Framework for Improving Strategic Competitiveness of Container Ports in the UAE

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Declaration

I hereby declare that:

1. I have not been enrolled for another award of the University or other academic or professional organisation, whilst undertaking my research degree.

2. None of the material contained in the thesis has been used in any other submission for an academic award.

3. I am aware of and understand the University's policy on plagiarism and certify that this thesis is my own work. The use of all published or other sources of material consulted has been properly and fully acknowledged.

4. The work undertaken towards the thesis has been conducted in accordance with the SHU Principles of Integrity in Research and the SHU Research Ethics Policy.

5. The word count of the thesis is 36908

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Abstract

Container-based shipping plays a pivotal role in the economic landscape of the United Arab Emirates (UAE), a nation strategically positioned at the crossroads of major trade routes between Asia, Europe, and Africa. Improving competitiveness in container-based shipping is crucial for the UAE to maintain and enhance its position in the global market. Therefore, the main aim of this research program is to develop a framework for improving the strategic competitiveness of container ports in the UAE.

An extensive literature review revealed that smart ports are the way forward for improving competitiveness. Perspectives collected via interviews and a questionnaire survey supported the view that a comprehensive and holistic approach is needed to transform UAE ports.

An extended definition of the smart port paved the way for developing the Smart Port Framework Repository (SaPFaR). Using the new definition as the catalyst, this work identified eight (8) different areas for further development. Having suggested that Industry 4.0 should be at the heart of smart port technologies, a library of use cases and a detailed maturity model are presented. Then, a framework and a maturity model are offered for each of the remaining seven (7) areas. The validation of SaPFaR using a panel of domain experts led to suggestions that Capgemini's Digital Transformation Framework be used to guide the implementation of SaPFaR.

This is the first-ever study of container ports in the UAE and offers a comprehensive and holistic framework for improving their strategic competitiveness.

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Chapter 1: Introduction, Aim and Objectives

1.1 Introduction

This chapter begins with an overview of maritime transport and its role in supply chains. It then presents the development of the constrainer port industry and the challenges in this vital global sector. Following an introduction to the container ports in the UAE, this chapter also argues a case for improving the competitiveness of UAE container ports. Finally, the aim of the research project and its objectives are presented.

1.2 Supply Chains and Transportation

Supply chains are the backbone of the global economy and livelihood (Varzandeh et al., 2014). They play a critical role in delivering goods from suppliers to end consumers. As most supply chains are globally diverse, the flow of goods through the supply chain requires using a series of transportation systems, typically involving a combination of ground, air, and sea transportation (Novack et al., 2023).

Sea Transportation (Maritime): Maritime transport is the backbone of international trade and the global economy. Around 80% of global trade by volume and over 70% by value is carried by sea and is handled by ports worldwide, according to the United Nations Conference on Trade and Development (Brooks & Faust, 2018).

Ground Transportation (Road and Rail): Road and rail transport are crucial for intra-continental and domestic trade. While their role in international logistics is not as dominant as sea transport, they play a significant part, especially in large landmass countries such as the U.S., China, and Russia. It is challenging to provide a precise percentage for ground transport on a global scale due to the vast number of domestic shipments. Still, for international trade, road and rail are often considered "first mile" or "last mile" legs, connecting the primary mode of transport (often maritime) to the destination (Bergmann et al., 2020).

Air Transportation: Air freight represents a smaller percentage of global trade by volume than maritime transport but is crucial for high-value, time-sensitive goods. In terms of value,

air cargo represents roughly 35% of global trade, even though it is less than 1% by volume, according to the International Air Transport Association (Shepherd et al.,2016)

1.3 Maritime Transportation

Efficient, cost-effective, and sustainable transportation ensures that goods are delivered to end-consumers on time, at the lowest possible cost, and with the minimum possible environmental damage. Maritime is recognised as the least expensive (Lapinskaitė & Kuckailytė, 2014). Maritime transportation is vital in logistics, connecting global markets and transporting a wide range of goods, from raw materials to finished products. It is the most cost-effective and efficient way to move large cargo volumes over long distances (Miola et al., 2009). Table 1.1 shows the advantages and disadvantages of maritime transportation.

Advantages	Disadvantages
Cost-effectiveness: Maritime transportation is the most cost-effective way to move large cargo volumes over long distances (Lapinskaitė & Kuckailytė, 2014). This is because ships can carry more cargo than trucks or trains, using less fuel per ton of cargo. **Efficiency:** Maritime transportation is also very efficient. Ships can travel long distances without stopping, and they can operate in all weather conditions. **Environmental friendliness:** Maritime transportation is a relatively environmentally friendly mode of transportation. Ships produce fewer emissions per ton of cargo than trucks or trains.	**Speed:** Maritime transportation is slower than other modes of transportation, such as air freight. This can be a disadvantage for goods that need to be transported quickly. **Reliability:** Maritime transportation can be less reliable than other modes of transportation due to weather conditions and other factors. **Infrastructure:** Maritime transportation requires ports and other infrastructure to support it. This can be a disadvantage in countries with underdeveloped infrastructure.

