763	11,924	12,862	47,292	143,418	10%
	Sum	0	76,227	8,339	38,902	4,848	32,053	21,170	97,108	278,647	10%
SM Line	Export	0	244	0	1,933	52	719	71	26,524	29,543	2%
	Import	0	1	0	3,692	129	352	440	29,379	33,993	2%
	Sum	0	245	0	5,625	181	1,071	511	55,903	63,536	2%
Pan Ocean	Export	0	22,928	664	5,528	0	0	0	6,288	35,408	3%
	Import	0	14,742	1,004	3,390	0	0	0	10,711	29,847	2%
	Sum	0	37,670	1,668	8,918	0	0	0	16,999	65,255	2%
KMTC	Export	14,411	74,232	18,121	34,340	19,163	59,619	47,458	76,008	343,352	25%
	Import	11,834	88,694	6,211	39,508	18,516	53,412	45,849	86,739	350,763	24%
	Sum	26,245	162,926	24,332	73,848	37,679	113,031	93,307	162,747	694,115	25%
Namsung Shipping	Export	0	16,979	2,218	9,608	0	0	0	23,277	52,082	4%
	Import	33	11,782	24	15,259	0	0	0	35,697	62,795	4%
	Sum	33	28,761	2,242	24,867	0	0	0	58,974	114,877	4%
Dongjin Shipping	Export	0	1,652	0	7,395	0	0	0	18,673	27,720	2%
	Import	0	5,320	0	8,540	0	0	0	26,478	40,338	3%
	Sum	0	6,972	0	15,935	0	0	0	45,151	68,058	2%
Pan Continental Shipping Co., Ltd.	Export	0	275	0	7,512	0	0	0	16,486	24,273	2%
	Import	0	166	0	1,139	0	0	0	26,877	28,182	2%
	Sum	0	441	0	8,651	0	0	0	43,363	52,455	2%

Source: Committee of Shipowners for Asian Liner Services (2022)

4.3.2 Second step (integrated AHP-TOPSIS): Determining weight of factors and finding preferred port alternatives

Numerous literature have incorporated AHP and TOPSIS methodologies separately or at times in conjunction with other methodologies in order to compute the importance of factors and optimal alternative. The use of integrated AHP and TOPSIS is known to have far more advantages than when used alone (Taylan et al., 2014). In port selection literature, Liu et al., (2020) have used the integrated AHP-TOPSIS approach to calculate the importance of factors and ultimately select the most attractive port. In humanitarian logistics, Roh et al., (2015) have used a two-stage AHP and fuzzy-TOPSIS methodology to first determine the relative importance of individual criteria and then to obtain final ranking of humanitarian warehouse locations. In humanitarian supply chains, Venkatesh et al., (2019) have used the hybrid AHP-TOPSIS to identify crucial criteria in its partnership selection and to solve partner selection problem. Further, in electronic supply chain management, Tyagi et al., (2014) have used the hybrid integrated AHP-TOPSIS to find weights of their eight criteria and assess their five alternatives. In short, the AHP methodology is useful in determining the relative importance of factors, while the TOPSIS methodology is preferred for being able to incorporate attribute weightings to compute optimal alternatives. Thus, AHP will be first used to compute the importance of the weights of key factors that have been narrowed from the experts in semi-structured interview. Next, TOPSIS will be used as a continuation of the AHP method to solve the second part of the problem which is to find the most optimal alternative ports. Additionally, it is not common to find the integrated use of AHP and TOPSIS in port selection literature. From the 71 identified port selection literature obtained through SLR, only two articles used the integrated AHP-TOPSIS method to evaluate importance of port selection factors and ranking of the most preferred ports. Further, these two studies focus on other regions of the world such as the Middle East region and Far East Asia region. To the author's best knowledge, there has been no use of integrated AHP-TOPSIS in the port selection literature in the Southeast Asian region.

4.3.2.1 AHP: Determining weight of factors

Normally, the AHP, which was introduced by Saaty (1977), is a technique to organise and analyse complex decisions. AHP collects opinions from a group of experts or decision-makers and converts complex system problems into a succinct hierarchy system (Roh et al., 2022). In the calculation process, first procedure is weighing the factors, and second procedure is selecting the optimal alternatives. Here, finding of the weight refers to finding the relative importance amongst the identified factors. This current research adopts only the first procedure of AHP, and weigh the importance of factors. According to Saaty (1994), the benefits of using AHP are numerous. Few include the following: the ability to make use of judgements from collected response that may be from intuition, emotion, or logic; the ability for AHP to allow the respondents to decide the relation and the strength of relation between criteria. Also, AHP provides objective weighing technique for both qualitative and quantitative data (Saaty, 1990). The AHP methodology has already been used for port selection literature for multiple regions around the world (Lirn et al., 2004; Ugboma et al., 2006; Chou, 2010a; Mittal and McClung, 2016).

Questionnaire will be sent to experts contributing to decision-making in Korean shipping companies to collect input data that will be used to run the AHP model and determine weights of factors. Experts will answer the questionnaire by taking into account of how much more preferable is one factor over another factor. Thus, using such pairwise comparison, the experts will aid in assigning relative weight to the factors from 1 (equal importance) to 9 (extreme importance). This will in turn give reciprocal values to other factors. Once all the factors have been compared, the weights will be normalised and averaged to yield average weight for each factor. Figure 4.3 shows the flowchart of AHP steps that was taken for this research for greater clarity.

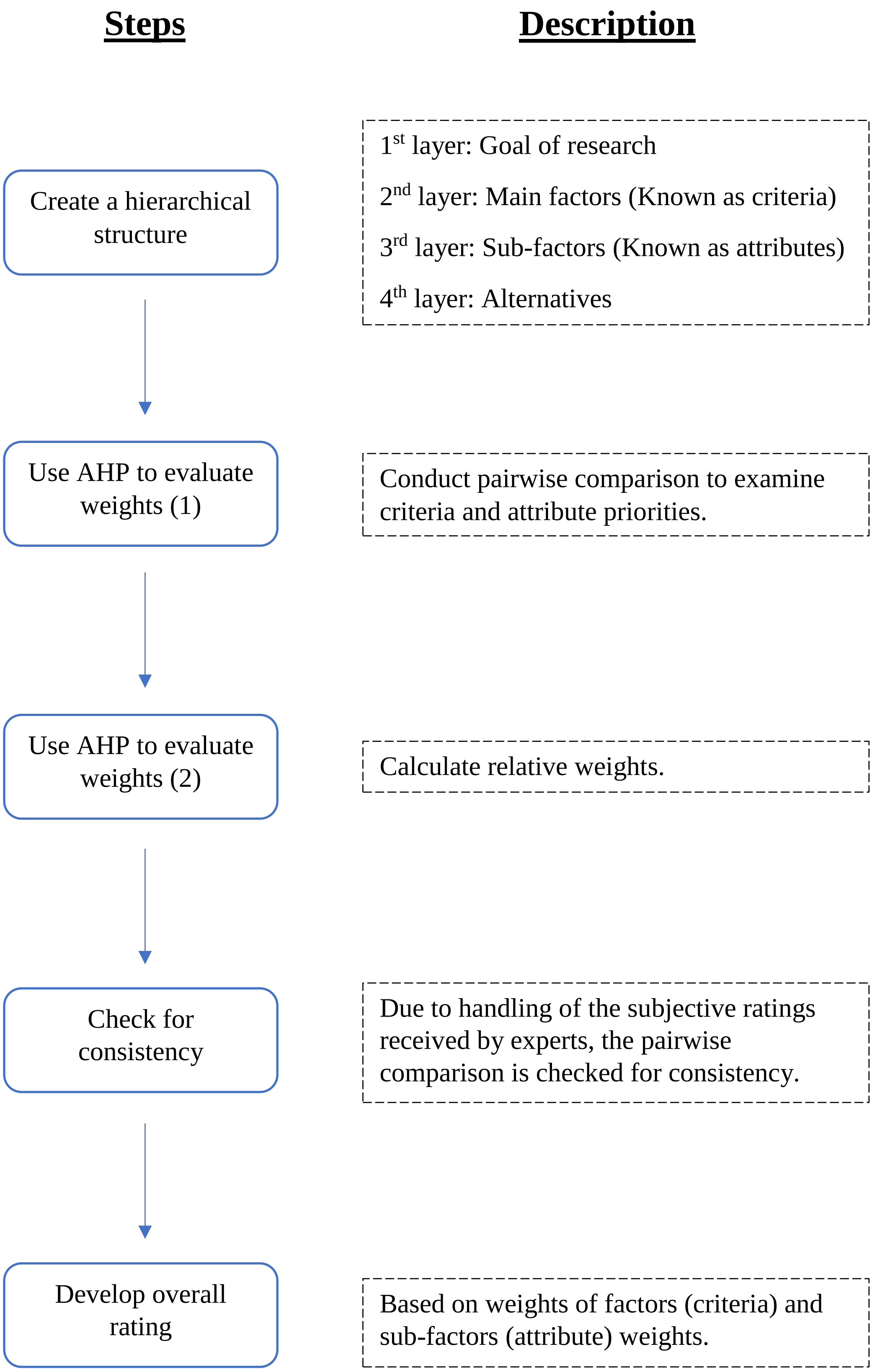

Figure 4.2 The flowchart of AHP based on Ho et al., (2006)

4.3.2.2 TOPSIS: Finding optimal port alternatives

The TOPSIS method was first developed by Hwang and Yoon in 1981 and is one of the common techniques for MCDM problems. Using the TOPSIS, the alternatives (i.e. calling ports in the ASEAN) are evaluated, and their ranking will be suggested. The weights of factors obtained through AHP from the previous step are used to evaluate alternatives using TOPSIS. According to Rahman (2012), the TOPSIS method has a good computational efficiency that provides a simple and rationally comprehensive way to represent the rationale of human choice. TOPSIS also calculates scalar value that encompasses both the best and worst alternatives at the same time (Shih et al., 2007). The TOPSIS methodology has also been already used in the port selection literature with integration of other methodologies such as AHP (Eker et al., 2013; Zabihi et al., 2016; Gorcun, 2019; Liu et al., 2020). In Figure 4.4, which gives a visual representation of the evaluation structure, the use of TOPSIS utilises the weight (obtained in this research from AHP) as well as the secondary data obtained for each of the factors that are shown in the middle level to evaluate for the optimal ranking of the 6 targeted ports.

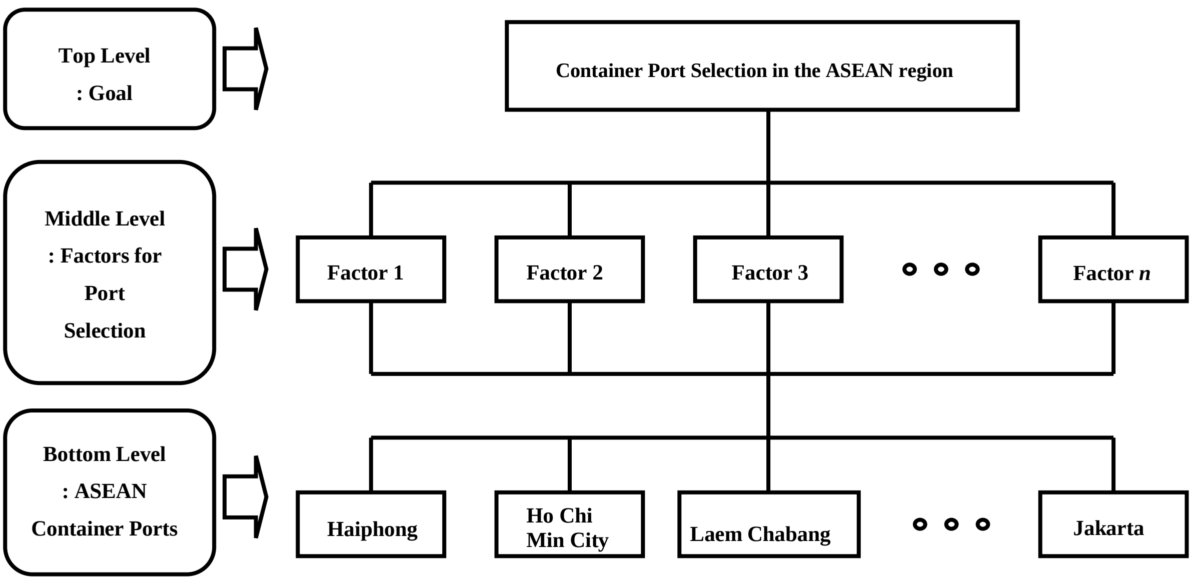

Figure 4.3 Visual representation of the evaluation structure

Source: Author

4.4 Research ethics

Research ethics pertaining to research has been defined by Saunders et al., (2019 p. 252) as *"standards of behaviour that guides your conduct in relation to the rights of those who become the subject of your work or are affected by it."* Saunders et al., (2019) recommends the researcher follows the conduct of research outlined by the researcher's university ethical guidelines or code of ethics to ensure that the researcher does not deviate from the expected behavioural norms that have been established by the university. This study has thus followed the research ethics guidelines set by the University of Plymouth. In regards to the interviews and surveys that this research has conducted, care has been taken on the researcher's part to make sure that the existence of such relationship like power relationship does not compromise the interviewees or participants in any way (Saunders et al., 2019). Therefore, caution was taken to remain impartial and objective as best as possible. Further, statements regarding the anonymous collection of personal information and the confidentiality of the responses were clearly communicated and assured to make sure that the respondents may deliver answers as accurately as possible.

Next, the role and importance of the research ethics committees is mentioned in Saunders et al., (2019). The committee is most likely composed of experienced researchers who will examine the research quality pertaining to ethics such as the following: *"protecting the rights, dignity and welfare of those who participate in this research as well as others who may be affected by it; and considering the safety of researchers"* (Saunders et al., 2019, p. 256). Thus, ethical considerations of this current research have been followed the guidelines set by the University of Plymouth and have been submitted for review for the research ethics committee. On April 2023, the author has received an ethical approval by the University of Plymouth's Faculty Research Ethics and Integrity Committee. The approval letter also listed several recommended changes relating to ethics, to which the author has followed and completed. The approved form can be seen in Appendix D.

4.5 Sampling techniques

4.5.1 Semi-structured interviews

Primary data collected using semi-structured interviews involved three senior-level experts from each of the top Korean shipping companies such as KMTC, Sinokor, and Namsung Shipping that operate SSS to ASEAN ports. Purposive sampling technique has been used to select the interviewees. The chosen interviewees have more than 10 years of experience in their respective companies. Additionally, the interviewed shipping companies make up for 52% of the sum share (both import and export) of the SSS from South Korea to Southeast Asia, as calculated per Table 4.1. As such, accounting for the interviewees' sufficient experience and background along with and taking into consideration that these three companies make up over half of the total sum share, the interviewees' responses are seen as adequate in representing the responses to the various questions asked in the interview. For each expert, the interview lasted an average length of 45 minutes, and the interviews were conducted face-to-face in June of 2023.

4.5.2 AHP questionnaire

For AHP questionnaire survey, this research has incorporated complete enumeration procedure. As seen in Table 4.1, there are a total of 8 Korean shipping companies dealing with SSS with Southeast Asia. Recently, Sinokor Merchant Marine has acquired Heunga Line through mergers and acquisitions. Accordingly, AHP survey has been conducted to the 7 companies. Further, through in-depth interviews with senior level experts in these Korean shipping companies, it was found that there are about 2 departments (sales department and marketing department) that deal with decision making for port selection. Thus, each company has been sent two questionnaires for each department, making the total number of questionnaires sent as 14. Additionally, as it will be further detailed in the upcoming chapter, 12 questionnaires have been collected, but since 1 questionnaire did not pass the consistency ratio test, a total of 11 questionnaires have been considered and analysed for this research. In summary, all the present Korean companies dealing with SSS with Southeast Asian ports have been investigated (as seen in Table 4.1) as well as all the known departments responsible for decision making in port selection (according to the senior level experts in the interviews).

4.6 Chapter summary

This chapter covered main topics about research methodology, which involve research design and research framework for this study. In addition, research ethics and sampling technique were explained toward the end of this chapter.

The research framework had been divided into two major steps. The first step covered pilot test and semi-structured interviews in order to, first, establish the hierarchical structure of container port selection factors that will be used in the second step. Then, the second step covered the process of using the integrated AHP-TOPSIS methodology to determine the weights of the port selection factors, and to find the most optimal ports amongst the 6 Southeast Asian ports.

In regards to both of these steps, employed sampling techniques are discussed. This study has used purposive sampling to logically select three top Korean shipping companies' senior-level experts, whose companies' added sum share best represents the answers in semi-structured interviews. As for the AHP questionnaire, complete enumeration procedure has been taken and all of the small and medium-sized Korean shipping companies involved in SSS to Southeast Asia have participated.

In the upcoming chapter, procedures of using AHP and AHP-TOPSIS will be explained in two parts, which aim to deliver instructions for the use of integrated AHP-TOPSIS framework.

CHAPTER 5: TWO STEP INTEGRATED AHP-TOPSIS METHODOLOGY

5.1 Chapter introduction

The integrated use of AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is known to have far more advantages than when used alone (Taylan et al., 2014). In port selection literature as well, a few studies apply the use of integrated AHP and TOPSIS (Sayareh and Alizmini, 2014; Zabihi et al., 2016; Liu et al., 2020). Therefore, this research also follows a two-step approach in calculating the weights of the factors with AHP and calculating the alternative rankings with TOPSIS. The combined use of these two methodologies will yield a better result to show the priorities of the alternatives selected for this research (6 container port terminals). The current chapter is comprised of two main parts that explain the procedures of using AHP and AHP-TOPSIS. Furthermore, each part is divided into steps to better display the process of using the two-step approach of AHP-TOPSIS. Both parts of this chapter aim to deliver instructions for the use of integrated AHP-TOPSIS framework containing detailed description and explanation of the procedure. This framework, in turn, will be used for a specific case study of Korean shipping companies dealing SSS in the ASEAN region in the subsequent chapter.

5.2 Part A - Calculating the factor weights using AHP

As it was briefly introduced in Chapter 4, AHP is a widely used MCDM (Multi-Criteria Decision-Making) method to assign weights to the criteria within the constructed hierarchical structure model. The five steps in this section describe the significance of each steps as well as provide theoretical representation of series of actions needed to be taken in order to calculate the factor weights using AHP for specific case studies.

5.2.1 Step 1: Creating hierarchical structure of main factors (criteria) and sub-factors (attributes)

Determining port choice factors that influence decision making process is a crucial step in understanding port selection. There have already been numerous studies that utilised the AHP methodology using both qualitative and quantitative criteria to examine the influence and the degree of impact they have on container port choice decision making from various port-related stakeholder's perspective (Lirn et al., 2003; Guy and Urli, 2006; Chou, 2010b; Sayareh and Alizmini, 2014; Gohomene et al., 2016; Zabihi et al., 2016; Kramberger et al., 2018; Kadaifci et al., 2019; Lin and Wang, 2019; Wang and Yeo, 2019; Ding et al., 2019; Liu et al., 2020).

It is crucial to establish a firm set of factors that will be used in this research. Work that occur in this current chapter draws on the obtained results from the previous chapters, namely Chapter 3 and Chapter 4, and continues on the work. This step will aid in creating a model that represents the decision-making process, for this research's instance, container port selection in the Southeast Asia from shipping companies' perspective.

The hierarchical structure is divided into three levels: goal, main factor (criteria), and sub-factor (attribute) as represented in Figure 5.1. The goal indicated in the figure refers to the study of container port choice decision making process between the alternatives identified in the earlier chapter (Ho Chi Minh City, Haiphong, Laem Chabang, Port Kelang, Jakarta, Singapore). The factors that can be seen in the structure are identified through such process as review of literature followed by further verification using pilot test and interviews. These factors consist of main factors that group sub-factors of similar context together. Also, whilst creating such hierarchical model, it is important to note that the total number of factors to be not too extreme in number. Additionally, names of the factors are to be chosen with care to best represent their meaning and aid the decision makers to comprehend better when they are presented with these factors in interviews or questionnaires (Onut et al., 2011).

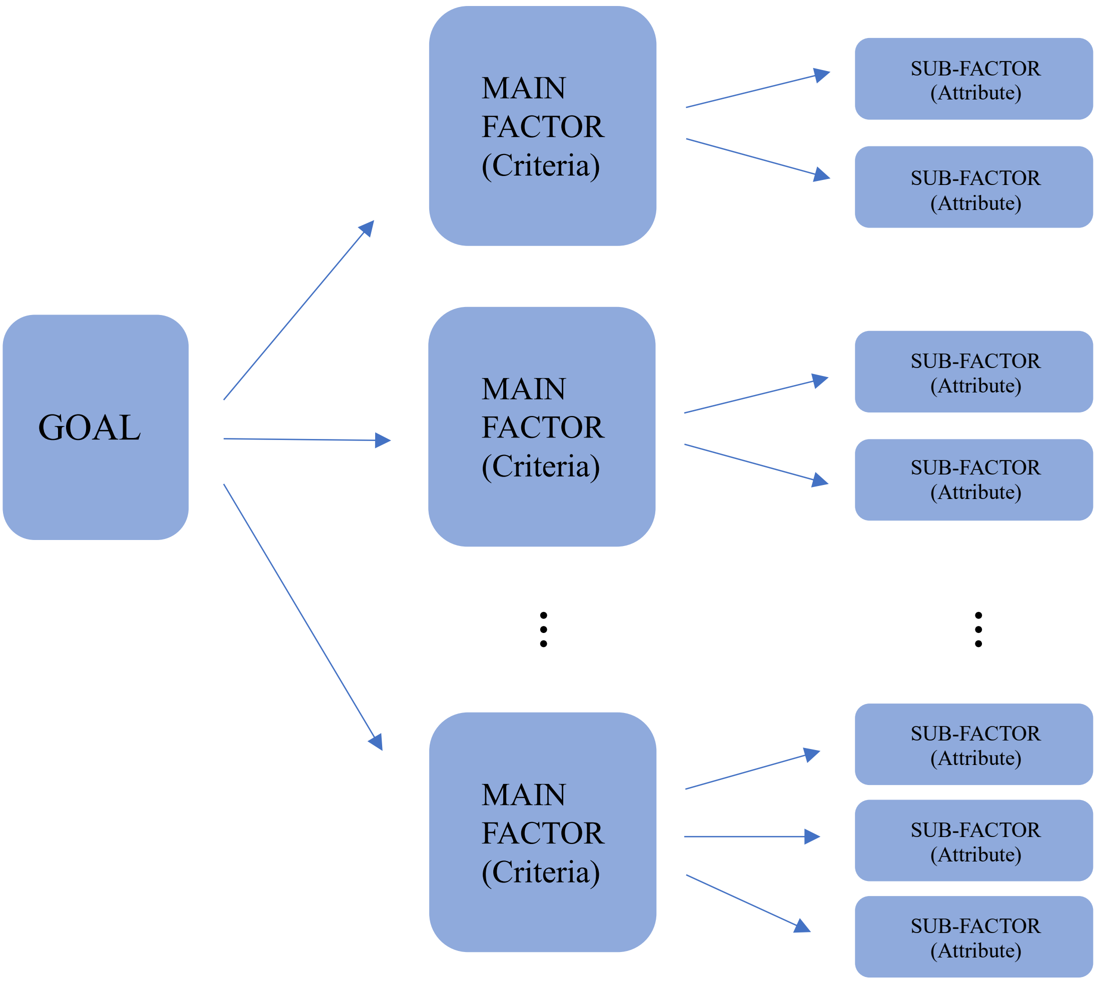

Figure 5.1 A hierarchical model example
Source: Author

5.2.2 Step 2: Constructing pairwise comparison questionnaire prior to data gathering

Using questionnaire or interview serve as a primary measurement tool to identify the importance of factors (both main factors and sub-factors) in port choice decision making (Chou, 2010b). Conducting pairwise comparison questionnaire to various experts, scholars in the relevant research field aid in obtaining relative weights of port choice evaluation factors has already been demonstrated in numerous literature (Ding et al., 2019). Also, taking a look at the pairwise comparisons themselves, they have been used in research since the beginning of the previous century (Yokoyama, 1921) and have been adopted into MCDM analysis as well like in AHP, for example. Pairwise comparison has been experimentally demonstrated to be more accurate than direct evaluations (Millet, 1997; Por and Budescu, 2017), and aid in helping the user to calculate for priorities of the decision items. Therefore, the process of pairwise comparison can help to contribute more empirical data to where there is a gap.

In the constructed questionnaire survey, the respondents would answer each pairwise comparison questions to note how much more importance one criterion has over another. As seen in Table 5.1, the scale ranges from 1 to 9 and respondents would mark 1 if they deem that the importance of the two criteria being compared share equal importance. On the other hand, they would mark 9 if they deem that one criterion is extremely more important than the other.

Table 5.1 AHP pairwise comparison scale

Numerical rating	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	For compromise between the above values

For example, as demonstrated in Figure 5.2 below, if a respondent deems that port location is of equal importance to port hinterland, the respondent would mark 1. If the respondent deems that port location is 9 times "more important" than port efficiency, the respondent would mark the 9 that is closer to the port location. Finally, if the respondent deems that port costs is 3 times "more important" than port location, then the respondent would mark the 3 that is closer to the port costs.

Evaluation Criterion (A)	Extreme importance				Strong importance				Equal importance				Strong importance				Extreme Importance	**Evaluation Criterion (B)**
Port location	9	8	7	6	5	4	3	2	✓1	2	3	4	5	6	7	8	9	Port hinterland
Port location	✓9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port efficiency
Port location	9	8	7	6	5	4	3	2	1	2	✓3	4	5	6	7	8	9	Port costs

Figure 5.2 Examples of pairwise comparisons

5.2.3 Step 3: Distributing completed pairwise comparison questionnaires

The AHP method is a "*measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales*," according to Saaty (2008). As the objective of the questionnaire is to obtain quality logical analytical thinking from experts or professionals to assign priority weights to the criteria, recruiting smaller number of relevant experts for their penetrating insights would be sufficient to obtain valuable insights to such empirical inquiry (Wong and Li, 2008). There is a general consensus that conducting AHP does not require a large sample size (Fabianek and Madlener, 2023). For AHP surveys, a small sample size is trustworthy due to the strict consistency measure (Hamadneh et al., 2022). Therefore, in can be seen in literature that there is no set restriction on the minimum number of sample size required to conduct AHP, and Robinson (1980) suggests that 5 to 7 experts are adequate in group decision-making. Additionally, with port choice being a specific professional decision-making issue, the participants were selected and contacted based on their sufficient level of experience and knowledge as senior level employees working in the relevant field (Hsu et al., 2020).

It can be seen already demonstrated throughout port selection literature using AHP, that only a handful of top decision makers or a small number of participants have been utilised for the collection of data for further AHP calculations. Below are some instances of port selection literature incorporating experts' judgments for AHP:

- In a study that focused on the Asian region from the perspective of shipping companies, by Lirn et al., (2003), the authors utilised 4 international shipping companies to determine the varying importance of port choice criteria.
- In a study that focused on the Asian region from the perspective of shipping companies, by Chou (2010b), the author invited 5 top decision makers from shipping companies to determine the importance weights of criteria in port selection.
- In a study that focused on Middle East region from shipping companies' perspectives by Zabihi et al., *(*2016), the authors invited 5 experts from Iran's maritime transportation to obtain their judgments of importance in port choice criteria through pairwise comparisons.
- In a study that focused on the West African region from the perspective of shipping companies, by Gohomene et al., (2016), the authors utilised 14 shipping lines and shipping business consulting companies to obtain data required to calculate the weights for AHP.

5.2.4 Step 4: Gathering completed pairwise comparison questionnaires

Questionnaires with pairwise comparisons are gathered from the senior-level experts in the relevant department of the industry. The experts will have followed the instructions at the start of each questionnaires on how to answer the pairwise comparison matrix questions, as partially demonstrated in step 2.

5.2.5 Step 5: Using the collected data to calculate factor weights

The process involved in calculating the factor weights are as follows:

1) Create pairwise comparison matrices.
2) Determine relative weights.
3) Compute for consistency index (CI) and consistency ratio (CR).
4) Convert local weights to global weights.
5) Use of software to implement AHP.

Creating pairwise comparison

Firstly, n criteria are to be set up in the row and column of n x n matrix in order to conduct pairwise comparison matrix. The number of matrix at each level depends on the number of factors present at that corresponding level of hierarchy. Comparison of the decision elements is organised into matrices which consist of n rows and n columns which makes it a square matrix ("A" matrix as shown below). It should be noted that each of the elements in the matrix represents the preference of factor in row i to the factor in column j. Also, on the comparison matrix, where i = j, the values will be 1 since the factor is compared with itself. If attribute Ai is judged to be of equal relative importance to attribute Aj, then aij = aji = 1. If aij = α, then aji = 1/α, α ≠ 0.

$$
\mathrm{A} = a_{ij} = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ {}^{a}/_{a_{12}} & 1 & \dots & \alpha_{2n} \\ . & . & \dots & . \\ {}^{1}/_{a_{1n}} & {}^{1}/_{a_{2n}} & \dots & 1 \end{bmatrix}
$$

Equation 5.1

Determining relative weights

Next, normalised relative weights are to be calculated for each matrix. Relative weights of factors could be calculated using the equation below. Here, a_{ij} represents entry of row i and column j.

$$
W_i = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{a_{ij}}{\sum_{i=1}^{n} \alpha ij}\right), \mathrm{i, j,} = 1, 2, 3, \dots, \mathrm{n}
$$

Equation 5.2

Computing consistency index (CI) and consistency ratio (CR)

The next important step is to check for consistency of the pairwise judgement. As human judgments are integrated into decisions, despite the participants' best efforts, their feelings and preferences are inconsistent and intransitive. Therefore, it is crucial to measure consistency since real-life problems are represented with a scale in pairwise comparisons. If the CR of pairwise comparison is zero, this means that the respondent keeps the consistency perfectly. Although perfect consistency is difficult to obtain (Lin et al., 2013), improving the consistency means that "*ratio estimates in the matrix, as a sample collection, are closer to being logically related than to being randomly chosen*" (Saaty, 1977, p. 237). According to Saaty (1994), a good consistency is a score that is below 0.1. Therefore, if the CR is above 0.1, this indicates lack of consistency and the researcher should decide whether the pairwise judgements from such respondent should be repeated or disregarded. Thus, in order to calculate for inconsistency, CI is first calculated using the equation below:

$$\mathrm{CI} = (\lambda_{max} - n)/(n - 1)$$

Equation 5.3

Then, the final CR is calculated as the ratio of the CI and the random index (RI) as indicated in the equation below. The values for RI to be used is determined by the number of criteria and is shown in Table 5.2 below.

$$\mathrm{CR} = \mathrm{CI}/\mathrm{RI}$$

Equation 5.4

Table 5.2 Random inconsistency indices (Saaty, 1994)

Number of criteria	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Converting local weights to global weights

As the hierarchy contains multilevel structures, further calculations need be made to obtain global weight of each sub-factor within the overall hierarchical model. This is done through multiplying the local weight of the sub-factor by the weight of its parent main factor.

Remainder of the AHP steps

After the inconsistencies have been checked, and global weights have been obtained, the final step involves using the weights of decision elements to obtain ratings for the alternatives (targeted ports). However, for this research, obtaining the ranking of alternatives have been carried out by using the TOPSIS methodology. Therefore, this step of the AHP has not been regarded.

Use of software to implement AHP

There are various ways to compute the required steps for AHP. Most notably, results could be obtained through manual calculations on Excel, or they could be obtained using AHP software such as *Expert Choice* or *Superdecisions*. This research has chosen to use the *Expert Choice* software to calculate the weights as it provides user-friendly graphical interfaces as well as automatic calculations of the weights and inconsistencies. Using the software not only offers the above-mentioned benefits, but also reduces any possible human error in calculations. The next chapter will explore the details of using this software to obtain factor weights.

5.3 Part B - Calculating optimal alternatives using AHP-TOPSIS

TOPSIS is a method developed by Hwang and Yoon in 1981 that is also another widely used method to tackle MCDM problems. TOPSIS allows for the evaluation of selected alternatives as well as determining the most optimal rankings of the selected alternatives. As it was introduced before, this research will be using integrated AHP-TOPSIS. Therefore, it is important to view the AHP process (to find weight) as the first part of the AHP-TOPSIS method and the TOPSIS process (to find ranks of alternatives) as the second part of the AHP-TOPSIS method. The weights obtained in Part A from AHP will be used in step 7 of this current section (Part B). The seven steps in this section describe the significance of each steps as well as provide theoretical representation of series of actions needed to be taken in order to calculate for the ranks of the alternatives using AHP-TOPSIS for specific case studies.

5.3.1 Step 1: Identifying attributes (sub-factors) used to assess the alternatives

As the first step of conducting the TOPSIS portion of the AHP-TOPSIS, it is important to make clear which attributes (sub-factors) will be used to ultimately determine the optimal alternatives in port choice decision making process. In order to maintain coherency, work in this chapter picks up from the results and attributes demonstrated and used in previous chapters and in Part A of AHP. Thus, the attributes used in Part A are also to be used in this current section (Part B) to determine the performance values of the selected alternatives, which will be further explained in the forthcoming steps.

5.3.2 Step 2: Identifying alternatives (ports) for decision making

It is important to establish the targeted alternatives that will be ultimately assessed using AHP-TOPSIS. As this research pertains to port selection, naturally the alternatives are going to be ports. The specific ports and the total number of targeted ports for assessment will vary depending on the focus of each studies, however, the following below explains the selection of the 6 container terminal ports for this study, as an example.

Significant amount of container cargo volume pass through South Korea as Busan container port in South Korea is amongst the top 10 container ports in the world in terms of handled cargo volume, according to the 2021 container volume statistics from the World Shipping Council. Looking at other ports that are most engaged in trade (in terms of volume) with South Korea, it is true that numerous ports in China have the highest trading volume with South Korea as shown in Chapter 2 under Table 2.4, which shows top 30 trading ports with South Korea. However, this research's case study is focused on SSS for container cargo within the geographical region of Southeast Asia from Korea. Therefore, top trading ports in Southeast Asia with South Korea are to be considered which, in this case, would be the following 6 ports listed in Table 2.4: Ho Chi Minh City, Haiphong, Laem Chabang, Port Kelang, Jakarta, and Singapore.

5.3.3 Step 3: Collecting data on attributes (sub-factors) for TOPSIS

Obtaining secondary data regarding the attributes on the selected alternatives as well as primary data via questionnaire are naturally necessary in order to further compute for the ranks of the alternatives. As there may be limit to how much publicly available data or exclusively available data (such as through paid subscription for dataset or through relevant companies' internal data by request) could be gathered, conducting a questionnaire to obtain experts' judgment and evaluation on certain attributes may greatly aid in completing data collection. It should be considered that the TOPSIS methodology incorporates normalisation process in its calculation, therefore, collecting data of different units of measurements is accounted for (Tzeng and Huang, 2011).

5.3.4 Step 4: Constructing a questionnaire to gather data for TOPSIS

Due to the difficulty of obtaining secondary data for attributes in regards to the chosen alternatives, be it from publicly available data or from exclusively accessible data, it may become necessary to also conduct questionnaire survey to collect qualitative data from experts. These data are necessary in determining the ranks of the selected alternatives.

Questionnaire based on predetermined criteria is to be constructed with the chosen rating scale to measure experts' evaluation. The following below explains the rating scale used to evaluate a criterion for the 6 selected alternatives for this study, as an example.

A matrix question consisting of score system from 1 to 10 is to be devised to collect the experts' evaluation of a certain attribute for the selected alternatives. As instructed in the questionnaire, the worst score the respondent could give is a 1 while the best score the respondent can give is a 10. For example, as demonstrated in Figure 5.3 below, if a respondent deems that Cat Lai Terminal (in Ho Chi Minh City) has an outstanding intermodal link, the respondent would mark a 10. If the respondent deems that Koja terminal (in Jakarta) has a very poor intermodal link, the respondent would mark a 1.

Whilst considering the sub (detailed) factor of "Intermodal links," what is your evaluation of the container terminals in each port below? Please indicate with a ✓ in each row. Please give a score between 1 and 10 for each row. (10 is the best score point you can give).

Container terminals for evaluation	1	2	3	4	5	6	7	8	9	10
Cat Lai terminal (Ho Chi Minh City)										✓
Koja terminal (Jakarta)	✓									

Figure 5.3 Example of matrix question

5.3.5 Step 5: Distributing completed question

It is necessary to collect all data on attributes regarding all selected alternatives in order to carry out further calculations to determine the ranks of alternatives. Therefore, appropriate data would be obtained through the collection of questionnaires constructed in the previous step in order to capture the evaluation of the experts that are from the relevant department of the industry. For this research, this additional portion of the questionnaire would be added at the end of the AHP questionnaire to collect the needed data. As such, experts with sufficient experience and knowledge that were utilised for this TOPSIS questionnaire were the same as those invited and utilised in Part A for AHP.

5.3.6 Step 6: Gathering completed questions

Questionnaire with scoring between 1 and 10 are gathered from the senior-level experts in the relevant department of the industry. The experts will follow the instructions at the start of the questionnaire to give their judgment on the score rating of each alternatives, as demonstrated with a sample matrix question in step 4.

5.3.7 Step 7: Using the collected data to calculate alternative rankings

The data that were collected throughout the previous steps are used to rank the priority of order for the selected alternatives, which in this research are the targeted 6 container ports. TOPSIS methodology is employed to yield this priority of order. This research has followed the TOPSIS process that have been used in supply chain and port literature (Shyur and Shih, 2006; Onut and Soner, 2008; Chen, 2011; Akyuz and Celik, 2014). The different steps of TOPSIS calculations could be summarised into 7 phases like below:

- Phase 1 - Constructing the decision matrix
- Phase 2 - Calculating the normalised decision matrix
- Phase 3 - Calculating the weighted normalised decision matrix
- Phase 4 - Determining positive ideal solution (PIS) and negative ideal solution (NIS)
- Phase 5 - Calculating the separation measure
- Phase 6 - Calculating the relative closeness to the ideal solution
- Phase 7 - Ranking the preference order

These 7 phases of TOPSIS calculation had been performed using the data obtained through either as secondary data source (such as data obtained from shipping companies) or as primary data source (a matrix question purposed to capture experts' evaluations through questionnaire).

Phase 1 - Constructing the decision matrix

This phase consists of representing all the data gathered in the previous steps for the attributes in the decision matrix. The decision matrix can be expressed as below:

$$D = \begin{bmatrix} & c_1 & c_2 & c_3 & \cdots & c_n \\ A_1 & x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ A_3 & x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{bmatrix}$$

Equation 5.5

where A_i = i^{th} alternative related and x_{ij} is the performance value of alternative with respect to criterion c_j.

The constructed decision matrix will display the collected secondary and primary data (intermodal link scores) evaluating 6 alternatives for each of the 12 sub-factors.

Phase 2 - Calculating the normalised decision matrix

This phase normalises the decision matrix D since the different attributes all have different units of measurement. Through this normalisation, different attribute units are transformed into the same unit matrix in order for correct comparison to be carried out. Calculating the normalised decision matrix is done by using the formula below.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = \mathbf{1}, \mathbf{2}, \mathbf{3}, \ldots, m \text{ and } j = \mathbf{1}, \mathbf{2}, \mathbf{3}, \ldots, n$$

Equation 5.6

Phase 3 - Calculating the weighted normalised decision matrix

The weighted normalised decision matrix (v_{ij}) is constructed by multiplying the values obtained in normalised decision matrix (from phase 2) by the weights obtained for each attribute through AHP. The calculation is carried out with the formula shown below:

$$v_{ij} = w_j \cdot r_{ij}, \qquad i = 1,2, \ldots, n, \quad j = 1,2, \ldots, n$$

Equation 5.7

where w_j is the weight of the j^{th} attribute or criterion.