Table 1.1: The advantages and disadvantages of maritime transportation

Despite some disadvantages, maritime transportation is the dominant mode of transportation in global logistics. It is the most cost-effective and efficient way to move large cargo volumes over long distances. With the advent of container-based shipping in 1960,

maritime transportation rapidly became the most popular form of transportation in supply chains in the modern era (Tenold et al., 2012).

1.4 Container-based Shipping

Container-based shipping revolutionised the global economy when it was introduced in the 1960s. Before that, goods were shipped in various ways, including loose cargo, bags, and crates. This was a time-consuming and labour-intensive process, and it was also prone to damage and theft.

Container-based shipping uses standardised shipping containers to transport goods from one place to another (Notteboom, 2004). Containers are typically made of steel and are designed to be durable and stackable, making them ideal for long-distance shipping. A standard 20-foot shipping container measures 20 feet long, 8 feet wide, and 8.5 feet tall. One 20-foot-long container is known as I TEU (Twenty-foot Equivalent Unit). Using the TEU makes it easier to quantify and standardise the capacity of container ships or the volume of cargo being transported. For instance, a ship that can carry 5,000 TEUs can accommodate a mix of 20-foot (1 TEU each) and 40-foot containers (2 TEUs each) that total 5,000 TEUs in capacity.

Container-based shipping made shipping more efficient and cost-effective. Containers can be loaded and unloaded quickly and easily and stacked on top of each other, allowing ships to carry more cargo. This has led to a significant reduction in the cost of shipping goods worldwide. Container-based shipping has also made it easier to trade with other countries. In the past, it wasn't easy to ship goods to countries with different infrastructure and shipping standards. However, container-based shipping is standardised, meaning containers can be transported on ships, trucks, and trains without unloading and reloading. This has made it easier for businesses to export and import goods, which has boosted global trade (Notteboom, 2012).

Today, container-based shipping is the dominant mode of transportation for goods worldwide. Over 90% of all non-bulk cargo is shipped in containers (Rezapour et al., 2014). Container-based shipping has played a significant role in globalisation and has made it

possible for people worldwide to enjoy goods and services from other countries. As shown in Figure 1.1, container-based shipping has rapidly increased since its inception in the 1960s.

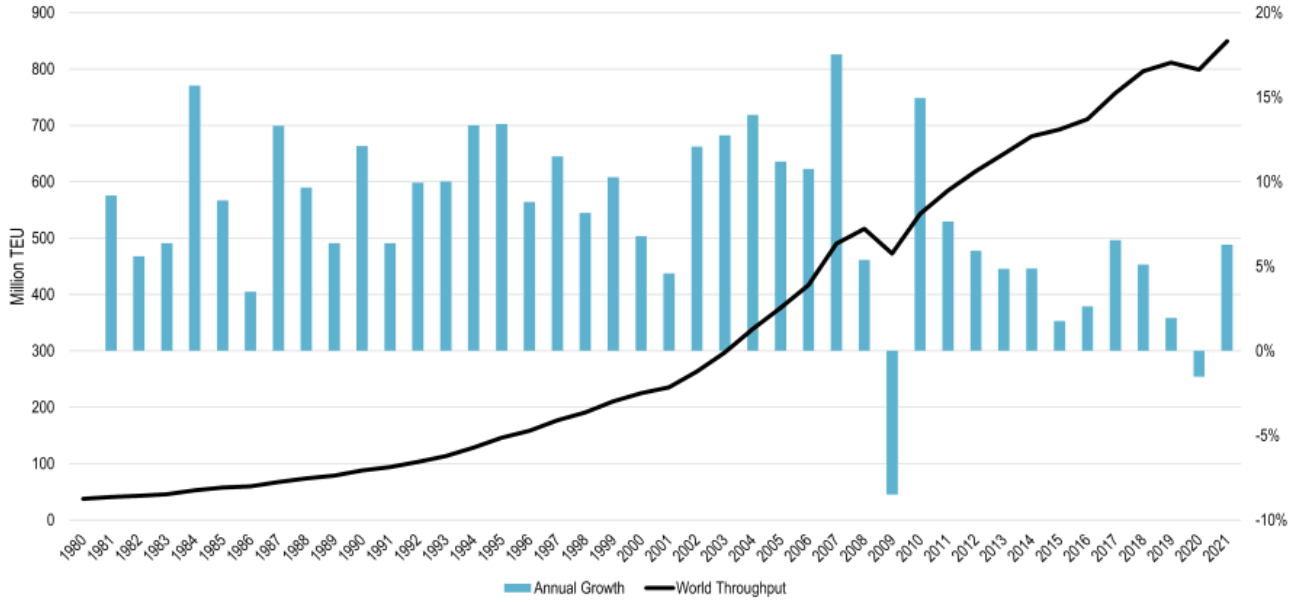

Figure 1.1 Rapid growth of container-based shipping (Source: Rodrigue, 2020).

Table 1.2 below lists the key benefits of container-based shipping (Notteboom, 2012)

Benefit	Description
Efficiency	Container-based shipping is a very efficient way to transport goods. Containers can be loaded and unloaded quickly and easily and stacked on each other, allowing ships to carry more cargo.
Cost-effectiveness	Container-based shipping has significantly reduced the cost of shipping goods worldwide. This is because containers can be transported on ships, trucks, and trains without unloading and reloading.
Flexibility	Container-based shipping is a very flexible mode of transportation. Containers can be used to ship various goods, from food and clothing to electronics and machinery.
Security:	Containers are sealed and locked, which helps to protect goods from theft and damage.