Phase 4 - Determining positive ideal solution (PIS) and negative ideal solution (NIS)

The PIS and NIS are determined by finding the maximum and the minimum values in each column of the weighted normalised decision matrix obtained from phase 3. Mathematical expression to find PIS and NIS are shown below:

$$A^{+} = \{(max\ v_{ij} \mid j \in J) \text{ or } (min\ v_{ij} \mid j \in J') \text{ for } i = 1,2,\dots,m\} = \{v_1^{+}, v_2^{+}, \dots, v_n^{+}\}$$

Equation 5.8

$$A^{-} = \{(min\ v_{ij} \mid j \in J\ ) \text{ or } (max\ v_{ij} \mid j \in J') \text{ for } i = 1,2,\dots,m\} = \{v_1^{-}, v_2^{-}, \dots, v_n^{-}\}$$

Equation 5.9

where J = 1,2,3,...,n. is associated with benefit (positive criteria) and J′ = 1,2,3,...,n is associated with cost (negative criteria).

Phase 5 - Calculating the separation measure

The equations below calculate Euclidean distance of the alternatives from the ideal solutions.

Separation of the alternatives from the PIS is found per equation below:

$$S_i^{+} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{+}\right)^2}, i = 1,2,\dots,m$$

Equation 5.10

Similarly, separation of the alternatives from the NIS is found per equation below:

$$S_i^{-} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{-}\right)^2}, i = 1,2,\dots,m$$

Equation 5.11

Phase 6 - Calculating the relative closeness to the ideal solution

The equation below has been used to calculate the relative closeness C_i. It represents the relative closeness of alternative A_i with respect to PIS A^+. The calculated relative closeness closer to 1 indicate better performance of the alternatives.

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}, \quad 0 < C_i < 1, \;\; i = 1,2,\dots,m$$

Equation 5.12

Phase 7 - Ranking the preference order

This is the final phase of the TOPSIS calculation that involves ranking the alternatives by ordering the values obtained for *Ci* in phase 6 in descending manner where the highest value of *Ci* (closest to the value of 1) represents the most optimal alternative.

5.4 Chapter summary

In this chapter, the procedure taken for the use of integrated AHP and TOPSIS to find the factor weights and the ranks of targeted alternatives (6 container terminal ports) has been explained. The combination of these methodologies has been used because this proves to be more advantageous than when each methodology is used alone.

As this chapter uses specific portions of the AHP methodology and the TOPSIS methodology, such integrated method has been delineated in 5 steps for AHP (to calculate for the weights of factors) and 7 steps for AHP-TOPSIS (to calculate for ranks of alternatives). As noted previously, for AHP, the calculation stops once the weights of the factors have been calculated.

Next, incorporating these weights, TOPSIS methodology is used to calculate the ranks of the alternatives. This chapter delivers instructions for the use of integrated AHP-TOPSIS framework with detailed description and explanation of the procedure.

Following such instructions, in the next chapter, a case study of Korean shipping companies dealing SSS in the ASEAN region will be covered by incorporating the integrated AHP-TOPSIS framework, which has been explained in this current chapter. Detailed calculation procedure and data collection process will be shown in the next chapter to determine the values of weights assigned to the container port selection factors (12 sub-factors) as well as the rankings of the most optimal alternatives (6 container port terminals in Southeast Asia).

CHAPTER 6: CASE STUDY: TWO STEP INTEGRATED AHP-TOPSIS METHODOLOGY TO ASSESS CONTAINER PORT SELECTION DECISION MAKING PROCESS

6.1 Chapter introduction

The use of integrated AHP and TOPSIS is known to have far more advantages than when used alone (Taylan et al., 2014). A few studies in port selection literature have applied the integrated use of AHP and TOPSIS (Sayareh and Alizmini, 2014; Zabihi et al., 2016; Liu et al., 2020). As explained previously, the combined use of these two methodologies will yield a better result to ultimately show the priorities of the 6 container port terminals selected for this research. Therefore, as it has been established previously, this research follows a two-step approach to calculate the weights of the factors with AHP and to calculate the alternative rankings with AHP-TOPSIS.

Just like the previous chapter, this current chapter is divided into two main parts: Part A being the determination of weights using AHP; and Part B being the choosing of optimal alternative using AHP-TOPSIS. In Part A, final global weights of each of the 12 attributes (sub-factors) have been determined using questionnaires with pairwise comparison and using an AHP software called *Export Choice*. Continuing onto Part B, the ranks of the most optimal 6 container port alternatives have been calculated and chosen with the use of the following components: the obtained weights from Part A; primary and secondary data gathered for each of the same 12 attributes (sub-factors) respective to the 6 alternatives from Korean shipping companies. Again, it should be clarified that the final rankings of the alternatives are calculated with TOPSIS, as part of the second phase (Part B) of using integrated AHP-TOPSIS.

In summary, this chapter follows the structure and the explanations of the previous Chapter 5. However, this chapter explores this research's case study and displays collected data, calculation process, and calculation results in detail pertaining to Korean shipping companies dealing SSS in the ASEAN region.

6.2 Part A - Determining factor weights using AHP

As it was stated in Chapter 5, AHP is a widely used MCDM method to assign weights to the criteria within the constructed hierarchical structure model. The five steps in this section follow the series of actions covered in Part A of Chapter 5, and detail the process of calculating for the 12 sub-factor weights in-depth using AHP for this research's case study.

6.2.1 Step 1: Creating hierarchical structure of main factors (criteria) and sub-factors (attributes)

As demonstrated in the literature review and SLR, numerous studies are present regarding port selection factors in various regions of the world focusing on different perspectives of port-related stakeholders. It is crucial to establish a firm grasp of factors that will be used in this research. Therefore, SLR has been conducted to yield the most relevant port selection studies that were used to identify and sort the most important and recurring port selection factors from the last forty years. Based on these yielded studies that are most relevant to this research, a preliminary hierarchical structure of factors has been drawn. Table 6.1 below shows the obtained main factors and sub-factors.

Table 6.1 Display of port selection factors according to the literature (SLR)

Goal	Main factors	Sub (detailed) factors after SLR
Container port selection factors	Port location	Proximity to feeder ports
		Proximity to main navigation routes
		Proximity to the markets (demand)
		Distance of shippers from port (supply)
	Port charge	Port charges (port dues, pilot cost, towage, etc.)
		Handling & storage cost of containers
		Inland transport cost
	Port hinterland	Total container cargo volume (import/export & transshipment containers)
		Frequency of port of call
		Intermodal links
	Port efficiency	Port infrastructure
		Container handling efficiency
		Container yard efficiency
		Customs efficiency

Afterwards, review of these factors took place by two academic scholars whose area of study lies in Asian and Korean calling port selection, and there were some changes to the sub-factors in the hierarchical structure. It is important to also note that the mentioned two academic scholars have experiences in using AHP and TOPSIS methodologies. Thus, the feedback received regarding changes to the structure not only considered the crucial factors that are representative of Korean or

Asian shipping companies, but also took into account of the mechanics of using AHP such as adjusting sub-factors to make them more practical and calculable. There were no changes to the main factors but some sub-factors underwent changes to become more specific and measurable. Table 6.2 below shows both the sub-factors obtained in SLR and the changed sub-factors after incorporating two academic scholars' recommendations.

Table 6.2 Port selection factors from the literature and after academic feedback

Goal	Main factors	Sub (detailed) factors (1) after SLR	Sub (detailed) factors (2) after academic feedback
Container port selection factors	Port location	Proximity to feeder ports	Proximity to main navigation routes
		Proximity to main navigation routes	
		Proximity to the markets (demand)	Proximity to the markets (demand)
		Distance of shippers from port (supply)	Distance of shippers from port (supply)
	Port charge	Port charges (port dues, pilot cost, towage, etc.)	Port charges (port dues, pilot cost, towage, etc.)
		Handling & storage cost of containers	Handling & storage cost of containers
		Inland transport cost	Inland transport cost
	Port hinterland	Total container cargo volume (import/export & transshipment containers)	Total container cargo volume (import/export & transshipment containers)
		Frequency of port of call	Frequency of port of call
		Intermodal links	Intermodal links
	Port efficiency	Port infrastructure	Port depth
		Container handling efficiency	Number of gantry cranes / gantry crane handling capacity per hour
		Container yard efficiency	Area of container yard
		Customs efficiency*	
			Port connectivity*

*Note that the academic scholars suggested for the deletion of customs efficiency as it was not a factor that contributed majorly in port selection in the research's region of focus. Recently important factor, port connectivity, was suggested to be used as it plays a crucial role in port selection.

At this point, a hierarchical structure of factors consisting two levels (main factors and sub-factors) has been constructed and it has undergone through two screenings: first, the formation of structure with most relevant literature obtained through SLR; then, the adjustments to the sub-factors using two academic scholars' recommendations. This constructed hierarchy of factors was then presented to the industry senior experts for their inputs on any edits, rearrangements, or deletion of factors in port selection. With their sufficient background and over 10 years of experiences in Korean shipping companies dealing SSS to Southeast Asian ports, three senior experts gave their inputs to the presented factors. Although the main factors have not changed, there were some changes to the sub-factors. Figure 6.1 shows the final hierarchical structure of port selection factors after incorporating inputs from the senior experts in the industry.

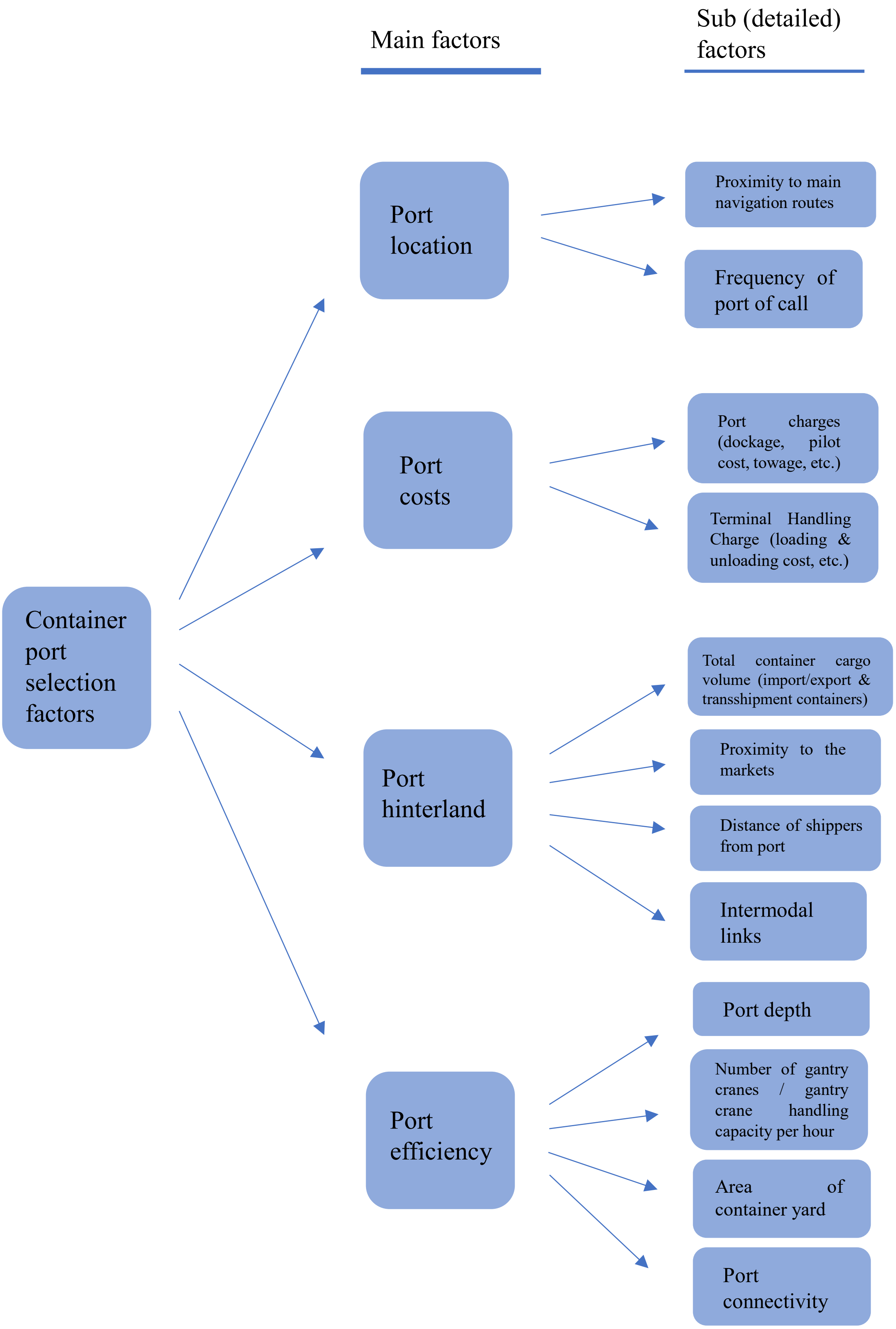

Figure 6.1 Final structure of hierarchy of port selection factors

6.2.2 Step 2: Constructing pairwise comparison questionnaire prior to data gathe ring

It is necessary to determine the weights of each criterion (main factors) and attributes (sub-factors) to investigate the importance of each factors to the Korean shipping companies. Using the final set of streamlined hierarchical structure devised after series of edits (Figure 6.1), a pairwise comparison questionnaire was created in order to put weights to each of the factors (as shown in Appendix C.1). In the constructed pairwise comparison, the participants would mark their preference according to the AHP pairwise comparison scale (Saaty, 1994) as shown in Table 6.3 below.

Table 6.3 AHP pairwise comparison scale

Numerical rating	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	For compromise between the above values

6.2.3 Step 3: Distributing completed pairwise comparison questionnaires

Drawing on the responses received from in-depth interviews, it can be confirmed that each shipping companies either has a slightly different name for departments responsible for selecting ports or has a different department entirely for selecting ports. However, the sales department and marketing department were found to be commonly mentioned in their involvement in selecting ports. Therefore, the pairwise comparison AHP questionnaires were distributed to the departments mentioned above.

Questionnaires were distributed to find the weight of importance for the main factors & sub (detailed) factors. All 7 of the targeted shipping companies were involved in the questionnaire. For each of these companies, questionnaires were sent via e-mail to two PIC's (person-in-charge) working in departments responsible for port selection. Therefore, the total number of questionnaires that were sent out was 14 (7 shipping companies X 2 staff in responsible departments = 14 questionnaires).

6.2.4 Step 4: Gathering completed pairwise comparison questionnaires

The following are the timeline for distributing and gathering of questionnaires.

- The questionnaire was distributed on June 23, 2023.
- First reminder e-mail was sent on June 30, 2023.
- Second reminder e-mail was sent on July 8, 2023.
- Collection of questionnaires ended on July 23, 2023.
- A total of 12 questionnaires were collected.

The gathered responses were almost all from senior level experts with sufficient experience in the shipping industry. As Table 6.4 shows, most of the respondents of the questionnaire possessed over 16 years of experience in the shipping industry. Additionally, it should be noted that the opinions of each experts were considered to carry the same weight. No one expert's inputs were considered to be of more importance over another.

Table 6.4 Experts' number of experiences in years

Number of years in the field	Number of experts
6-10 years	1
11-15 years	4
Over 16 years	7

6.2.5 Step 5: Using the collected data to calculate factor weights

The collected data from the questionnaires was used to determine the weights of the factors (main factors and sub-factors) in the hierarchical structure shown in Figure 6.1. AHP methodology was used to calculate the weights.

The process involved in calculating the factor weights have been explained in Chapter 5 and are as displayed again below:

1) Create pairwise comparison matrices.
2) Determine relative weights.
3) Compute for consistency index (CI) and consistency ratio (CR).
4) Convert local weights to global weights.
5) Use of software to implement AHP.

Use of software to implement AHP

As already explained in the previous chapter, an AHP software, *Expert Choice*, has been implemented in this research. The user-friendly graphical interfaces as well as the automatic calculations of weights and inconsistencies that the software provides assist in reducing any possible human error in calculations; hence the reason for the use of this software. In the previous step 4, a total of 12 questionnaires have been collected out of the 14 questionnaires that have been sent out. However, during the process of calculating CR, 1 respondent's questionnaire was omitted as it gave a high CR of 0.3. Thus, 11 questionnaires were under the acceptable range of CR of 0.1 and were used for this research. It should be noted that despite not being able to collect all 14 questionnaires, at least 1 valid questionnaire from each of the 7 shipping companies was obtained and used for this research. Thus, using the software, the weights of the main factors are shown in Figure 6.2.

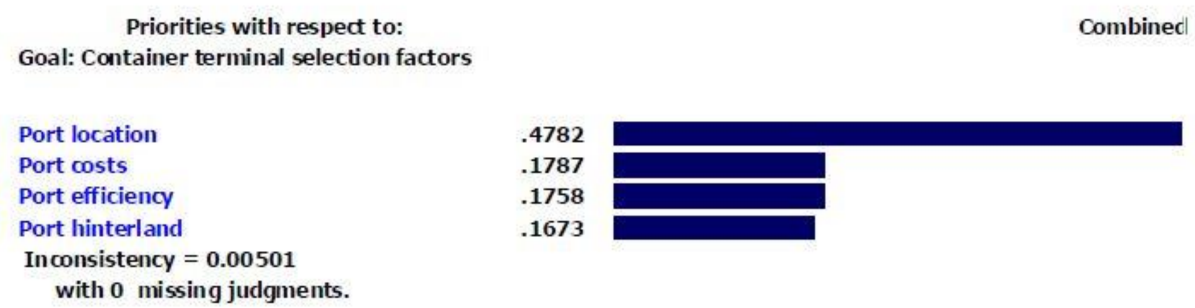

Figure 6.2 Priorities of main factors with their weights

Afterwards, the weights of sub-factors were also calculated using the software and Figure 6.3 shows the results below.

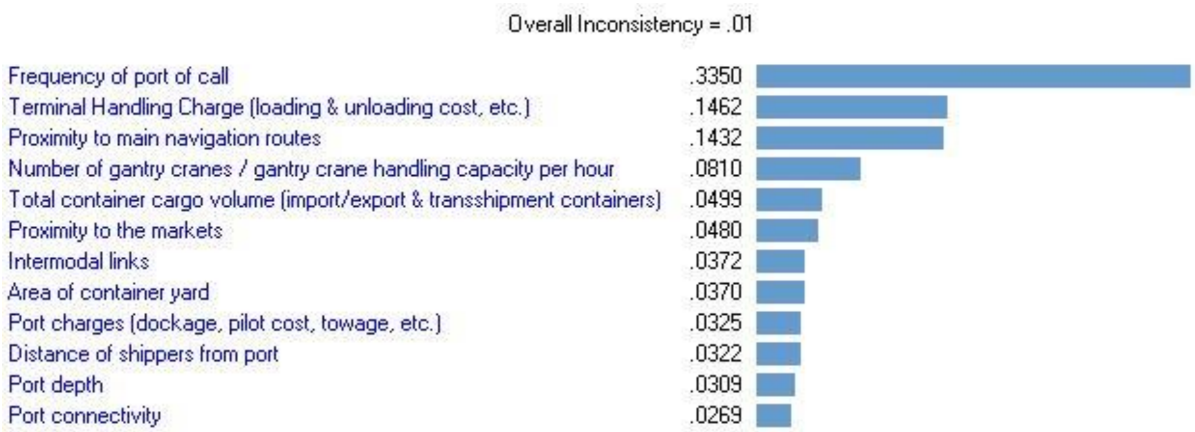

Figure 6.3 Priorities of sub-factors with their weights

In *Expert Choice* software, it should be noted that there are two synthesis methods to calculate global weights of the attributes (sub-factors): “distributive mode” and “ideal mode.”

“Distributive mode” of synthesis has been the original and the only mode of synthesis in *Expert Choice* software to calculate global weights in the program. The equation for this is simply the local weight multiplied by their respective parent group weight. This mode is used when resources are limited, and the research is seeking for dominance within the alternatives (Millet and Saaty, 2000). It should be noted that all are dependent on each other, and ultimately the weights add up to 1 (Maruthur *et. al.* 2015).

“Ideal mode” of synthesis has been introduced by Forman (1993). It is an added feature later on into the *Expert Choice* software to account for some situations where using “distributive mode” would not fit the context of choosing the alternatives in the real life. “Ideal mode” of synthesis is used when picking the one single best alternative (Oyatoye and Odulana, 2016).

For this research, “distributive mode” of synthesis is more fitting for use because the research is not looking for merely one single best port. Rather, it is interested in investigating the ranks of all 6 targeted ports. Also, the context of this research fits the description of using “distributive mode” of synthesis since the choosing of the alternatives (ports) are within limited resources by the shipping companies, and these alternative ports are also dependent on each other, connected with each other, and are not entirely separate secluded entities (Barfod, 2014).

6.2.6 Discussion

It is noteworthy to mention that the overall inconsistency is 0.01, which is aligned with keeping the consistency below the CR score of 0.1 according to Saaty (1994). This means that the respondents executed pairwise comparisons in the questionnaires very consistently. The minimalistic design of the main factors and their sub-factors yielding fewer numbers of comparison and the additional written tips that the respondents could use to guide them on consistently marking their responses may have helped greatly to keep the inconsistency down to its minimum. So, with this, it is safe to consider that the respondents have produced a reliable set of data which could be used to further investigate priorities of port selection factors.

As it can be seen in Figure 6.3, frequency of port of call factor dominantly takes the greatest share of weights compared to 11 other factors. Terminal Handling Charge (THC) factor took the second highest weight. Closely following the second highest weight by a very minute difference, proximity to main navigation routes factor took the third place in terms of its weight. It is worth noting that as seen in Figure 6.2, the port location main factor took a leading share of weights amongst the 3 other main factors. Therefore, it is very viable that two of the top three leading factors are the attributes (sub-factors) of the port location criterion (main factor). Although the top factor had dominantly taken the most share of the weights, it is also worth considering the top five factors as these contribute to 75.53% of the total weight of port selection factors.

The following below lists top five factors in terms of weight:

1. Frequency of port of call (33.50%)
2. Terminal Handling Charge (loading & unloading cost, etc.) (14.62%)
3. Proximity to main navigation routes (14.32%)
4. Number of gantry cranes / gantry crane handling capacity per hour (8.10%)
5. Total container cargo volume (import/export & transshipment containers) (4.99%)

6.3 Part B - Choosing optimal alternatives using AHP-TOPSIS

As it was mentioned in Chapter 5, TOPSIS methodology will be incorporated with the use of weights obtained from AHP from Part A in this chapter, thus completing the two step AHP-TOPSIS framework. The seven steps in this section follow the series of actions covered in Part B of Chapter 5, and detail the process of calculating for the ranks of the selected alternatives (6 container port terminals) using AHP-TOPSIS for this research's case study.

6.3.1 Step 1: Identifying attributes (sub-factors) used to assess the alternatives

Previously - through SLR, pilot test, and semi-structured interviews - criteria (main factors) and attributes (sub-factors) were determined as factors fit for container port selection in this research's context. Additionally, AHP methodology was used through a software, *Expert Choice*, to calculate the weights of these criteria and attributes and ultimately yield the global weights of the 12 attributes (sub-factors). These same 12 attributes (sub-factors) were used again to assess the 6 alternatives (optimal container terminals) through the use of TOPSIS methodology. Note that the alternatives (container terminals) had been further determined from semi-structured interviews.

The attributes (sub-factors) that will be used to assess the 6 alternatives are the following (note that they have been listed in the order of highest weight obtained from AHP):

1. Frequency of port of call
2. Terminal Handling Charge (loading & unloading cost, etc.)
3. Proximity to main navigation routes
4. Number of gantry cranes / gantry crane handling capacity per hour

5. Total container cargo volume (import/export & transshipment containers)
6. Proximity to the markets
7. Intermodal links
8. Area of container yard
9. Port charges (dockage, pilot cost, towage, etc.)
10. Distance of shippers from port
11. Port depth
12. Port connectivity

6.3.2 Step 2: Identifying alternatives (ports) for decision making

6 container ports have been selected as alternatives, which are the following:

- Ho Chi Minh City,
- Haiphong,
- Jakarta,
- Laem Chabang,
- Port Kelang,
- Singapore.

These 6 container ports have been selected based on their presence in South Korea's top trading ports in terms of volume, as already mentioned in Chapter 2. There were many other countries from different geographical regions that were on the list of 30 top trading ports displayed in Table 2.4, such as from Eastern Asia like China and Japan, or from Northern America like U.S. and Canada. However, as Southeast Asian region is the focus of this research, ports from this region was selected from the list of top 30 ports, which came to be the 6 ports mentioned above.

6.3.3 Step 3: Collecting data on attributes (sub-factors) for TOPSIS

Most of the data regarding the 12 sub-factors were gathered either through publicly available secondary data such as from statistics table of UNCTAD, Google Maps, and terminals' official websites or through exclusively available secondary data such as data obtained from the interviewed Korean shipping companies and the Alphaliner Distance Table that they have used. All of the data for the sub-factors were gathered through above-mentioned methods except for data regarding intermodal links. A matrix question had been constructed to capture experts' evaluation of 6 targeted container terminals in regards to the "intermodal link" sub-factor, which is further explained in the next step. Table 6.5 below briefly shows each way that the data for 12 sub-factors were collected. Afterwards, following text will give elaborations on how each sub-factor was collected and calculated as well as present the data that have been obtained for each sub-factor.

Table 6.5 Data collection sources for 12 sub-factors

Sub-factors	Data collection source
Frequency of port of call	Internal data from shipping company
Terminal Handling Charge (loading & unloading cost, etc.)	Internal data from shipping company
Proximity to main navigation routes	Calculations obtained from shipping company that have used Alphaliner Distance Table
Number of gantry cranes / gantry crane handling capacity per hour	Internal data from shipping company, publicly available information on terminal websites
Total container cargo volume (import/export & transshipment containers)	Internal data from shipping company

Proximity to the markets	Use of Google Maps
Intermodal links	Scores of terminals' intermodal link evaluation obtained from experts through questionnaire
Area of container yard	Internal data from shipping company, publicly available information on terminal websites
Port charges (dockage, pilot cost, towage, etc.)	Internal data from shipping company
Distance of shippers from port	Use of Google Maps
Port depth	Internal data from shipping company, publicly available information on terminal websites
Port connectivity	Use of statistics table of UNCTAD

Frequency of port of call

The data for this sub-factor has been collected from internal data provided by the Korean shipping companies that have been contacted throughout the interview and questionnaire phase of this research. Different shipping companies provided different unit for the frequency of port of call - some gave data in units of per week while others gave in units per month. In order to unify the measurement, this research has changed all units for frequency of port of call into per month (calculating that there are 4 weeks in 1 month). Additionally, due to some Korean shipping companies having smaller scale of operation in comparison, some do not have services to all the 6 targeted terminals. Therefore, these absent data were considered to be 0 when performing TOPSIS calculations. Table 6.6 below shows the data obtained.

Table 6.6 Frequency of port of call to 6 targeted port terminals

Frequency of port of call	**KMTC**	**SinoKor**	**Namsung Shipping**	**Dongjin**	**Pancon**	**Panocean**	**SM Line**
Cat Lai terminal (Ho Chi Minh City)	27	32	8	2.7	12	12	10
Green port (Haiphong)	2	8	4	2	12	0	0
Koja terminal (Jakarta)	1	12	1	0	0	0	0
LCMT (Laem Chabang)	11	28	5.5	2.7	12	4	4
North port terminal (Port Kelang)	10	12	0	0	0	0	0
PSA terminals, Pasir Panjang terminal (Singapore)	14	16	0	0	0	0	0
Note	Data for several Korean shipping companies that do not have services to all the 6 targeted terminals have been displayed as 0.						

Terminal Handling Charge (loading & unloading cost, etc.)

The data for this sub-factor has been collected from internal data provided by the Korean shipping companies. It should be noted that the charges are subject to vary depending on contract terms for different shipping companies. The charges that are included in this sub-factor are the following: loading and discharging cost; handling charges within the container yard; tally charge; and lashing charge. USD per 40 ft full container has been used as the unit of measurement this sub-factor. Further, it should be noted that for all 7 Korean shipping companies, congruent amount of charges was applied for each of the corresponding terminal. So essentially, although different terminals have different charge values, all 7 Korean shipping companies would have the same value for Ho Chi Minh City, same value for Haiphong, and so on. Table 6.7 below shows the charges for 6 targeted ports.

Table 6.7 Terminal Handling Charge for 6 targeted ports

Target container ports	**Terminal Handling Charges**
Ho Chi Minh City	$ 62.00/40ft Full
Haiphong	$ 45.00/40ft Full
Jakarta	$ 132.00/40ft Full
Laem Chabang	$ 75.05/40ft Full
Port Kelang	$ 107.40/40ft Full
Singapore	$ 155.80/40ft Full
Note	Terminal Handling Charges includes: loading & discharging, handling charges within the container yard, tally charge, lashing charge

Proximity to main navigation routes

The data for this sub-factor has been obtained from shipping company that has used the Alphaliner Distance Table. The main navigation sea route used for east-west routes in Asia-Europe trade has been considered. For this research, with its focus starting from South Korea and extending to the Southeast region, it has considered that the standard for the main navigation route has its starting point in Busan New Port and its ending point in Port Kelang. For the sake of clarity, the 6 targeted ports in this research are the following: Ho Chi Minh City, Haiphong, Jakarta, Laem Chabang, Port Kelang, and Singapore. 2 of the targeted ports - Port Kelang and Singapore - are located directly on the main navigation route. Therefore, their proximity to the main navigation route has been calculated by their distance from the port entrance to the targeted container terminals. For the remaining 4 targeted ports, deviations from this main navigation route to the targeted container ports have been calculated. Table 6.8 below shows how the distance for this sub-factor has been calculated for each of the 6 targeted ports. Additionally, Figure 6.4 provides an easier visualisation of the distance for each targeted port from the main navigation route.

Table 6.8 Calculations made to obtain distance regarding proximity to the main navigation routes

Target container ports	**Distance / Deviation from the main trunk route (Nautical miles)**	
Ho Chi Minh City		
	Busan → Ho Chi Minh City: 1,985 Ho Chi Minh City → Port Kelang: 843	
	• (Busan → Ho Chi Minh City → Port Kelang):	2,828
	• Busan → Port Kelang:	– 2,700
	• Distance from main trunk route:	**128**

Haiphong	Busan → Haiphong: 1,588 Haiphong → Port Kelang: 1,528 • (Busan → Haiphong → Port Kelang): 3,116 • Busan → Port Kelang: – 2,700 • Distance from main trunk route: **416**
Jakarta	Busan → Jakarta: 2,792 Jakarta → Port Kelang: 710 • (Busan → Jakarta → Port Kelang): 3,502 • Busan → Port Kelang: – 2,700 • Distance from main trunk route: **802**
Laem Chabang	Busan → Laem Chabang: 2,528 Laem Chabang → Port Kelang: 1,009 • (Busan → Laem Chabang → Port Kelang): 3,537 • Busan → Port Kelang: – 2,700 • Distance from main trunk route: **837**
Port Kelang	Pilot Station to North Terminal = **14**
Singapore	Pilot Station to PSA Terminal = **5**
Note (Method of measurement)	• Standard for sea route (starting and end points): Busan New Port to Port Kelang • Measured deviation (travelled distance from the main trunk route) of each port using Alphaliner Distance Table (obtained from shipping company) • Note that Port Kelang and Singapore are on the main trunk. The deviations for these ports are calculated by distance from the port entrance to the targeted container terminal

Figure 6.4 Visual representation of proximity to main navigation routes

Number of gantry cranes / gantry crane handling capacity per hour

The data for this sub-factor has been collected from internal data provided by the Korean shipping companies and through publicly available information that could be accessed through each terminals' official websites. Firstly, the data for the number of gantry crane has been collected for the respective targeted container terminals. Subsequently, the data for gantry crane handling capacity per hour has been gathered based on how many 20 ft container boxes could be handled per hour (TEU / hour). Then, the number of gantry cranes was multiplied by the gantry crane handling capacity per hour to yield a total number of how many 20 ft container boxes each terminal could handle per hour. Table 6.9 below displays the collected data for this sub-factor.

Table 6.9 Number of gantry cranes / gantry crane handling capacity per hour data

Target container ports	Number of gantry crane / Gantry crane handling capacity per hour	Total number of TEU handled per hour
Cat Lai terminal (Ho Chi Minh City)	26 crane / 25 TEU per hour	650 TEU per hour
Green port (Haiphong)	5 crane / 23 TEU per hour	115 TEU per hour
Koja terminal (Jakarta)	7 crane / 20 TEU per hour	140 TEU per hour
LCMT (Laem Chabang)	9 crane / 20 TEU per hour	180 TEU per hour
North port terminal (Port Kelang)	32 crane / 25 TEU per hour	800 TEU per hour
PSA terminals, Pasir Panjang terminal (Singapore)	148 crane / 25 TEU per hour	3,700 TEU per hour
Note	The number of gantry cranes was multiplied by the gantry crane handling capacity per hour to yield a total number of how many 20 ft container boxes each terminal could handle per hour.	

Total container cargo volume (import/export & transshipment containers)

The data for this sub-factor has been collected from internal data provided by the Korean shipping companies. The unit of measurement for this sub-factor is the number of TEU per year (gathered from the year 2022). This sub-factor considered all volume from import, export and from transshipment containers. Since there are some Korean shipping companies that do not have services to all 6 targeted container terminals, absent data for this sub-factor was considered to be 0 when performing TOPSIS calculations. There is a case where one of the 7 Korean shipping companies uses slots to ship containers to a few container terminals. In this case, even if the data for frequency of port of call may be 0, the container cargo volume have still been considered for these shipping companies. Table 6.10 shows the data collected for this sub-factor.

Table 6.10 Annual total container cargo volume for 6 targeted port terminals

Annual total container cargo volume (TEU)	**KMTC**	**SinoKor**	**Namsung Shipping**	**Dongjin**	**Pancon**	**Panocean**	**SM Line**
Cat Lai terminal (Ho Chi Minh City)	290,000	318,000	110,000	30,000	51,000	29,000	48,000
Green port (Haiphong)	30,000	98,000	45,000	22,000	10,800	5,000	0
Koja terminal (Jakarta)	110,000	81,000	4,500	0	0	0	0
LCMT (Laem Chabang)	105,000	110,000	15,400	16,000	8,400	4,000	17,000
North port terminal (Port Kelang)	180,000	106,000	6,000	0	0	0	0
PSA terminals, Pasir Panjang terminal (Singapore)	170,000	48,000	6,000	0	0	0	0
Note	Data for several Korean shipping companies that do not have services to all the 6 targeted terminals have been displayed as 0. Namsung Shipping uses slots to ship cargo to North port terminal and PSA terminals.						

Proximity to the markets

The data for this sub-factor has been calculated using Google Maps. Distance was measured from the targeted container terminals to their respective major cities in the vicinity which is the site of consumption. For each container ports, these major cities were designated as follows: Ho Chi Minh City - Central Ho Chi Minh; Haiphong - Hanoi city; Jakarta - Central Jakarta city; Laem Chabang - Bangkok; Port Kelang - Kuala Lumpur; and Singapore - Central Singapore. Table 6.11 provides the distance calculated for this sub-factor.

Table 6.11 Distance of targeted ports' proximity to the markets

Target container ports	**Proximity to the markets**
Ho Chi Minh City	29 km to Central Ho Chi Minh
Haiphong	130 km to Hanoi city
Jakarta	22 km to Central Jakarta city
Laem Chabang	127 km to Bangkok
Port Kelang	49 km to Kuala Lumpur
Singapore	20 km to Central Singapore
Note (Method of measurement)	Using Google Maps, measured the distance from the container terminal to a major city in the vicinity (site of consumption)

Intermodal links

The data for this sub-factor has been collected via matrix question that asked the experts in the 7 Korean shipping companies on their evaluation of each of the 6 targeted container terminals in regards to its intermodal links. Scores of 1 to 10 have been collected for each container terminal to be used for further TOPSIS calculation, and are displayed in Table 6.12 below. Further details regarding this sub-factor will be explained in the upcoming steps.

Table 6.12 Intermodal scores obtained from questionnaire

Intermodal link scores	**KMTC (1)**	**SinoKor (2)**	**Namsung Shipping (1)**	**Dongjin (1)**	**Pancon (2)**	**Panocean (2)**	**SM Line (2)**
Cat Lai terminal (Ho Chi Minh City)	8	6	7	5	5.5	6	6.5
Green port (Haiphong)	6	6.5	4	8	5.5	4	5.5
Koja terminal (Jakarta)	6	6.5	4	5	5	4.5	5
LCMT (Laem Chabang)	6	6.5	5	8	7	6	7
North port terminal (Port Kelang)	8	8	5	8	5	7.5	6.5
PSA terminals, Pasir Panjang terminal (Singapore)	8	9	5	5	7	9.5	6.5
Note	(n) noted after the name of each Korean shipping companies stand for the number of responses obtained for the corresponding companies since not all participants responded to the questionnaires. For companies with 2 respondents, the average scores for each targeted terminal have been considered.						

Area of container yard

The data for this sub-factor was collected from internal data provided by the Korean shipping companies as well as through publicly available information on each terminals' official websites. The unit of measurement for container yards has been unified to hectare. Table 6.13 below shows the data obtained for the 6 targeted container terminals.

Table 6.13 Area of container yard for targeted port terminals

Target container ports	Area of container yard (Hectare)
Cat Lai terminal (Ho Chi Minh City)	160 ha
Green port (Haiphong)	20 ha
Koja terminal (Jakarta)	26 ha
LCMT (Laem Chabang)	19 ha
North port terminal (Port Kelang)	93 ha
PSA terminals, Pasir Panjang terminal (Singapore)	550 ha

Port charges (dockage, pilot cost, towage, etc.)

The data for this sub-factor has been collected from internal data provided by the Korean shipping companies. It should be noted that the charges are subject to variation depending on contract terms for different shipping companies. The charges that are included in this sub-factor are the following: dockage; light due; tonnage; entrance/clearance; quarantine; pilotage; towage; and line handling charge. The standard of measurement for this sub-factor is the cost of a single calling of an 1,800 TEU vessel in USD. It should be noted that congruent amount of charges was applied for each of the corresponding terminal for all 7 Korean shipping companies. As an example, although different terminals have different charge values, all 7 Korean shipping companies would have the same value for Ho Chi Minh City, same value for Haiphong, and so on. Table 6.14 below shows the port charges gathered for the 6 targeted container ports.

Table 6.14 Port charges obtained for targeted container ports

Target container ports	**Port charges (Cost of a single calling of an 1,800 TEU vessel) in USD**
Ho Chi Minh City	$ 13,200
Haiphong	$ 13,000
Jakarta	$ 17,290
Laem Chabang	$ 6,450
Port Kelang	$ 7,000
Singapore	$ 6,000
Note (Method of measurement)	Costs included in port charges: Dockage, light due, tonnage, entrance/clearance, quarantine, pilotage, towage, line handling charge.

Distance of shippers from port

Similar to calculating "proximity to the markets" sub-factor, the data for this sub-factor has also been calculated using Google Maps. In this case, the distance was measured from the manufacturing factories of major Korean companies in the local areas of the targeted ports to the container terminal. The locations of these manufacturing factories have been obtained through semi-structured interviews and through communication with the Korean shipping companies during the primary data gathering process. The manufacturing factories for the 6 targeted ports are mostly Samsung Electronics manufacturing factories and Hyundai Motors manufacturing factories. Table 6.15 below shows the 6 targeted ports with their respective manufacturing factories location and its distance.

Table 6.15 Manufacturing locations for 6 targeted ports

Target container ports	**Major Korean companies' manufacturing factories in the local area**
Ho Chi Minh City	10 km from Samsung Electronics manufacturing factory (Samsung Electronics Ho Chi Minh CE Complex, SEHC)
Haiphong	164 km from Samsung Electronics manufacturing factory (Samsung Electronics Viet Nam Thai Nguyen, SEVT)
Jakarta	58 km from Hyundai Motors manufacturing factory (Bekasi, Delta Mas factory)
Laem Chabang	9 km from Samsung Electronics manufacturing factory (Thai Samsung Electronics in Sriracha, TSE)
Port Kelang	5 km from Samsung Electronics manufacturing factory (Samsung Electronics Malaysia in Port Kelang, SEMA)
Singapore	18 km from Hyundai Motor Group Innovation Center (Jurong Innovation District, JID)
Note	Using Google Maps, measured the distance **from** the manufacturing factories of major Korean companies in the local area **to** the container terminals.

Port depth

The data for this sub-factor has been collected from internal data provided by the Korean shipping companies as well as through publicly available information on each terminals' official websites. The unit of measurement used for calculating port depth was in metres. Table 6.16 below shows port depths for each container terminals.