Table 1.2: Key benefits of container-based shipping

As container-based shipping became popular, nations worldwide began to build container ports (Tomlinson, 2009).

1.5 Container Ports

The primary function of a container port is to facilitate the transfer of containers and cargo between ships and other modes of transport, such as ground-based transportation systems such as trains and trucks. In line with the rapid growth of container-based shipping, the number of container ports and the volume of containers handled by container ports have also increased, as shown in Figure 1.2.

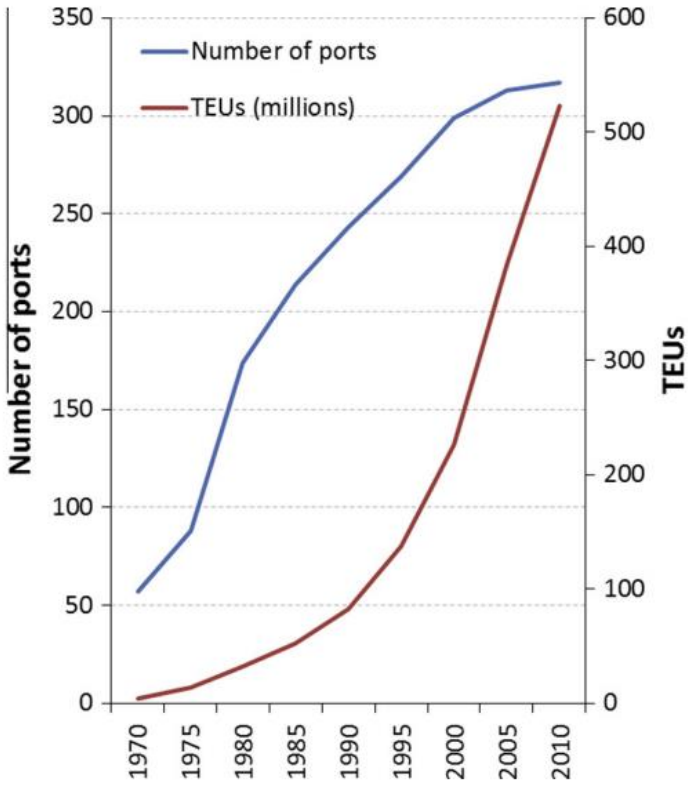

Figure 1.2 The growth of the number of container ports and TEUs between 1970 and 2010 (Guerrero & Rodrigue,2014)

1.6 Container Port Operations

Figure 1.3 shows the critical operational areas of a container port.

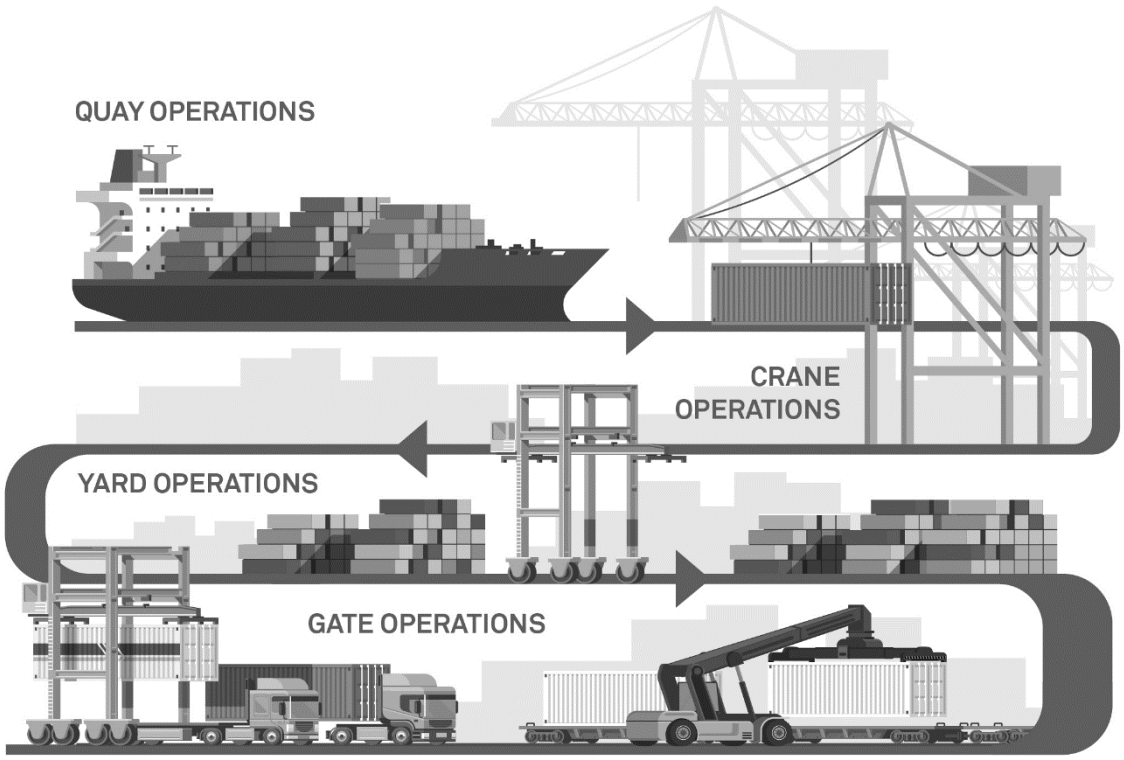

Figure 1.3: Key operations of container port (Source: Camso, 2020)

Quay operation refers to activities at the quay (or wharf) within a port. The quay is the waterfront section of the port where ships berth to load and unload cargo. Specialised ship-to-shore cranes load and unload standardised cargo containers from large vessels. Once offloaded, containers are organised in dedicated storage areas (yard operations), often stacked several units high, awaiting onward transportation. Advanced systems track and manage container movements, ensuring efficient handling and rapid transfer to trucks, railways, or smaller vessels (gate Operations). The reverse process takes place when containers are delivered for outbound shipments. The role of ports has also grown from handling cargo to providing logistic services to meet the growing needs of supply chains (Figure 1.4).

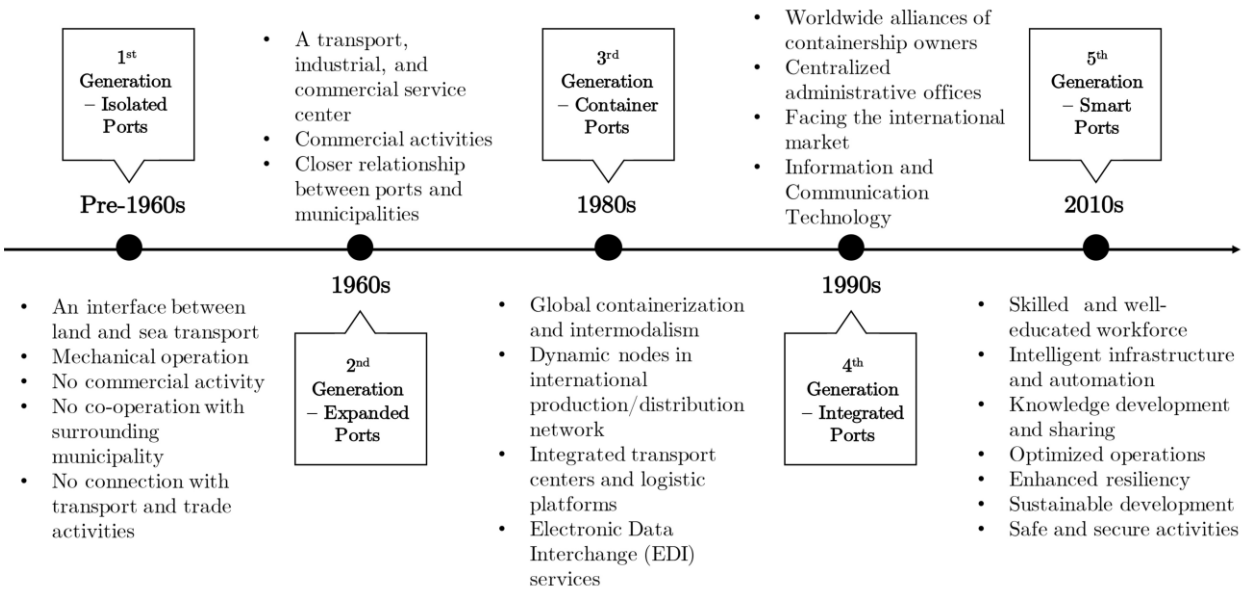

Figure 1.4 Ports development throughout the history (Molavi et al.,2020).

The continual growth of container-based shipping, the number of ports, and the transformation of services provided by container ports have created a highly competitive environment (Lau et al., 2013). The incorporation of emerging technologies has further intensified this competitive environment.

1.7 Challenges of the Container Port Industry – Global Perspectives

As shown in Table 1.3, the continuing growth of the container industry has led to many challenges.

Aspect	Details
Congestion:	Port congestion is a significant problem in many parts of the world, caused by increased demand, larger ships, and limited capacity. Congestion can lead to delays in cargo handling, increased costs, and disruptions to supply chains (Steinbach, 2022; Maguire et al., 2010)
Environmental regulations:	The container port industry is under increasing pressure to reduce its environmental impact. Regulations are being implemented worldwide to reduce air pollution, greenhouse gas emissions, and noise pollution. These regulations can add to the cost of operating a port and may

	make it more difficult to expand capacity. (Hakam & Solvang, 2013; Bergqvist & Monios 2019).
Digitalisation:	The container port industry is transforming digitally, adopting new technologies such as automation, big data, and artificial intelligence. These technologies can help to improve efficiency and productivity, but they also require significant investment (Heikkilä et al., 2022; Anwar et al.,2019).
Geopolitical tensions	Geopolitical tensions can disrupt trade flows and make it more difficult for ports to operate efficiently. For example, the ongoing conflict in Ukraine has led to shipping route disruptions and increased shippers costs (Noorali & Ahmadi, 2023; Habova, 2015).
Rising costs:	The cost of operating a container port is rising due to labour costs, fuel prices, and environmental regulations. This can make it more difficult for ports to be profitable and may lead to consolidation in the industry (Cho, 2014; Dappe & Suárez-Alemán, 2016).
Security threats:	Container ports are vulnerable to various security threats, including terrorism, piracy, and cyber attacks. These threats can disrupt operations, damage property, and endanger people (Leonard et al,, 2015; Scholliers et al., 2016)

Table 1.3 Global Challenges of the Container Port Industry

The above trends and challenges have created a highly competitive environment, and container port operators who can address the above challenges successfully stay ahead of the competition. The primary purpose of the above sections is to provide global perspectives on the development of container ports. With those insights, the rest of the chapter focuses on developing container ports in the UAE, the challenges, and the need for this research.