Table 6.16 Port depths of targeted port terminals

Target container ports	**Port depth (Metres)**
Cat Lai terminal (Ho Chi Minh City)	11.5 m
Green port (Haiphong)	11.25 m
Koja terminal (Jakarta)	13 m
LCMT (Laem Chabang)	14 m
North port terminal (Port Kelang)	13 m
PSA terminals, Pasir Panjang terminal (Singapore)	18 m

Port connectivity

The data for this sub-factor has been collected from the statistics table available from UNCTAD. Data taken from Q2 of 2023 of the port liner shipping connectivity index, quarterly (PLSCI) has been used to measure port connectivity for the 6 targeted ports. According to UNCTADSTAT (2023), PLSCI reflects the ports' position in its liner shipping network around the world, with 100 being set as the highest value in the first quarter of 2006 as the basis. The higher the PLSCI, the better the port's performance in terms of its connectivity. Table 6.17

displays port connectivity values for Q2 of 2023, and Figure 6.5 is taken from UNCTADSTAT to provide clearer explanation of PLSCI and the index.

Table 6.17 Port connectivity values for targeted ports

Target container ports	**Port liner shipping connectivity index**
Ho Chi Minh City	38.5
Haiphong	53.3
Jakarta	37.8
Laem Chabang	77.7
Port Kelang	94.3
Singapore	130.2
Note **(Method of measurement)**	• Index (Maximum Q1 2006 = 100) • Used data from UNCTAD Data taken from Q2 2023

Port Liner Shipping Connectivity Index (PLSCI) explained
The PLSCI is generated for more than 900 container ports in the world. It is generated from 6 components, provided by MDSTransmodal:
(a) The number of scheduled ship calls per week in the port. (b) Deployed annual capacity in Twenty-Foot-equivalent Units (TEU): total deployed capacity offered at the port. (c) The number of regular liner shipping services from and to the port. (d) The number of liner shipping companies that provide services from and to the port. (e) The size in TEU (Twenty-Foot-equivalent Units) of the largest ship deployed on services from and to the port; (f) The number of other ports that are connected to the port through direct liner shipping services. A direct service is defined as a regular service between two ports; it may include other stops in between, but the transport of a container does not require transshipment.
Note: The index is generated as follows: For each component, we divide the port's value by the maximum value for the component in 2006 and then calculate the average of the six components for the port. The port average is then again divided by the maximum value for the average in Q1 2006 and multiplied with 100. The result is a maximum PLSCI of 100 in Q1 2006. This means that the index for the port China, Hong Kong SAR, Hong Kong in Q1 2006 is 100 and all other indices are in relation to this value.

Figure 6.5 Explanation of Port Liner Shipping Connectivity Index (PLSCI) according to UNCTADSTAT

Source: UNCTADSTAT (2023)

6.3.4 Step 4: Constructing a questionnaire to gather data for TOPSIS

Due to lack of publicly available data and difficulty in retrieving needed information to assess intermodal links for the selected 6 container terminals, a matrix question was formed to obtain scores of experts' judgement of the 6 terminals whilst considering the "intermodal link" sub-factor. As shown in Appendix C.1, the matrix question in Part 2 of the questionnaire consisted of a table that allows the experts to tick a score from 1 to 10 to each of the 6 targeted container terminals on their performance of the intermodal link. It had been added after the pairwise comparison questions for AHP.

6.3.5 Step 5: Distributing completed question

In the previous Part A, the total number of questionnaires distributed was decided after confirming from in-depth interviews that there were commonly 2 departments being mentioned in their involvement for selecting ports. Therefore, since there is a total of 7 Korean shipping companies for this research, 14 sets of questionnaires were sent out (7 shipping companies X 2 staff in responsible departments = 14 questionnaires). For the TOPSIS question, the same experts had been chosen to gather the appropriate data for the sub-factor of intermodal link. It was appropriate to ask the same experts for input on their evaluation of intermodal links in the 6 targeted terminals since this sub-factor is one of the attributes that is considered for Korean shipping companies when selecting ports in the ASEAN region.

6.3.6 Step 6: Gathering completed questions

The matrix question to be used for TOPSIS calculation had been added to the end of the AHP questionnaires as they were sent out from June 2023 to July 2023. Therefore, the timeline for the distributing and gathering of questionnaires for this matrix question is same as that of AHP as described in section 6.2.4.

Additionally, since the same experts from the AHP questionnaires have been used, it can be noted that most of the gathered responses from the respondents possessed over 16 years of experience in the shipping industry. Table 6.18 below shows the number of years in the field for the total of 12 respondents.

Table 6.18 Experts' number of experiences

Number of years in the field	Number of experts
6-10 years	1
11-15 years	4
Over 16 years	7

6.3.7 Step 7: Using the collected data to calculate alternative rankings

In order to calculate for priority of order for the selected alternatives (6 container ports), this step uses the data that have been collected throughout the previous steps. The full steps of TOPSIS methodology is employed to yield the priority of order. It is important to note that in one of the phases of TOPSIS calculations, weights of the factors are required. The weights used here, as stated before, were obtained from AHP of Part A of this chapter; thus, fulfilling the use of two-step integrated AHP-TOPSIS. The different steps of TOPSIS calculations have been summarised into 7 phases in Chapter 5, and are displayed again like below:

- Phase 1 - Constructing the decision matrix
- Phase 2 - Calculating the normalised decision matrix

- Phase 3 - Calculating the weighted normalised decision matrix
- Phase 4 - Determining positive ideal solution (PIS) and negative ideal solution (NIS)
- Phase 5 - Calculating the separation measure
- Phase 6 - Calculating the relative closeness to the ideal solution
- Phase 7 - Ranking the preference order

As noted before, these 7 phases of TOPSIS calculation had been performed using the data obtained through either as secondary data source (statistics table from UNCTAD, Google Maps, terminals' official websites, data from Korean shipping companies, data from shipping company that used the Alphaliner Distance Table) or as primary data source (a matrix question purposed to capture experts' evaluations through questionnaire).

Phase 1 - Constructing the decision matrix

This phase consists of representing all the data gathered in the previous steps for the attributes in the decision matrix. The decision matrix can be expressed as below:

$$D = \begin{bmatrix} & c_1 & c_2 & c_3 & \cdots & c_n \\ A_1 & x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ A_3 & x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{bmatrix}$$

Equation 6.1

where A_i = i^{th} alternative related and x_{ij} is the performance value of alternative with respect to criterion c_j.

The constructed decision matrix is shown in Table 6.19, which displays the collected secondary and primary data (intermodal link scores) evaluating 6 alternatives for each of the 12 sub-factors (labelled as "SF") that had been previously explained in Step 3 of section 6.3.3 in this chapter.

Phase 2 - Calculating the normalised decision matrix

This phase normalises the decision matrix D since the different attributes all have different units of measurement. Through this normalisation, different attribute units are transformed into the same unit matrix in order for correct comparison to be carried out. Calculating the normalised decision matrix is done by using the formula below.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = \mathbf{1}, \mathbf{2}, \mathbf{3}, \dots, m \text{ and } j = \mathbf{1}, \mathbf{2}, \mathbf{3}, \dots, n$$

Equation 6.2

Each collected value in its column, as shown in Table 6.19, was divided by the square root of the sum of squares of all values in that respective column. Taking the first alternative, "Cat Lai" as an example, the value of r_{ij} was calculated as follows:

r_{ij} =

$$\frac{128}{\sqrt{(128^2)+(416^2)+(802^2)+(837^2)+(14^2)+(5^2)}}$$

= 0.103365932

Similarly, all other values of alternatives with respect to the sub-factors have been calculated with above calculation technique per Equation 6.2 to yield their respective r_{ij} values and are displayed in the normalised decision matrix shown in Table 6.20.

Phase 3 - Calculating the weighted normalised decision matrix

The weighted normalised decision matrix (v_{ij}) is constructed by multiplying the values obtained in normalised decision matrix (from phase 2) by the weights obtained for each attribute through AHP in the previous Part A of this chapter. The calculation is carried out with the formula shown below:

$$v_{ij} = w_j \cdot r_{ij}, \qquad i = 1,2, \ldots, n, \quad j = 1,2, \ldots, n$$

Equation 6.3

where w_j is the weight of the j^{th} attribute or criterion.

As found in Part A of this chapter, the weights of the 12 sub-factors are the following: 0.1432, 0.3350, 0.0325, 0.1462, 0.0499, 0.0480, 0.0322, 0.0372, 0.0309, 0.0810, 0.0370, and 0.0269. The weight values are multiplied with each column of the normalised decision matrix obtained in the previous phase. For example, the value for v_{ij} of the alternative, “Cat Lai” with respect to the sub-factor 1 (Proximity to main navigation routes) is calculated as follows:

v_{ij} = 0.1432 X 0.1034 = 0.0148

Similarly, all other values of have been calculated with above calculation technique per Equation 6.3 to yield their respective v_{ij} values and are displayed in the weighted normalised decision matrix shown in Table 6.21.

Table 6.19 Decision matrix

Decision matrix	(SF1) Proximity to main navigation routes	(SF2) Frequency of port of call	(SF3) Port charges	(SF4) Terminal Handling Charge	(SF5) Total container cargo volume	(SF6) Proximity to the markets	(SF7) Distance of shippers from port	(SF8) Intermodal links	(SF9) Port depth	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	(SF12) Port connectivity
Cat Lai	128	14.814	13,200	62	125,143	29	10	6.286	11.5	650	160	38.5
Green port	416	4	13,000	45	30,114	130	164	5.643	11.25	115	20	53.3
Koja	802	2	17,290	132	27,929	22	58	5.143	13	140	26	37.8
LCMT	837	9.6	6,450	75.05	39,400	127	9	6.5	14	180	19	77.7
North port	14	3.143	7,000	107.4	41,714	49	5	6.857	13	800	93	94.3
PSA terminals	5	4.286	6,000	155.8	32,000	20	18	7.143	18	3,700	550	130.2

Table 6.20 Normalised decision matrix

Normalised decision matrix	(SF1) Proximity to main navigation routes	(SF2) Frequency of port of call	(SF3) Port charges	(SF4) Terminal Handling Charge	(SF5) Total container cargo volume	(SF6) Proximity to the markets	(SF7) Distance of shippers from port	(SF8) Intermodal links	(SF9) Port depth	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	(SF12) Port connectivity
Cat Lai	0.1034	0.7809	0.4761	0.2437	0.8502	0.1504	0.0570	0.4074	0.3441	0.1689	0.2751	0.1985
Green port	0.3359	0.2109	0.4689	0.1769	0.2046	0.6744	0.9346	0.3657	0.3366	0.0299	0.0344	0.2748
Koja	0.6477	0.1054	0.6236	0.5188	0.1897	0.1141	0.3305	0.3333	0.3890	0.0364	0.0447	0.1949
LCMT	0.6759	0.5061	0.2326	0.2950	0.2677	0.6589	0.0513	0.4213	0.4189	0.0468	0.0327	0.4005
North port	0.0113	0.1657	0.2525	0.4221	0.2834	0.2542	0.0285	0.4444	0.3890	0.2078	0.1599	0.4861
PSA terminals	0.0040	0.2259	0.2164	0.6124	0.2174	0.1038	0.1026	0.4629	0.5386	0.9612	0.9458	0.6712

Table 6.21 Weighted normalised decision matrix

Weighted normalised decision matrix	(SF1) Proximity to main navigation routes	(SF2) Frequency of port of call	(SF3) Port charges	(SF4) Terminal Handling Charge	(SF5) Total container cargo volume	(SF6) Proximity to the markets	(SF7) Distance of shippers from port	(SF8) Intermodal links	(SF9) Port depth	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	(SF12) Port connectivity
Cat Lai	0.0148	0.2616	0.0155	0.0356	0.0424	0.0072	0.0018	0.0152	0.0106	0.0137	0.0102	0.0053
Green port	0.0481	0.0706	0.0152	0.0259	0.0102	0.0324	0.0301	0.0136	0.0104	0.0024	0.0013	0.0074
Koja	0.0927	0.0353	0.0203	0.0758	0.0095	0.0055	0.0106	0.0124	0.0120	0.0029	0.0017	0.0052
LCMT	0.0968	0.1695	0.0076	0.0431	0.0134	0.0316	0.0017	0.0157	0.0129	0.0038	0.0012	0.0108
North port	0.0016	0.0555	0.0082	0.0617	0.0141	0.0122	0.0009	0.0165	0.0120	0.0168	0.0059	0.0131
PSA terminals	0.0006	0.0757	0.0070	0.0895	0.0108	0.0050	0.0033	0.0172	0.0166	0.0779	0.0350	0.0181

Phase 4 - Determining positive ideal solution (PIS) and negative ideal solution (NIS)

The PIS and NIS are determined by finding the maximum and the minimum values in each column of the weighted normalised decision matrix obtained from phase 3. Mathematical expression to find PIS and NIS are shown below:

$$A^{+} = \{(max\ v_{ij} \mid j \in J) \text{ or } (min\ v_{ij} \mid j \in J') \text{ for } i = 1,2,\dots,m\} = \{v_1^{+}, v_2^{+}, \dots, v_n^{+}\}$$

Equation 6.4

$$A^{-} = \{(min\ v_{ij} \mid j \in J) \text{ or } (max\ v_{ij} \mid j \in J') \text{ for } i = 1,2,\dots,m\} = \{v_1^{-}, v_2^{-}, \dots, v_n^{-}\}$$

Equation 6.5

where J = 1,2,3,...,n. is associated with benefit (positive criteria) and J′ = 1,2,3,...,n is associa ted with cost (negative criteria).

Values determined per Equation 6.4 and Equation 6.5 can be seen in Table 6.22.

Table 6.22 Positive & Negative Ideal solutions

Normalised decision matrix	(SF1) Proximity to main navigation routes	(SF2) Frequency of port of call	(SF3) Port charges	(SF4) Terminal Handling Charge	(SF5) Total container cargo volume	(SF6) Proximity to the markets	(SF7) Distance of shippers from port	(SF8) Intermodal links	(SF9) Port depth	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	(SF12) Port connectivity
A^+	0.0006	0.2616	0.0070	0.0259	0.0424	0.0050	0.0009	0.0172	0.0166	0.0779	0.0350	0.0181
A^-	0.0968	0.0353	0.0203	0.0895	0.0095	0.0324	0.0301	0.0124	0.0104	0.0024	0.0012	0.0052

Phase 5 - Calculating the separation measure

The equations below calculate Euclidean distance of the alternatives from the ideal solutions.

Separation of the alternatives from the PIS is found per equation below:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2}, i = 1,2, \dots , m$$

Equation 6.6

Taking the first alternative, "Cat Lai" as an example, the value of S_i^+ was calculated as follows:

S_i^+ =

$$\sqrt{\begin{array}{l}(0.0148 - 0.0006)^2 + (0.2616 - 0.2616)^2 + (0.0155 - 0.0070)^2 + (0.0356 - 0.0259)^2 \\ + (0.0424 - 0.0424)^2 + (0.0072 - 0.0050)^2 + (0.0018 - 0.0009)^2 + (0.0152 - 0.0172)^2 \\ + (0.0106 - 0.0166)^2 + (0.0137 - 0.0779)^2 + (0.0102 - 0.0350)^2 + (0.0053 - 0.0181)^2\end{array}}$$

= 0.0729

Calculations made per Equation 6.6 and yielded values that can be seen in Table 6.23 (calculation process displaying results of $v_{ij} - v_j^+$ for all alternatives with respect to the sub-factors and the corresponding A^+ values) and Table 6.24.

Table 6.23 Calculation process to obtain S_i^+ for each alternative

Calculating for S_i^+	(SF1) Proximity to main navigation routes	(SF2) Frequency of port of call	(SF3) Port charges	(SF4) Terminal Handling Charge	(SF5) Total container cargo volume	(SF6) Proximity to the markets	(SF7) Distance of shippers from port	(SF8) Intermodal links	(SF9) Port depth	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	(SF12) Port connectivity
Cat Lai	0.0142	0.0000	0.0084	0.0098	0.0000	0.0022	0.0009	-0.0021	-0.0060	-0.0642	-0.0248	-0.0127
Green port	0.0475	-0.1910	0.0082	0.0000	-0.0322	0.0274	0.0292	-0.0036	-0.0062	-0.0754	-0.0337	-0.0107
Koja	0.0922	-0.2263	0.0132	0.0500	-0.0330	0.0005	0.0097	-0.0048	-0.0046	-0.0749	-0.0333	-0.0128
LCMT	0.0962	-0.0921	0.0005	0.0173	-0.0291	0.0266	0.0007	-0.0015	-0.0037	-0.0741	-0.0338	-0.0073
North port	0.0010	-0.2061	0.0012	0.0359	-0.0283	0.0072	0.0000	-0.0007	-0.0046	-0.0610	-0.0291	-0.0050
PSA terminals	0.0000	-0.1859	0.0000	0.0637	-0.0316	0.0000	0.0024	0.0000	0.0000	0.0000	0.0000	0.0000

Table 6.24 Separation of the alternatives from the positive ideal solution

Alternatives	S_i^+
Cat Lai	0.0729
Green port	0.2201
Koja	0.2655
LCMT	0.1621
North port	0.2219
PSA terminals	0.1991

Similarly, separation of the alternatives from the NIS is found per equation below:

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}, i = 1,2, \dots, m$$

Equation 6.7

Taking the first alternative, "Cat Lai" as an example, the value of S_i^- was calculated as follows:

S_i^- =

$$\sqrt{\begin{array}{l}(0.0148 - 0.0968)^2 + (0.2616 - 0.0353)^2 + (0.0155 - 0.0203)^2 + (0.0356 - 0.0895)^2 \\ + (0.0424 - 0.0095)^2 + (0.0072 - 0.0324)^2 + (0.0018 - 0.0301)^2 + (0.0152 - 0.0124)^2 \\ + (0.0106 - 0.0104)^2 + (0.0137 - 0.0024)^2 + (0.0102 - 0.0012)^2 + (0.0053 - 0.0052)^2\end{array}}$$

= 0.2522

Calculations made per Equation 6.7 and yielded values that can be seen in Table 6.25 (calculation process displaying results of $v_{ij} - v_j^-$ for all alternatives with respect to the sub-factors and the corresponding A^- values) and Table 6.26.

Table 6.25 Calculation process to obtain S_i^- for each alternative

Calculating for S_i^-	(SF1) Proximity to main navigation routes	(SF2) Frequency of port of call	(SF3) Port charges	(SF4) Terminal Handling Charge	(SF5) Total container cargo volume	(SF6) Proximity to the markets	(SF7) Distance of shippers from port	(SF8) Intermodal links	(SF9) Port depth	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	(SF12) Port connectivity
Cat Lai	-0.0820	0.2263	-0.0048	-0.0539	0.0330	-0.0252	-0.0283	0.0028	0.0002	0.0113	0.0090	0.0001
Green port	-0.0487	0.0353	-0.0050	-0.0637	0.0007	0.0000	0.0000	0.0012	0.0000	0.0000	0.0001	0.0021
Koja	-0.0040	0.0000	0.0000	-0.0137	0.0000	-0.0269	-0.0195	0.0000	0.0016	0.0005	0.0004	0.0000
LCMT	0.0000	0.1342	-0.0127	-0.0464	0.0039	-0.0007	-0.0284	0.0033	0.0025	0.0014	0.0000	0.0055
North port	-0.0952	0.0202	-0.0121	-0.0278	0.0047	-0.0202	-0.0292	0.0041	0.0016	0.0144	0.0047	0.0078
PSA terminals	-0.0962	0.0404	-0.0132	0.0000	0.0014	-0.0274	-0.0268	0.0048	0.0062	0.0754	0.0338	0.0128

Table 6.26 Separation of the alternatives from the negative ideal solution

Alternatives	S_i^-
Cat Lai	0.2522
Green port	0.0878
Koja	0.0362
LCMT	0.1456
North port	0.1094
PSA terminals	0.1400

Phase 6 - Calculating the relative closeness to the ideal solution

The equation below has been used to calculate the relative closeness C_i. It represents the relative closeness of alternative A_i with respect to PIS A^+. The calculated relative closeness closer to 1 indicate better performance of the alternatives.

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}, \quad 0 < C_i < 1, \;\; i = 1,2,\dots,m$$

Equation 6.8

Taking the first alternative, "Cat Lai" as an example, its C_i value is calculated as follows:

C_i of Cat Lai = $\frac{0.2522}{0.0729+0.2522}$ = 0.7758

Calculations made per Equation 6.8 yielded values that can be seen in Table 6.27.

Phase 7 - Ranking the preference order

This is the final phase of the TOPSIS calculation that involves ranking the alternatives by ordering the values obtained for *Ci* in phase 6 in descending manner where the highest value of *Ci* (closest to the value of 1) represents the most optimal alternative. The results obtained from phase 5 (separation from PIS, NIS), phase 6 (relative closeness to ideal solution), and phase 7 (final ranks of alternatives) are shown in the Table 6.27.

Table 6.27 S_i^+ , S_i^- , C_i values and alternative rankings

	Separation from PIS (S_i^+)	**Separation from NIS (S_i^-)**	**Relative closeness to ideal solution (C_i)**	**Final ranks of alternatives**
Cat Lai terminal (Ho Chi Minh City)	0.0729	0.2522	0.7758	**1**
Green port (Haiphong)	0.2201	0.0878	0.2851	**5**
Koja terminal (Jakarta)	0.2655	0.0362	0.1199	**6**
LCMT (Laem Chabang)	0.1621	0.1456	0.4732	**2**
North port terminal (Port Kelang)	0.2219	0.1094	0.3303	**4**
PSA terminals, Pasir Panjang terminal (Singapore)	0.1991	0.1400	0.4128	**3**

6.4 Chapter summary

In this chapter, integrated use of AHP and TOPSIS has been incorporated to find both the weights of the 12 port selection factors (attributes), and the optimal ranks of 6 targeted container ports selected for this research. The combination of these methodologies has been applied because this proves to be more advantageous than when they are used alone. Additionally, as mentioned previously, the 12 factors have been determined through various processes involving SLR, pilot test, and interviews, while the 6 targeted container ports have been chosen based on their high port trade volume with South Korea in 2020.

Following the same steps that were mentioned in Chapter 5, this current chapter first covered the details involved in the AHP method used to determine the weights of the 12 factors. Again, these 12 factors have been identified by incorporation of various adjustments as the initial set of factors passed through numerous processes that included SLR, pilot test with academic experts, and semi-structured interviews with senior industry experts in the mentioned order. Afterwards, using questionnaires, 11 senior experts' judgment on the importance of weights have been collected using pairwise comparisons. Then, the weights have been calculated using the *Expert Choice* AHP software as it provides user-friendly graphical interfaces as well as automatic calculations of the weights and inconsistencies that help with reducing human error in calculations. It was found that the sub-factor of "frequency of port of call" was the most important factor with a very dominant weight.

Next, this chapter moves onto AHP-TOPSIS part. It has first identified the attributes (sub-factors) used to assess the alternatives (6 targeted ports). These 12 identified sub-factors are the same as the ones used in Part A of this chapter regarding AHP. The global weights of the 12 sub-factors calculated with AHP are also brought from Part A to be further used in Part B as well. Then, data regarding the 12 sub-factors have been gathered either through publicly available secondary data sources such as statistics table of UNCTAD, Google Maps, and terminals' official websites or through exclusively available secondary data sources such as data obtained from the interviewed Korean shipping companies and the Alphaliner Distance Table that they have used. With the collection of these data and the incorporation of the results obtained from Part A, TOPSIS calculation was carried out to yield the rankings of the 6 targeted container ports. It was found that Cat Lai terminal in Ho Chi Minh City was the most preferred container port for Korean shipping companies dealing in SSS to Southeast Asian countries.

In the next chapter, numerous scenarios and simulations will be conducted and sensitivity analysis will be carried out to determine how the rankings of the alternatives (6 targeted ports) will change depending on different adjustments to the original input data. Through such sensitivity analysis and construction of scenarios, action plan and strategies could be drawn up from observing how much of certain aspect of the port need to be increased or decreased to overtake its higher ranked ports.

CHAPTER 7: SENSITIVITY ANALYSIS AND SCENARIO TESTING

7.1 Chapter introduction

This chapter is divided into two main parts: the first part covering sensitivity analysis of the AHP-TOPSIS framework, which has been utilised in the previous chapters; and the second part covering multiple scenario and simulation tests that manipulate performance input values to instigate desired changes to the rankings of the 6 ports.

The first part of this chapter uses sensitivity analysis to test the robustness of the previously used AHP-TOPSIS framework. The second part of this chapter is further divided into two sections that have different kinds of testing. The first section increases or decreases the percentages of performance input values independently, for example, by increasing just the frequency of port of call factor by 10% whilst all the other factor values remain the same. The second section increases or decreases the percentages of performance input values as well, however, it also considers the displaced number that occurs with the change to compensate for the change in the total amount. Both of these testing provide insight to what and how much changes are needed to tweak and affect the obtained rankings of the 6 ports.

7.2 Sensitivity analysis of AHP-TOPSIS framework

Sensitivity analysis is incorporated in order to test and find out how the ranking of the alternatives will change depending on how much change is made to the input data. Triantaphyllou et al., (1998) also notes that the purpose of conducting sensitivity analysis is to observe and obtain new output values when the input data change. Changes in the original weights of the sub-factors (obtained through AHP in Chapter 6) will be made to test the final changes of the ranking of the alternatives in this sensitivity analysis. There are already numerous studies in port and supply chain literature that has incorporated the use of sensitivity analysis after performing AHP and TOPSIS (Roh et al., 2015; Deng et al., 2017; Celik and Akyuz, 2018; Li et al., 2023). In MCDM methods, sensitivity analysis is a commonly suggested method to validate the feasibility and robustness of MCDM methods (Satty and Ergu, 2015). Additionally, according to Saltelli (2002), sensitivity analysis verifies the robustness of the used model and it is considered to be necessary for model building in diagnostic (estimation) or prognostic (forecast) settings.

Sensitivity analysis is performed in this chapter on the proposed MCDM method by making changes to the criteria weight. There are ample amounts of studies that discuss how the obtained results from MCDM methods are sensitive to changes in criteria weight (Pamucar and Cirovic, 2015; Stevic et al., 2020). Thus, applying sensitivity analysis to observe the impact of the criteria weight on the final alternative rankings is essential (Animah et al., 2018). In this study, such changes to the weights occur by swapping one criterion's weight - obtained through AHP - with another criterion's weight in a pairwise combination fashion; this type of weight swapping has been demonstrated in logistics and port selection literature in Onut and Soner, (2008), Onut et al., (2010), and Zyoud et al., (2016). Also, this pairwise swapping of criteria's weights occurs whilst the remaining criteria's weights remain the same and each swap is stated as a condition. Next, relative closeness to the ideal solutions (C_i) for these conditions are calculated to observe changes in the ranking of the alternatives. This exchange of criteria's weights further enables an examination into the changing effects of criteria weight on the ranks of alternatives and allows the authors to observe, with ease, as to which factor would bring about the most change if swapped.

As Bottero and Ferretti (2010) points out, sensitivity analysis considers the "what if" questions to see how stable the outcome is when the input such as the criteria weight is changed. Analysis was carried out on the proposed model's 12 sub-factors. The 12 sub-factors for the sensitivity analysis are labelled from A to L in which the order of the letter labelling is congruent to that of the previous sub-factor number labelling seen in Chapter 6, in Table 6.19. For the sub-factors, the weight of each sub-factors has been exchanged in a pairwise fashion with other sub-factors, and each different combination represent different conditions of the change in the weight, as mentioned before. It should be noted that the main condition indicated in the upcoming tables for sensitivity analysis refer to the original weight and original relative closeness to the ideal solutions (C_i) values obtained from AHP in Part A and TOPSIS in Part B of Chapter 6. For each condition, C_i values are calculated. As 2 of the sub-factor weights are exchanged at a single time for each condition, a total of 66 conditions was devised. Further detailed display of 66 sub-factor weight changes are shown in Appendix F.1.

Figures 7.1 and 7.2 below show the calculated results of the C_i under 66 conditions. It can be seen that the rankings of the ports according to their C_i values remained almost unchanged for the 1st and 6th place which are Cat Lai and Koja, respectively. The C_i values for other ports also remain mostly the same. It is important to note that from AHP, it was found that the sub-factor B (frequency of port of call) has the highest weight of 0.3350, which is a value that is more than double the value of the sub-factor with the second highest weight of 0.1462. Additionally, top 3 sub-factors with highest weights take up around 62% of the overall weight. So naturally, when such high weights were swapped with other lower weights, the C_i values exhibited fluctuations that led to changes in the overall rankings of the most optimal ports.

Looking at Figure 7.1 and 7.2, it could be observed that there were fluctuations of C_i values - primarily among the conditions AB, and BC to BL - when the sub-factor weight of B was exchanged with other sub-factor weights. The C_i values for the remaining conditions remained mostly the same. Additionally, there were minor fluctuations when the 2nd highest (sub-factor D) and the 3rd highest (sub-factor A) sub-factor weights were exchanged with places with lower sub-factors such as proximity to the markets (sub-factor F) and distance of shippers from port (sub-factor G).

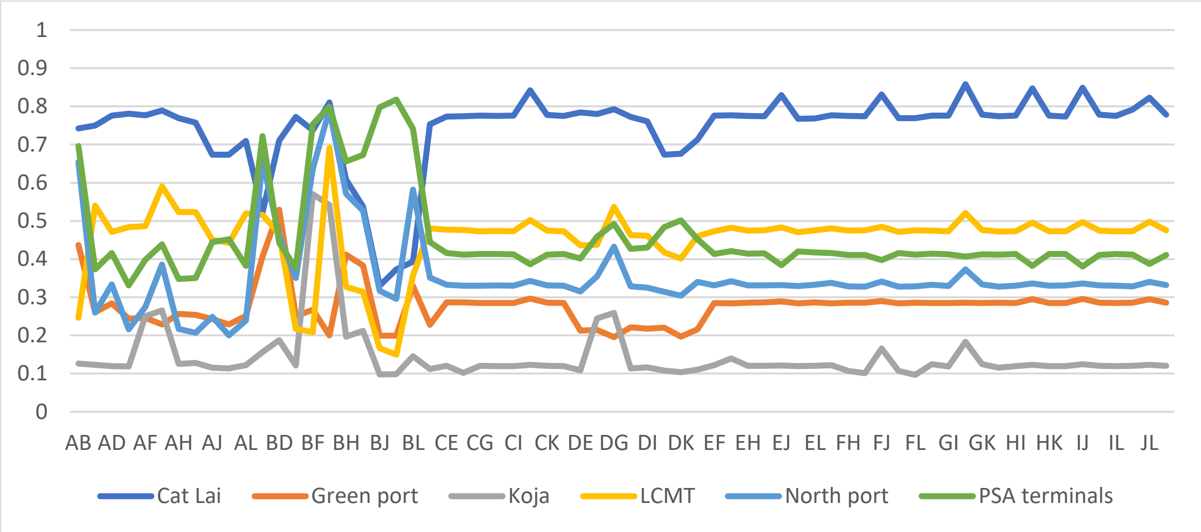

Figure 7.1 Line chart sensitivity analyses of sub-factors

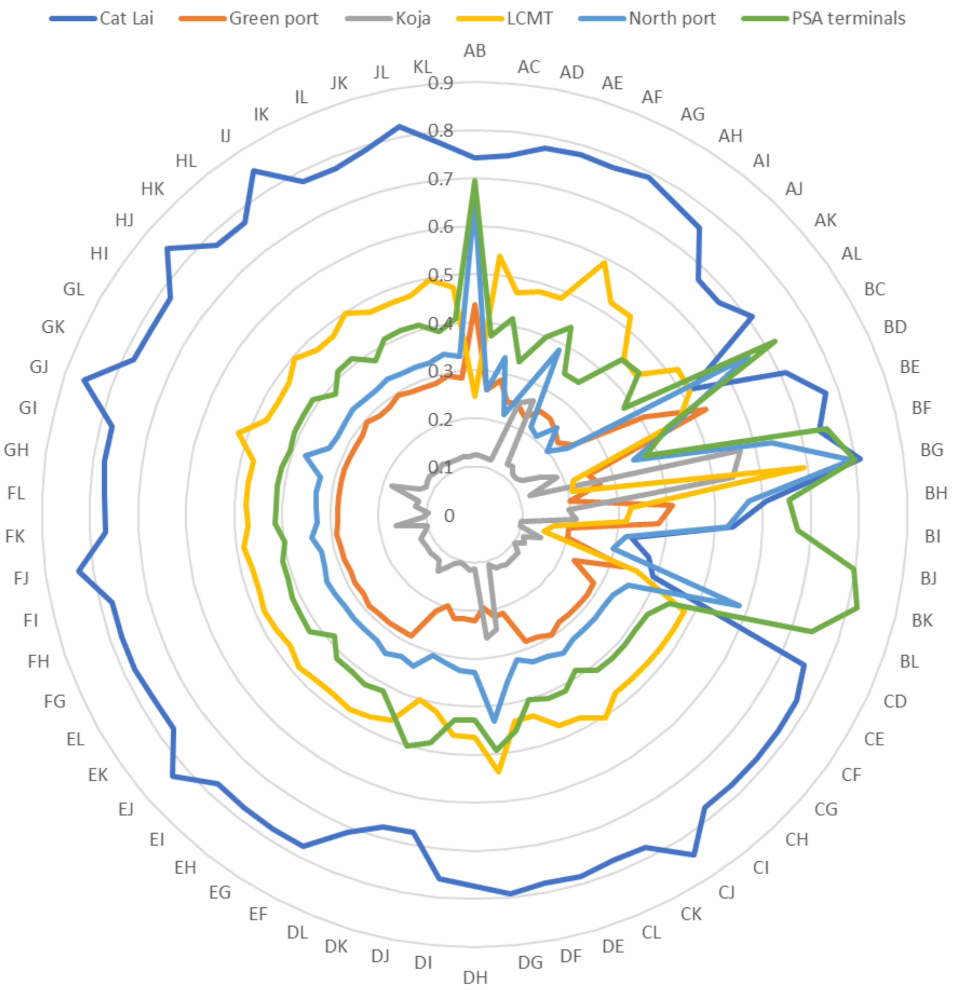

Figure 7.2 Radar chart sensitivity analyses of sub-factors

According to the Figures 7.1 and 7.2, with the C_i values of all 66 conditions numerically represented in Appendix F.2, the following below are the highest and lowest C_i values that each of the 6 alternatives yielded within the 66 conditions:

- Cat Lai terminal displayed its highest C_i value of 0.8582 under the condition GJ (Distance of shippers from port & Number of gantry cranes / gantry crane handling capacity per hour). On the other hand, Cat Lai terminal exhibited its lowest C_i value of 0.3302 under the condition BJ (Frequency of port of call & Number of gantry cranes / gantry crane handling capacity per hour).

- Green port displayed its highest C_i value of 0.5294 under the condition BD (Frequency of port of call & Terminal Handling Charge). On the other hand, Green port exhibited its lowest C_i value of 0.1955 under the condition DG (Terminal Handling Charge & Distance of shippers from port).
- Koja terminal displayed its highest C_i value of 0.5702 under the condition BF (Frequency of port of call & Proximity to the markets). On the other hand, Koja terminal exhibited its lowest C_i value of 0.0967 under the condition FL (Proximity to the markets & Port connectivity).
- LCMT displayed its highest C_i value of 0.6915 under the condition BG (Frequency of port of call & Distance of shippers from port). On the other hand, LCMT exhibited its lowest C_i value of 0.1495 under the condition BK (Frequency of port of call & Area of container yard).
- North port displayed its highest C_i value of 0.7914 under the condition BG (Frequency of port of call & Distance of shippers from port). On the other hand, North port exhibited its lowest C_i value of 0.2003 under the condition AK (Proximity to main navigation routes & Area of container yard).
- PSA terminals displayed its highest C_i value of 0.8178 under the condition BK (Frequency of port of call & Area of container yard). On the other hand, PSA terminals exhibited its lowest C_i value of 0.3310 under the condition AE (Proximity to main navigation routes & Total container cargo volume).

Examining the patterns of the combinations that yielded each alternatives their highest values, it can be observed again that such occurrences took place when sub-factor B (Frequency of port of call) was exchanged with other sub-factors.

7.3 Scenario testing using AHP-TOPSIS framework

In this section, modifications to the original input data (obtained for sub-factors in TOPSIS in chapter 6) will be made to test the final changes in the order of the alternatives. It is important to note that the results obtained through MCDM method are strongly related to the values corresponding to the evaluating data as well as the weights of the criteria; therefore, great care has to be taken whilst interpreting the results of such methods (Wolters and Mareschal, 1995). There are already numerous studies in port and logistics literature that adjusts the input data by certain increments to observe the change in the rankings of the alternatives (Park et al., 2015; Wang and Yeo, 2017; Pham and Yeo, 2018; Lu et al., 2022). Thus, in this current section, scenarios are constructed and presented for further analysis. This section is comprised of two different kinds of testing: one where there are independent (ceteris paribus) improvements to the performance input values; and another where there are proportionate increases or decreases to the performance input values. Both of these kinds of testing provide various scenarios and simulations to see how much change to the performance values are needed for one port to overtake the preceding port in its ranking.

7.3.1 Independent (ceteris paribus) improvements to performance input values

The use of scenarios to run simulations on the components of the proposed model to stimulate changes in the result of interest is useful in observing how much change is needed. There are numerous studies in the port literature as well that make use of such scenarios. O'Connor et al., (2020) used the outputs obtained from its discrete choice model to run scenarios based on policies to examine probability changes of carriers choosing Irish port terminals. Mueller et al., (2020) investigated important port choice factors and their influence on market shares in the hinterland. In their study, the authors created scenarios that demonstrate how the changing oil price impacts the transport cost by different hinterland transport modes. Chou (2010a) depicted multiple scenarios that assumed hypothetical situations where the values of port choice factors would increase or decrease and how these changes would affect the final rankings of the best candidate for a transshipment hub port. Considering that the use of scenarios and manipulation of direct input variable of the sub-factors are already well used in port selection literature to observe changes toward a certain outcome, this current study also developed scenarios with various simulations to achieve hypothetical outcomes.

In the following section, three scenarios have been constructed to see what changes are needed to alter the final alternative rankings of the most optimal port. Within these scenarios, various simulations are conducted that, ceteris paribus, increase or decrease values of one or two sub-factors by designated percentages. In this study, these designated percentage points may reach high numbers in order to see how much change it would take to satisfy each scenario. In regards to the use of high percentage points, in port selection literature, it should be noted that there are studies that allow great changes in the input factors to obtain the desired outcome. Such literature includes a study from Button et al., (2015) that has allowed changes between -50% and +50% on four input factors whilst conducting sensitivity analysis to observe altering results in the final attractiveness of the ports. Another port selection literature from Aversa et al., (2005) tested to see what the minimum independent (ceteris paribus) improvements in the original input value of the factors were required to satisfy the study's hypothetical condition, and consequently, the study noted an increase in a factor that reached 350%. Just like the simulations developed for this study's scenarios, Aversa et al., (2005) also constructed scenarios and applied certain percentage changes to either one or two original input values simultaneously to reach the desired level of reference value. Further, although port selection study from Guy and Urli (2006) does not state specific percentage points of change to the performance values, the study creates scenarios that give twofold advantage of one or two criteria for the performance of one port over another. *"In other words, each port is alternatively supposed to be twice as good as the other in terms of cost, service and both"* (Guy and Urli. 2006, p. 178). This may in turn create cases where the percentage points of increase or decrease may reach exceedingly high numbers as well.

For this study, changes to the values of targeted sub-factors in multiple simulations will vary by each scenario and will occur while the rest of the parameters remain unchanged. It should be noted that the changes to the input values refer to the original values obtained in the decision matrix as can be seen in Table 6.19, which displays the collected secondary and primary data evaluating 6 alternatives for each of the 12 sub-factors.

Additionally, prior to viewing the changes that are applied to performance input values through different scenarios constructed in this section, it may be useful to view the list of sub-factors by their order of weights in Figure 6.3 and the ranks of the alternatives in Table 6.27. For the ease of referring to the sub-factors in this section, below are abbreviated titles to the particular sub-factors that are used in this section. Just as in Chapter 6, "SF" stands for Sub-Factor, and the numbers at the end of the "SF" below correspond to the same numbering that was used initially in Chapter 6, as seen in Table 6.19.