1.8 Container Ports in the UAE

Historically, the region now known as the UAE was home to maritime traders and pearl divers. Its location between Asia and Europe made it a nexus for trade routes. However, the

transition from traditional dhow ports to state-of-the-art container ports began in earnest in the latter half of the 20th century, after the country's formation in 1971. However, the discovery of oil in the region led to a boom in economic activity, and the need for a more modern and efficient port system became apparent (Akhavan, 2017).

In 1979, the government of Dubai opened Port Rashid, the first modern container port in the UAE. Port Rashid quickly became a central hub for trade in the region, and it helped to transform Dubai into a global trade centre. In 1977, Port Zayed was opened in Abu Dhabi, and it soon became the second-largest port in the UAE. In the 1990s, the UAE continued to invest in its container port infrastructure. In 1999, Port Jebel Ali was opened in Dubai, quickly becoming the largest port in the Middle East (Padron et al., 2007). Port Jebel Ali is a state-of-the-art port equipped to handle the largest container ships in the world. It is also a free trade zone, making it an attractive business destination. The UAE's container port industry has grown rapidly in recent years. In 2021, the UAE handled over 13 million TEUs of container traffic, making it the 11th busiest container port in the world.

Several key factors have contributed to the evolution of container ports in the UAE (Table 1.4):

Factor	Description
Government investment	The UAE government has invested heavily in its container port infrastructure in recent decades. This investment has helped to create world-class ports that can handle the growing demand for container traffic (Sushil & Tandon,2019).
Strategic location	The UAE is strategically important at the crossroads of Europe, Asia, and Africa, making it an ideal hub for trade between these regions.
Free trade zones	The UAE has several free trade zones that offer attractive incentives to businesses. This has made the UAE an attractive destination for businesses involved in international trade (Shayah & Qifeng, 2015).
Modern technology	The UAE has invested in modern technology to improve the efficiency of its container ports. This technology includes automated cargo handling, IT, and security systems.

Table 1.4 Key factors behind the growth of container ports in the UAE

The UAE government claims that 61% of cargo destined for Gulf Cooperation Countries (i.e., Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and UAE) arrives via the UAE's seaports. There are seven major container ports in the UAE (Table 1.5), and Figure 1.5 shows their approximate locations.

Port No (Figure 1.4)	Port Name	Location	Key Features	TEU Capacity (million) per annum
1	Jebel Ali Port	Dubai	Recognised as a turning point for the UAE's maritime ambitions. Its free zone (JAFZA) further strengthened its position, attracting businesses with benefits like tax exemptions and foreign ownership. The largest port in the Middle East and a global hub. One of the world's largest marine terminals.	19.30
2	Khalifa Port	Abu Dhabi	State-of-the-art infrastructure and home to the Khalifa Industrial Zone Abu Dhabi (KIZAD).	7.80
3	Fujairah Port	Fujairah	Key global oil and container port and Connects to important shipping routes	2.50
4	Mina Khalid	Sharjah	Multi-purpose port.	1.70
5	Port Rashid	Dubai	Dubai's first commercial port.	1.50
6	Sharjah Container Terminal	Sharjah	An Important regional hub.	0.69
7	Mina Saqr	Ras Al Khaimah	One of the major bulk-handling ports in the region.	0.35
8	Mina Zayed	Abu Dhabi	Has played a key role in trade historically.	0.15

Table 1.5 Container Ports in the UAE

Figure 1.5: Locations of UAE container ports

1.9 Competitive challenges of the UAE container port industry

Although the United Arab Emirates is home to two of the world's largest and most modern container ports (Jebel Ali Port and Khalifa Port), the country's port operators are also experiencing the global challenges presented in Table 1.3. In addition, there are internal and region-specific challenges as well.

Internal Competition: Shaw-Smith (2022) argues that the two largest ports (Jabel Ali Port and Khalifa Port) are competing with each other for the cargo businesses. Both are largely government-owned (Jabel Ali Port - the government of Dubai, and Khalifa Port - the government of Abu Dhabi), and both have ambitious plans for large-scale master plans for expansion.