- Frequency of port of call (SF2)
- Terminal Handling Charge (loading & unloading cost, etc.) (SF4)
- Proximity to main navigation routes (SF1)
- Number of gantry cranes / gantry crane handling capacity per hour (SF10)
- Total container cargo volume (import/export & transshipment containers) (SF5)

- Area of container yard (SF11)
- Port charges (dockage, pilot cost, towage, etc.) (SF3)

7.3.1.1 Scenario 1

- Could Laem Chabang, LCMT (2nd ranking) overtake Ho Chi Minh City, Cat Lai's (1st ranking) port competitiveness in terms of ranking?

SF2 (Frequency of port of call) is 1st in weight ranking. The values can be changed depending on the shipping company's strategy.

SF4 (Terminal Handling Charge) is 2nd in weight ranking. The values can be changed depending on various factors that can be influenced by shipping company's decisions such as contractual agreement or through change in policies.

SF1 (Proximity to main navigation routes) is 3rd in weight ranking and very closely follows the 2nd place by only a minute difference of around 2%.

Although SF1 may have great importance in weight – unlike SF2 and SF4 – its values cannot be changed since this is a measurement of distance and the port locations of these 6 targeted container ports cannot be physically changed unless they relocate themselves to some significant distance away. Therefore, in scenario 1, improvements have been given to the input values of the top 2 highest weighted factors (SF2 and SF4) in order to see if changes could be made to the port ranking. The following below are 3 simulations for this scenario:

Simulation 1. What if the SF2 (highest weight) for Laem Chabang increased by 5%, 10%, 15%?

Simulation 2. What if SF4 (2nd highest weight) for Laem Chabang decreased by 5%, 10%, 15%?

Simulation 3. With SF2 increases (5%, 10%, 15%), what if SF4 changes also occurred simultaneously? How & at what point would both of these changes affect the Laem Chabang overtaking Ho Chi Minh City in terms of ranking?

Simulation 1

As part of testing simulation 1, the input values for the port factor of "frequency of port of call" in regards to Laem Chabang have been increased by 5%, 10%, and 15%. However, the Laem Chabang, LCMT (2nd ranking) failed to overtake the Ho Chi Minh City, Cat Lai (1st ranking). Table 7.1 below displays how much change the 15% of increase brought to the overall C_i values, which determines the rankings. The "original decision matrix" on the left displays values per original while the "changed decision matrix" on the right displays yellow highlighted value that experienced 15% increase from the original. It can be seen that the gap in the C_i values between the 1st ranking and the 2nd ranking still is far apart.

Table 7.1 Decision matrix values before & after change (+15% to SF2 for LCMT)

Original Decision matrix	(SF2) Frequency of port of call	C_i	Rank	**Changed Decision matrix**	(SF2) Frequency of port of call	C_i	Rank
Cat Lai	14.814	0.7758	1	Cat Lai	14.814	0.7702	1
Green port	4	0.2851	5	Green port	4	0.2899	5
Koja	2	0.1199	6	Koja	2	0.1229	6
LCMT	9.6	0.4732	2	LCMT	11.04	0.5248	2
North port	3.143	0.3303	4	North port	3.143	0.3376	4
PSA terminals	4.286	0.4128	3	PSA terminals	4.286	0.4204	3

Simulation 2

As part of testing simulation 2, the input values for the port factor of "THC" in regards to Laem Chabang have been decreased by 5%, 10%, and 15%. However, the Laem Chabang, LCMT (2nd ranking) failed to overtake the Ho Chi Minh City, Cat Lai (1st ranking). Table 7.2 below displays how much change the 15% of decrease brought to the overall C_i values, which determines the rankings. The "original decision matrix" on the left displays values per original while the "changed decision matrix" on the right displays yellow highlighted value that experienced 15% decrease from the original. It can be seen that the decrease had barely an effect on the overall C_i values and the rankings remain the same.

Table 7.2 Decision matrix values before & after change (-15% to SF4 for LCMT)

Original Decision matrix	(SF4) Terminal Handling Charge	C_i	Rank	**Changed Decision matrix**	(SF4) Terminal Handling Charge	C_i	Rank
Cat Lai	62	0.7758	1	Cat Lai	62	0.7758	1
Green port	45	0.2851	5	Green port	45	0.2864	5
Koja	132	0.1199	6	Koja	132	0.1200	6
LCMT	75.05	0.4732	2	LCMT	63.7925	0.4781	2
North port	107.4	0.3303	4	North port	107.4	0.3304	4
PSA terminals	155.8	0.4128	3	PSA terminals	155.8	0.4125	3

Simulation 3

As part of testing simulation 3, the input values for the port factor of "frequency of port of call" has been increased while the "THC" has been decreased at the same time. However, Laem Chabang, LCMT (2nd ranking) failed to overtake Ho Chi Minh City, Cat Lai (1st ranking). Table 7.3 below displays how much change the 15% of increase and decrease brought to the overall C_i values, which determines the rankings. The "original decision matrix" on the left displays values per original while the "changed decision matrix" on the right displays yellow highlighted values that experienced 15% increase and 15% decrease in SF2 and SF4, respectively, from the original. It can be seen that although the changes in both the factors simultaneously had more impact on increasing the C_i value of the 2nd ranking, there is still a considerable gap between the 1st ranking and the 2nd ranking.

Table 7.3 Decision matrix values before & after change (+15% to SF2 & -15% to SF4 for LCMT)

Original Decision matrix	(SF2) Frequency of port of call	(SF4) Terminal Handling Charge	C_i	Rank	**Changed Decision matrix**	(SF2) Frequency of port of call	(SF4) Terminal Handling Charge	C_i	Rank
Cat Lai	14.814	62	0.7758	1	Cat Lai	14.814	62	0.7703	1
Green port	4	45	0.2851	5	Green port	4	45	0.2912	5
Koja	2	132	0.1199	6	Koja	2	132	0.1231	6
LCMT	9.6	75.05	0.4732	2	LCMT	11.04	63.7925	0.5291	2
North port	3.143	107.4	0.3303	4	North port	3.143	107.4	0.3377	4
PSA terminals	4.286	155.8	0.4128	3	PSA terminals	4.286	155.8	0.4201	3

Discussion for Scenario 1

As demonstrated above in simulation 3, even when both factors were changed simultaneously, the change failed to bring the 2nd ranking to overtake the 1st ranking. In order to see how much change would be needed for the overtaking, value for SF2 was increased until the 2nd rank overtook the 1st rank. This increase in percentage halted at 120% when the overtaking took place. Table 7.4 below shows such results.

Table 7.4 Decision matrix values before & after change (+120% to SF2 for LCMT)

Original Decision matrix	(SF2) Frequency of port of call	C_i	Rank	**Changed Decision matrix**	(SF2) Frequency of port of call	C_i	Rank
Cat Lai	14.814	0.7758	**1**	Cat Lai	14.814	0.6451	**2**
Green port	4	0.2851	5	Green port	4	0.2589	5
Koja	2	0.1199	6	Koja	2	0.1155	6
LCMT	9.6	0.4732	**2**	LCMT	21.12	0.6486	**1**
North port	3.143	0.3303	4	North port	3.143	0.3114	4
PSA terminals	4.286	0.4128	3	PSA terminals	4.286	0.3809	3

Another simulation was played out to see how much changing both SF2 and SF4 would yield in rank overtaking. The SF4 had been first decreased by around 40% to meet the lowest SF4 value possible amongst the 6 alternatives, which was $45. Then, the percentage increase of SF2 value continued until the rank overtaking occurred, which in this case turned out to be 117% increase in SF2. Thereby, it can be noted here also that the contribution of the decrease in SF4 value was small compared to the increase of SF2 value.

7.3.1.2 Scenario 2

- Could Singapore, PSA terminals (3rd ranking) overtake Ho Chi Minh City, Cat Lai's (1st ranking) port competitiveness in terms of ranking?

As stated before, 1st highest weight (SF2) can be changed. 2nd highest weight (SF4) can also be changed. 3rd highest weight (SF1), however, cannot be changed since its values deal with fixed distances. As for the 4th highest weight as well (SF10), it is very difficult to change as the increase in the numbers of gantry crane is a long-term project and pertains to future development plans. 5th highest weight (SF5) is very closely related to the highest weight of frequency of port of call, so changing this factor alone would be very difficult unless there is change to frequency of port of call.

Prior to the construction of the second scenario, it may be worth giving attention to the details that may not be readily be visible regarding SF3 (Port charges) and SF4 (THC). SF3 could be found on port's official websites. Although these charges may seem cheaper in some port terminals in comparison to others, SF4 - which is not shown on the websites - could be much more expensive in comparison to other port terminals. From AHP, it was calculated that SF3 is very low in the weight ranking whilst SF4 is very high. So, it may be sensible to make judgment that it is more important to consider the less-visible SF4 than the SF3, which is more visible for port users.

Further to the comparison between these port costs above, taking a look at the 1st ranking and the 3rd ranking whilst considering SF3 (Port charges) and SF4 (THC) is noteworthy. Looking at SF3 (Port charges), Cat Lai could be seen as disadvantageous: Cat Lai with $13,200 and PSA terminals with $6,000. However, looking at SF4 (THC), the situation is the other way around: Cat Lai with $62.00 and PSA terminals with $155.80. However, it was mentioned previously that SF4 is the factor that is much more important to consider than SF3, given its weight of importance. Therefore, a scenario could be constructed to adjust (improve) the input values of more importantly considered SF4. Additionally, in order for the possibility of the overtaking of rank to occur, the factor with the highest weight, SF2 (Frequency of port of call), is also considered. The following below are 3 simulations for this scenario:

Simulation 1. What if the SF2 (highest weight) for Singapore increased by 5%, 10%, 15%?

Simulation 2. What if SF4 (2nd highest weight) for Singapore decreased by 5%, 10%, 15%?

Simulation 3. With SF2 increases (5%, 10%, 15%), what if SF4 changes also occurred simultaneously? How & at what point would both of these changes affect the Singapore overtaking Ho Chi Minh City in terms of ranking?

Simulation 1

As part of testing simulation 1, the input values for the port factor of "frequency of port of call" in regards to Singapore have been increased by 5%, 10%, and 15%. However, the Singapore, PSA terminals (3rd ranking) failed to overtake the Ho Chi Minh City, Cat Lai (1st ranking). Table 7.5 below displays how much change the 15% of increase brought to the overall C_i values, which determines the rankings. The "original decision matrix" on the left displays values per original while the "changed decision matrix" on the right displays yellow highlighted value that experienced 15% increase from the original. It can be seen that the port of focus for this simulation (PSA terminals) could not even overtake the 2nd ranking of North port.

Table 7.5 Decision matrix values before & after change (+15% to SF2 for PSA terminals)

Original Decision matrix	(SF2) Frequency of port of call	C_i	Rank	**Changed Decision matrix**	(SF2) Frequency of port of call	C_i	Rank
Cat Lai	14.814	0.7758	1	Cat Lai	14.814	0.7746	1
Green port	4	0.2851	5	Green port	4	0.2861	5
Koja	2	0.1199	6	Koja	2	0.1205	6
LCMT	9.6	0.4732	2	LCMT	9.6	0.4721	2
North port	3.143	0.3303	4	North port	3.143	0.3318	4
PSA terminals	4.286	0.4128	3	PSA terminals	4.9289	0.4340	3

Simulation 2

As part of testing simulation 2, the input values for the port factor of "THC" in regards to Singapore have been decreased by 5%, 10%, and 15%. However, the Singapore, PSA terminals (3rd ranking) failed to overtake the Ho Chi Minh City, Cat Lai (1st ranking). Table 7.6 below displays how much change the 15% of decrease brought to the overall C_i values, which determines the rankings. The "original decision matrix" on the left displays values per original while the "changed decision matrix" on the right displays yellow highlighted value that experienced 15% decrease from the original. As it was seen previously in Scenario 1, the decrease had barely an effect on the overall C_i values and the rankings remain the same.

Table 7.6 Decision matrix values before & after change (-15% to SF4 for PSA terminals)

Original Decision matrix	(SF4) Terminal Handling Charge	C_i	Rank	**Changed Decision matrix**	(SF4) Terminal Handling Charge	C_i	Rank
Cat Lai	62	0.7758	1	Cat Lai	62	0.7741	1
Green port	45	0.2851	5	Green port	45	0.2676	5
Koja	132	0.1199	6	Koja	132	0.1118	6
LCMT	75.05	0.4732	2	LCMT	75.05	0.4673	2
North port	107.4	0.3303	4	North port	107.4	0.3248	4
PSA terminals	155.8	0.4128	3	PSA terminals	132.43	0.4167	3

Simulation 3

As part of testing simulation 3, the input values for the port factor of "frequency of port of call" has been increased while the "THC" has been decreased at the same time. However, Singapore, PSA terminals (3rd ranking) failed to overtake Ho Chi Minh City, Cat Lai (1st ranking), let alone Laem Chabang, LCMT (2nd ranking). Table 7.7 below displays how much change the

15% of increase and decrease brought to the overall C_i values, which determines the rankings. The "original decision matrix" on the left displays values per original while the "changed decision matrix" on the right displays yellow highlighted values that experienced 15% increase and 15% decrease in SF2 and SF4, respectively, from the original. It can be seen that although the changes in both the factors simultaneously had more impact on increasing the C_i value of the 3rd ranking, there is still a considerable gap between the 1st ranking and the 3rd ranking.

Table 7.7 Decision matrix values before & after change (+15% to SF2 & -15% to SF4 for LCMT)

Original Decision matrix	(SF2) Frequency of port of call	(SF4) Terminal Handling Charge	C_i	Rank	**Changed Decision matrix**	(SF2) Frequency of port of call	(SF4) Terminal Handling Charge	C_i	Rank
Cat Lai	14.814	62	0.7758	1	Cat Lai	14.814	62	0.7729	1
Green port	4	45	0.2851	5	Green port	4	45	0.2685	5
Koja	2	132	0.1199	6	Koja	2	132	0.1124	6
LCMT	9.6	75.05	0.4732	2	LCMT	9.6	75.05	0.4662	2
North port	3.143	107.4	0.3303	4	North port	3.143	107.4	0.3263	4
PSA terminals	4.286	155.8	0.4128	3	PSA terminals	4.9289	132.43	0.4384	3

Discussion for Scenario 2

As demonstrated above in simulation 3, even when both factors were changed simultaneously, the change failed to bring the 3rd ranking to overtake the 1st ranking, let alone the 2nd ranking. In order to see how much change would be needed for the overtaking, value for SF2 was increased until the 3rd rank overtook the 1st rank. This increase in percentage halted at 221% when the overtaking took place. Table 7.8 below show such results.

Table 7.8 Decision matrix values before & after change (+221% to SF2 for PSA terminals)

Original Decision matrix	(SF2) Frequency of port of call	C_i	Rank	**Changed Decision matrix**	(SF2) Frequency of port of call	C_i	Rank
Cat Lai	14.814	0.7758	**1**	Cat Lai	14.814	0.7486	**2**
Green port	4	0.2851	5	Green port	4	0.3085	5
Koja	2	0.1199	6	Koja	2	0.1347	6
LCMT	9.6	0.4732	2	LCMT	9.6	0.4471	3
North port	3.143	0.3303	4	North port	3.143	0.3659	4
PSA terminals	4.286	0.4128	**3**	PSA terminals	13.75806	0.7491	**1**

Another simulation was played out to see how much of changing both SF2 and SF4 would yield in rank overtaking. The SF4 had been decreased by around 71% to meet the lowest SF4 value possible amongst the 6 alternatives, which was $45. Then, the percentage was increased for SF2 value until the rank overtaking occurred, which in this case turned out to be 159% increase in SF2. It can be seen here that as the SF4 value for PSA terminals was the highest, its decrease to the lowest value amongst the 6 alternatives had a more drastic effect in increasing the C_i value for PSA terminals. The results are shown in Table 7.9 below.

Table 7.9 Decision matrix values before & after change (+159% to SF2 AND -71.1168% to SF4 for PSA terminals)

Original Decision matrix	(SF2) Frequency of port of call	(SF4) Terminal Handling Charge	C_i	Rank	**Changed Decision matrix**	(SF2) Frequency of port of call	(SF4) Terminal Handling Charge	C_i	Rank
Cat Lai	14.814	62	0.7758	**1**	Cat Lai	14.814	62	0.7562	**2**
Green port	4	45	0.2851	5	Green port	4	45	0.2970	5
Koja	2	132	0.1199	6	Koja	2	132	0.1200	6
LCMT	9.6	75.05	0.4732	2	LCMT	9.6	75.05	0.4515	3
North port	3.143	107.4	0.3303	4	North port	3.143	107.4	0.3473	4
PSA terminals	4.286	155.8	0.4128	**3**	PSA terminals	11.10074	45	0.7564	**1**

The simulation above shown in Table 7.9 involves, by first, reducing the SF4 value to the lowest extreme value of 45. However, another simulation is run where the SF4 value is reduced to the average value of SF4 of all 6 terminals, which is around 96.21. It may be more feasible to adjust the SF4 value to such value. Therefore, SF4 value has been decreased by 38% and then the percentage of SF2 value had been increased until the rank overtaking occurred, which in this case turned out to be 175%. Table 7.10 below shows the results.

Table 7.10 Decision matrix values before & after change (+175% to SF2 AND -38% to SF4 for PSA terminals)

Original Decision matrix	(SF2) Frequency of port of call	(SF4) Terminal Handling Charge	C_i	Rank	**Changed Decision matrix**	(SF2) Frequency of port of call	(SF4) Terminal Handling Charge	C_i	Rank
Cat Lai	14.814	62	0.7758	**1**	Cat Lai	14.814	62	0.7562	**2**
Green port	4	45	0.2851	5	Green port	4	45	0.2970	5
Koja	2	132	0.1199	6	Koja	2	132	0.1200	6
LCMT	9.6	75.05	0.4732	2	LCMT	9.6	75.05	0.4515	3
North port	3.143	107.4	0.3303	4	North port	3.143	107.4	0.3473	4
PSA terminals	4.286	155.8	0.4128	**3**	PSA terminals	11.78571	96.596	0.7564	**1**

7.3.1.3 Scenario 3

- Could there be shift in port competitiveness in terms of ranking amongst the 4th, 5th, and 6th ranked ports if these ports underwent port expansion / development?

Scenario 3 focuses on the ports that were placed on the lower end of the ranking: Port Kelang (4th ranking), Haiphong (5th ranking), and Jakarta (6th ranking).

In order to increase port competitiveness and ultimately see the changes in these ports' rankings, various factors would need to be considered such as SF2 (Frequency of port of call), SF4 (THC), SF10 (Number of gantry cranes / gantry crane handling capacity per hour), SF5 (Total container cargo volume (import/export & transshipment containers), and SF11 (Area of container yard). The mentioned factors are within the top 8 of their weights, so changes in these factors will have more impact on the final change in the port rankings as well.

As opposed to the already well-established ports like Singapore, it may be worth focusing on the fact that the ports in the lower end of the ranking could have possibility of improvement due to further development and expansion such as for North port terminal in Port Kelang (4th rank) and Koja terminal in Jakarta (6th rank), for example. Such expansion would yield to increase in gantry crane (pertaining to SF10) or increase in the area of container yard (pertaining to SF11).

So, a scenario could be constructed like below for the three ports mentioned.

The following is a scenario for Port Kelang (4th ranking):

Simulation 1. Under a situation where the Port Kelang undergoes expansion and development, what if SF10 (4th highest weight) increased by 5%, 10%, 15%?

Simulation 2. Under a situation where the Port Kelang undergoes expansion and development, what if SF11 (8th highest weight) increased by 5%, 10%, 15%?

Simulation 3. With SF10 increases (5%, 10%, 15%), what if SF11 changes also occurred simultaneously? How & at what point would both of these changes affect Port Kelang to overtake Singapore (3rd ranking), in terms of their rankings?

The following is a scenario for Haiphong (5th ranking):

Simulation 4. Under a situation where port Haiphong undergoes expansion and development, what if SF10 (4th highest weight) increased by 5%, 10%, 15%?

Simulation 5. Under a situation where port Haiphong undergoes expansion and development, what if SF11 (8th highest weight) increased by 5%, 10%, 15%?

Simulation 6. With SF10 increases (5%, 10%, 15%), what if SF11 changes also occurred simultaneously? How & at what point would both of these changes affect port Haiphong to overtake Port Kelang (4th ranking) and Singapore (3rd ranking), in terms of their rankings?

The following is a scenario for Jakarta (6th ranking):

Simulation 7. Under a situation where the port Jakarta expansion and development, what if SF10 (4th highest weight) increased by 5%, 10%, 15%?

Simulation 8. Under a situation where the port Jakarta undergoes expansion and development, what if SF11 (8th highest weight) increased by 5%, 10%, 15%?

Simulation 9. With SF10 increases (5%, 10%, 15%), what if SF11 changes also occurred simultaneously? How & at what point would both of these changes affect port Jakarta to overtake Haiphong (5th ranking), Port Kelang (4th ranking), and Singapore (3rd ranking), in terms of their rankings?

Simulation 1 & 2 for Port Kelang (4th ranking)

Simulations 1 & 2 were run for the input values of SF10 and SF11 in regards to Port Kelang, North port (4th ranking). However, noting back at the list of factor weights obtained in Chapter 6, Figure 6.3, there were notable differences in weight allocation especially within the top 5 factors with highest weights. Therefore, even though SF10 was determined to be a factor of 4th highest weight (importance), its weight was still around 1.75 times less than the 3rd highest weight and around 4 times less than the 1st highest weight. Thus, the weights for SF10 and SF11, being 4th and 8th weight respectively, are considerably low and have a very slight effect on the input values in comparison to the factors with highest weight. Consequently, changes made to SF10 and SF11 had almost no effect to the C_i values for simulations 1 and 2. The changes made here refer to the input values for the port factor for SF10 in regards to Port Kelang having been increased to 15%, and the input values for the port factor for SF11 in regards to Port Kelang having been increased to 15%, separately. Again, despite the changes, there were almost no changes to the C_i values as explained above.

Simulation 3 for Port Kelang (4th ranking)

As part of testing simulation 3, the input values for the SF10 has been increased while the SF11 has been also increased at the same time. However, Port Kelang, North port (4th ranking) failed to overtake Singapore, PSA terminals (3rd ranking). Table 7.11 below displays how much change the 15% of increases in SF10 and SF11 brought to the overall C_i values, which determines the rankings. The "original decision matrix" on the left displays values per original while the "changed decision matrix" on the right displays yellow highlighted values that both experienced 15% increases in SF10 and SF11 from the original. As it was mentioned above for

Simulation 1 & 2, due to the trivial impact that SF10 and SF11 have on the input values, very miniscule change can be observed in the changed C_i value.

Table 7.11 Decision matrix values before & after change (+15% to SF10 & +15% to SF11 for North port)

Original Decision matrix	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	C_i	Rank	**Changed Decision matrix**	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	C_i	Rank
Cat Lai	650	160	0.7758	1	Cat Lai	650	160	0.7768	1
Green port	115	20	0.2851	5	Green port	115	20	0.2853	5
Koja	140	26	0.1199	6	Koja	140	26	0.1200	6
LCMT	180	19	0.4732	2	LCMT	180	19	0.4736	2
North port	800	93	0.3303	4	North port	920	106.95	0.3320	4
PSA terminals	3,700	550	0.4128	3	PSA terminals	3,700	550	0.4123	3

Additional simulations for Port Kelang (4th ranking)

As demonstrated above in simulation 3, even when both factors were changed simultaneously, the change failed to bring the 4th ranking to overtake the 3rd ranking. In order to see how much change would be needed for the overtaking, value for SF10 was increased until the 4th rank overtook the 3rd rank. This increase in percentage halted at 825% when the overtaking took place. Table 7.12 below show such results.

Table 7.12 Decision matrix values before & after change (+825% to SF10 for North port)

Original Decision matrix	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	C_i	Rank	**Changed Decision matrix**	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	C_i	Rank
Cat Lai	650	0.7758	1	Cat Lai	650	0.77214	1
Green port	115	0.2851	5	Green port	115	0.28646	5
Koja	140	0.1199	6	Koja	140	0.12033	6
LCMT	180	0.4732	2	LCMT	180	0.47565	2
North port	800	0.3303	**4**	North port	7,400	0.37806	**3**
PSA terminals	3,700	0.4128	**3**	PSA terminals	3,700	0.37805	**4**

Another simulation was played out to see how much of changing both SF10 and SF11 would yield in rank overtaking. The SF11 had been increased by around 491% to meet the highest SF11 value possible amongst the 6 alternatives, which was 93 hectares. Then, the percentage was increased for SF10 value until the rank overtaking occurred, which in this case turned out to be 627% increase in SF10. It can be seen here that as the SF11 value for PSA terminals was the highest by a big contrast compared to other port terminals, there had to be drastic increase in North port's SF11 value to meet the PSA terminals' values. However, even still, this was not enough for North port to overtake PSA terminals, and a large number of increase had to take place for SF10 values to be successful in rank overtaking. The results are shown in Table 7.13 below.

Table 7.13 Decision matrix values before & after change (+627% to SF10 AND +491.398% to SF11 for North port)

Original Decision matrix	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	C_i	Rank	**Changed Decision matrix**	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	C_i	Rank
Cat Lai	650	160	0.7758	1	Cat Lai	650	160	0.78872	1
Green port	115	20	0.2851	5	Green port	115	20	0.28893	5
Koja	140	26	0.1199	6	Koja	140	26	0.12119	6
LCMT	180	19	0.4732	2	LCMT	180	19	0.48135	2
North port	800	93	0.3303	**4**	North port	5,816	550	0.38013	**3**
PSA terminals	3,700	550	0.4128	**3**	PSA terminals	3,700	550	0.38007	**4**

Simulation 4 & 5 & 6 for Haiphong (5th ranking)

Simulations 4 & 5 & 6 have been run for the input values of SF10 and SF11 in regards to Haiphong, Green port (5th ranking). Noting back to the explanation given for Simulations 1 & 2 regarding the very slight effect on the input values that SF10 and SF11 have in comparison to other factors with highest weight, again, despite the changes, there were almost no changes to the C_i values for Haiphong. As it can be seen in Table 7.14, even when 1,000% increase to the values of SF10 and SF11 have been implemented, Haiphong, Green port (5th ranking) failed to overtake Port Kelang, North port (4th ranking). Since the input values needed to be increased by much more for the overtake to occur, the increase in input values stopped here.

Table 7.14 Decision matrix values before & after change (+1,000% to SF10 AND +1,000% to SF11 for Green port)

Original Decision matrix	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	C_i	Rank	**Changed Decision matrix**	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	C_i	Rank
Cat Lai	650	160	0.7758	1	Cat Lai	650	160	0.7838	1
Green port	115	20	0.2851	5	Green port	1,265	220	0.3026	5
Koja	140	26	0.1199	6	Koja	140	26	0.1204	6
LCMT	180	19	0.4732	2	LCMT	180	19	0.4764	2
North port	800	93	0.3303	4	North port	800	93	0.3310	4
PSA terminals	3,700	550	0.4128	3	PSA terminals	3,700	550	0.4080	3

Simulation 7 & 8 & 9 for Jakarta (6th ranking)

Simulations 7 & 8 & 9 have been run for the input values of SF10 and SF11 in regards to Jakarta, Koja terminal (6th ranking). Noting back to the explanation given for Simulations 1 & 2 regarding the very slight effect on the input values that SF10 and SF11 have in comparison to other factors with highest weight, again, despite the changes, there were almost no changes to the C_i values for Jakarta. Similar to Simulations 4 & 5 & 6, even when 1,000% increase to the values of SF10 and SF11 have been implemented, Jakarta, Koja terminal (6th ranking) failed to overtake Haiphong, Green port (5th ranking). Table 7.15 demonstrate such results. Since the input values needed to be increased by much more for the overtake to occur, the increase in input values stopped here.

Table 7.15 Decision matrix values before & after change (+1,000% to SF10 AND +1,000% to SF11 for Koja terminal)

Original Decision matrix	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	C_i	Rank	**Changed Decision matrix**	(SF10) Number of gantry cranes / gantry crane handling capacity per hour	(SF11) Area of container yard	C_i	Rank
Cat Lai	650	160	0.7758	1	Cat Lai	650	160	0.7875	1
Green port	115	20	0.2851	5	Green port	115	20	0.2872	5
Koja	140	26	0.1199	6	Koja	1,540	286	0.1580	6
LCMT	180	19	0.4732	2	LCMT	180	19	0.4779	2
North port	800	93	0.3303	4	North port	800	93	0.3315	4
PSA terminals	3,700	550	0.4128	3	PSA terminals	3,700	550	0.4065	3

7.3.2 Proportionate changes to performance input values

The previous section of 7.3.1 consisted of scenarios and simulations that gave independent increases or decreases to particular input values whilst other input values remained the same and unaffected from the change. For example, in simulation 1 of scenario 1 of section 7.3.1.1, the input values of SF2 (frequency of port of call) for Laem Chabang (2nd ranking) have been increased by set number of percentages until its C_i value overtook the C_i value of Ho Chi Minh City (1st ranking). In this case, input values for all other sub-factors have remained the same whilst input values for SF2 increased.

In this current section, increases or decreases to the input values will still occur by set number of percentages for particular input values like the previous section 7.3.1. However, unlike previously, after such amount of increase or decrease is made to a particular input value, the amount will be offset by also increasing or decreasing other input values of the same sub-factor to compensate for the amount of total change. Below should be noted to understand under which condition the increases and decreases to the input values have been made:

- The total amount of resources already provided in the performance values data per decision matrix of Table 6.19 will stay the same. This means that the overall amount of collected or measured data for each sub-factor has to stay the same even when percentages of increase or decrease come to a particular input value within that sub-factor.
- Therefore, 6 performance input values of each sub-factor are converted proportionately to add up to 1. This way, each time a single value is increased or decreased, it will be possible to equally adjust the rest of the 5 values of that particular sub-factor to all add up to 1.
- It should be noted that by making sure the total amount of performance input values is fixed, simulations that administer increase or decrease in input values present more accurate depiction of results when the focus is to see how the shifts of resource allocations regarding currently collected data will affect the rankings.

In this section, calculations on each of these input values have been made by first increasing or decreasing them by 10%. Then, further cases of increases and decreases were carried out in 10% increments, with each increment requiring 72 calculations (12 sub-factors multiplied by 6 alternatives). Ultimately, the changes in the ranking were observed when the input values were decreased by 20% and when the input values were increased by 60%, after a total of 576 calculations (72 calculations multiplied by 8 increment cases). Although the changes in the ranking were not observed when the input values were decreased by 10%, and when increased by 10%, 20%, 30%, 40%, 50%, the results obtained from these still prove to be valuable in that they indicate which factor and alternative is affected the most when such change occurs.

Additionally, before viewing the changes that are applied to the performance input values through different simulations run for this section, it may be useful to view the list of sub-factors by their order of weights in Figure 6.3 and the ranks of the alternatives in Table 6.27. For the ease of referring to the sub-factors in this section, below are abbreviated titles to the 12 sub-factors that are used in this section. Again, just as stated previously, "SF" stands for Sub-Factor, and the numbers at the end of the "SF" below correspond to the same numbering that was used initially in Chapter 6, as seen in Table 6.19.

- (SF1) Proximity to main navigation routes
- (SF2) Frequency of port of call
- (SF3) Port charges (dockage, pilot cost, towage, etc.)
- (SF4) Terminal Handling Charge (loading & unloading cost, etc.)
- (SF5) Total container cargo volume (import/export & transshipment containers)
- (SF6) Proximity to the markets
- (SF7) Distance of shippers from port
- (SF8) Intermodal links
- (SF9) Port depth
- (SF10) Number of gantry cranes / gantry crane handling capacity per hour
- (SF11) Area of container yard
- (SF12) Port connectivity

7.3.2.1 Decreases and increases in input values "before" change occurs in the alternative ranking

Although decrease and increase in the input values by 10% did not lead to any changes in the alternatives, the data obtained from such manipulation of data do prove to be useful. It can be observed in Figure 7.3 and Figure 7.4 that changes in the SF2 (frequency of port of call) affected the adjusted C_i values of the 6 alternatives the most. The adjusted C_i values of SF2 experienced significant changes in comparison to other sub-factors since SF2's weight importance is the highest amongst the 12 sub-factors. Further, it can be seen that out of these alternatives, LCMT was most affected by the decrease and increase in its SF2 input value. Therefore, care should be given if there ought to be any changes to the input data of SF2 factor since it affects the final C_i values the most when compared with other alternatives.

Next, it can be observed in Figure 7.3 and Figure 7.4 that changes in SF1 (proximity to main navigation routes) and SF4 (THC) affected their adjusted C_i values of the alternatives greatly. These adjusted C_i values experienced notable changes since SF1's and SF4's weight importance are 3rd and 2nd highest, respectively, amongst the 12 sub-factors. It can be seen that for SF1, Green port was most affected when there was a decrease per Figure 7.3, however, Koja terminal was most affected when there was an increase per Figure 7.4. As for SF4, Koja terminal was most affected for both decrease and increase.

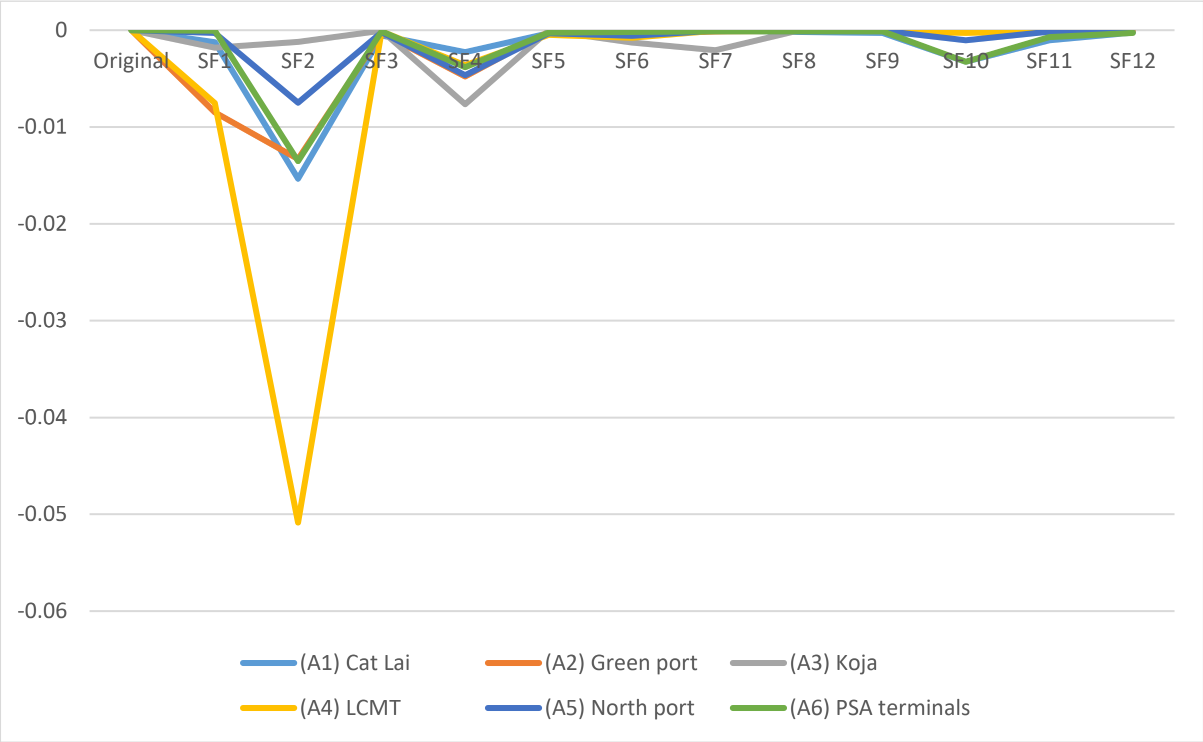

Figure 7.3 Difference between the original C_i values and adjusted C_i values after decreasing all sub-factors by 10%

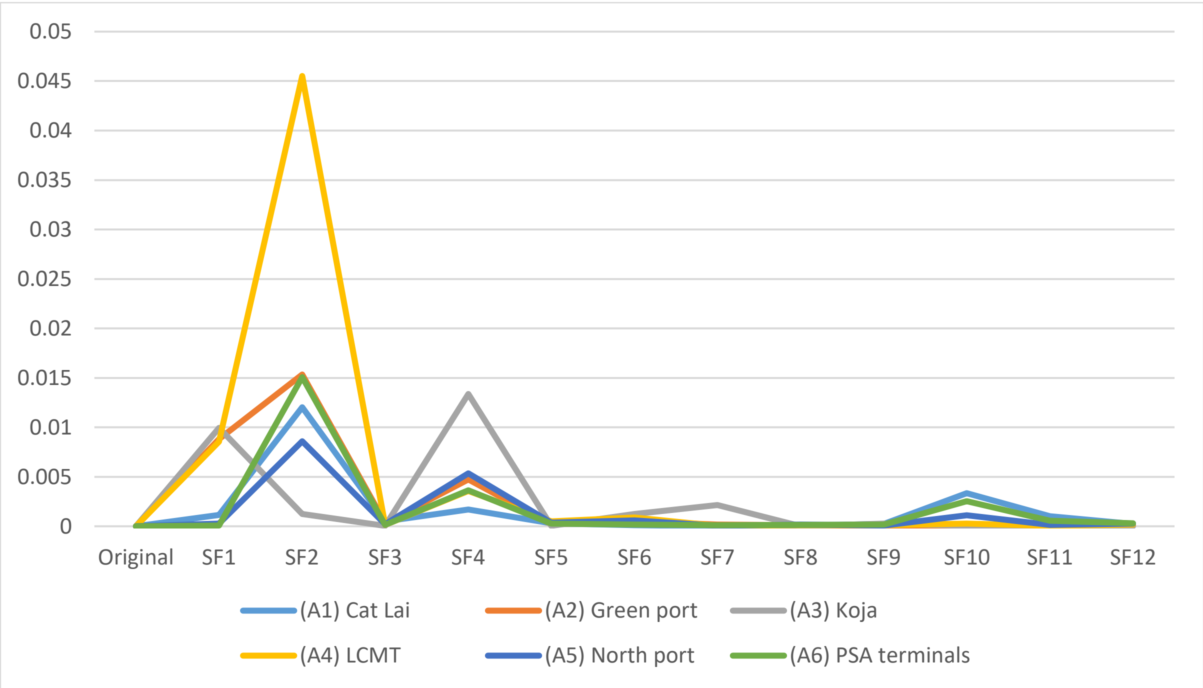

Figure 7.4 Difference between the original C_i values and adjusted C_i values after increasing all sub-factors by 10%

As it has been noted before, differences between 12 sub-factor weights differ greatly, specifically within the top 4 highest sub-factors. Therefore, when looking at the illustrated graphs of change in the C_i values when all the input values are increased or decreased like Figure 7.3 and Figure 7.4, naturally, the C_i values of these 4 sub-factors experience more notable changes on the graphs. However, since these graphs show changes in C_i values for all 6 alternatives, it is worth noting that the graphs also give an indication to which alternative is most affected by such increase or decrease of each sub-factor. This may prove useful for industrial stakeholders in practice as they could use this information to note for which sub-factor and alternative affect the C_i values (ranking) the most when there are changes to the input values.

7.3.2.2 Decreases and increases in input values "when" change occurs in the alternative ranking

After a series of simulations, it was found that changes in the ranking occurred when input values were decreased by 20% and when the input values were increased by 60%. Figure 7.5 below illustrates the differences that were experienced when input values were decreased by 20%. It should be noted that both Figure 7.5 and Figure 7.6 represent the same data, but Figure 7.6 is presented to provide a closer view of the data where the changes may not be so visible in Figure 7.5.