Competition from other regional ports: The UAE is in a region with several other major container ports, such as Mina Salman in Bahrain and Sohar Port in Oman (Figure 1.6). These ports are all investing heavily in new infrastructure and services to attract more traffic (Khalili, 2021; Khalid & Al-Mamery, 2019)

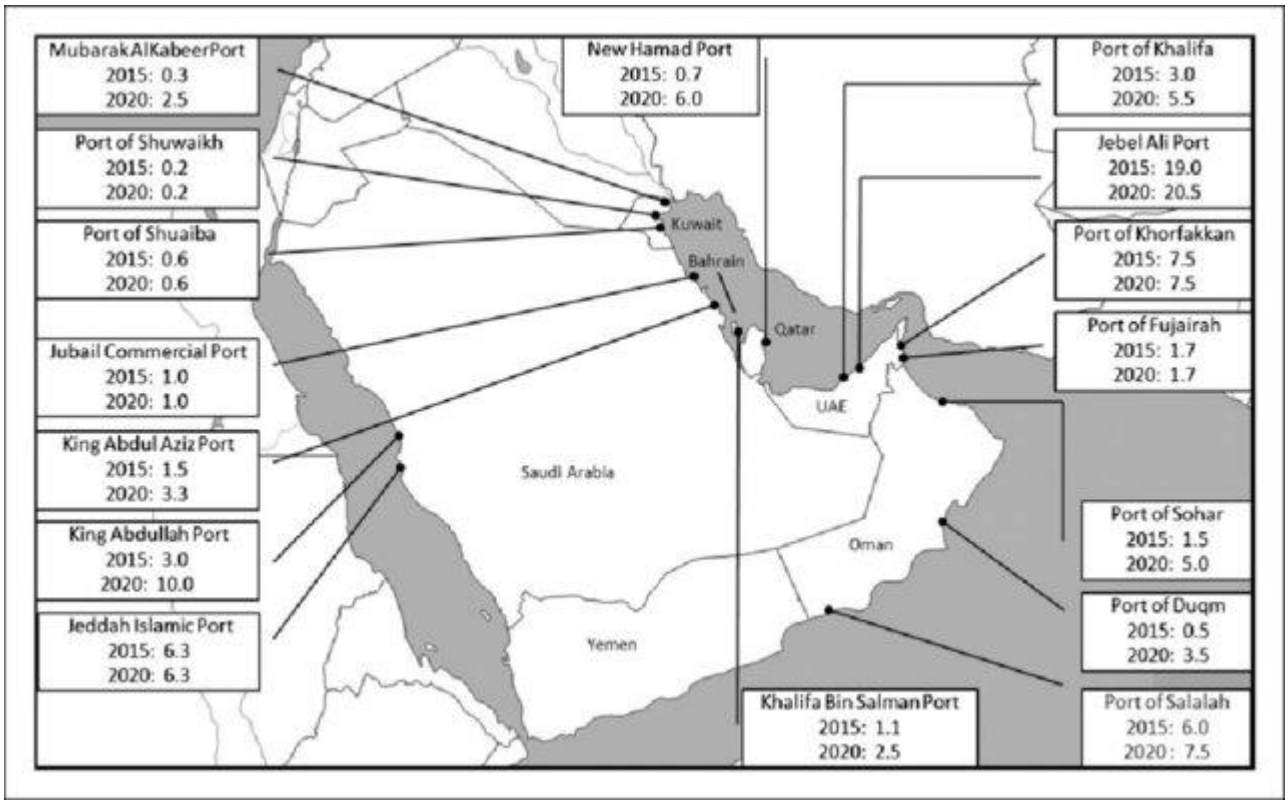

Figure 1.6: Major ports in Gulf Cooperation Counties – (Source: Ziadah, 2018).

Impact of Israel-UAE Normalisation – As this development might change geopolitics in the region, other Gulf Cooperation countries might regroup to challenge the commercial might of the UAE. Maritime logistics can be a part of this challenge (AlMaashi, 2021)

Given the regional and global challenges, the UAE container ports industry needs to continually improve competitiveness to stay ahead.

1.10 Aim, Research Questions and Objectives

With ever-rising challenges in the constrainer port industry, it is critically important that the UAE container ports continue to improve their competitiveness. Preliminary discussions with port operators revealed that they have aspirations to improve the competitiveness of their ports, but they voiced a lack of a strategic framework as a significant impediment. A brief literature survey also revealed there is no coherent and inclusive framework that can be used to improve the competitiveness of container ports.

The research work, therefore, aims to *develop a framework for improving the strategic competitiveness of container ports in the UAE*.

The specific research questions are.

> **RQ1**: What are the underlying causes and key factors driving the need to enhance the competitiveness of UAE container ports, and how do these elements influence the strategic positioning of the UAE in the global maritime and logistics industry?
>
> **RQ2:** What is the most effective strategy for enhancing the competitiveness of container ports, especially considering the context of global trade dynamics and technological advancements??

RQ3: What are the elements of a comprehensive and holistic approach to implementing the best strategy for enhancing the competitiveness of container ports?The objectives of the proposed research programme is as follows:

OB1: Conduct a comprehensive literature review to identify the current challenges in the container port sector, the strategies employed to enhance competitiveness, and recent research developments.

OB: Capture the perspectives of UAE container ports regarding their challenges and opportunities.

OB3: Develop a detailed research methodology to effectively address the research questions.

OB4: Design, develop, and validate a framework aimed at enhancing the competitiveness of UAE container ports.OB5-: Discuss the limitations of the research and propose future research directions

1.11 The structure of the thesis

The structure of thesis is as follows.

Chapter 1 – introduces the context, outlines the challenges in the UAE container port industry ase set outs the aim, objectives and research questions.

Chapter 2 – presents the outcomes of the literature review and identifies the research gap.

Chapter 3 – brings out industrial perspectives of ports operators in the UAE, gathered through interviews and a questionnaire survey.