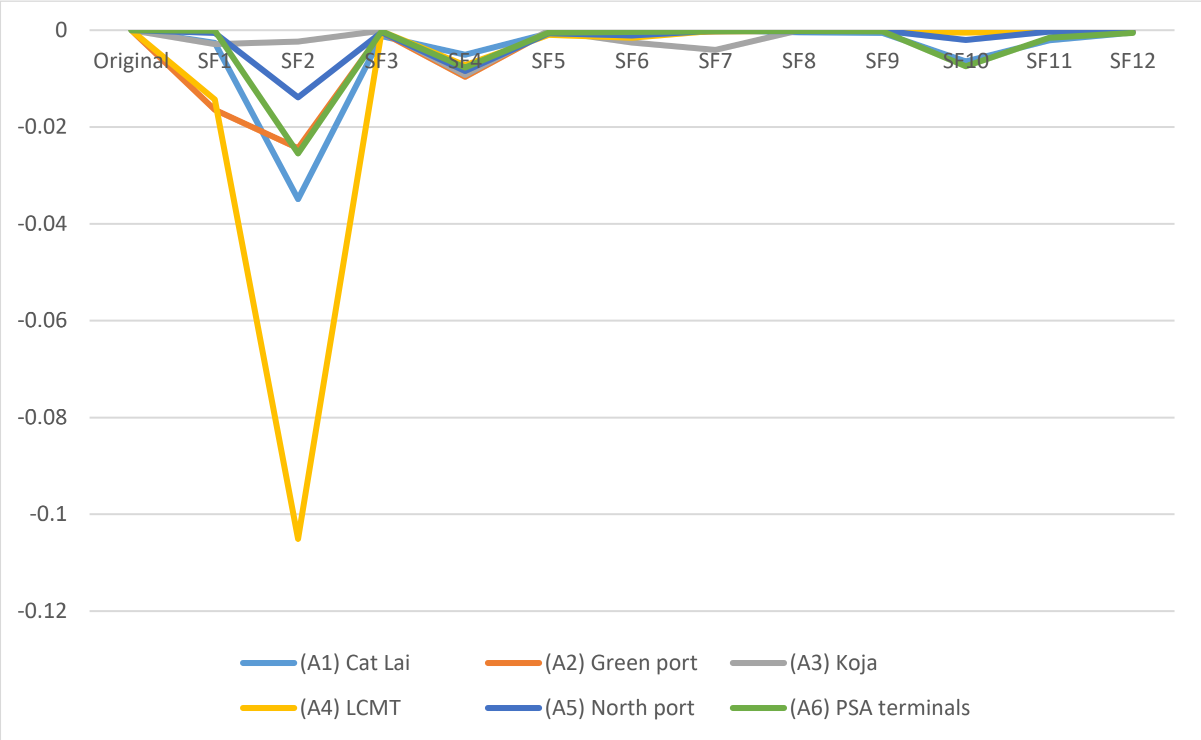

Figure 7.5 Difference between the original C_i values and adjusted C_i values after decreasing all sub-factors by 20%

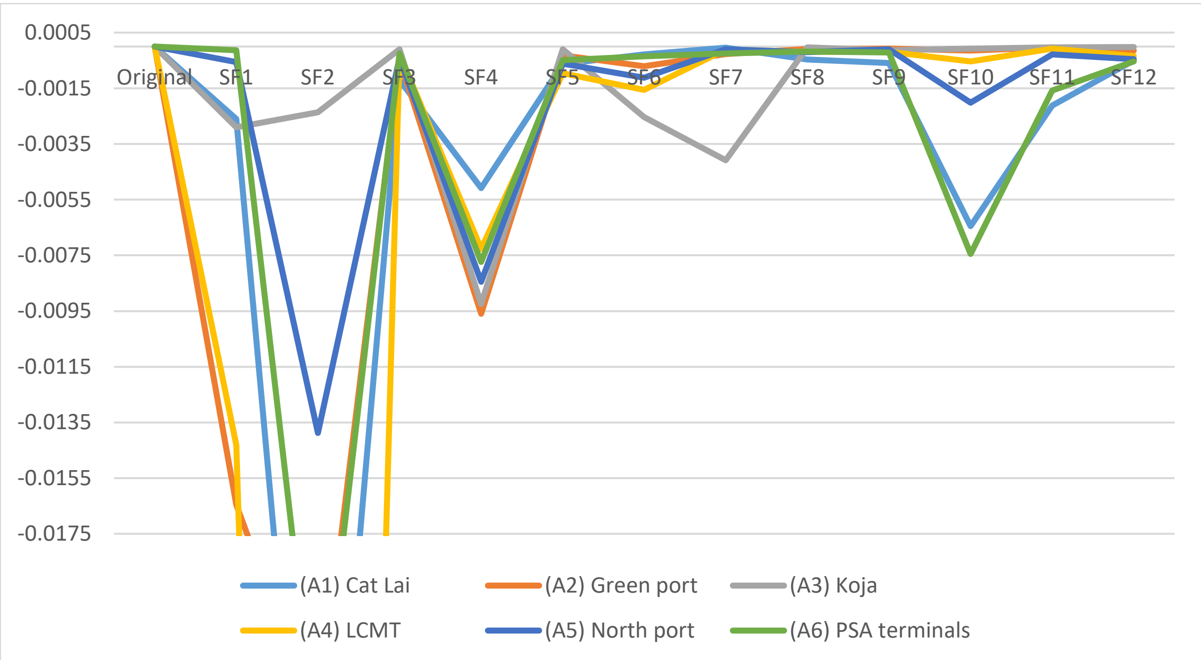

Figure 7.6 Difference between the original C_i values and adjusted C_i values after decreasing all sub-factors by 20% - closer view

There are a total of 72 input values in the decision matrix, which consists of 12 sub-factors by 6 alternatives, that displays all of the collected secondary and primary data. As noted before, in this section, 72 calculations have been made (12 sub-factors multiplied by 6 alternatives) on each of these input values by increasing or decreasing them by set amount of percentages. Obtaining adjusted C_i values is the final step of these calculations, and each of these adjusted C_i values is then plotted onto the graph like Figure 7.7 below. Figure 7.7 illustrates the adjusted C_i values of the 6 alternatives when their input values of each sub-factor (total of 72 input values) were decreased by 20%. As it can be observed, PSA terminals (3rd ranking) overtook LCMT (2nd ranking) when SF2 was decreased by 20%. Table 7.16 below also shows the adjusted C_i values for these two alternatives in numerical format for better interpretation.

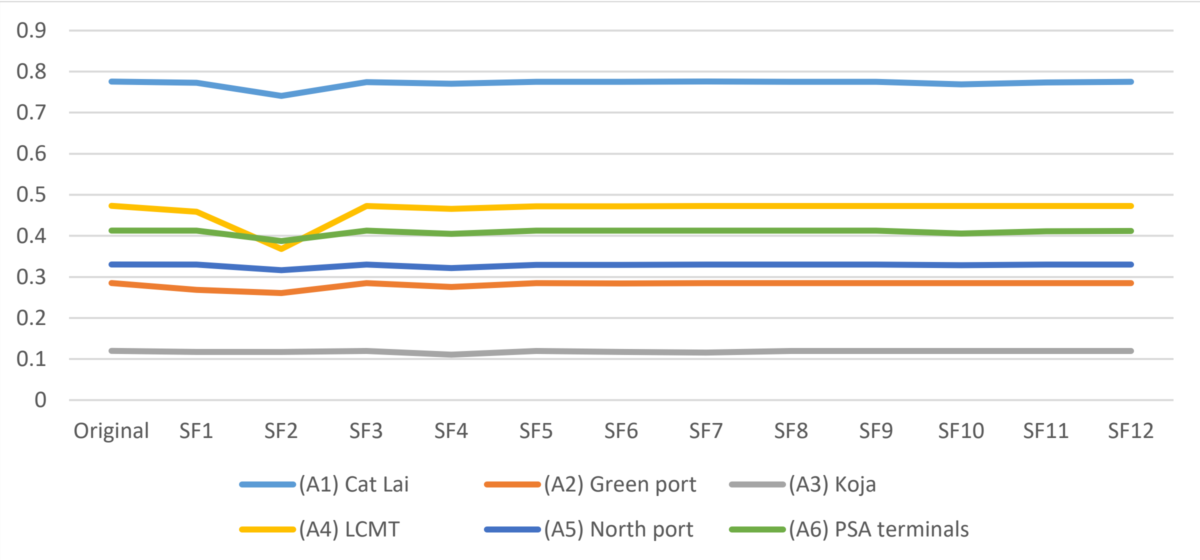

Figure 7.7 Adjusted C_i values after decreasing all sub-factors by 20%

Table 7.16 Adjusted C_i values of alternatives where their ranks were reversed after decreasing all sub-factors by 20%

Adjusted C_i values	(A4) LCMT	(A6) PSA terminals
SF2	0.3680	0.3873

When simulations were run by increasing the input values with increments of 10% until a change in the alternative ranking has been achieved, it took multiple runs reaching up until 60%. Figure 7.8 below illustrate the differences that were experienced when input values were increased by 60%. It should be noted that both Figure 7.8 and Figure 7.9 represent the same data, but Figure 7.9 is presented to provide a closer view of the data where the values of changes may not be best represented in Figure 7.8.

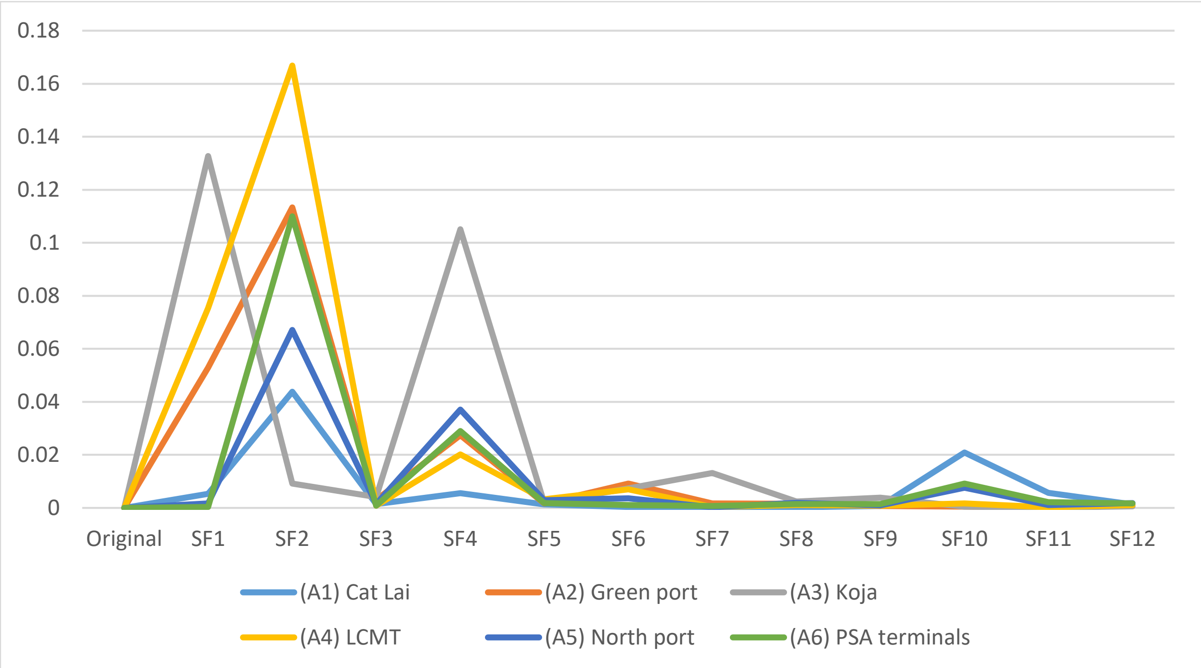

Figure 7.8 Difference between the original C_i values and adjusted C_i values after increasing all sub-factors by 60%

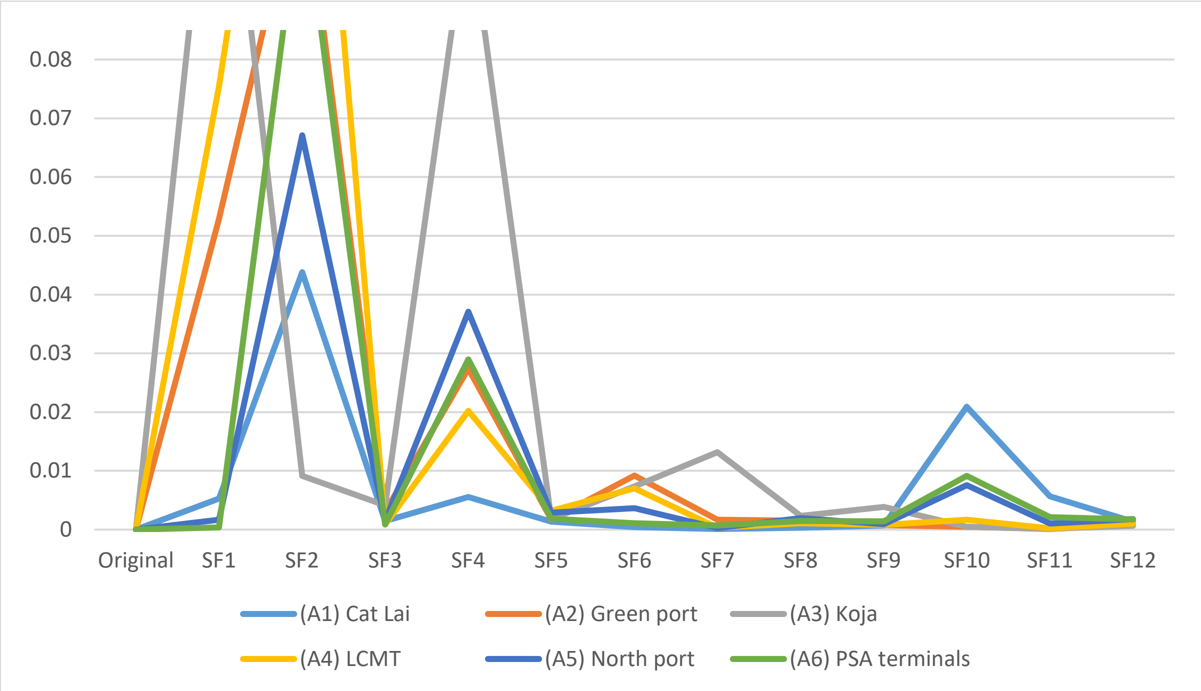

Figure 7.9 Difference between the original C_i values and adjusted C_i values after increasing all sub-factors by 60% - closer view

Just like the illustration of adjusted C_i values when input values were decreased by 20% previously, Figure 7.10 below illustrates the adjusted C_i values of the 6 alternatives when their input values of each sub-factor (total of 72 input values) were increased by 60%. As it can be observed, Green port (5th ranking) overtook North port (4th ranking) at two cases when SF1 was increased by 60% and when SF2 was increased by 60%. Table 7.17 below also shows the adjusted C_i values for these two alternatives in numerical format for better interpretation.

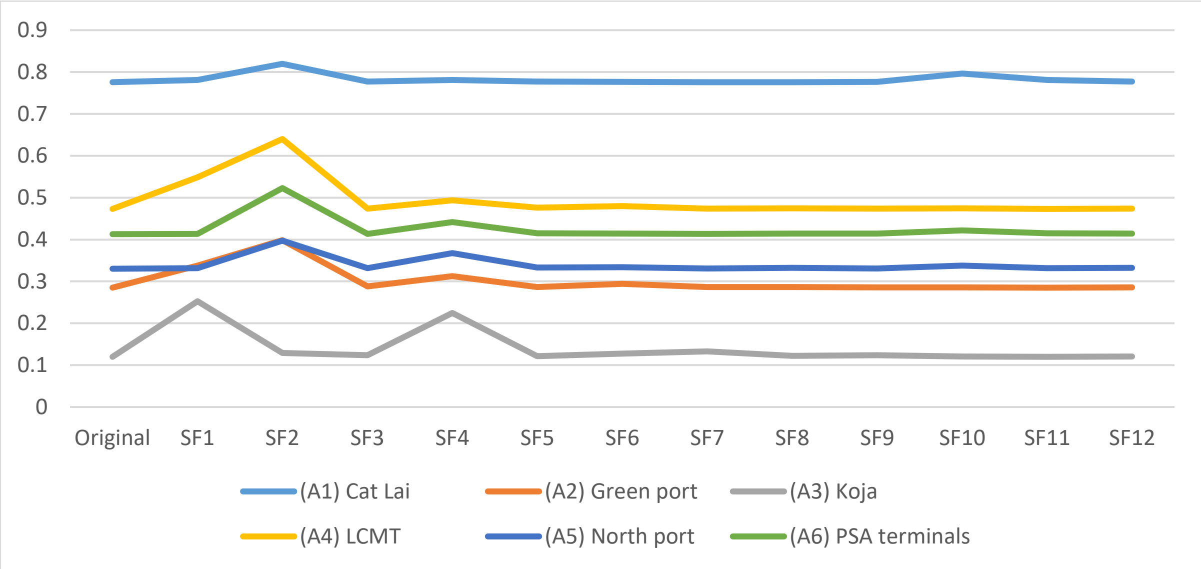

Figure 7.10 Adjusted C_i values after increasing all sub-factors by 60%

Table 7.17 Adjusted C_i values of alternatives where their ranks were reversed after increasing all sub-factors by 60%

Adjusted C_i values	(A2) Green port	(A5) North port
SF1	0.3379	0.3319
SF2	0.3984	0.3973

7.4 Chapter summary

This chapter firstly covered sensitivity analysis of the previously used AHP-TOPSIS framework. It is important to note that, through AHP, sub-factor B (frequency of port of call) had been determined to possess the highest weight of 0.3350, which is a value that is more than double the value of the sub-factor with the second highest weight of 0.1462. Additionally, top 3 sub-factors with highest weights take up around 62% of the overall weight. Therefore, as it could be seen through figures and graphs, there were natural fluctuation to the (C_i) values primarily when sub-factor B (highest weight) had been exchanged with others.

Then the second part of this chapter covered multiple scenario and simulation testing using the AHP-TOPSIS framework. This second part of the chapter was further divided into two sections that have different kinds of testing. As explained, the first section increased or decreased the percentages of performance input values independently, for example, by increasing just the frequency of port of call factor by 10%, ceteris paribus. The second section increased or decreased the percentages of performance input values as well, but, it also considered the displaced number that occurred with the change to compensate for the change in the total amount. The results to both of these testing indicate that significant changes to the performance values are needed for one port to overtake the preceding port in terms of ranking.

CHAPTER 8: DISCUSSION

8.1 Chapter introduction

The use of SLR in Chapter 3 followed by pilot test and semi-structured interviews in Chapter 4 and 6 yielded the hierarchical structure of key container port selection factors for Korean shipping companies in the ASEAN region. Moreover, the meticulous demonstration of two-step AHP-TOPSIS applied on case study of Korean shipping companies in Chapter 6 yielded two major sets of results: the weight importance of port selection factors and the rankings of optimal ports. This chapter revisits the research gap as well as the 3 research aims established at the beginning of this research and discusses how each aim has been addressed. Also, this chapter provides discussion on the weights of importance of container port selection factors obtained through AHP and discussion on the optimal rankings of the 6 alternative ports in the ASEAN region obtained through AHP-TOPSIS.

8.2 Addressing research gap, and research aims

Despite the presence of vast amount of literature on port selection, there is a gap in the literature in port selection focusing on Korean shipping companies in the Southeast Asian region. Port selection literature can be majorly categorised in the following way: according to the specific perspective that the study is focusing or collecting data from; according to the specific region or country that the study is exploring; and combination of both above. From the review of literature and through SLR in Chapter 3, the major port-related stakeholders in port selection were identified as: shipping company (carrier); shipper or freight-forwarder; and port authority or port operator. Additionally, each study mostly focuses on a specific country being involved in maritime shipping with a broader geographical region such as Northeast Asia, Europe, and Southeast Asia. From this vast array of possible port selection literature, there is, indeed, some literature that deals with port selection in respect to the Southeast Asian region. However, there is an absence of port selection literature in this Southeast Asian region from the perspective of Korean shipping companies.

It is of great worth to investigate this topic of port selection in the Southeast Asia from Korean shipping companies' perspective. Related logistics, shipping, and port companies will follow the manufacturing hub as they have done throughout the past three major global manufacturing relocations in the modern history (Chen et al., 2018). Recently since 2011, due to circumstances such as the waning cost advantage in China and the recent trade war between China and the U.S., relocation of production facilities has been accelerating to the Southeast Asian countries (Bhaskaran, 2020). Hence, it is worthy to give attention to the trend of the relocation of global manufacturing hub in the Southeast Asian region.

Meanwhile, in close physical proximity to this region of attention, South Korea is considered to be a major participant in maritime transport business with a strong economy of having 10th highest GDP in the world as of 2020 (World Bank, 2022). Moreover, relevant statistics (in Chapter 2) show that there are increases in shipping service routes and export container cargo volumes from South Korea to the Southeast Asian region. Therefore, considering that South Korean trade and investment to the Southeast Asian countries have been increasing, it is then worthwhile to identify the key factors that the shipping companies use to connect these two key regions as well as also evaluate which port the Korean shipping companies find the most optimal. In order to investigate such key factors and the optimal ports that shipping companies in South Korea consider when choosing ports to call in the ASEAN region, the author has developed research aims, which have been outlined in Chapter 1 and will be recalled again shortly below.

The overarching research aim of this study was thus to explore port selection for container ports by providing and implementing empirical evidence to determine attractive port selection factors and optimal ports. In the effort to break down this overarching research aim and delve into more particular topics within addressing this overarching research aim, three further major research aims of this research were established:

Research aim 1: Investigate selection factors that influence container port selection from the perspective of shipping company.

In order to address this aim, the following research methods and tools were used: the use of SLR, pilot test, and in-depth interview in the form of semi-structured interview. From the use of SLR, a total of 71 quality port selection articles relevant to author's research have been found. After analysing these 71 articles, the researcher has been able to draw a hierarchical structure of factors that contains 4 main factors, which encompass a total of 14 sub-factors. In order to verify the validity of the hierarchical structure of factors obtained from SLR, a pilot test was conducted with two academic experts. The pilot test involved two academic experts in Korean maritime shipping field who have experience in utilising MCDM methods of AHP and TOPSIS to evaluate calling port selection in South Korea. The pilot test assisted in refining the hierarchical structure found through SLR, and resulted in deletion of 2 sub-factor, addition of 1 sub-factor, and revision of 3 sub-factors. As a result of the pilot test, the author was able to obtain a hierarchical structure of factors that contains 4 main factors, encompassing a total of 13 sub-factors. The refined factors were then presented to senior-level industrial experts through in-depth interviews in the form of semi-structured interviews. Through the interviews, 1 sub-factor was deleted, and 3 sub-factors were re-arranged under different main factors. As a result of the semi-structured interviews, the author was able to obtain a final hierarchical structure of factors that contains 4 main factors, encompassing a total of 12 sub-factors.

Research aim 2: Analyse Korean shipping companies' focus on targeting the growing markets in the ASEAN region.

In order to address this aim, two methods (quantitative and qualitative) were utilised: (A) use of secondary data to gather relevant statistics and information that indicate increase in South Korean shipping companies' maritime transportation to the ASEAN region; (B) use of semi-structured interviews to collect data that is unobtainable to the author through publicly accessible means (not present or only accessible through exclusive subscription). Through these quantitative and qualitative collection and examination of data, the author was able to obtain and set 6 target container ports in the ASEAN region (through method A), and obtain the most used container terminal for each of the mentioned targeted ports that yielded a total of 6 targeted container port terminals in the ASEAN region (through method B).

Research aim 3: Find optimal ports in the ASEAN region for Korean shipping companies and present advantage and disadvantage of these container ports for related industrial stakeholders.

In order to address this aim, a two-step integrated AHP-TOPSIS methodology was used. By utilising this integrated methodology, the author was able to obtain two major results: A) weight of importance of the factors in the hierarchical structure of port selection; B) ranking of the most optimal container port terminal from the 6 targeted container port terminals.

Figure 8.1 below visually displays the above-mentioned explanations and include the overarching research aim and 3 major research aims as well as the methods utilised and final results obtained under each research aim. In the next section, detailed explanation of the research methods and findings obtained under each research aims will be presented.

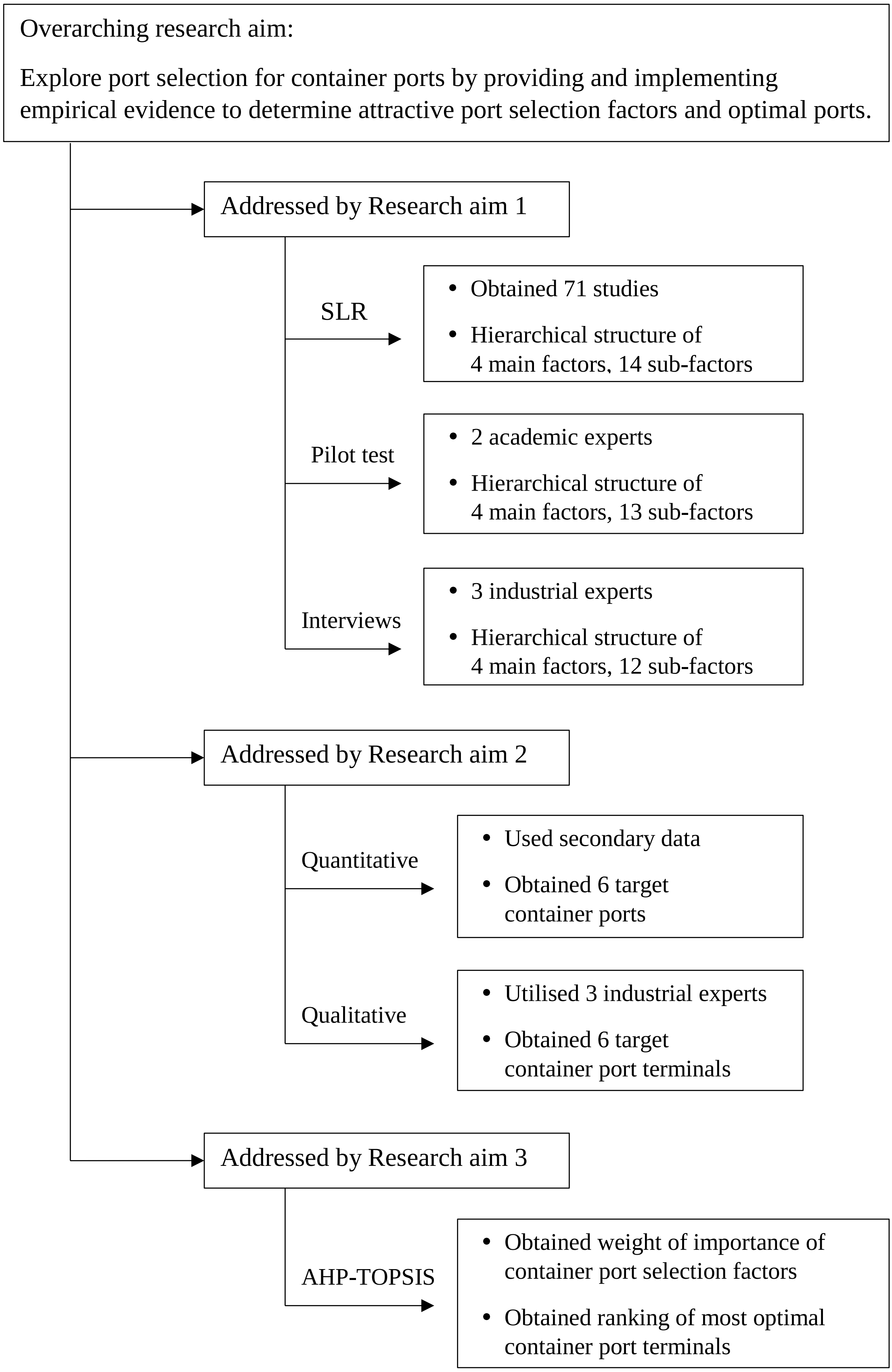

Figure 8.1 Overarching research aim, 3 research aims, methods, and results

8.3 Detailed consolidation of research findings and discussion

Combining qualitative and quantitative methods with data collected from key sources enriches this study's contribution to both the academic research and for practice in port selection. The use of SLR to pick a specific selection of relevant literature, the invitation of highly experienced experts in the relevant field for interviews as well as for questionnaires, and the utilisation of MCDM methodologies like AHP-TOPSIS all provide strong foundation in allowing this study to be an addition of knowledge in the port selection literature. By also covering the under-researched topic of port selection in the ASEAN region from Korean shipping companies' perspectives, this study provides a valuable contribution to fill the gap in the literature. This section further addresses, in detail, the answers to the 3 research aims, which have been lightly covered in the previous section. The obtained findings, utilised methods, and detailed discussion for each of the 3 research aims are addressed in this section.

8.3.1 Addressing Research aim 1

Research aim 1 is the following: investigate selection factors that influence container port selection from the perspective of shipping company. This research aim has been fully covered and answered using findings obtained in Chapter 3, Chapter 4, and Chapter 6. As covered in Chapter 3, initially, through narrative literature review of port selection, numerous studies with varying focuses such as their geographical region of focus and perspective of focus (amongst the port-related stakeholders) were identified. With much literature on port selection, there was a need to systematically filter and compile the most relevant studies that adhere to the focus of this research in order to avoid extracting information that may be irrelevant to this study. Therefore, SLR was implemented to narrow down, scrutinise, and select the most relevant and quality articles pertaining to container port selection. Through Denyer and Tranfield (2009)'s 5 steps of SLR, this study has determined 71 studies to be fit for analysis. Using these 71 studies, top 10 most frequently mentioned factors were organised per Table 3.6. Taking a look at the port selection factors introduced in these studies, it should be noted that there were several port selection factors that also were in line with the literature and were repeatedly considered as important factors for shipping companies, such port location (Ng, 2006; Zabihi et al., 2016; Ergin and Eker, 2019), port cost (Tongzon and Sawant, 2007; Tongzon, 2009; Nazemzadeh and Vanelslander, 2015), and port infrastructure (Lirn et al., 2004; Tongzon and Sawant, 2007; Tang et al., 2011). The rest of the factors in Table 3.6 had slightly different characteristics from one another depending on the aim and focus of each study, be it geographical or perspective-wise.

Next, categorisation separated the 71 studies, which were filtered from the process of SLR, to best allow the focus on one specific port-related stakeholder of shipping companies. Thus, articles that only dealt with the perspectives of shipping companies have been analysed. However, it was found that vast majority of the 71 studies, counting those that had focused on one specific perspective, have already been predominantly researched from shipping companies' perspectives. Therefore, the results of the most frequently appearing port selection factors of the entire 71 studies turned out to be very similar to those only focusing on the perspective of shipping companies.

Based on the aforementioned top 10 most frequently appearing port selection factors, a hierarchical structure was devised consisting of the following: main goal, main factors, and sub-factors. The main goal was set to be "container port selection factors" as this is the focus of this research. Then, a structure of 4 main factors that encompassed a total of 14 sub-factors was devised. The main factors were determined from the top 10 most frequently mentioned port selection factors (Table 3.6) after considering which factors possessed comprehensive coverage of port choice criteria that were able to encompass other detailed sub-factors. The sub-factors have been determined and assigned to their corresponding main factors based on extensively reviewing the 71 selected studies. Hence, a hierarchical structure of port selection that contains 4 main factors encompassing a total of 14 sub-factors has been obtained and are as follows: (A) port location, which encompassed sub-factors of (i) proximity to feeder ports; (ii) proximity to main navigation routes; (iii) proximity to the markets (demand); (iv) distance of shippers from the port (supply), (B) port charge, which encompassed sub-factors of (i) port charges (port dues, pilot cost, towage, etc.); (ii) handling & storage cost of containers; (iii) inland transport cost, (C) port hinterland, which encompassed sub-factors of (i) total container cargo volume (import/export & transshipment containers); (ii) frequency of port of call; (iii) intermodal links, and (D) port efficiency, which encompassed sub-factors of (i) port infrastructure; (ii) container handling capacity; (iii) container yard efficiency; (iv) customs efficiency. This list of main factors and sub-factors that have been obtained from SLR could be seen in Table 6.1.

Hierarchical structure of port selection factors has been obtained from the literature through SLR and this was to be examined and verified by industrial experts. However, before doing so, a pilot test involving 2 academic experts took place. This process not only made this structure "ready" before its presentation to the industrial experts, but also helped to raise critical questions that should be considered to be asked during the interview for gathering key information. The 2 academic experts both hold managing editor positions in journals that publish articles on Asian port selection and evaluation; they have also utilised AHP and TOPSIS methodologies in their studies. These experts were more than fit to review the hierarchical structure of port selection factors and gave a recommendation of deletion of 2 sub-factors, addition of 1 sub-factor, and revision of 3 sub-factors, to which the author has followed. The deleted sub-factors were "proximity to feeder ports" and "customs efficiency," whilst the added sub-factor was "port connectivity." "Proximity to feeder ports" sub-factor has been deleted as, according to the pilot test, this particular sub-factor would be better suited for a different geographical region that contains ports of higher ranking and activities in terms of their world throughput volume. It is true that a factor such as "proximity to feeder ports" is a significant criterion in transshipment terminal selection (Lirn et al., 2004), and feeders provide connection between hubs and other ports for large container vessels that visit large transshipment terminals (Lee et al., 2012). However, the focus of this current research is in selecting the most optimal ports that involve a more direct shipment via SSS of smaller vessel sizes. So, the literature also suggests that the use of this sub-factor would not align with this current research. If this research had been selecting and evaluating ports that rank within top 10 ports of East Asia, this sub-factor would be more appropriate. However, since many ports in the ASEAN region do not possess high container port rankings, it was best that the sub-factor be deleted. In the literature as well, studies that dealt with "proximity to feeder ports" focused on the East Asian region where there are concentrations of high performing container ports (Lirn et al., 2004; Kim, 2014). "Customs efficiency" has been deleted because according to an academic expert in pilot test, "customs efficiency" was not a factor that contributes significantly to the port selection process in the ASEAN region. Instead, sub-factor of "port connectivity" had been suggested to be added in in its place as it plays a vital role in port selection. 3 sub-factors obtained from SLR ("port infrastructure," "container handling capacity," and "container yard efficiency") had undergone revisions to become "port depth," "area of container yard," and "number of gantry crane / gantry crane handling capacity per hour" with the recommendations from the academic experts. These revised 3 sub-factors give more specified definitions of the originally chosen factors and this specification could also be seen in Lirn et al., (2004) in which the authors divide port selection factors into 4 levels where the level of detail increases with each level.

Hence, as a result of the pilot test, the author obtained a hierarchical structure of factors that contains 4 main factors that encompass a total of 13 sub-factors as follow: (A) port location, which encompassed sub-factors of (i) proximity to main navigation routes; (ii) proximity to the markets (demand); (iii) distance of shippers from the port (supply), (B) port charge, which encompassed sub-factors of (i) port charges (port dues, pilot cost, towage, etc.); (ii) handling & storage cost of containers; (iii) inland transport cost, (C) port hinterland, which encompassed sub-factors of (i) total container cargo volume (import/export & transshipment containers); (ii) frequency of port of call; (iii) intermodal links, and (D) port efficiency, which encompassed sub-factors of (i) port depth; (ii) number of gantry cranes / gantry crane handling capacity per hour; (iii) area of container yard; (iv) port connectivity. This list of main factors and sub-factors that have been obtained from the pilot test could be seen in Table 6.2.

Next, in-depth interviews in the form of semi-structured interviews have been carried out with 3 senior-level industrial experts who are currently in departments involved in port selection at the Korean shipping companies that engage in SSS with countries in Southeast Asia. The experts were presented with the port selection factor structure, which has been obtained from the previous pilot test, and were asked to provide comments for addition, deletion, or revision of the factors. Accordingly, 1 sub-factor has been deleted and 3 sub-factors have been re-arranged under different main factors. “Inland transport cost” sub-factor has been deleted after compiling feedback from the industrial experts. One of the experts had commented that it is very rare that they (Korean shipping company) take responsibility for the inland transportation portion since they do not have the competitive edge and the rates that they can secure with the local trucking companies most likely would not be better than the rates that the local shippers can secure with the same local trucking companies. Yang et al., (2016) also supports the above-mentioned statement as the study states that in most cases, shippers are responsible for the inland transportation costs going to and from the ports. Additionally, the industrial experts had deemed that some rearrangement of sub-factors may be necessary for a more natural fit in the main factor and sub-factor relationship. Therefore, “frequency of port of call” had been re-arranged to be under the main factor of “port location.” Further, “proximity to the markets” and “distance of shippers from port” had been re-arranged to be under the main factor of “port hinterland.”

As a result, the author has been able to obtain a final hierarchical structure of factors that contains 4 main factors that encompass a total of 12 sub-factors as follows: (A) port location, which encompassed sub-factors of (i) proximity to main navigation routes; (ii) frequency of port of call, (B) port costs, which encompassed sub-factors of (i) port charges (dockage, pilot cost, towage, etc.); (ii) terminal handling charge (loading & unloading cost, etc.), (C) port hinterland, which encompassed sub-factors of (i) total container cargo volume (import/export & transshipment containers); (ii) proximity to the markets; (iii) distance of shippers from port; (iv) intermodal links, and (D) port efficiency, which encompassed sub-factors of (i) port depth; (ii) number of gantry cranes / gantry crane handling capacity per hour; (iii) area of container yard; (iv) port connectivity. The finally obtained port selection factors are represented in Figure 6.1.

With these results, research aim 1 has been fully addressed. Through SLR, the author has presented a hierarchical structure of container port selection factors that are pertinent to shipping companies’ perspectives. Next, through pilot test with academic experts and in-depth interviews with industrial experts, the author has been able to obtain container port selection factors that are more specifically pertinent to Korean shipping companies' perspective in the ASEAN region.

8.3.2 Addressing Research aim 2

Research aim 2 is the following: analyse Korean shipping companies' focus on targeting the growing markets in the ASEAN region. This research aim has been fully covered and answered majorly through Chapter 1 and Chapter 2. The identification and examination of the growing economic relations between the ASEAN countries and South Korea help in understanding how the Korean shipping companies' interest and focus toward ports in the ASEAN region is naturally growing and deserve further investigation.

Maritime shipping transportation is crucial for South Korea as the country is situated on a peninsula that is separated from its connection to the Asia continent via land transport due to its unique status with North Korea. It can be seen according to the statistics shown in Table 2.1 that exported container cargo volume from South Korea has been steadily increasing to countries in Southeast Asia. Amongst them, Vietnam proved to be the South Korea's top 3 export market. Further, the prevalence in the number of shipping service routes from two of South Korea's biggest ports (Busan port and Incheon port) to Southeast Asian countries also indicates South Korea's priority in their maritime shipping to Southeast Asian countries, as shown in Table 2.2 and Table 2.3. These numbers of shipping service routes to Southeast Asia took the 2nd and the 1st place from Busan port and Incheon port, respectively.

As explained above, the significance of South Korea's economic interest and importance in trade with countries in Southeast Asia is clear. According to the top 30 container ports that traded with South Korea per Table 2.4, it can be seen that 6 of the ports in the list are from Southeast Asia, 5 of which are also within the ranks of world's top 30 container ports. These 6 ports are further utilised in the later stages of the thesis as alternatives and are used to determine the ranking of the most optimal ports using port selection factors, which have been initially identified through Research aim 1. The 6 ports are the following: Ho Chi Minh City in Vietnam, Haiphong in Vietnam, Laem Chabang in Thailand, Port Kelang in Malaysia, Jakarta in Indonesia, and Singapore. Thus, this study's 6 targeted ports have been identified using quantitative data gathered using secondary sources. However, it was difficult to further hone in on which specific terminal for each port that this study will focus on using secondary sources that were obtainable to the author. In order to determine the key terminal for each of the targeted ports, the author has utilised qualitative method of interviews to gather such information.

Semi-structured interviews with 3 highly experienced experts in the relevant port selection departments in Korean shipping companies have been carried out. As shown in Appendix B.1, a series of questions were asked to the experts in order to gain a better understanding of the Korean shipping companies' involvement and activity in the ASEAN region. Additionally, the most called terminals within these 6 targeted ports have been identified. As there are multiple terminals present in such busy port locations, it was useful to have discovered the terminals that the Korean shipping companies widely use. Such identification provided a clearer picture of which terminals the 6 targeted ports were referring to as the ranks of port were to be evaluated in the later stages of the thesis. The terminals are the following: Tan Cang Cat Lai (TCCL) terminal at Ho Chi Minh City, Green port terminal at Haiphong, LCMT at Laem Chabang, North port terminal at Port Kelang, Koja terminal at Jakarta, and Pasir Panjang Terminals (PSA) at Singapore.

8.3.3 Addressing Research aim 3

Research aim 3 is the following: find optimal ports in the ASEAN region for Korean shipping companies and present advantage and disadvantage of these container ports for related industrial stakeholders. This research aim has been fully covered and answered through Chapter 5, Chapter 6, and Chapter 7. In order to cover this research aim, the latter chapters of the thesis lead on from the results obtained from the previous chapters and previous research aims. After deciding from Chapter 4 that the integrated use of AHP-TOPSIS methodology is suitable to find the rankings of the optimal ports, this two-step AHP-TOPSIS methodology has been applied to this research's interest in finding the most optimal ports in the ASEAN region from Korean shipping companies' perspective. This study takes a portion of the AHP procedure to only calculate for the factor weights. Next, whilst this study makes full use of the TOPSIS methodology calculation process, it replaces its weight calculation portion by inserting the weights that had been already obtained from AHP. The full procedure taken to achieve the final results using AHP-TOPSIS has been explained in multiple steps in Chapter 5; and specific details as well as the process involving numerical calculations following these steps have been thoroughly outlined in Chapter 6.

Diving into the AHP part of the AHP-TOPSIS methodology, the first step was to identify the container port selection factors, which had been initially identified through answering Research aim 1 with SLR, pilot test, and in-depth interviews. These identified factors then have been further refined through feedback from academic scholars followed by comments from senior-level industrial experts. Then, the weight of importance of these refined port selection factors have been determined by collecting questionnaire responses from senior-level experts who completed pairwise comparisons for factors of port selection. Following the AHP calculations, which have been executed through *Expert Choice* software, weights of these factors have been determined. The following below lists sub-factors in the order of their importance with their respective weights.

1. Frequency of port of call (33.50%)
2. Terminal Handling Charge (loading & unloading cost, etc.) (14.62%)
3. Proximity to main navigation routes (14.32%)
4. Number of gantry cranes / gantry crane handling capacity per hour (8.10%)
5. Total container cargo volume (import/export & transshipment containers) (4.99%)
6. Proximity to the markets (4.80%)
7. Intermodal links (3.72%)
8. Area of container yard (3.70%)
9. Port charges (dockage, pilot cost, towage, etc.) (3.25%)
10. Distance of shippers from port (3.22%)
11. Port depth (3.09%)
12. Port connectivity (2.69%)

Next, before diving into the TOPSIS part of the AHP-TOPSIS methodology, it is first worthy to mention that the weight distribution of the sub-factors was not uniform and that the top 4 of the 12 sub-factors took over 70% of the whole weight. Therefore, during the TOPSIS calculation portion, these 4 highly weighted sub-factors naturally had strong influences on the performance values for these sub-factors – consequently having a great impact on the final C_i (relative closeness) values. It is important to note again that the rankings of the 6 alternative ports are made using C_i values, which represent relative closeness, with values closer to 1 indicating better performance.

Almost all of the data regarding the 12 sub-factors for each of the 6 targeted container ports were collected either through publicly available sources or through requests to the shipping companies that had been interviewed. There was also data in regards to "intermodal links" that was difficult to obtain through secondary source and was collected through senior-level experts' evaluation, which had been gathered via questionnaire, shown in Part 2 of Appendix C.1. These collected performance value data underwent TOPSIS calculation process, and the weights obtained from the earlier step of AHP had been used on these performance values. Ultimately, the final calculations gave result to rankings of the most optimal ports, which are listed below in order with their respective C_i values.

1. Cat Lai terminal in Ho Chi Minh City port (0.7758)
2. LCMT in Laem Chabang port (0.4732)
3. PSA terminals (Pasir Panjang terminal) in Singapore port (0.4128)
4. North port terminal in Port Kelang (0.3303)
5. Green port terminal in Haiphong port (0.2851)
6. Koja terminal in Jakarta port (0.1199)

Also, it may be worthy to note that sensitivity analysis has been carried out on the AHP-TOPSIS framework that had been used to obtain factor weights and alternative ranking. As it had been suggested in the earlier chapter, sensitivity analysis is a commonly suggested method to validate feasibility and robustness of MCDM methods (Satty and Ergu, 2015). Also, it is essential to observe the impact that changes in the criteria weight bring to the final alternative rankings (Animah et al., 2018). Upon performing sensitivity analysis by swapping the criteria weights with each other, it was found that the final (C_i) values, which determine the ranking, were very sensitive when the criteria weights were swapped with one particular criterion of "frequency of port of call." "Frequency of port of call" alone takes up 33.5% of the total weight of the 12 criteria; therefore, it was a natural and expected occurrence for the results to indicate very sensitive changes when other criteria with lower weights were swapped with the criterion with the highest weight.

8.3.3.1 Discussion on the rankings of the 12 port selection factors obtained through AHP

As demonstrated through the case study in Chapter 6, factors that are considered importantly from Korean shipping companies' perspective dealing in SSS in the ASEAN region have been determined through various processes, which included SLR, pilot test, and semi-structured interviews. The obtained hierarchical structure of factors, which is comprised of 4 main factors encompassing 12 sub-factors, give light to the decision-making process that Korean shipping companies use when selecting port of call. Through AHP, it was obtained that, from the 12 sub-factors, the top 5 most heavily weighted sub-factors constituted for 75.53% of the total weight in this port selection decision-making process. The following are the aforementioned top 5 sub-factors, listed in order by their weights:

1) Frequency of port of call (33.50%)
2) Terminal Handling Charge (loading & unloading, etc.) (14.62%)
3) Proximity to main navigation routes (14.32%)
4) Number of gantry cranes / gantry crane handling capacity per hour (8.10%)
5) Total container cargo volume (import / export & transshipment containers) (4.99%)

Next, it may be efficient to analyse the top 3 most heavily weighted sub-factors to observe their influences on port selection decision-making process. These top 3 sub-factors make up for 62.44% of the total weight and are as follows: "Frequency of port of call"; "Terminal Handling Charge (loading & unloading, etc.)"; and "Proximity to main navigation routes." As these top 3 factors represent more than half of the total weight in such decision-making process, it is viable to note that the 6 alternative ports that have high performance values in these 3 factors are more likely to be ranked as most optimal ports. Additionally, it may be worthwhile to give an analysis as to why "port connectivity" factor placed to be the least important with the lowest weight. Thus, the top 3 factors as well as the last ranking factor are analysed and discussed below.

Frequency of port of call

Frequency of port of call factor was found to be the most important factor in this research. Its dominating weight value that takes up a third of the weight from the overall sum of weights of all 12 port selection factors indicates its great importance to the Korean shipping companies.

The importance of "frequency of port of call" has been already substantiated from numerous port selection literature, including that of Nir et al., (2003), Brooks and Trifts (2008), and Puckett et al., (2011), to name a few. A study by Tongzon (2009) is also among these supporting literature and is especially more relevant to this research as Tongzon (2009) focuses on the Southeast Asian region, albeit for freight-forwarder's perspective. According to Vega et al., (2019), it has also been directly investigated that increasing the frequency has positive correlation to the increased attractiveness of a port. Additionally, Kapros and Panou (2007) discusses about SSS in regards to Greece, and the "frequency of port of call" is mentioned frequently in the study as a factor that has been used to strengthen the competitive maritime position of its offered services between Greece and Italy. In this context, research findings from Svindland et al., (2019) on SSS and the importance of frequency of port of call are insightful. According to the interviewed experts in Svindland et al., (2019), the study mentioned that competitive advantage of SSS could be increased with increased frequency of port of call which also creates higher cargo volumes. Feo-Valero and Martínez-Moya (2022) also provide a research that mentions the importance of frequency of port of call to the shippers and freight-forwarders. According to the authors, the high frequency reduces the possible delay times and allows the shipments to be adjusted to desired days and be loaded in the shortest possible time.

Albeit the mentioned importance of "frequency of port of call" factor and the presence of numerous port selection literature that also focuses on shipping companies' perspectives like this current research, it seems that this factor is regarded of more importance from the shippers and freight-forwarders' perspective according to the current literature. It seems that from shipping companies' perspectives, other factors relating to port location, port costs, and port infrastructure were of more importance. However, as this research focused on shipping companies on a smaller scale (small and medium-sized companies) dealing in SSS to Southeast Asian region, it is possible that the factor of importance for shipping companies in this case may be more particular and different. It is likely that frequency of port of call factor has resulted as the most important factor to the Korean shipping companies due to the large amounts of production from the MNC's located throughout Southeast Asian countries. This is also in line with the explanation from Feo-Valero and Martínez-Moya (2022) as well that although factors such as geographical port location, costs, efficiency, and infrastructure are more notable port factors for shipping companies, there are cases in which each client and traffic type of the port yield different requirements. In sum, as the case study in this research deals with small and medium-sized shipping companies engaging in SSS to countries where MNC's and growing investments are located, "frequency of port of call," which is normally most importantly considered by shippers and freight-forwarders, has been found to be most importantly considered for shipping companies in this research.

Terminal Handling Charge (loading & unloading cost, etc.)

In contrast to the "frequency of port of call" factor, which turned out to be an interesting find given that this research is from a shipping company's perspective, THC factor ranking as the second most important factor was to be expected. According to numerous existing port selection literature conducted from shipping companies' perspective, it would seem that port location, port cost, and port infrastructure surfaced as the most crucial selection factors.

It should be noted that there are two sub-factors under the main factor of "port costs," which are THC sub-factor and "port charge (dockage, pilot cost, towage, etc.)" sub-factor. As shown in Table 6.2 and Figure 6.1, there have been efforts to coin the most suitable terms to best represent the main factor of "port cost." As noted in previous chapters, especially in the case study, the "inland transport cost" factor has been deleted after conducting semi-structured interviews with the experts. One of the experts has noted that it is very rare that they take responsibility for the inland transportation portion since they do not have competitive advantage and the rates that they can secure with the local trucking companies most likely would not better than the rates that the local shippers can get with the same local trucking companies. Therefore, it has been deemed that inland transport cost factor may not be suitable in port selection decision for the Korean shipping companies and has been taken out. As for the "port charge" and THC sub-factors, the interviewees suggested that from shipping companies' perspectives, it may be best to group the costs according to two activities: one in which charges occur from the point a vessel enters the port until it berths (port charge); and another in which, after the berth, charges occur as container handling crane unloads the containers and the containers are positioned onto the container yard until a shipper comes to pick them up (THC). It was in this suggestion that sub-factors of port charge and THC emerged for this research.

Further to the categorisation of port costs, Meersman et al., (2014) discusses multi-pricing structures in port pricing and list that the costs are usually in three categories: port-calling costs, terminal handling costs, and concession pricing. According to Meersman et al., (2014 p. 2), the definitions and costs related to these categories are as follows: "*By port-calling costs, we mean* *costs of all services offered to the vessel, ranging from access to quay or terminal, to pilotage, to the supply of water and bunkering, i.e. they encompass all ship-handling costs. Terminal-handling costs comprise costs for loading or unloading, storage, customs clearance, repacking and forwarding, i.e. they cover all services required for moving the cargo onwards through the port and down the supply chain. By terminal concession costs, we mean the cost of acquiring a dedicated terminal*." According to the authors, port-calling costs and terminal handling costs pertain to the shipping line while terminal concession costs pertain to concessionaire with terminal operators. Thus, it can be seen that the categories of costs outlined by Meersman et al., (2014) (port-calling costs & terminal-handling costs), agree with the sub-factors that were assigned for this current research (port charge and THC).

It can be seen that in comparison to the port charge sub-factor which ranked as the 9th most important factor, THC was highly regarded by the Korean shipping companies. The reason for this may be that as the THC is calculated per container depending on its size, the final price depends on how much cargo is being handled. With the vessel sizes for the Korean shipping companies engaging in SSS with ASEAN region being between 700 TEU and 6,500 TEU, according to the interviews, THC takes priority over the port charge sub-factor since cargo handling services and charges are considered most important to port users in terms of the total cost (Trujillo and Nombela, 1999). Additionally, costs related to THC are more prone to be negotiated whilst the costs related to port charge are generally less negotiable. According to Notteboom and Pallis (2022), in setting port dues (part of "port charges" sub-factor), port authorities would follow various objectives that consider macro-economic, port-centric, and sustainability aspects. Additionally, port dues contain indivisible charges that include calculating on the basis of ship's tonnage and goods unloaded / loaded in terms of tons. Also, marine services such as pilotage and towage (also part of "port charges" sub-factor) are compulsory costs paid by the shipping companies. Dependent on the port, "*these types of services [marine services] are offered by the central or local government, the port authority, and one or more private companies*" (Notteboom and Pallis, 2022). Therefore, cost negotiation pertaining to port charges sub-factor may be less flexible. As for terminal handling charges, in many cases where the port authority acts as a landlord, port operations (especially cargo handling) are carried out by private companies (Pallis, 2022). Also, costs pertaining to ship cargo handling at a terminal are collected by terminal operators (Notteboom and Pallis, 2022), which are generally private companies, making the cost negotiation more likely to be flexible.

It is observable that larger ports, in terms of their container throughput, generally charge higher THC than smaller ports. Muller et al., (2020) also has observed this pattern during their data collection for various port-related costs including THC. In this current research, it could be seen that out of the 6 targeted ports, Singapore (port with the highest world port throughput ranking amongst the targeted 6) had the highest THC whilst Haiphong (port with the lowest world port throughput ranking amongst the targeted 6) had the lowest THC. According to the semi-structured interviews, the interviewee suggested that costs related to THC at Vietnam and Laem Chabang are cheaper because there is a fierce competition acting on these ports to reduce their price. The interviewee commented that port-related costs at Jakarta is expensive due to government's direct involvement in setting prices in order to safeguard its prices whilst port at Singapore is expensive as the living expenses are high. The interviewee stated that these variables ultimately determine the loading and unloading charges of THC.

Proximity to main navigation routes

As mentioned in Chapter 6, the main navigation route in regards to this sub-factor in this research is the east-west routes in Asia-Europe trade with the starting point being at Busan New

Port in South Korea and the ending point being at Port Kelang. Further, proximity to main navigation route has been calculated based on the deviation from this main route that vessels would need to make to reach this research's 6 targeted ports. This current research has determined that a "port location" main factor is comprised of two sub-factors, which are "proximity to main navigation routes" and "frequency of port of call." The findings of this current research have placed "proximity to main navigation routes" as the third most important criterion, closely following the second place of THC. The importance of this sub-factor is also supported by the findings from Lirn et al., (2004) as well that has found that out of its determined 12 sub-criteria, "proximity to main navigation routes" was ranked as the second most important port selection criteria. It should be noted that the design of the study by Lirn et al., (2004) is closely related to this current research in that it has categorised similarly to this current research by using a major criterion of "geographical location" and its sub-criterion of "proximity to main navigation routes." Further, Lirn et al., (2004) has incorporated AHP to find the weights of port selection factors and the study's port-related stakeholder of focus had been predominately shipping companies just like this current research.

Port connectivity

Besides from discussing the heavily weighted factors, it is also important to discuss the last ranking factor by importance obtained through AHP: "port connectivity." Although the "port connectivity" factor has ranked last in its importance out of the 12 sub-factors chosen for this research, it is still nevertheless a significant port selection factor that plays a crucial determining role in the attractiveness of a port. A good port connectivity has the potential to maintain or assist a port in becoming a hub port (Tovar et al., 2015) and port connectivity also has been found to drive port competitiveness (Yeo et al., 2008). It is important to note that, as also shown in the study from Caballé Valls et al., (2020), there is a distinction between maritime connectivity and intermodal connectivity. This research refers more specifically to maritime connectivity as opposed to port's intermodal connectivity that some literature may refer to. Additionally, as mentioned previously, this research has used UNCTAD's PLSCI measures to determine ports' connectivity as shown in Figure 6.5.

It is indicated that ports with high transshipment volume have high port connectivity (Tang et al., 2011). Indeed, two of the targeted ports for this research, Port Kelang and Singapore, do display very high measures for their port connectivity according to Figure 6.5. If this research had been focused on hub port competition, it could be feasible that the "port connectivity" factor be placed within the top rankings as demonstrated through such literature (Wang and Yeo, 2019; Munim et al., 2022). However, it would seem that "port connectivity" does not seem to be of great importance to the Korean shipping companies in this research's context. As indicated in Table 6.15, South Korea already has established its MNC's manufacturing factories in near vicinities of all of the six targeted ports for this research. Therefore, it can be more cost-effective for the Korean shipping companies to engage in direct services for each of the targeted ports. Further to such direct services, Tagawa et al., (2021) investigated at which point it would be more cost-effective to engage in direct shipment over transshipment; and has found that direct shipment can be more effective for short distances for smaller vessels. Specifically, Tagawa et al., (2021) indicated the short distance to be 2,000 nautical miles and relatively low cargo demand (small vessel) to be up to 4,000 TEU, which approximately fits this current research's range of distance and vessel size.

Additionally, if the end destination ports do not have good port conditions, it could cost less and save more time for the shipping companies to drop cargo at a major port and have the cargo transported via feeder service to their end destinations. However, in recent times, the ports in

Southeast Asia have developed better facilities to accommodate and receive more shipments thanks to the increased presence of MNC's and foreign investments. Also, given that this research focuses on SSS, the size of the vessels is not as big as the vessels calling on main trunk route. Therefore, the vessels are able to call to this research's chosen ports without much hindrance due to their size and may lead the Korean shipping companies to utilise transshipment less, which is an indicator of port connectivity according to Tang et al., (2011).

8.3.3.2 Discussion on the rankings of the 6 alternative ports obtained through AHP-TOPSIS

As it has been described in previous chapters, the container ports for this research have been chosen based on their presence in South Korea's top trading ports in terms of volume. In the list of top 30 trading ports with South Korea (Table 2.4), there were 6 ports from Southeast Asian countries. As the ASEAN region is of focus for this research, all 6 of these ports have been chosen to be target alternative ports.

Using the port selection factors obtained from SLR, pilot test, and semi-structured interviews, AHP-TOPSIS methodology has then been utilised to ultimately provide the ranking of the most optimal ports amongst the 6 targeted ports. The results of the AHP-TOPSIS are displayed at the end of Chapter 6 in Table 6.27. For quicker view of the results, the following below lists the 6 targeted ports by the order of their ranking with their respective C_i values:

1) Ho Chi Minh City (Cat Lai terminal) - (0.7758)
2) Laem Chabang (LCMT) - (0.4732)
3) Singapore (PSA terminals) - (0.4128)
4) Port Kelang (North port terminal) - (0.3303)
5) Haiphong (Green port terminal) - (0.2851)
6) Jakarta (Koja terminal) - (0.1199)

Ho Chi Minh City port ranked to be the most optimal port. Recalling back to the top 3 heavily weighted factors that constituted for more than 62.44% of the total weight, Ho Chi Minh City port's performance values for these factors were outstanding in comparison to other ports. Ho Chi Minh City port's performance value for "frequency of port of call" was around 1.5 times that of the second highest port (Laem Chabang), and THC's performance value was second lowest. Also, proximity to main navigation route's performance value was third, only to be placing behind ports (Singapore and port Kelang) that are situated directly on the east-west main navigation route in Asia – Europe trade.

Laem Chabang port ranked to be the second most optimal port. The performance values for Laem Chabang regarding the top 3 heavily weighted factors were also greater than those of most other ports. Befitting of its second place, Laem Chabang has the second highest performance value for "frequency of port of call." As for THC, Laem Chabang's value was third lowest. Value for "Proximity to main navigation route" however was the highest – meaning that Laem Chabang's deviation from the main navigational route is the highest. Although this deviation may have acted negatively on determining Laem Chabang's ranking, the excellent performance values that the port had in regards to the top 2 heavily weighted factors, which constitute nearly half (48.12%) of the total weight, allowed the port to claim the high ranking of second place.

Closely following behind, Singapore port ranked to be the third most optimal port. Although the port has the third highest value for "frequency of port of call," the difference between the second and third highest values for "frequency of port of call" is great. Laem Chabang (second ranking)'s value for "frequency of port of call" is around 2.2 times that of Singapore port (third ranking). As for the THC, Singapore port had the highest value, which acted disadvantageously in determining its optimal ranking in port selection. Despite the low value in the "frequency of port of call" as well as possessing the most expensive THC, it seems that the Singapore port was able to place a high ranking due to its extremely advantageous location of being directly on the main navigational route. The extremely beneficial performance value for "proximity to main navigation routes" played a great role in placing Singapore port as the third most optimal port.

Port Kelang ranked to be the fourth most optimal port. Just like Singapore port, Port Kelang has a highly advantageous location of being on the main east-west navigation route. However, the poor performance values for "frequency of port of call" (fifth highest) and THC (fourth lowest) placed Port Kelang in a low ranking of fourth place.

Haiphong port ranked to be the fifth most optimal port. The port has the fourth highest value for "frequency of port of call" and fourth lowest value for "proximity to main navigation routes." Despite the poor values for the two mentioned factors, Haiphong port has the most advantage in having the lowest THC value. However, it seems that due to the heavy influence of "frequency of port of call" factor coupled with poor performance values in the rest of the 9 factors, Haiphong port placed as fifth place.

Jakarta port ranked to be the least optimal port. In terms of the top 3 heavily weighted factors, Jakarta port has poor performance values. The performance value of "frequency of port of call" is the lowest in comparison to others, making Ho Chi Minh City's (first ranking) values to be around 7.4 times that of Jakarta port. Jakarta port also has the second highest THC as well as being second furthest away from the main navigation route according to its "proximity to main navigation route values." The overall poor performance values placed Jakarta port to be the least optimal port.

8.3.4 Discussion on ranking of optimal ports through scenario testing

The details of each of these targeted ports have been outlined in Chapter 2, and Chapter 7 covered various hypothetical scenarios and simulations that manipulated increases or decreases to the performance values to try to alter the optimal rankings of the targeted ports obtained through AHP-TOPSIS. In the process of achieving changes to the rankings, it could be observed that the changes to performance values affected the C_i values (relative closeness, with values closer to 1 indicating better performance) of the 6 ports differently under different circumstances for certain sub-factors. Specifically, the observers could discern which port's sub-factor performance values induce greater effect on changing the final C_i values when there are uniform increases or decreases in the values for all 6 ports. These useful simulations give insights to the positive or negative impact that such increases or decreases in certain port's sub-factor performance values will bring, and these insights help in forming future strategic plans in order to improve the attractiveness of these ports.

Scenario testing in Chapter 7 was divided into two different kinds of testing. One of these tests included 3 sets of simulations where there were independent improvements (ceteris paribus) to the performance input values. The second of these testing include proportionate changes to the performance input values. The main difference between these different kinds of testing is that the former (ceteris paribus testing) merely increases the performance value of a desired sub-factor for the targeted alternative by itself whilst the performance values of all else are kept the same as before. The latter (proportionate change testing) assumes that the total amount of performance input values is fixed and any changes to a certain sub-factor's performance value for a specific port will be offset by the same sub-factor's performance values of the remaining 5 ports (this research deals with 6 ports). This means that, for example, if the total number of "frequency of port of call" performance values for all 6 targeted ports equate to 38, this total value will remain fixed even if the author instigates a change to increase the "frequency of port of call" value of one specific port by 10%. This is done by decreasing "frequency of port of call" values of the other 5 ports by equal amounts that had been increased. The purpose of this latter kind of testing (proportionate change testing) was to see how shift of resources, both positively and negatively, in the collected data of this research will affect the final rankings. On the other hand, the purpose of the former kind of testing (ceteris paribus testing) was to see how "raw" increase – only positively – in just a specific resource will affect the final rankings.

8.3.4.1 Independent (ceteris paribus) improvements

As discussed above, the first kind of scenario testing involved first setting a goal (such as trying to get 2nd ranked port to overtake the 1st ranked port in terms of the overall performance) and then targeting a specific sub-factor to alter in order to achieve such goal (such as improving performance value of THC by 10%). As noted before, the scenarios in this testing include independent improvements, ceteris paribus; meaning that all else performance values remain the same. After such increase has been made to specific performance values, the altered decision matrix of Table 6.19 is re-entered into the AHP-TOPSIS calculation process to yield a new set of C_i values, which help to ultimately determine the altered ranking of the ports.

A total of three scenarios have been constructed to determine the following: (1) what would it take for the 2nd ranked port to overtake the 1st ranked port? (2) what would it take for the 3rd ranked port to overtake the 1st ranked port? (3) looking at the 4th, 5th, 6th ranked ports, what would it take for each port to overtake their immediately preceding port of higher rank? For each of the scenarios, two sub-factors have been considered to be subject to improvement. For scenarios 1 and 2, sub-factors of “frequency of port of call” and “THC” have been chosen to be improved since these are the top two sub-factors in terms of their weight of importance (33.50% and 14.62%, respectively) that provide the best chance of aiding desired changes in the final rankings of ports. Sub-factor of “proximity to main navigation routes,” which closely follows the “THC” with a weight of 14.32%, has not been regarded since it pertains to an unalterable measurement of physical distance of the ports from the main navigation routes. For scenario 3, sub-factors of “number of gantry cranes / gantry crane handling capacity per hour” and “area of container yard” (8.10% and 3.70% in weight, respectively) have been chosen to be improved because the ports that placed on the lower end of the rankings could have possibility for further port development and expansion such as for North port terminal in Port Kelang (4th rank) and Koja terminal in Jakarta (6th rank). Such development to the ports would bring about natural increases to the gantry crane number and the overall container yard area.

Additionally, it should be noted that for a more visual presentation, Table 8.1, presented at the end of this section, provides summary of the purpose of each scenario, sub-factors involved, and the results.

Scenario 1

The purpose of this scenario was to see how much improvements need to be made to the 2nd ranked port to overtake the 1st ranked port. The performance values of two sub-factors, “frequency of port of call” and “THC” have been improved alone and simultaneously to see how much increase need to be made before the overtaking occurred. As expected, increasing “frequency of port of call” value brought on more prominent improvements. “THC,” however, proved to be ineffective in aiding the 2nd rank to overtake the 1st rank. Ultimately, when the “frequency of port of call” value alone was increased by 120%, the 2nd rank overtook the 1st rank. As a test to display the insufficient role of the change in “THC,” this value had been decreased to the lowest “THC” value amongst the 6 ports, and then “frequency of port of call” value was increased until 2nd rank overtook the 1st rank. The results showed that 117% increase in “frequency of port of call” would still need to be made even after the “THC” value had been decreased to its potentially lowest value. Here, the lowest potential decrease to the “THC” value only affects the “frequency of port of call” by 3%, proving the change in “THC” as ineffective. Currently, the 2nd rank has calls from Korean shipping companies roughly 2.4 times per week, on average. If the port could increase the frequency to call roughly 5.3 times per week, the port could overtake the 1st ranked port.

Scenario 2

The purpose of this scenario was to see how much improvements need to be made to the 3rd ranked port to overtake the 1st ranked port. In this case as well, the performance values of two sub-factors, “frequency of port of call” and “THC” have been improved alone and simultaneously. Compared to scenario 1, since there is more C_i value to overcome in order to overtake the 1st ranked port, more improvement to the “frequency of port of call” sub-factor needed to be made. By increasing this sub-factor alone, there needed to be a 221% increase for the overtaking to occur. When considering simultaneous improvements of the two sub-factors, there needed to be 38% reduction in “THC” and 175% increase in “frequency of port of call.” Here, 38% reduction represents the amount needed to reduce the 3rd ranked port’s “THC” performance value to the average “THC” values of all 6 ports. Once this reduction had been made, the performance value for “frequency of port of call” had been steadily increased until the rank overtaking happened. Currently, the 3rd rank has calls from Korean shipping companies roughly around 1.1 time per week. Also, the “THC” for the 3rd rank is the highest amongst the 6 ports at $155.80. If the port could increase the frequency to call roughly 2.9 times per week, and reduce the "THC" to $96.60, the port could overtake the 1st ranked port.

Scenario 3

The purpose of this scenario was to see how much improvements need to be made to the 4th, 5th, 6th ranked ports to overtake their respective immediate higher-ranked ports. In this scenario, the performance values of two sub-factors, "number of gantry cranes / gantry crane handling capacity per hour" and "area of container yard" have been improved alone and simultaneously to see how much increase need to be made before the overtaking occurred. For these ports, a significantly large amount of improvements needed to be made as the two sub-factors (mentioned above) that were subjected to change took a mere 11.8% of the total weight, combined. Again, the reasoning to have chosen these two particular sub-factors was because of the fact that these ports (4th, 5th, 6th ranked ports) were more subject to possibility for further port development and expansion such as for North port terminal in Port Kelang (4th rank) and Koja terminal in Jakarta (6th rank).

The amount of improvements to the two sub-factors that were needed to made simultaneously for the 4th rank to overtake the 3rd rank was significantly large. Considering that the "area of container yard" for the 4th rank had been increased to the biggest of the 6 ports, which yielded 491% increase, there also had to be an increase of 627% to the "number of gantry cranes / gantry crane handling capacity per hour." Currently, the 4th rank port has 93 hectares of container yard and performance value of 800 for the gantry crane operational capacity. In order for the rank overtaking to take place, the 4th rank port would need to increase the container yard to 550 hectares and increase the gantry crane operational capacity to the value of 5,816.

The amount of improvements to the two sub-factors that were needed to made simultaneously for the 5th rank to overtake the 4th rank as well as for the 6th rank to overtake the 5th rank was even significantly larger. Simultaneous increase to the two sub-factors for these two cases were very ineffective. No overtaking of the ranks occurred even after 1,000% of simultaneous increase to both sub-factor performance values. Therefore, it could be seen in this study that these ports would need to put focus in improving other aspects of its port attractiveness that arise out of the completion of port development or expansion. Those aspects could include increased frequency of port of call and total cargo volume from the terminal's bigger handling capacity and potentially shorter port dwell time.

For a more visual presentation, Table 8.1 provides summary of the purpose of each scenario, sub-factors involved, and the results.

Table 8.1 Summary of 3 scenarios conducted for independent (ceteris paribus) improvements

Scenario 1		
Purpose	**Changes instigated**	**Results**
For 2nd rank to overtake 1st rank	• Increasing frequency of port of call • Decreasing THC	• Decreasing THC brought ineffective results. • Overtaking occurred when there was 120% increase just to the frequency of port of call.
Scenario 2		
Purpose	**Changes instigated**	**Results**
For 3rd rank to overtake 1st rank	• Increasing frequency of port of call • Decreasing THC	• Overtaking occurred when there was 221% increase just to the frequency of port of call. • Reducing THC needed to be in reasonably moderate amount. So, reducing THC by 38% (to the average THC value of all 6 terminals) and simultaneously increasing frequency of port of call by 175% led to the overtaking.
Scenario 3		
Purpose	**Changes instigated**	**Results**
For 4th rank to overtake 3rd rank	• Increasing number of gantry crane / gantry crane handling capacity per hour • Increasing area of container yard	• Overtaking occurred when the area of container yard was increased to the biggest of the 6 terminals (491% increase) and when number of gantry crane / gantry crane handling capacity per hour was simultaneously increased by 627%.
For 5th rank to overtake 4th rank For 6th rank to overtake 5th rank	• Increasing number of gantry crane / gantry crane handling capacity per hour. • Increasing area of container yard	• Simultaneous increase to both sub-factors were ineffective as no overtaking was observed even over 1,000%.

8.3.4.2 Proportionate changes

As discussed previously, this second kind of scenario testing involved first setting conditions in which the testing will entail. The total amounts of performance input values remain fixed as opposed to the "raw" improvements of values as seen in the first kind of scenario testing that involved independent (ceteris paribus) improvements. The purpose of this current kind of scenario testing was to see how different shifts of resources in this research's currently collected data will affect the final rankings. Unlike the first kind of testing, this current kind of testing involved both positively improving as well as negatively diminishing the targeted sub-factor's performance value for its respective 6 ports.

For this proportionate change to work, the total amount of resources indicated by the performance values in Table 6.19 will stay the same. In order to simplify this process, the 6 performance values of each sub-factor were converted proportionally to add up to 1. So, each column of the 12 columns of sub-factors in Table 6.19 would add up to a sum of 1. Then, each time that a change occurred to a sub-factor performance value for a particular port, the performance value of the rest of the 5 ports for the same sub-factor would also undergo equal changes to make sure that the total still would add up to 1. As a demonstration, for simplicity-sake, take a hypothetical example where THC sub-factor has the converted values of 0.25 for Ho Chi Minh City port and 0.15 for the remaining 5 ports. If there was an 80% increase to THC performance value for Ho Chi Minh City port, its value would increase to 0.45. If the calculation stops here, the total sum for THC for all 6 ports would go over 1 by 0.20. Therefore, this 0.20 is offset by evenly distributing it negatively amongst the performance values of THC of the other 5 ports; meaning that the THC values of other 5 ports will experience decrease in 0.04. Thus, if there was an 80% increase to THC for Ho Chi Minh City port, its value would increase from 0.25 to 0.45, and the values for the remaining 5 ports would decrease from 0.15

to 0.11. It should be noted that after performing each proportionate increase or decrease, the altered decision matrix of data of Table 6.19 would be re-entered into the AHP-TOPSIS process to observe changes in the C_i values (determine the ranking of ports).

The increments of increase or decrease to the performance values was set at 10%, and a total of 8 series of increments (2 increments in decreasing and 6 increments in increasing) was carried out in total until changes in the ranking have been observed. Changes in the ranking was observed when the performance values decreased by 20% and when the performance values increased by 60%. It should be noted that for a more visual presentation, Table 8.2 provides a summary of when the rank overtaking occurred and the observations made based on the amount of change in the final C_i values (determine ranking of ports).

When the performance values have been proportionately decreased by 20% for all the 12 sub-factors, it was observed that there was an overtaking of rank when there was such decrease in the "frequency of port of call" sub-factor. In this case, the 3rd ranked port overtook the 2nd ranked port. Also, looking at the differences in the changed C_i values (ranking values) resulting from the decrease, it was observed that amongst all 6 ports, when there was a decrease in the "frequency of port of call" sub-factor, 2nd ranked port (LCMT) was most drastically affected. This shows that LCMT relies much more on this sub-factor to make its port attractive compared to how much the 5 other ports rely on this sub-factor. For "frequency of port of call," LCMT has performance value of 9.6 whilst 1st ranked port (Cat Lai) has performance value of 14.814. The decrease did not have such drastic impact on Cat Lai, however, since Cat Lai's performance values for the other highly weighted sub-factors of "THC" and "proximity to the main navigation routes" were quite ideal. LCMT's performance value of "proximity to the main navigation routes" is the poorest of all 6 ports. Therefore, LCMT shows to have reacted more sensitively to the change.

Next, when the performance values have been proportionately increased by 60% for all the 12 sub-factors, an overtaking of rank occurred on two separate accounts when there was such increase in the "frequency of port of call" sub-factor and in the "proximity to the main navigation routes" sub-factor. For both of these cases, the 5th ranked port overtook the 4th ranked port. Also, when all the 12 sub-factors have each been increased proportionately by 60%, several observations were made, according to the differences in the changed C_i values (ranking values). When there was an increase in the "frequency of port of call" sub-factor, 2nd ranked port (LCMT) again was most drastically affected. Again, this demonstrates that LCMT relies much more on the performance value of this sub-factor compared to the degree of reliance that the other 5 ports have on this sub-factor. When there was an increase in the "proximity to the main navigation routes," 6th ranked port (Koja) was most drastically affected. Following after LCMT, Koja is the 2nd farthest away from the main navigation routes, making its performance value the 2nd poorest for this sub-factor. Therefore, when there was a positive improvement to this sub-factor, Koja was the most sensitive to change. Another observation worth noting is that when there was an increase in the "THC" sub-factor, Koja was again most drastically affected. Following PSA terminals, Koja has the 2nd most expensive THC out of the 6 ports. As Koja's performance in the other highly weighted sub-factors of "frequency of port of call" and "proximity to the main navigation routes" are quite poor, if not the poorest, the positive improvement to the "THC" sub-factor has the most significant impact to Koja in comparison to the other 5 ports.

For a more visual presentation, Table 8.2 below provides a summary of when the rank overtaking occurred and the observations made based on the amount of change in the final C_i values (determines ranking of ports).

Table 8.2 Percentage increments where rank overtaking occurred and the observations made

20% Decrease	
Ports that experienced rank overtaking	**Observations on the 20% decrease and on changes in the final C_i values resulting from the decrease**
3rd rank overtook 2nd rank	• 20% decrease to the frequency of port of call resulted in the overtaking. • Decrease in frequency of port of call most drastically affects 2nd rank port (LCMT).
60% Increase	
Ports that experienced rank overtaking	**Observations on the 60% increase and on changes in the final C_i values resulting from the increase**
5th rank overtook 4th rank	• 60% increase to the frequency of port of call resulted in the overtaking. • 60% increase in the proximity to the main navigation routes also resulted in the overtaking. • Increase in frequency of port of call still most drastically affects 2nd rank port (LCMT). • Increase in proximity to the main navigation routes most drastically affects 6th rank port (Koja). • Increase in THC most drastically affects 6th rank port (Koja).

8.4 Chapter summary

This chapter firstly revisited and addressed the research gap as well as the 3 research aims that have been established at the beginning of this study. Discussion for each research aim has been presented in different sections, which thoroughly detail specific research methods used to address the aims and discuss the findings arising from utilising such methods.

Discussion has been presented on the weight rankings of container port selection factors for

Korean shipping companies that had been obtained through AHP. Of the 12 sub-factors, the top 5 most heavily weighted factors made up for 75.53% of the total weight, and the top 3 factors made up for 62.44% of the total weight. As these top 3 factors represent more than half of the total weight, these factors have been analysed in detail. It was interesting to note that the "frequency of port of call" factor was found to be the most important factor for Korean shipping companies. This factor is generally considered more important by shippers / freight-forwarders according to the literature. However, this was not true in this case potentially due to the presence of Korean MNC's in the ASEAN region and the growing investments. This chapter also discussed why port connectivity factor may have placed as the least important factor. One possible reasoning could be that South Korea has already established MNC's manufacturing plants in close distance to all the 6 targeted ports that therefore led Korean shipping companies to engage in direct services with less transshipments.

Afterwards, this chapter took these top 3 important factors to discuss how the 6 targeted ports' rankings have been determined, which have been obtained through AHP-TOPSIS. As was expected, the amount of performance values of the factor with the most prevailing weight (frequency of port of call) almost accurately determined the order of the optimal rankings of the 6 ports. Furthermore, numerous scenario testing has been conducted to try to instigate changes in the port rankings for one port to overtake another. The results from such scenario testing give a sense of how much performance input value need to be increased for there to be a change, and also an understanding of which sub-factor performance values that certain ports react more sensitively to when there was a change.

CHAPTER 9: CONCLUSION

9.1 Chapter introduction

The topic of container port selection in Southeast Asian ports for Korean shipping companies has been extensively examined in this study. This chapter discusses the main research findings and the research processes undertaken to address each research aims, which had been supplemented by research objectives. Then, the chapter presents limitations of this study, recommendations for further research, and finally theoretical and practical contributions of this study.

9.2 Main conclusions

Maritime shipping transportation is essential part of world trade as most international trade between one country and another is achieved using sea transport. It is therefore crucial to also be able to discern what attractive factors are considered the most when port-related stakeholders are choosing which ports to direct the cargo to. This thesis focused on the maritime shipping pertaining to Korean shipping companies as South Korea is one of the top participants of maritime global trade in the world, and is also one of world's largest economies. Further, the study dives into giving an overview of South Korea's maritime trade with ports in Southeast Asia as the ASEAN region has been a major growing market for Korean MNCs. The ten members of ASEAN collectively have contributed to be South Korea's 2nd largest trading partner since 2017; South Korea's interest and investment in the ASEAN region is considerable. In light of this, this study digs deeper to specifically involve South Korean port-related stakeholder and ports in the ASEAN region as a case study to find the most optimal alternative from the study's chosen stakeholder's perspective.