Chapter 4 – presents the development of the research method, informed by Saunder's Research Onion.

Chapter 5 – captures the development of the Smart Port Framework Repository (SaPFaR) which covers all aspects of smart port operations.

Chapter 6 – explains the role of focus group interviews in validating SaPFaR

Chapter 7 – concludes the research work by highlighting the key contributions to the field of research and outlines future research directions.

Chapter 2

2.1 Introduction

This chapter presents a literature review on the topic of container port competitiveness. It begins by providing a brief overview of the relevant literature, including the evolution of container ports, key concepts, theories, and findings. The chapter then goes on to identify gaps in the literature, which this study aims to address.

2.2 Evolution of container ports

Containerisation, a revolutionary concept introduced in the mid-20th century, has and profound impact on global trade and transportation. This section offers a comprehensive historical analysis of container ports, explaining their evolution by considering their early years, growth phases, and the pivotal role of technological innovations.

2.2.1 Early Containerisation (1950s-1960s)

Early containerisation, spanning the 1950s to the 1960s, marks a pivotal period in the evolution of global trade and transportation. During this era, the concept of containerisation emerged as a transformative solution to the inefficiencies and labor-intensive processes of traditional cargo handling. The visionary efforts of Malcom McLean (Talley, 2000), who introduced the world's first container ship, the SS Ideal X, in 1956, played a central role. This pioneering voyage led the era of standardised container sizes, enabling the seamless movement of goods between different modes of transport—ships, trucks, and trains. The introduction of the ISO container in 1961 (Egyedi, 2000) further solidified the standardisation, fostering interoperability across global supply chains. Early containerisation brought about a paradigm shift, drastically reducing cargo handling times, lowering shipping costs, and ultimately facilitating the globalisation of trade. This period laid the foundation for the subsequent exponential growth of container ports and their vital role in the modern world economy.

2.2.2 Proliferation of Container Ports (1970s-1980s)

The proliferation of container ports during the 1970s and 1980s marked a significant phase in the evolution of global trade infrastructure (Robinson, 1998). This era witnessed the rapid expansion of container port facilities and the establishment of new terminals in strategic locations worldwide. A confluence of factors contributed to this growth, including the increasing adoption of containerisation as the preferred method of cargo transportation, the growth of international trade, and the realisation of the efficiency gains associated with container handling. Governments and port authorities recognized the economic advantages of embracing containerisation, which led to investments in infrastructure development, expansion of port capacity, and modernisation of handling equipment (Helmick, 1994). . As container ships grew in size and cargo volumes continued to soar, container ports played a pivotal role in facilitating the smooth flow of goods, thereby becoming essential nodes in the global supply chain network. This expansion era laid the foundation for container ports' further evolution and innovation in subsequent decades.

2.2.3 Profound Transformation of Container Ports (1980s-1990s)

The transformation of the port industry in these two decades was driven by several factors.

Trade Liberalization: In the context of the container industry, trade liberalisation has been a driving force behind its growth and evolution. Trade liberalisation policies, such as reduced tariffs and trade barriers, have facilitated the global exchange of goods and fueled the demand for containerised shipping (Wacziarg & Welch, 2008). By lowering the costs of importing and exporting goods, trade liberalisation has led to increased international trade volumes, which, in turn, have necessitated the expansion and modernisation of container ports and shipping infrastructure. The standardization of container sizes and handling procedures further enhances the efficiency and cost-effectiveness of container shipping, making it a preferred choice for businesses engaged in cross-border trade. Thus, trade liberalisation has not only stimulated the container industry but also played a crucial role in shaping its modern landscape, enabling the seamless movement of goods across the world's oceans and continents (Llanto & Navarro, 2012)

Technological Advancements: They have been a driving force in the ongoing transformation of the container industry, revolutionising its efficiency, safety, and capacity (Wijnolst et al., 2009). Innovations in container ship design have led to the development of larger vessels capable of carrying significantly more containers, resulting in economies of scale and reduced shipping costs per unit. Furthermore, container handling equipment has seen remarkable improvements, with the adoption of automated cranes, straddle carriers, and conveyor systems, allowing for faster and more precise cargo handling at container terminals (Pielage et al., 2008). Information technology has also played a pivotal role, integrating digital systems for tracking, scheduling, and optimising container movements, thereby enhancing supply chain visibility and efficiency (Wan, et al., 1992; Spector, et al., 2003). Blockchain technology has introduced new levels of security and transparency in container industry transactions, reducing fraud and errors (Li & Zhou, 2021). These technological advancements have not only increased the industry's capacity but have also contributed to its sustainability efforts through energy-efficient equipment and eco-friendly practices, further solidifying the container industry's crucial role in modern global trade (Lirn et. al., 2014)

Government and Industry Initiatives: The symbiotic relationship between government and industry initiatives and their profound impact on container ports is distinctive. Government investments in port infrastructure, regulatory frameworks, and trade facilitation create a robust foundation for the industry to flourish (Tae-Woo & Flynn, 2011) . In an increasingly interconnected global trade landscape, the interplay of government and industry initiatives is instrumental in shaping the evolution and continued significance of container ports as vital conduits of international commerce.