The thesis first introduced the research background, purpose, research gap, and the research aims and objectives for this study in Chapter 1. The overview of South Korea's SSS with ports in the ASEAN region is covered in Chapter 2. The background of port selection literature and the use of SLR to further pinpoint the port selection factors that are more particular to shipping companies' perspective are covered in Chapter 3. Chapter 4 provides review of research design as well as research framework that was incorporated for this study. Chapter 5 and 6 then further dives into a case study using the chosen AHP-TOPSIS methodology framework to find the weights of key port selection factors and the ranking of the most optimal ports in the ASEAN region from Korean shipping companies' perspective. Chapter 7, sensitivity analysis is executed in order to validate the feasibility and robustness of the obtained results, and various scenario simulations are carried out to experiment what elements could be changed by how much in order to facilitate different results. Finally, Chapter 8 details discussion from the findings obtained throughout the thesis.

To conclude the thesis, the overarching research aim, three detailed research aims, and research objectives are recalled. The overarching research aim of this study was to explore port selection for container ports by providing and implementing empirical evidence to determine attractive port selection factors and optimal ports. In order to break down this overarching research aim and delve into more particular topics, three further major research aims of this research were established:

1. Investigate selection factors that influence container port selection from the perspective of shipping company.
2. Analyse Korean shipping companies' focus on targeting the growing markets in the ASEAN region.
3. Find optimal ports in the ASEAN region for Korean shipping companies and present advantage and disadvantage of these container ports for related industrial stakeholders.

In order to achieve these research aims, 6 objectives were used and are addressed in the following sections:

9.2.1 Research objective 1

Research objective 1 is the following: identify the driving port selection factors within container port selection literature. It was first a preliminary task to establish what the driving port selection factors were in container port selection literature. In order to fulfil this objective, a narrative literature review had been conducted to review the fundamental background knowledge of port selection such as the importance of ports, various types of ports, port selection, and various port-related stakeholders involved. Then, using SLR, the literature had been more narrowly filtered to draw out the most relevant container port selection studies. Analysing such quality filtered port selection studies relevant for this research, a hierarchical structure of driving container port selection factors for shipping companies has been developed.

9.2.2 Research objective 2

Research objective 2 is the following: develop a hierarchical model of factors that influence Korean shipping companies' container port selection. Having identified such hierarchical structure of key container port selection factors, this structure has been verified through a group of academic experts and industrial experts. The hierarchical structure of factors first underwent review and changes through pilot test with academic experts who hold respectable positions and experiences in the maritime shipping field. Then, the revised hierarchical structure of factors has been further scrutinised and discussed through semi-structured interviews with industrial experts. These industrial experts altogether hold an average of 19 years of experience in the relevant maritime shipping field and were more than fit to provide their input. As a result, a finally refined hierarchical structure of driving container port selection factors that is tailored for the South Korean shipping companies in the ASEAN region has been constructed.

9.2.3 Research objective 3

Research objective 3 is the following: examine South Korea's growing maritime transport activities with the ASEAN region and its target container ports in the ASEAN region. This objective focused on using secondary data to investigate and outline South Korea's increasing maritime shipping activities in the ASEAN region. The obtained statistics verified that the export container volumes as well as number of shipping service routes from South Korea to the ASEAN region have been on a positive increase. Additionally, data regarding top 30 container ports trading with South Korea displayed that Southeast Asian countries are also major participants to maritime trade with South Korea. With the help of these secondary data, 6 container ports in the ASEAN region that are actively involved in maritime trade with South Korea have been confirmed.

9.2.4 Research objective 4

Research objective 4 is the following: investigate South Korean shipping companies' involvement in maritime trade with the ASEAN region and their widely used container terminals. Having confirmed the 6 container ports in the ASEAN region that this research will focus on from the third objective, this fourth objective focused on investigating the specific terminals that the South Korean shipping companies utilise the most. Therefore, semi-structured interviews with senior-level industrial experts in the relevant field have been invited to provide their companies' most frequented terminals for each of the 6 container ports. Additionally, the interviews gave a clearer picture on the South Korean shipping companies' trading cargo heading to the ASEAN region by receiving responses on what commodity goes to which final destinations. Ultimately, a specific terminal for each container ports (6 terminals in total) has been confirmed.

9.2.5 Research objective 5

Research objective 5 is the following: evaluate the weight of importance of container port selection factors. With the hierarchical structure of container port selection factors established from the previous fourth objective, this fifth objective sought to determine the weight of importance of each factor in the hierarchical structure. This research deployed questionnaire survey to the relevant personnel in all small and medium-sized South Korean shipping companies involved in SSS with ASEAN region. The vast majority (around 60%) of these industrial experts have over 16 years of experience in the relevant maritime shipping field and provided responses that reflect their long and invaluable experience in the field. With the collected questionnaire, this research implemented AHP methodology to calculate and obtain the weights of the factors with the aid of AHP software, *Expert Choice*.

9.2.6 Research objective 6

Research objective 6 is the following: evaluate the ranking of the most optimal ports in the ASEAN region to the Korean shipping companies. Using the weights of the factors obtained from the previous fifth objective, this sixth objective sought to evaluate the most optimal ports using the targeted 6 ports. For such evaluation, secondary data on each of the factors in regards to the 6 ports have been gathered. These data include those gathered from publicly available sources as well as data obtained from the interviewed Korean shipping companies. Then, incorporating both the gathered secondary data and the factor weights, this research used AHP-TOPSIS methodology to calculate and finally obtain the optimal ranking of 6 ports in the ASEAN region for South Korean shipping companies.

9.3 Research limitations

Although this research makes significant contribution to the body of port selection literature and the findings also allow for practical implication, there are limitations that need to be addressed.

This study has made use of integrated AHP and TOPSIS to calculate the weights of factors with AHP and the rankings of alternatives with TOPSIS portion of AHP-TOPSIS. The two-step integrated use of AHP-TOPSIS has been outlined in Chapter 5 and Chapter 6. The data needed in order to perform the AHP portion of the AHP-TOPSIS were the following: established hierarchical structure of container port selection factors, and collection of questionnaires containing pairwise comparisons to determine the degree of importance of these selection factors from industrial experts. The data required for AHP methodology has been seamlessly collected from highly experienced experts in the field. Next, the data needed in order to perform the TOPSIS portion of the AHP-TOPSIS in this research were the following: performance values of port selection criteria on each port (this research has collected data from all Korean shipping companies that deal SSS to Southeast Asian countries). The data required for this TOPSIS portion of AHP-TOPSIS has been collected either through publicly available sources or through requests to the Korean shipping companies. However, it was difficult to obtain secondary data regarding one of the port selection criteria, "intermodal links." Thus, the performance value for this criterion has been measured using the experts' judgment through questionnaire. Therefore, had the quantitative data for "intermodal links" been collected from reliable secondary source as well instead of gathering experts' opinions through questionnaire, the results may have reflected to be more objective.

Another limitation of this study pertains to the ease and practical usage of this study's proposed AHP-TOPSIS methods. Though the thesis has gone in lengths to outline detailed instructions and explanations for the steps required to perform AHP-TOPSIS as well as demonstrate a case study with calculation process that follows these exact same steps, the decision makers in shipping companies and port authority / operator may find it difficult to practically utilise the explained methods. If the whole calculation process of the two-step AHP-TOPSIS could be systemised for practical purposes and made as a program that contain automated processes, decision makers would be able to input relevant acquired data into this system and calculate for the selection of optimal ports with more ease and accuracy.

9.4 Recommendations for further research

Throughout the investigating, collecting, and writing processes to complete this PhD project, there were several points that could have been worth considering for the improvement of this project or taking note for a future research. Majorly, as this study uses a case study regarding Korean shipping companies dealing in SSS in the ASEAN region, the results and their analysis adhere to only a narrow focus in container port selection. The decision-making process of container port selection take on slightly different characteristics depending on the region of focus and the perspective of a particular port-related stakeholder that the research focuses on. The driving port selection factors differ slightly or greatly depending on these different angles, and this current research deals with one of these angles: Korean shipping companies in the Southeast Asian region. Therefore, should resources and time allow it, it may be worth considering interviews and conducting questionnaire survey for the different port-related stakeholders in this study's same context of container port selection in the ASEAN region for Korea. Compiling such obtained results from different stakeholders' perspective may provide a more comprehensive package of up-to-date overview of container port selection decision-making patterns in the Southeast Asia. Also, conducting such further research may provide abundant results for comparison analysis of key factors and patterns that are regarded differently to various stakeholders, which is crucial in forming necessary strategies in increasing port attractiveness.

Additionally, the target ports set for this research were obtained from a data source that listed top 30 trading container ports with South Korea. If more time and resources were available, it may be worth considering to extend this list of most traded container ports with South Korea in order to capture more ports in the ASEAN region. Further, should resources allow it, it may be worth collecting data for all container terminals for the targeted ports. Collecting and utilising these data may help to evaluate targeted ports more comprehensively.

9.5 Research contributions

There are numerous amounts of literature regarding port selection that are tailored for their specific focus of their studies. These focuses could vary geographically depending on which region or even country that the study is investigating; or the focuses could vary perspective-wise depending on which stakeholders' perspective the study sets out to investigate from (shipping companies, freight forwarders / shippers, and port authority / port operator for this current study). After conducting literature review and SLR, it was found that literature on the analysis of port selection factors and assessment of attractive ports in the Southeast Asian region from Korean shipping companies' perspectives have been under-researched.

It is noteworthy to draw attention to the growing economic trade relations between South Korea and countries in Southeast Asia. South Korea's interest and investment to countries in Southeast Asia have been considerable as seen also from the increase in shipping service routes and export container cargo volume into Southeast Asian region. Given South Korea's high position in the maritime transport business and its high ranking as one of the world's largest economies, investigating into the niche market of Southeast Asia from South Korea's perspective is meaningful and beneficial. Additionally, in the already competitive market for marine container cargo shipping, it is a good strategy to shift focus and find a niche market such as trading to Southeast Asian ports to increase profitability. Thus, identifying such importance and gap in literature, research into this topic contributes in investigating driving port selection factors from the perspective of Korean shipping companies as well as the ranking of optimal calling ports in the ASEAN region from Korean shipping companies' perspectives.

9.5.1 Theoretical contribution

As it has already been mentioned, there are already numerous literature pertaining to port selection regarding different geographical regions around the world, each with focus on its perspective as well. However, port selection literature that focused on Southeast Asia was sparse. Further, topic pertaining to this study (port selection in the ASEAN region from Korean shipping companies' perspectives) was not able to be identified in the current port selection literature in English. Therefore, this study contributes to the existing literature by investigating and identifying the driving port selection factors from this study's particular geographical region (Southeast Asia) and perspective (Korean shipping companies) by systematically conducting literature review and verifying its results with senior-level experts in the relevant field. This research is the first to investigate and present Korean shipping companies' evaluation structure. Further, this study enhances the literature by finding the ranking of the optimal ports particular to this research's topic using MCDM methods, which utilise the collection of evaluation data and judgments of senior-level experts.

To the author's best knowledge, this study is the first to research the perception and perspective of port selection from Korean shipping companies engaging in SSS. In this study, the researched Korean shipping companies engaged in SSS, which involves operating maritime transport of goods over relatively short distances (Dalli, 2021), operate to Southeast Asia with size of the vessels ranging as low as 700 TEU to as high as 6,500 TEU, according to interviews with Korean shipping companies. In contrast to numerous research on large shipping companies operating on the main trunk routes, there has not yet been a research in regards to SSS in this study's targeted region.

When conducting semi-structured interviews for this research, the process of port selection for calling ports was described to the author during the interviews with highly experienced industrial experts. It may be beneficial to be illuminated on the procedure in choosing calling ports at Korean shipping companies. First, the sales and marketing department would predominantly share information and work in coordination to find where the sales demand is and where the profits could be made. Then, expert opinion from staff in the field are taken, reviewed, and reported to the upper management. Finally, decisions on port selection are made by directors in charge. It should be reiterated here that since there are numerous evaluation factors involved to select the best port amongst multiple ports, this problem is a standard MCDM problem. Hence, this study solves this MCDM problem regarding port selection for the first time for Korean shipping companies engaging in SSS.

This study outlined the overview of South Korea's increasing economic trade with countries in the Southeast Asia and provided crucial background knowledge that substantiates this increased economic interest. Additionally, this study draws upon the significance of Southeast Asian region by making connection to the potential shift in production grounds from the most widely recognised China to Southeast Asia. This potential shift entails such reasons like the decline in Chinese manufacturing's cost advantage in various capital and labour costs and the influence that the China - U.S. trade war brought to the reconfiguration of supply chains and relocation of production facilities.

The use of well-known and reliable MCDM methods, such as AHP and TOPSIS, have been demonstrated. These methodologies have been integrated in their use to reap the advantages of each one, and the robustness of each methods has been also checked by calculating for the CR and executing sensitivity analysis. Additionally, this study contributes knowledge from the academic scholars and industrial experts whose expertise lie directly in this research topic. They have been invited to participate in pilot-test and semi-structured interviews that asked for their input on various research topics revolving around port selection factors. Their level of experience and professional knowledge prove to be valuable contribution to the body of port selection literature.

This study contributes to the literature by enhancing the understanding of port selection and port attractiveness, especially in this study's region (Southeast Asia) and perspective of focus (shipping companies), which is under-researched. This research identifies the extent of influence that the port selection factors have by determining their weights, and also evaluates the rankings of most optimal ports in the study's region of focus using the aforementioned MCDM methods. Such findings add to the literature and help to understand what criteria that the shipping companies consider in their decision-making process in port selection. Further, to the best of author's knowledge, this research is the first to investigate port selection for small and medium-sized Korean shipping companies engaging in SSS, thus could provide an important reference point for future port selection research on small and medium-sized shipping companies.

9.5.2 Practical implication

Based on the findings and their discussion throughout the thesis, numerous practical implications have been formed depending on the different port-related stakeholders. This section thus presents practical implications by each stakeholder. At the end of this section, Table 9.1 and Table 9.2 are presented to provide visual summaries of these implications by their respective stakeholders.

Additionally, before the start of this section, it is worth recalling that this thesis used MCDM methodologies and obtained two main findings, which are the weights of key container port selection factors and the rankings of optimal ports. As the implications for different port-related stakeholders are discussed below, it should be noted that the weights of key container port selection factors are relevant and serve more importance to policymakers and port managers. The rankings of the most optimal ports are more relevant to shipping companies and shippers / freight-forwarders.

Policymakers

This study implemented SLR to systematically organise and filter out the most relevant port selection literature of quality, and invited senior-level experts and academic scholars for their input to provide better understanding of which port selection factors are considered to be most important to Korean shipping companies. This research identified 4 main factors encompassing 12 sub-factors to be driving port selection factors in this study's particular context of Korean shipping companies engaging in SSS with ASEAN region. The weights of importance have been determined for these factors (how important each selection factor is) through the use of AHP methodology. Considering these driving factors, implication could be suggested for the policymakers to improve the performance of these factors. In efforts to increase the "frequency of port of call," policies to promote development of port hinterland, establish free trade zone, and support investment in port equipment and modernisation and automation may be considered. In order to improve the "proximity to main navigation routes," construction of deep-sea large container port in close proximity to the East-West main route of East Asia to Europe may be considered. As for better port-hinterland connections, policies on development and integration of port railway intermodal system or road network to address the "proximity to the markets" and "intermodal links" factors may be worth considering. Lastly, policies that aid in facilitating competitive port charges (port due, light due, tonnage, pilot cost, towage, etc.) may assist in ports becoming more attractive.

Port managers

As mentioned earlier, through AHP methodology, the weights of importance (how important each selection factor is) have been determined for the driving port selection factors. These weights of importance are crucial indicators to the port's involved parties such as port operator or port authority as to which factor may deserve more resource allocation when striving for improvement in attracting Korean shipping companies. It should be noted that this research is the first to determine that "frequency of port of call" was calculated to be the most important factor for South Korean shipping companies engaging in SSS. For the port authorities or the port-related stakeholders in the ASEAN region, it would be best to increase the frequency of port of call through such means like port marketing or port optimisation, which may include reduction in idle time (when vessels are not actively engaged in moving, loading, or unloading) or efficient collaboration amongst port-related stakeholders. Both Ahn et al., (2014) and Yang and Chen (2016) suggest that port authorities could provide incentives (such as reduced dockage charges or equipment usage fees) to increase the frequency of port of call through marketing, which would lead to increased cargo volume. Along with targeting to increase the frequency, increasing the number of shipping routes may also be of interest to port managers to improve port connectivity.

Additionally, this research has found that small and medium-sized Korean shipping companies place great importance to THC – far greater in comparison to "port charges" sub-factor. Noting such importance, port authorities could deploy strategies to target their port efficiency such as by reducing labour costs through automation. This way, the ports may present more competitive rates for THC in order to increase their attractiveness to Korean shipping companies. As for the "proximity to the main navigation route," since it is a factor that cannot be changed as it is directly related to the port's physical location, there must be strategies in place to reduce the costs that occur with the distance needed to travel to the main trunk route. One possible strategy could be to focus on improving the productivity of the gantry cranes by purchasing high-performing model or through upgrades such as equipping cranes with dual-spreader mode. Other equipment and machinery with high handling capacity and implementation of state-of-the-art port systems to optimise port operation could lead to improve the attractiveness of the port. Additionally, striving for container terminal automation and modernisation to reduce the port stay time for container vessels as well as maintaining the port facilities, such as by dredging to preserve the water depth, could aid in increased port attractiveness.

Shipping companies

A hierarchical structure of driving container port selection factors has been obtained through SLR, pilot test, and interviews. Having obtained the weights of importance for these factors (how important each selection factor is) through AHP, the shipping companies could consider prioritising the most important factors of "frequency of port of call" (ports offering most port calling) and "THC" (ports offering most competitive THC) for future port selection.

This study also provides the rankings of the optimal ports in the ASEAN region from Korean shipping companies' perspectives using AHP-TOPSIS methodology. This research has found that the most optimal and attractive container port terminals were Cat Lai terminal in Ho Chi Minh City port (1st ranking), LCMT in Laem Chabang port (2nd ranking), and PSA (Pasir Panjang terminal) in Singapore port (3rd ranking). The shipping companies may take this ranking into consideration for future port selection. Also, the two-step integrated use of MCDM methodologies (AHP-TOPSIS) can potentially be adopted to be used by managerial-level decision makers when providing justification in choosing a certain alternative port. Lastly, considering that a port selection factor pertaining to port equipment (number of gantry cranes / gantry crane handling capacity per hour) was found to be crucial as well, shipping companies may consider ports with modernised high-performing port equipment for port selection.

Shippers

In the process of carrying out AHP-TOPSIS calculations, valuable secondary and primary data have been collected that may be useful to the shippers. By utilising the data from “proximity to the markets” factor, the shippers could confirm the distance of the ports to their major cities in vicinity. Additionally, by using the data from “distance of shippers from port” factor, the shippers could identify the major Korean companies’ manufacturing factories in the local areas of this research’s 6 targeted ports as well as their distance to the ports. These data allow the shippers to confirm ports in the ASEAN region that have the most favourable and competitive conditions regarding these factors. It is also possible for the shippers to confirm ports in the ASEAN region with the most favourable conditions if they are planning to construct manufacturing factories in close vicinity to ports.

Furthermore, this research lays out and runs multiple scenarios and simulations based on the original results obtained from the AHP-TOPSIS framework. Using the obtained rankings of the optimal ports, the scenarios and simulations reflect multiple potentially desirable situations that may arise, such as what it will take for one port to rise in its ranking. Various simulations were carried out by manipulating performance data values, and the simulations indicate possible ways in which the overall optimal ranking of the ports can be raised. Recognising how much improvement is needed in certain performance value for a port's selection criteria helps the port-related stakeholders (the customer ports in ASEAN region and shipping companies) to use this study's scenarios and simulations as a reference point when devising plans to decide which aspect of port attractiveness to improve.

Practical implications for different stakeholders have been discussed in this section. Table 9.1 and Table 9.2 provide summaries of these implications by their respective stakeholders, visually. In Table 9.1, bolded numbers indicate to which sub-factor the corresponding implication will target to improve. The number pertains to the list of 12 driving sub-factors in the order of their weight of importance, and this list has been recalled for ease of view and has been inserted at the bottom half of Table 9.1.

Table 9.1 Implications by stakeholders – policymakers & port managers

Stakeholder	**Implication & Action**
Policymakers	Support and investment in port equipment modernisation and automation **(1)**
	Promote development of port hinterland **(1)**
	Establishment of free trade zone **(1)**
	Construction of deep-sea large container port in close proximity to the main navigation routes **(3)**
	Development and integration of port railway intermodal system or road network to facilitate better port-hinterland connections **(6) & (7)**
	Adopting competitive port charges **(9)**
Port managers	Attracting shipping companies through port marketing **(1)**
	Adopting competitive THC rate **(2)**
	Purchase of high-performing gantry crane and equipment (such as a crane with dual-spreader mode, equipment with high handling capacity, state-of-the-art port system to manage real-time containers and optimise port operation) **(4)**
	Construction of automated container yard **(8)**
	Maintenance of port facilities (such as dredging to maintain and preserve water depth) **(11)**
	Increasing shipping routes to improve port connectivity **(12)**
Note: The bolded numbers in brackets **(x)** shown above correspond to the bolded sub-factor numbers in brackets shown below. Each implication indicates its respective sub-factor that it will target to improve.	

Port selection factors in the order of weight	**(1)** → Frequency of port of call (33.50%)
	(2) → Terminal Handling Charge (loading & unloading cost, etc.) (14.62%)
	(3) → Proximity to main navigation routes (14.32%)
	(4) → Number of gantry cranes / gantry crane handling capacity per hour (8.10%)
	(5) → Total container cargo volume (import/export & transshipment containers) (4.99%)
	(6) → Proximity to the markets (4.80%)
	(7) → Intermodal links (3.72%)
	(8) → Area of container yard (3.70%)
	(9) → Port charges (dockage, pilot cost, towage, etc.) (3.25%)
	(10) → Distance of shippers from port (3.22%)
	(11) → Port depth (3.09%)
	(12) → Port connectivity (2.69%)

Table 9.2 Implications by stakeholders – shipping companies & shippers

Stakeholder	**Implication & Action**
Shipping companies	This research found that the most attractive and optimal container port terminals are Cat Lai terminal in Ho Chi Minh City port (1st ranking), LCMT in Laem Chabang port (2nd ranking), and PSA (Pasir Panjang terminal) in Singapore port (3rd ranking). Shipping companies could consider such ranking for future port selection.
	This research found that the most important factor that South Korean shipping companies consider for container port selection in the ASEAN region is “frequency of port of call.” Shipping companies could consider prioritising this factor for future port selection.
	For future selection of port of call, shipping companies could consider ports with the most competitive Terminal Handling Charge.
	For future port selection, shipping companies could consider ports with high-performing port equipment that is modernised.
Shippers	Shippers could confirm ports in the ASEAN region that have the most favourable and competitive conditions in regards to “proximity to the markets” by using the secondary data collected in the calculation process of this research.
	Shippers could confirm ports in the ASEAN region that have the most favourable and competitive conditions in regards to “distance of shippers from port” by using the secondary data collected in the calculation process of this research.
	By using the secondary data collected in this research, shippers could confirm ports in the ASEAN region that have the most favourable and competitive conditions if they decide to, for example, construct manufacturing factories in close vicinity to ports.

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APPENDIX A: Systematic Literature Review references

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APPENDIX B.1: Sheet for Semi-Structured Interview (English)

UNIVERSITY OF PLYMOUTH
Plymouth Business School

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This interview's questions and/or including documents have been constructed and collected from the obtained results after conducting systematic literature review. The results and data will not be used none other than solely for the purpose of research. Your responses are strictly confidential.

Interview questions, Part 1:
Questions regarding this study's targeted container ports

1. **Which department & of what rank of the company staff decide the selection of ports?**

   (Liner/logistics department, Marketing department, Sales department, Operation Management department)

2. **What is the size of frequently deployed container vessels?**

Ho Chi Minh City	**( ) TEU vessel**
Haiphong	**( ) TEU vessel**
Jakarta	**( ) TEU vessel**
Laem Chabang	**( ) TEU vessel**
Port Kelang	**( ) TEU vessel**
Singapore	**( ) TEU vessel**

3. **What type of goods are most frequently loaded onto the container?**

Ho Chi Minh City	
Haiphong	
Jakarta	

Laem Chabang	
Port Kelang	
Singapore	

4. What is the final place of demand (final destination) for the containers (cargo) for each of the below's ports?

Ho Chi Minh City	
Haiphong	
Jakarta	
Laem Chabang	
Port Kelang	
Singapore	

5. What is the shipping cost per ton to transport cargos inland from each of the below's ports?

Ho Chi Minh City	
Haiphong	

Jakarta	
Laem Chabang	
Port Kelang	
Singapore	

6. What are the shippers' location (such as cargo's starting point or point of origin) for each of the below's ports?

Ho Chi Minh City	
Haiphong	
Jakarta	
Laem Chabang	
Port Kelang	
Singapore	

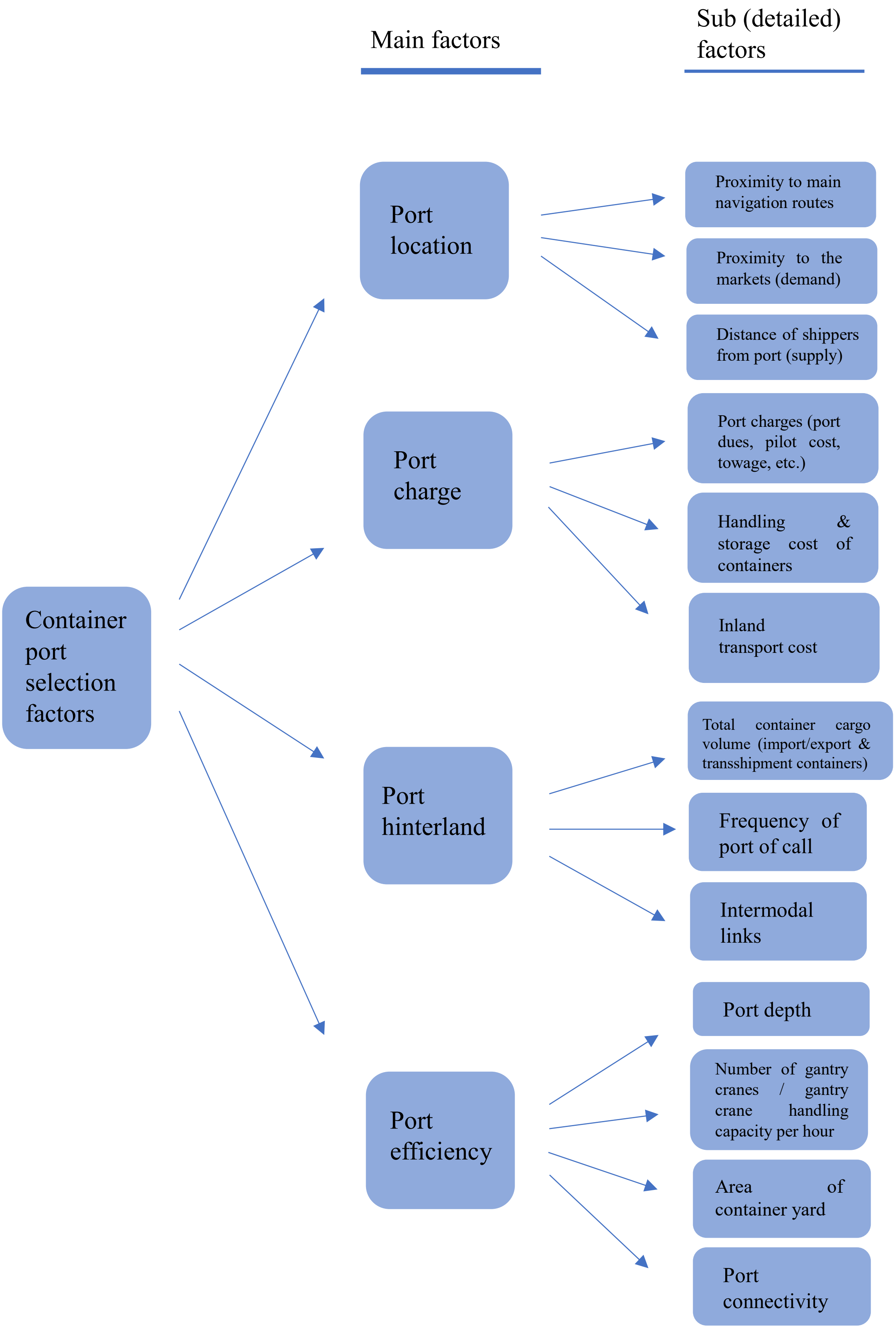
7. What are the top 3 container terminals that are most frequently called for each of the below's ports?

Ho Chi Minh City	1) 2) 3)

Haiphong	1) 2) 3)
Jakarta	1) 2) 3)
Laem Chabang	1) 2) 3)
Port Kelang	1) 2) 3)
Singapore	1) 2) 3)

Interview questions, Part 2:
Questions regarding this study's port selection factors

Figure below represents important port selection factors that have been organised after analysing studies obtained through systematic literature review.


Main factors
Sub (detailed) factors
Container port selection factors
Port location
Port charge
Port hinterland
Port efficiency
Proximity to main navigation routes
Proximity to the markets (demand)
Distance of shippers from port (supply)
Port charges (port dues, pilot cost, towage, etc.)
Handling & storage cost of containers
Inland transport cost
Total container cargo volume (import/export & transshipment containers)
Frequency of port of call
Intermodal links
Port depth
Number of gantry cranes / gantry crane handling capacity per hour
Area of container yard
Port connectivity

1. From the **figure**, could you please provide feedback on whether there should be any deletion, revision, or addition to the sub (detailed) factors listed regarding "Port location?"

2. From the **figure**, could you please provide feedback on whether there should be any deletion, revision, or addition to the sub (detailed) factors listed regarding "Port charge?"

2.1. Could you please indicate if there are data on port tariff for below ports?
If so, could you please indicate if they are available to share with the interviewer?

Ho Chi Minh City	**Yes ☐ / No ☐**
Haiphong	**Yes ☐ / No ☐**
Jakarta	**Yes ☐ / No ☐**
Laem Chabang	**Yes ☐ / No ☐**
Port Kelang	**Yes ☐ / No ☐**
Singapore	**Yes ☐ / No ☐**

3. From the **figure**, could you please provide feedback on whether there should be any deletion, revision, or addition to the sub (detailed) factors listed regarding "Port hinterland?"

4. From the **figure**, could you please provide feedback on whether there should be any deletion, revision, or addition to the sub (detailed) factors listed regarding "Port efficiency?"

APPENDIX B.2: Sheet for Semi-Structured Interview (Korean)

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본 인터뷰 질문은 학술 선행연구를 통하여 획득한 결과를 바탕으로 구성되었습니다. 본 연구의 결과 및 데이터는 학술연구 목적 이외에는 사용되지 않습니다. 응답은 익명 처리하여 통계 기술적으로 분석됨을 알려드립니다.

인터뷰 질문, Part 1:

본 연구의 대상이 되는 컨테이너 항만(동남아)에 관한 질문

1. 항만(동남아) 선택은 "어느 부서"의 "어느 직급"의 직원이 수행합니까? (예: 정기선/물류부서, 마케팅 부서, 영업부서, 운항관리 등)

2. **아래 항만에는 주로 어느 크기의 컨테이너 선박이 취항합니까?**

호치민	**( ) TEU vessel**
하이퐁	**( ) TEU vessel**
자카르타	**( ) TEU vessel**
램차방	**( ) TEU vessel**
포트캘랑	**( ) TEU vessel**
싱가포르	**( ) TEU vessel**

3. 아래 항만을 향하는 컨테이너에는 주로 어떤 화물이 적재됩니까?

호치민	
하이퐁	
자카르타	
램차방	
포트캘랑	
싱가포르	

4. 다음 각 항만별 컨테이너(화물)의 최종 수요지는 어디입니까?

호치민	
하이퐁	
자카르타	
램차방	
포트캘랑	
싱가포르	

5. 아래 항만에서 내륙운송시, 컨테이너의 톤당 운임비는 얼마입니까?

호치민	
하이퐁	
자카르타	
램차방	
포트캘랑	
싱가포르	

6. 다음 각 항만별 화주(shippers)의 위치 (화물의 출발지, Origin)는 어디입니까?

호치민	
하이퐁	
자카르타	
램차방	
포트캘랑	
싱가포르	

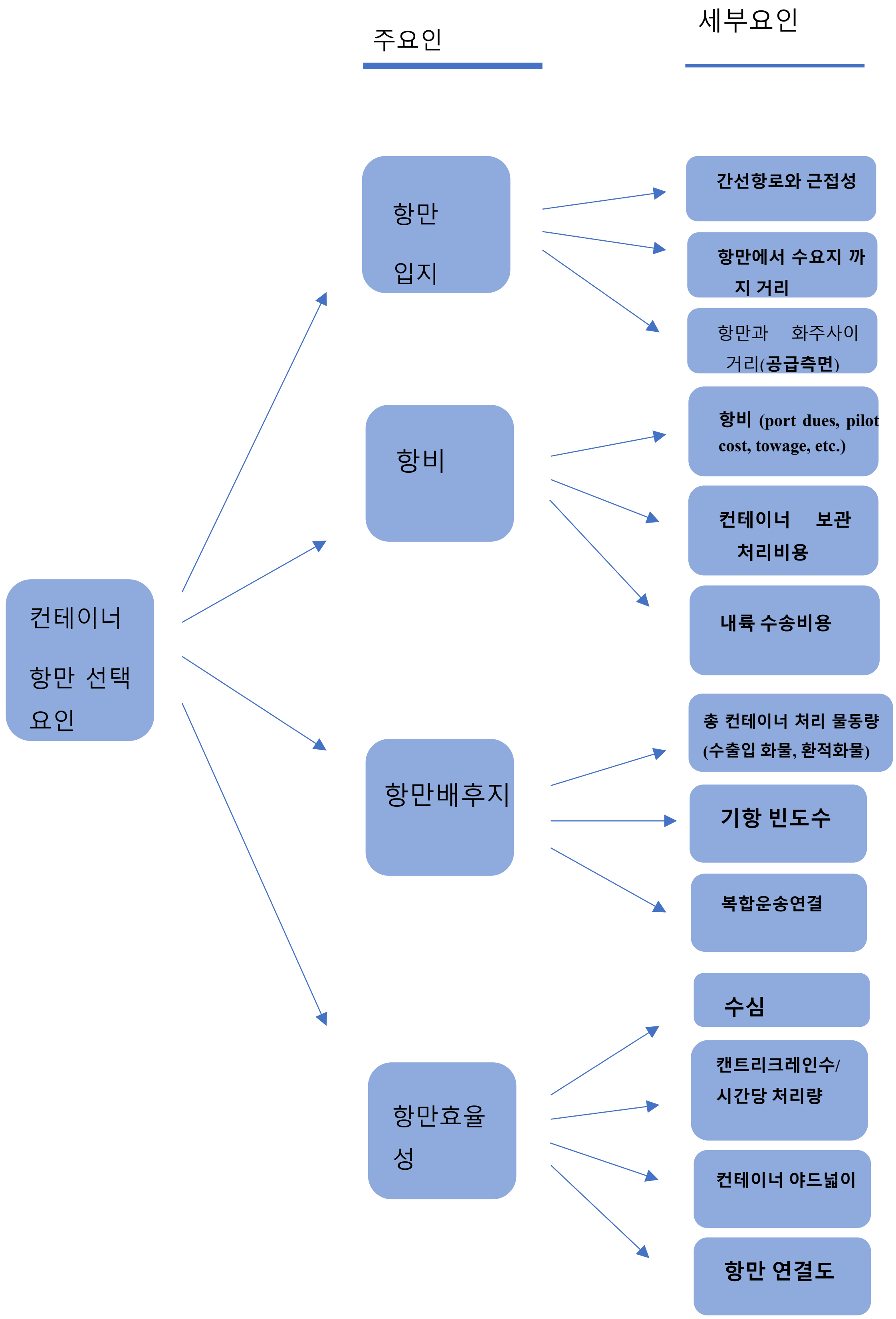
7. 아래 항만별로 귀사에서 주로 기항하는 3개의 컨테이너 터미널은 어디입니까?

호치민	1) 2) 3)
하이퐁	1) 2) 3)
자카르타	1) 2) 3)
램차방	1) 2) 3)
포트캘랑	1) 2) 3)
싱가포르	1) 2) 3)

인터뷰 질문, Part 2:

항만선택 요인에 대한 질문

아래 그림은 학술 선행연구를 통하여 획득한 항만선택 요인의 계층도입니다.


주요인
세부요인
컨테이너 항만 선택 요인
항만 입지
항비
항만배후지
항만효율성
간선항로와 근접성
항만에서 수요지 까지 거리
항만과 화주사이 거리(공급측면)
항비 (port dues, pilot cost, towage, etc.)
컨테이너 보관 처리비용
내륙 수송비용
총 컨테이너 처리 물동량 (수출입 화물, 환적화물)
기항 빈도수
복합운송연결
수심
캔트리크레인수/ 시간당 처리량
컨테이너 야드넓이
항만 연결도

1. 평가 구조도에서 “항만입지” 아래 세부요인에서 삭제, 수정, 추가 사항이 있는지 의견을 부탁합니다.

2. 평가 구조도에서 “항비”아래 세부요인에서 삭제, 수정, 추가 사항이 있는지 의견을 부탁합니다.

2.1. 아래 각 항만의 요율자료가 있는지 확인 부탁드립니다. 혹시 자료가 있다면 질문자에게 자료 공유가 가능한지 답변 부탁드립니다.

호치민	**Yes ☐ / No ☐**
하이퐁	**Yes ☐ / No ☐**
자카르타	**Yes ☐ / No ☐**
램차방	**Yes ☐ / No ☐**
포트캘랑	**Yes ☐ / No ☐**
싱가포르	**Yes ☐ / No ☐**

3. 평가 구조도에서 “항만배후지” 아래 세부요인에서 삭제, 수정, 추가 사항이 있는지 의견을 부탁합니다.

4. 평가 구조도에서 “항만효율성” 아래 세부요인에서 삭제, 수정, 추가 사항이 있는지 의견을 부탁합니다.

APPENDIX C.1: AHP Survey Questionnaire (English)

UNIVERSITY OF PLYMOUTH

Plymouth Business School

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This questionnaire conducts a survey to aid in researching the priority of factors in choosing container terminals in the ASEAN region. The set of questions in this document will ask for your expert input in choosing which container terminal selecting factor has greater importance over another. Please note that the results and data will not be used none other than solely for the purpose of research. Your responses are strictly confidential.

Part 1:
Pairwise comparisons between two criteria (factors)

This research is about selecting the most optimal container terminal in the ASEAN region from the Korean shipping companies' perspectives. The Figure 1 below shows hierarchy of factors that are considered when selecting the most optimal container terminal. This questionnaire is conducted to collect expert inputs regarding the factors shown in the hierarchy. After referring to the example shown below, please begin the questionnaire and indicate your evaluations on factors that you think are important.

Below is an example of how each question (row) should be checked

Example) If you think that "Port location" is "3" score points more important than "Port hinterland" for container terminal selection, then you would indicate with ✓ like below.

Evaluation Criterion (A)	Extreme importance			Strong importance					Equal importance				Strong importance				Extreme Importance	**Evaluation Criterion (B)**
Port location	9	8	7	6	5	4	✓3	2	1	2	3	4	5	6	7	8	9	Port hinterland

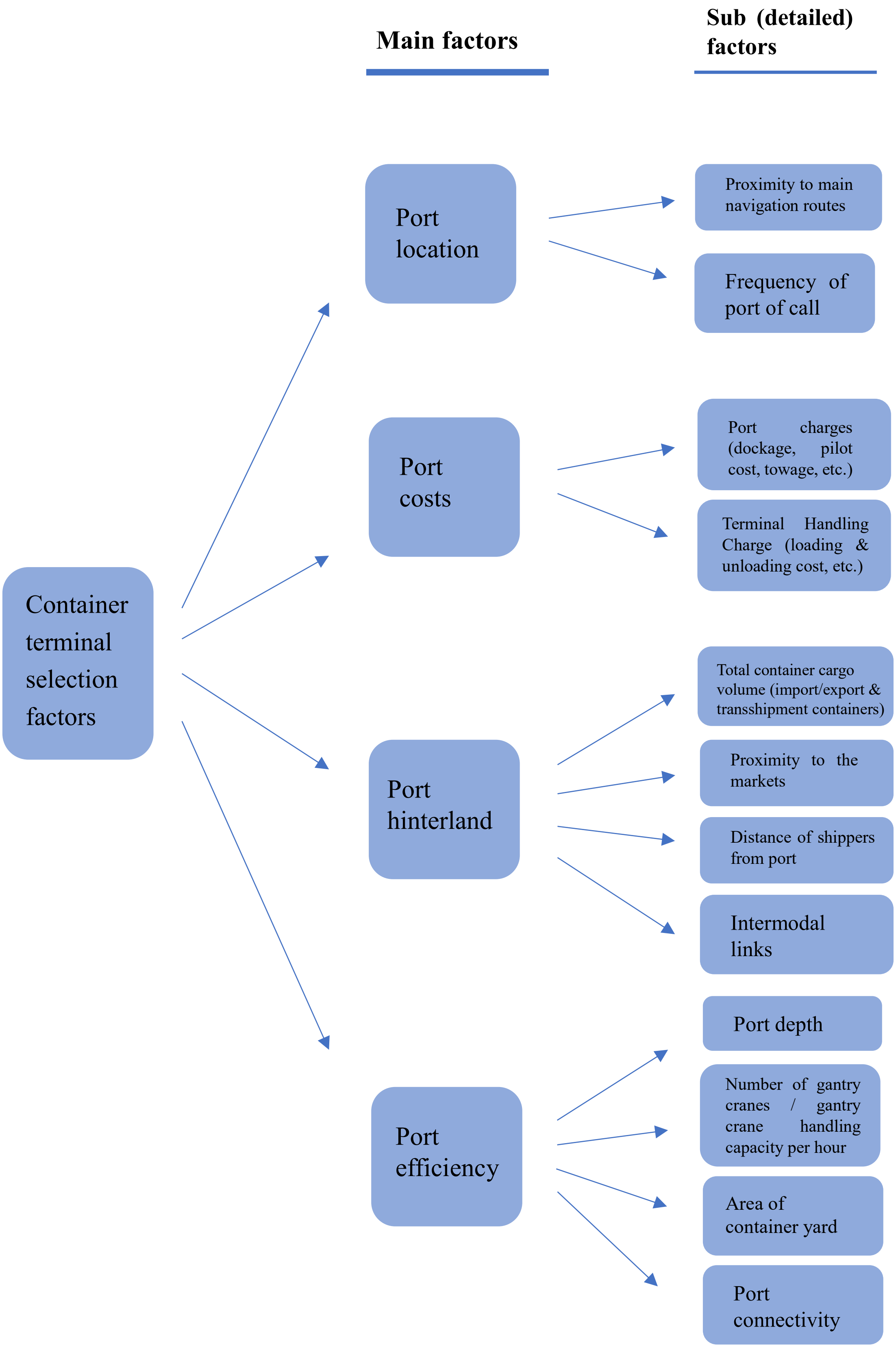

Figure 1 Hierarchy of container terminal selection factors

* Tips for answering:

1) Determine and write the "Ranking of priority" and "Score points" of the 4 main factors of evaluation criteria (from score points between 1 and 9). It will be easier to keep a consistent set of answers if you use these during the comparison between two factors.

2) For example, let's say that you determine the following: [1st ranking: Port location (9 score points), 2nd ranking: Port costs (7 score points), 3rd ranking: Port hinterland (5 score points), 4th ranking: Port efficiency (3 score points)]. Then, you could make a note of this and use it for your reference.

3) Below question is comparing "Port location" vs "Port costs." According to what has been determined above, "Port location (9 points) > Port costs (7 points)," and the difference is by 2 points. Therefore, it is reasonable to indicate with ✓ like below.

Evaluation Criterion (A)	Extreme importance		Strong importance						Equal importance					Strong importance			Extreme importance	**Evaluation Criterion (B)**
Port location	9	8	7	6	5	4	3	✓2	1	2	3	4	5	6	7	8	9	Port costs

1) Comparison of main factors

■ **In regards to evaluation criteria "A" and "B" below, please determine by how much more importance you consider one factor over the other, and indicate with a ✓.**

Evaluation criteria (A)	Extreme importance		Strong importance						Equal importance					Strong importance			Extreme importance	**Evaluation criteria (B)**
Port location	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port costs
Port location	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port hinterland
Port location	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port efficiency
Port costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port hinterland
Port costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port efficiency
Port	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port

hinterland																		efficiency

2) Comparison of sub (detailed) factors

■ **In regards to evaluation criterion "A" and "B" below, please determine by how much more importance you consider one factor over the other, and indicate with a ✓.**

<Comparison of sub (detailed) factors pertaining to "Port location">

Evaluation criterion (A)	Extreme importance			Strong importance				Equal importance				Strong importance				Extreme importance	**Evaluation criterion (B)**
Proximity to main navigation routes	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Frequency of port of call

<Comparison of sub (detailed) factors pertaining to "Port costs">

Evaluation criterion (A)	Extreme importance			Strong importance				Equal importance				Strong importance				Extreme importance	**Evaluation criterion (B)**
Port charges (dockage, pilot cost, towage, etc.)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Terminal Handling Charge

<Comparison of sub (detailed) factors pertaining to "Port hinterland">

Evaluation criteria (A)	Extreme importance			Strong importance				Equal importance				Strong importance				Extreme importance	**Evaluation criteria (B)**
Total container cargo volume	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Proximity to markets from ASEAN ports
Total container	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Distance of shippers

cargo volume																	from ASEAN ports
Total container cargo volume	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Intermodal links
Proximity to markets from ASEAN ports	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Distance of shippers from ASEAN ports
Proximity to markets from ASEAN ports	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Intermodal links
Distance of shippers from ASEAN ports	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Intermodal links

<Comparison of sub (detailed) factors pertaining to “Port efficiency”>

Evaluation criteria (A)	Extreme importance				Strong importance				Equal importance					Strong importance				Extreme importance	**Evaluation criteria (B)**
Port depth	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of gantry cranes / gantry crane handling capacity per hour
Port depth	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Area of container yard
Port depth	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port connectivity
Number of gantry cranes / gantry crane handling capacity per hour	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Area of container yard
Number of gantry cranes / gantry crane handling capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port connectivity

per hour																	
Area of container yard	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Port connectivity

Part 2:
Evaluation of targeted container terminals

Whilst considering the sub (detailed) factor of "Intermodal links," what is your evaluation of the container terminals in each port below? Please indicate with a ✓ in each row. Please give a score between 1 and 10 for each row. (10 is the best score point you can give).

Container terminals for evaluation	1	2	3	4	5	6	7	8	9	10
Cat Lai terminal (Ho Chi Minh City)										
Green port terminal (Haiphong)										
Koja terminal (Jakarta)										
LCMT (Laem Chabang)										
North port terminal (Port Kelang)										
PSA terminals (Pasir Panjang terminal) (Singapore)										

Please provide your information below. Please check with a ✓ to indicate your answer.

Working department	☐ Operation department ☐ Sales department ☐ Marketing department ☐ Other department ( )
Working years	☐ 1-5 years ☐ 6-10 years ☐ 11-15 years ☐ More than 16 years
Gender	☐ Male ☐ Female

-Thank you very much for participating in this survey-

APPENDIX C.2: AHP Survey Questionnaire (Korean)

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본 설문은 아세안 지역의 컨테이너 터미널을 선택할 때 사용하는 요인의 우선순위를 도출하는데 있습니다. 질문은 어떤 요소가 컨테이너 터미널 선택시 중요한지 전문가로서 표시하도록 구성되어 있습니다. 본 연구의 결과 및 데이터는 학술연구 목적 이외에는 사용되지 않습니다. 응답은 익명 처리하여 통계 기술적으로 분석됨을 알려드립니다.

Part 1:

요인간 쌍대비교 (두 요인간 비교)

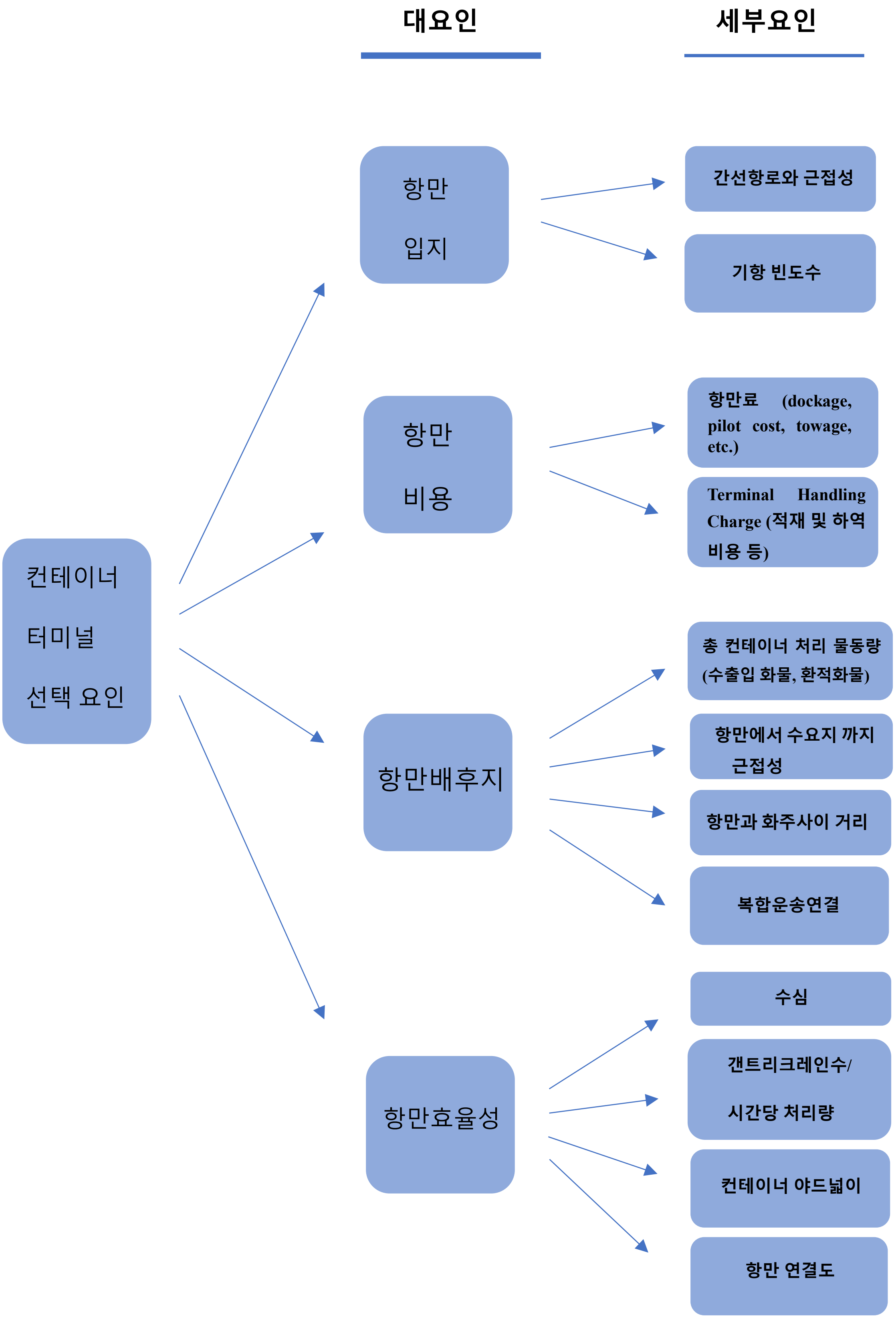
본 연구는 한국 해운선사 측면에서 본 아세안 지역의 최적 컨테이너 터미널 선정에 관련된 연구입니다. 아래 <그림 1>은 최적 컨테이너터미널 선정시 고려되는 요인의 계층도입니다. 본 설문조사는 계층도에 표시된 요인에 대하여 전문가의 의견을 수집하기 위하여 실시되고 있습니다. 아래의 예시를 참고하시어 중요하다고 생각하시는 요인에 대하여 표시를 해주시기 바랍니다.

아래는 답변을 작성하는 예시입니다.

예시) "**항만입지**"가 "**항만배후지**"에 비해 **"3"**만큼 중요하다고 생각하시면 다음과 같이 ✓ 표시하시면 됩니다.

.

평가항목 (A)	절대 중요		매우중요						같다				매우중요			절대 중요	평가항목 (B)
항만입지	9	8	7	6	5	4	✓3	2	1	2	3	4	5	6	7	8	9	항만배후지



<그림 1> 컨테이너 터미널 선정 모형

* 답변 Tip:

1) 대요인 4 개 평가항목에 대하여 본인이 생각하는 "선호순위"와 "점수"를 적어봅니다.(1-9 점 사이). 이를 두 요인간 점수 비교에 사용하면 답변의 일관성을 유지하기 쉽습니다.

2) 예를 들어 답변자께서 [1 순위: 항만입지 (9 점), 2 순위: 항만비용 (7 점), 3 순위: 항만배후지 (5 점), 4 순위: 항만효율성 (3 점)] 이라고 판단하시면, 메모해 두셨다가 활용하면 됩니다.

3) 아래 질문은 "항만입지" vs "항만비용" 비교인데요, 위 기준에 의하면, "항만입지(9 점) > 항만비용(7 점)" 이고, 차이는 2 점입니다. 따라서 아래와 같이 ✓ 표시하면 합리적입니다.

평가항목 (A)	절대 중요		매우중요					같다				매우중요				절대 중요	평가항목 (B)
항만입지	9	8	7	6	5	4	3	✓2	1	2	3	4	5	6	7	8	9	항만비용

1) 대요인 비교

■ **아래 표의 평가항목 "A"와 "B" 중 어느 요인을 얼마만큼 중요하게 생각하는지 해당 란에**

✓ **표시해 주세요.**

평가항목 (A)	절대 중요		매우중요						같다				매우중요				절대 중요	평가항목 (B)
항만입지	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만비용
항만입지	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만배후지
항만입지	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만효율성
항만비용	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만배후지
항만비용	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만효율성
항만배후지	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만효율성

2) 세부요인 비교

■ **아래 표의 평가항목 "A"와 "B" 중 어느 요인을 얼마만큼 중요하게 생각하는지 해당 란에**

✓ **표시해 주세요.**

<"항만 입지"에 해당하는 세부요인간 비교>

평가항목 (A)	절대 중요				매우중요				같다				매우중요				절대 중요	평가항목 (B)
간선항로와 근접성	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	기항 빈도수

<"항만비용"에 해당하는 세부 요인간 비교>

평가항목 (A)	절대 중요				매우중요				같다				매우중요				절대 중요	평가항목 (B)
항만료 (dockage, pilot cost, towage, etc.)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Terminal Handling Charge

<"항만 배후지"에 해당하는 세부 요인간 비교>

평가항목 (A)	절대 중요				매우중요				같다				매우중요				절대 중요	평가항목 (B)
총 컨테이너 처리 물동량	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만(ASEAN)에서 수요지까지 근접성
총 컨테이너 처리 물동량	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만(ASEAN)에서 화주사이 거리

총 컨테이너 처리 물동량	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	복합운송연결
항만(ASEAN)에서 수요지 까지 근접성	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만(ASEAN)에서 화주사이 거리
항만(ASEAN)에서 수요지 까지 근접성	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	복합운송연결
항만(ASEAN)에서 화주사이 거리	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	복합운송연결

<"항만 효율성"에 해당하는 세부 요인간 비교>

평가항목 (A)	절대 중요				매우중요				같다				매우중요				절대 중요	평가항목 (B)
수심	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	갠트리크레인수/시간당 처리량
수심	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	컨테이너 야드넓이
수심	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만 연결도
갠트리크레인수/시간당 처리량	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	컨테이너 야드넓이
갠트리크레인수/시간당 처리량	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만 연결도
컨테이너	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	항만 연결도

야드넓이																	

Part 2:

대상 터미널 평가

세부 요인 복합운송연결을 고려할 때, 귀하께서는 아래 각 항만의 컨테이너 터미널에 대하여 어떻게 평가하십니까? 해당 란에 ✓ 표시해 주세요. 1-10점 사이에서 점수를 주시고, 10점이 가장 좋은 점수입니다.

평가대상 터미널	1	2	3	4	5	6	7	8	9	10
Cat Lai terminal (Ho Chi Minh City)										
Green port terminal (Haiphong)										
Koja terminal (Jakarta)										
LCMT (Laem Chabang)										
North port terminal (Port Kelang)										
PSA terminals (Pasir Panjang terminal) (Singapore)										

아래 해당 란에 응답자 정보를 기입해주시기 바랍니다. 해당 란에 ✓ 표시해 주세요.

근무부서	☐ 운항부서 ☐ 영업부서

	□ 마케팅 부서 □ 기타 부서 ( )
근무연수	□ 1-5 년 □ 6-10 년 □ 11-15 년 □ 16년 이상
성별	□ 남성 □ 여성

-설문에 참여해 주셔서 감사합니다-

APPENDIX D: Research Ethical Approval Form

UNIVERSITY OF
PLYMOUTH

04/04/2023

Mr. Inhyeok Yeo

Confidential

Research Ethics Application Approval - Faculty Research Ethics and

Integrity Committee Project ID 3719

Project Full Title Container Port Selection in the ASEAN region: Korean Shipping Companies Perspective

Project End Date 01/10/2024

Outcome: Approval Dear Mr. Inhyeok Yeo

We are pleased to inform you that the Committee has granted ethical approval to you to conduct this research or providing the following changes are undertaken:

Title	Comment
Participant Information Sheet	It would be useful to note that data collected will also be stored on the UoP OneDrive.
Participant Information Sheet	Respondents' right to '. . . withdraw at anytime . . .' may not be very practical especially given the limited sample size. Much better if the right to withdraw is time limited possibly up to when data analysis commences.
Participant Information Sheet	Please change the name of the Research Ethics Administrator as an independent contact for participants to the generic contact information: 'If you have any concerns or complaints about the ethical conduct of this study, please contact the Research Ethics Administrator, Faculty of Arts, Humanities and Business Research Ethics and Integrity Committee, University of Plymouth, Level 2 Marine Building, Drake Circus, Plymouth PL4 8AA Email: AHBethics@plymouth.ac.uk
Consent form	Again, respondents' right to '. . . withdraw at anytime . . .' may not be very practical especially given the limited sample size. Much better if the right to withdraw is time limited possibly up to when data analysis commences.
Right to withdraw	Respondents' right to '. . . withdraw. . . at any point of time . . .' may not be very practical especially given the limited sample size. Much better if the right to withdraw is time limited possibly up to when data analysis commences.
Risk Assessment	Please refer to the UoP Health and Safety webpage to find and complete the relevant form for this assessment..
Research Data Management Plan	This is a very thorough Data Management Plan. For completeness please add the right of respondents to withdraw from the research at any point. Also, please consider how long the data will be stored for and how you will ensure the destruction of data ones this period has passed.

Please note that approval is for the duration of the project until . If you wish to continue beyond this date, you will need to seek an extension via the PEOS amendments process.

Please note that if you wish to make any minor changes to your research, you will need to complete an amendment form or for major changes you will need to resubmit an application with PEOS. Should there be any changes regarding governance related matters, please let us know.

We wish you all the success for your project.

Yours sincerely,

Stacey Haynes

Sent on behalf of Mr. Derek Shepherd,

Chair, Faculty of Arts, Humanities & Business - Business Research Ethics and Integrity Committee

APPENDIX E: Consent Form for Participants

UNIVERSITY OF PLYMOUTH
Plymouth Business School

Inhyeok Yeo (PhD candidate)

International Logistics, Supply Chain and Shipping Management

University of Plymouth

Drake Circus, Plymouth PL4 8AA

E-mail: inhyeok.yeo@plymouth.ac.uk

Tel : + 44 (0)77 6134 5228

Participant Consent Form

The results and data will not be used none other than solely for the purpose of research. Your responses are strictly confidential.

Title of Research

Container Port Selection in the ASEAN region: Korean Shipping Companies' Perspective

Name of Principal Researcher

Inhyeok Yeo

Brief statement of purpose of work

The aim of the study is to first and foremost investigate selection factors that influence container port selection from the perspective of shipping company. Further, the study will focus on Korean shipping companies involved with maritime trade with ports in Southeast Asia as a case study. Thereby, your responses will greatly aid in refining port selection factors both in their order of importance and in their composition (main factors and sub-factors) for this research. Using the data obtained, ultimately, this study will investigate the most optimal ports in the ASEAN region for Korean shipping companies and present advantages and disadvantages of these container ports for related industrial stakeholders.

Please tick each check box to indicate that you agree with each statement:

☐ I confirm that I have been informed on the participation information sheet for the above study, and I understand the objective of this research.

☐ I understand that the audio for this interview will be recorded. The findings of the study, which may include anonymised quotations, will be submitted in this research thesis and may be published in research journals and presented at conferences.

☐ I understand that my participation is voluntary and that I am free to withdraw from the research without consequences. Should I wish to withdraw from this research, I will notify the principal investigator within three months of participation.

☐ I agree to take part in the above study.

Please add your name and the date you completed this form:

Participant Name:

Date:

Signature:

KMTC Consent Form

Title of Research

Container Port Selection in the ASEAN region: Korean Shipping Companies' Perspective

Name of Principal Researcher

Inhyeok Yeo

Brief statement of purpose of work

The aim of the study is to first and foremost investigate selection factors that influence container port selection from the perspective of shipping company. Further, the study will focus on Korean shipping companies involved with maritime trade with ports in Southeast Asia as a case study. Thereby, your responses will greatly aid in refining port selection factors both in their order of importance and in their composition (main-factors and sub-factors) for this research. Using the data obtained, ultimately, this study will investigate the most optimal ports in the ASEAN region for Korean shipping companies and present advantages and disadvantages of these container ports for related industrial stakeholders.

Please tick each check box to indicate that you agree with each statement:

☑ I confirm that I have been informed on the participation information sheet for the above study, and I understand the objective of this research.

☑ I understand that the audio for this interview will be recorded. The findings of the study, which may include anonymised quotations, will be submitted in this research thesis and may be published in research journals and presented at conferences.

☑ I understand that my participation is voluntary and that I am free to withdraw from the research without consequences. Should I wish to withdraw from this research, I will notify the principal investigator within three months of participation.

☑ I agree to take part in the above study.

Please add your name and the date you completed this form:

Participant Name:

Date: 2023. 6. 9.

Signature: [redacted]

Sinokor Merchant Marine Consent Form

Title of Research

Container Port Selection in the ASEAN region: Korean Shipping Companies' Perspective

Name of Principal Researcher

Inhyeok Yeo

Brief statement of purpose of work

The aim of the study is to first and foremost investigate selection factors that influence container port selection from the perspective of shipping company. Further, the study will focus on Korean shipping companies involved with maritime trade with ports in Southeast Asia as a case study. Thereby, your responses will greatly aid in refining port selection factors both in their order of importance and in their composition (main-factors and sub-factors) for this research. Using the data obtained, ultimately, this study will investigate the most optimal ports in the ASEAN region for Korean shipping companies and present advantages and disadvantages of these container ports for related industrial stakeholders.

Please tick each check box to indicate that you agree with each statement:

- [x] I confirm that I have been informed on the participation information sheet for the above study, and I understand the objective of this research.
- [x] I understand that the audio for this interview will be recorded. The findings of the study, which may include anonymised quotations, will be submitted in this research thesis and may be published in research journals and presented at conferences.
- [x] I understand that my participation is voluntary and that I am free to withdraw from the research without consequences. Should I wish to withdraw from this research, I will notify the principal investigator within three months of participation.
- [x] I agree to take part in the above study.

Please add your name and the date you completed this form:

Participant Name: [redacted]

Date: 2022. 06. 14

Signature: [redacted]

Namsung Shipping Consent Form

Title of Research

Container Port Selection in the ASEAN region: Korean Shipping Companies' Perspective

Name of Principal Researcher

Inhyeok Yeo

Brief statement of purpose of work

The aim of the study is to first and foremost investigate selection factors that influence container port selection from the perspective of shipping company. Further, the study will focus on Korean shipping companies involved with maritime trade with ports in Southeast Asia as a case study. Thereby, your responses will greatly aid in refining port selection factors both in their order of importance and in their composition (main-factors and sub-factors) for this research. Using the data obtained, ultimately, this study will investigate the most optimal ports in the ASEAN region for Korean shipping companies and present advantages and disadvantages of these container ports for related industrial stakeholders.

Please tick each check box to indicate that you agree with each statement:

- ☑ I confirm that I have been informed on the participation information sheet for the above study, and I understand the objective of this research.
- ☑ I understand that the audio for this interview will be recorded. The findings of the study, which may include anonymised quotations, will be submitted in this research thesis and may be published in research journals and presented at conferences.
- ☑ I understand that my participation is voluntary and that I am free to withdraw from the research without consequences. Should I wish to withdraw from this research, I will notify the principal investigator within three months of participation.
- ☑ I agree to take part in the above study.

Please add your name and the date you completed this form:

Participant Name: [redacted]

Date: 16th/June/2023.

Signature: [redacted]

APPENDIX F.1: Sensitivity analysis weight changes of all conditions

	Sub-factor weights											
	A	B	C	D	E	F	G	H	I	J	K	L
Main	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
1 (AB)	0.3350	0.1432	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
2 (AC)	0.0325	0.3350	0.1432	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
3 (AD)	0.1462	0.3350	0.0325	0.1432	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
4 (AE)	0.0499	0.3350	0.0325	0.1462	0.1432	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
5 (AF)	0.0480	0.3350	0.0325	0.1462	0.0499	0.1432	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
6 (AG)	0.0322	0.3350	0.0325	0.1462	0.0499	0.0480	0.1432	0.0372	0.0309	0.0810	0.0370	0.0269
7 (AH)	0.0372	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.1432	0.0309	0.0810	0.0370	0.0269
8 (AI)	0.0309	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.1432	0.0810	0.0370	0.0269
9 (AJ)	0.0810	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.1432	0.0370	0.0269
10 (AK)	0.0370	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.1432	0.0269
11 (AL)	0.0269	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.1432
12 (BC)	0.1432	0.0325	0.3350	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
13 (BD)	0.1432	0.1462	0.0325	0.3350	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
14 (BE)	0.1432	0.0499	0.0325	0.1462	0.3350	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
15 (BF)	0.1432	0.0480	0.0325	0.1462	0.0499	0.3350	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
16 (BG)	0.1432	0.0322	0.0325	0.1462	0.0499	0.0480	0.3350	0.0372	0.0309	0.0810	0.0370	0.0269
17 (BH)	0.1432	0.0372	0.0325	0.1462	0.0499	0.0480	0.0322	0.3350	0.0309	0.0810	0.0370	0.0269

18 (BI)	0.1432	0.0309	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.3350	0.0810	0.0370	0.0269
19 (BJ)	0.1432	0.0810	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.3350	0.0370	0.0269
20 (BK)	0.1432	0.0370	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.3350	0.0269
21 (BL)	0.1432	0.0269	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.3350
22 (CD)	0.1432	0.3350	0.1462	0.0325	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
23 (CE)	0.1432	0.3350	0.0499	0.1462	0.0325	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
24 (CF)	0.1432	0.3350	0.0480	0.1462	0.0499	0.0325	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
25 (CG)	0.1432	0.3350	0.0322	0.1462	0.0499	0.0480	0.0325	0.0372	0.0309	0.0810	0.0370	0.0269
26 (CH)	0.1432	0.3350	0.0372	0.1462	0.0499	0.0480	0.0322	0.0325	0.0309	0.0810	0.0370	0.0269
27 (CI)	0.1432	0.3350	0.0309	0.1462	0.0499	0.0480	0.0322	0.0372	0.0325	0.0810	0.0370	0.0269
28 (CJ)	0.1432	0.3350	0.0810	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0325	0.0370	0.0269
29 (CK)	0.1432	0.3350	0.0370	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0325	0.0269
30 (CL)	0.1432	0.3350	0.0269	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0325
31 (DE)	0.1432	0.3350	0.0325	0.0499	0.1462	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
32 (DF)	0.1432	0.3350	0.0325	0.0480	0.0499	0.1462	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
33 (DG)	0.1432	0.3350	0.0325	0.0322	0.0499	0.0480	0.1462	0.0372	0.0309	0.0810	0.0370	0.0269
34 (DH)	0.1432	0.3350	0.0325	0.0372	0.0499	0.0480	0.0322	0.1462	0.0309	0.0810	0.0370	0.0269
35 (DI)	0.1432	0.3350	0.0325	0.0309	0.0499	0.0480	0.0322	0.0372	0.1462	0.0810	0.0370	0.0269
36 (DJ)	0.1432	0.3350	0.0325	0.0810	0.0499	0.0480	0.0322	0.0372	0.0309	0.1462	0.0370	0.0269
37 (DK)	0.1432	0.3350	0.0325	0.0370	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.1462	0.0269
38 (DL)	0.1432	0.3350	0.0325	0.0269	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.1462

39 (EF)	0.1432	0.3350	0.0325	0.1462	0.0480	0.0499	0.0322	0.0372	0.0309	0.0810	0.0370	0.0269
40 (EG)	0.1432	0.3350	0.0325	0.1462	0.0322	0.0480	0.0499	0.0372	0.0309	0.0810	0.0370	0.0269
41 (EH)	0.1432	0.3350	0.0325	0.1462	0.0372	0.0480	0.0322	0.0499	0.0309	0.0810	0.0370	0.0269
42 (EI)	0.1432	0.3350	0.0325	0.1462	0.0309	0.0480	0.0322	0.0372	0.0499	0.0810	0.0370	0.0269
43 (EJ)	0.1432	0.3350	0.0325	0.1462	0.0810	0.0480	0.0322	0.0372	0.0309	0.0499	0.0370	0.0269
44 (EK)	0.1432	0.3350	0.0325	0.1462	0.0370	0.0480	0.0322	0.0372	0.0309	0.0810	0.0499	0.0269
45 (EL)	0.1432	0.3350	0.0325	0.1462	0.0269	0.0480	0.0322	0.0372	0.0309	0.0810	0.0370	0.0499
46 (FG)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0322	0.0480	0.0372	0.0309	0.0810	0.0370	0.0269
47 (FH)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0372	0.0322	0.0480	0.0309	0.0810	0.0370	0.0269
48 (FI)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0309	0.0322	0.0372	0.0480	0.0810	0.0370	0.0269
49 (FJ)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0810	0.0322	0.0372	0.0309	0.0480	0.0370	0.0269
50 (FK)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0370	0.0322	0.0372	0.0309	0.0810	0.0480	0.0269
51 (FL)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0269	0.0322	0.0372	0.0309	0.0810	0.0370	0.0480
52 (GH)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0372	0.0322	0.0309	0.0810	0.0370	0.0269
53 (GI)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0309	0.0372	0.0322	0.0810	0.0370	0.0269
54 (GJ)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0810	0.0372	0.0309	0.0322	0.0370	0.0269
55 (GK)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0370	0.0372	0.0309	0.0810	0.0322	0.0269
56 (GL)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0269	0.0372	0.0309	0.0810	0.0370	0.0322
57 (HI)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0309	0.0372	0.0810	0.0370	0.0269
58 (HJ)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0810	0.0309	0.0372	0.0370	0.0269
59 (HK)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0370	0.0309	0.0810	0.0372	0.0269

60 (HL)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0269	0.0309	0.0810	0.0370	0.0372
61 (IJ)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0810	0.0309	0.0370	0.0269
62 (IK)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0370	0.0810	0.0309	0.0269
63 (IL)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0269	0.0810	0.0370	0.0309
64 (JK)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0370	0.0810	0.0269
65 (JL)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0269	0.0370	0.0810
66 (KL)	0.1432	0.3350	0.0325	0.1462	0.0499	0.0480	0.0322	0.0372	0.0309	0.0810	0.0269	0.0370

APPENDIX F.2: Sensitivity analysis C_i values and rankings

Port / Condition	Cat Lai	Green port	Koja	LCMT	North port	PSA terminals
			C_i values & their rankings			
Main (original)	0.7758	0.2851	0.1199	0.4732	0.3303	0.4128
	1	5	6	2	4	3
1 (AB)	0.7427	0.4368	0.1259	0.2462	0.6546	0.6961
	1	4	6	5	3	2
2 (AC)	0.7496	0.2609	0.1230	0.5402	0.2597	0.3731
	1	4	6	2	5	3
3 (AD)	0.7759	0.2841	0.1194	0.4708	0.3336	0.4158
	1	5	6	2	4	3
4 (AE)	0.7813	0.2441	0.1190	0.4838	0.2160	0.3310
	1	4	6	2	5	3
5 (AF)	0.7768	0.2464	0.2502	0.4862	0.2751	0.3979
	1	6	5	2	4	3
6 (AG)	0.7895	0.2283	0.2656	0.5905	0.3854	0.4387
	1	6	5	2	4	3
7 (AH)	0.7690	0.2561	0.1254	0.5235	0.2166	0.3479
	1	4	6	2	5	3
8 (AI)	0.7575	0.2538	0.1277	0.5230	0.2072	0.3507
	1	4	6	2	5	3
9 (AJ)	0.6735	0.2432	0.1151	0.4501	0.2486	0.4446
	1	5	6	2	4	3
10 (AK)	0.6735	0.2290	0.1141	0.4427	0.2003	0.4518
	1	4	6	3	5	2
11 (AL)	0.7099	0.2510	0.1221	0.5198	0.2388	0.3821
	1	4	6	2	5	3
12 (BC)	0.5221	0.4069	0.1562	0.5159	0.6574	0.7223
	3	5	6	4	2	1

13 (BD)	0.7106 1	0.5294 2	0.1872 6	0.4661 3	0.4616 4	0.4431 5
14 (BE)	0.7727 1	0.2501 4	0.1216 6	0.2173 5	0.3508 3	0.3761 2
15 (BF)	0.7370 2	0.2677 5	0.5702 4	0.2082 6	0.6364 3	0.7533 1
16 (BG)	0.8103 1	0.1999 6	0.5420 5	0.6915 4	0.7914 3	0.7993 2
17 (BH)	0.6082 2	0.4117 4	0.1969 6	0.3269 5	0.5708 3	0.6555 1
18 (BI)	0.5372 2	0.3828 4	0.2123 6	0.3144 5	0.5265 3	0.6723 1
19 (BJ)	0.3302 2	0.1990 4	0.0974 6	0.1668 5	0.3172 3	0.7975 1
20 (BK)	0.3730 2	0.1993 4	0.0989 6	0.1495 5	0.2958 3	0.8178 1
21 (BL)	0.3934 3	0.3295 5	0.1458 6	0.3570 4	0.5820 2	0.7411 1
22 (CD)	0.7530 1	0.2280 5	0.1117 6	0.4806 2	0.3509 4	0.4448 3
23 (CE)	0.7734 1	0.2866 5	0.1202 6	0.4767 2	0.3330 4	0.4161 3
24 (CF)	0.7740 1	0.2862 5	0.1022 6	0.4761 2	0.3299 4	0.4116 3
25 (CG)	0.7758 1	0.2851 5	0.1202 6	0.4732 2	0.3304 4	0.4129 3
26 (CH)	0.7755 1	0.2852 5	0.1199 6	0.4734 2	0.3307 4	0.4131 3
27 (CI)	0.7758 1	0.2851 5	0.1199 6	0.4731 2	0.3302 4	0.4128 3
28 (CJ)	0.8424 1	0.2967 5	0.1228 6	0.5020 2	0.3429 4	0.3865 3

29 (CK)	0.7777	0.2857	0.1200	0.4747	0.3311	0.4115
	1	5	6	2	4	3
30 (CL)	0.7749	0.2850	0.1199	0.4728	0.3301	0.4130
	1	5	6	2	4	3
31 (DE)	0.7845	0.2130	0.1089	0.4362	0.3150	0.4014
	1	5	6	2	4	3
32 (DF)	0.7800	0.2147	0.2442	0.4374	0.3546	0.4584
	1	6	5	3	4	2
33 (DG)	0.7926	0.1955	0.2590	0.5371	0.4327	0.4921
	1	6	5	2	4	3
34 (DH)	0.7726	0.2214	0.1140	0.4629	0.3285	0.4272
	1	5	6	2	4	3
35 (DI)	0.7611	0.2180	0.1162	0.4613	0.3256	0.4305
	1	5	6	2	4	3
36 (DJ)	0.6734	0.2203	0.1074	0.4172	0.3142	0.4842
	1	5	6	3	4	2
37 (DK)	0.6763	0.1969	0.1040	0.4013	0.3045	0.5015
	1	5	6	3	4	2
38 (DL)	0.7132	0.2159	0.1107	0.4602	0.3405	0.4519
	1	5	6	2	4	3
39 (EF)	0.7757	0.2851	0.1223	0.4732	0.3307	0.4134
	1	5	6	2	4	3
40 (EG)	0.7764	0.2839	0.1395	0.4820	0.3418	0.4207
	1	5	6	2	4	3
41 (EH)	0.7751	0.2861	0.1202	0.4749	0.3311	0.4143
	1	5	6	2	4	3
42 (EI)	0.7739	0.2863	0.1205	0.4755	0.3312	0.4151
	1	5	6	2	4	3
43 (EJ)	0.8296	0.2891	0.1212	0.4833	0.3317	0.3842
	1	5	6	2	4	3
44 (EK)	0.7672	0.2841	0.1196	0.4705	0.3296	0.4199
	1	5	6	2	4	3

45 (EL)	0.7684	0.2862	0.1202	0.4758	0.3327	0.4175
	1	5	6	2	4	3
46 (FG)	0.7767	0.2838	0.1224	0.4807	0.3377	0.4157
	1	5	6	2	4	3
47 (FH)	0.7754	0.2857	0.1073	0.4745	0.3289	0.4111
	1	5	6	2	4	3
48 (FI)	0.7745	0.2859	0.1009	0.4751	0.3281	0.4104
	1	5	6	2	4	3
49 (FJ)	0.8317	0.2901	0.1659	0.4843	0.3413	0.3978
	1	5	6	2	4	3
50 (FK)	0.7688	0.2841	0.1066	0.4708	0.3277	0.4157
	1	5	6	2	4	3
51 (FL)	0.7696	0.2858	0.0967	0.4753	0.3289	0.4119
	1	5	6	2	4	3
52 (GH)	0.7762	0.2845	0.1248	0.4747	0.3328	0.4143
	1	5	6	2	4	3
53 (GI)	0.7757	0.2852	0.1187	0.4728	0.3297	0.4125
	1	5	6	2	4	3
54 (GJ)	0.8582	0.2857	0.1830	0.5204	0.3731	0.4066
	1	5	6	2	4	3
55 (GK)	0.7786	0.2851	0.1248	0.4760	0.3332	0.4125
	1	5	6	2	4	3
56 (GL)	0.7743	0.2856	0.1151	0.4717	0.3281	0.4119
	1	5	6	2	4	3
57 (HI)	0.7755	0.2851	0.1199	0.4731	0.3302	0.4129
	1	5	6	2	4	3
58 (HJ)	0.8469	0.2951	0.1233	0.4958	0.3362	0.3824
	1	5	6	2	4	3
59 (HK)	0.7757	0.2851	0.1199	0.4731	0.3303	0.4129
	1	5	6	2	4	3
60 (HL)	0.7734	0.2850	0.1198	0.4731	0.3307	0.4137
	1	5	6	2	4	3

61 (IJ)	0.8491	0.2955	0.1242	0.4974	0.3359	0.3806
	1	5	6	2	4	3
62 (IK)	0.7786	0.2858	0.1202	0.4748	0.3308	0.4108
	1	5	6	2	4	3
63 (IL)	0.7751	0.2851	0.1198	0.4731	0.3305	0.4131
	1	5	6	2	4	3
64 (JK)	0.7922	0.2855	0.1201	0.4732	0.3290	0.4118
	1	5	6	2	4	3
65 (JL)	0.8226	0.2948	0.1227	0.4978	0.3404	0.3874
	1	5	6	2	4	3
66 (KL)	0.7782	0.2861	0.1202	0.4757	0.3315	0.4104
	1	5	6	2	4	3