2.2.4 Towards smart ports (2000s +)

The year 2000 marked the beginning of a transformative era in the maritime industry with the emergence of smart ports (Karaś, 2020). This development was driven by the rapid integration of advanced technologies, such as Internet of Things (IoT) devices, data analytics, and automation, into port operations. Smart ports aim to optimise efficiency, security, and sustainability by leveraging real-time data to streamline cargo handling, enhance vessel navigation, and improve supply chain visibility (Yang et al., 2018).

Implementing smart technologies enabled ports to reduce congestion, minimise turnaround times, and lower environmental impacts. Moreover, deploying intelligent systems for logistics management and cybersecurity measures reinforced the resilience and competitiveness of these ports in the digital age. The evolution of smart ports in 2000 set the stage for an ongoing transformation that continues to reshape the maritime industry, ensuring its adaptability to the demands of the modern global trade landscape.

2.2.5 Smart ports as the future

Given the digital transformation across the globe, traditional container ports will undoubtedly undergo transformational changes to become smart ports. Heikkilä et al. (2022) argue that innovations driven by Industry 4.0 are "directed towards digitalisation, making the ports more automated, green and collaborative." Their work also presents four possible future scenarios for the development of smart ports (Figure 2.1).

Figure 2.1: Four potential scenarios of future smart ports (Heikkilä et al., 2022)

Most nations aim to develop their own smart infrastructures (Habirun et al., 2023), so the port ecosystem would be a natural choice.

2.3 Evolution of Container Ports in the UAE

The United Arab Emirates (UAE), strategically located at the crossroads of international trade routes, has witnessed a remarkable evolution of its container ports over the years.

The growth of containerisation and the UAE's strategic geographic position have played pivotal roles in shaping the development of its container ports. This section explores the journey of container ports in the UAE, tracing their historical development, technological advancements, and current status as global trade hubs.

Historical Development - The history of containerisation in the UAE can be traced back to the 1970s when the region began to embrace this revolutionary mode of cargo transportation. Dubai's Port Rashid was the UAE's pioneer container terminal, handling its first container vessel in 1976 (Akhavan, 2019). As international trade continued to surge, the UAE recognised the importance of expanding its port facilities to accommodate the growing demand for container shipping. This led to the establishment of Jebel Ali Port in 1979, which quickly emerged as one of the region's largest and most advanced container terminals (Padron et al.,2007).

Technological Advancements - The evolution of the UAE's container ports has been closely tied to technological advancements. Jebel Ali Port, in particular, has been at the forefront of innovation, introducing state-of-the-art container handling equipment and adopting automation and digitalisation (Ramos, 2016). The port's integration of cutting-edge technologies, such as automated stacking cranes and terminal operating systems, has enabled it to handle vast volumes of cargo efficiently. Additionally, advanced security measures, including container tracking and inspection systems, have enhanced the safety and security of shipments passing through UAE ports (Akhavan & Akhavan, 2020)

Current Status -Today, the UAE is home to some of the world's busiest and most technologically advanced container ports. Jebel Ali Port, operated by DP World, is consistently ranked among the top container ports globally (Wang, 2019). It boasts a deep-water harbour, advanced container terminals, and extensive logistics facilities. Abu Dhabi's Khalifa Port, inaugurated in 2012, has also emerged as a significant player, offering modern container handling capabilities and connecting the UAE's capital to global trade routes (Pluijm, 2014). These ports are major transhipment hubs, facilitating trade between Asia, Europe, Africa, and the Middle East.

2.4 Challenges in the UAE Container Port Sector

Despite the significant advancements in the development of container ports in the United Arab Emirates (UAE), there have been instances where the lack of competitiveness has posed challenges.

Port Congestion: One notable concern is port congestion, particularly in Dubai's Jebel Ali Port, which, despite its impressive infrastructure, has faced capacity issues due to high demand (Akhavan, 2017). A simulation study conducted by Piccoli (2014) to assess the port performance between 2014 and 2030 (for the predicted demand) identified berth unavailability as the leading cause of delay. This study also concluded that "existing infrastructure cannot cope with the demand when 1200 vessels per year are added to the 2030 forecast".

Competition from regional players: The UAE's geographic proximity to other rapidly growing regional hubs has put pressure on its ports. The Port of Sohar of Oman (Figure 2.2) could potentially be the leading competitor. A study by Khalid & Al-Mamery (2019) concluded that the Port of Sohar "has a better opportunity to be the gateway of the Gulf Cooperation Council (GCC) States and all Cargo could have dropped in the port and transferred to other GCC States by road, rail, and other transportation modes". The strategic location of Sohar Port outside of the Strait of Hormuz is the main advantage.

Figure 2.2: The strategic location of Sohar Port of Oman (Author. Using Google Maps)

Saudi Arabia is also planning US$ 36 billion worth of investments in logistics as an integral part of its National Industrial Development and Logistics Programme (Kingdom of Saudi Arabia (n.d.).

Bureaucratic inefficiencies – A comparative study of Singapore and UAE container ports undertaken by Akhavan (2017) revealed that UAE ports considerably lag on customs, tracing and tracking and timeliness. The most recent assessments of the Logistics Performance Index by the World Bank (2023) show (Figure 2.3) considerable improvements; however the UAE still lags behind those measures.

2023 LPI scores

Economy	LPI score	Customs score	Infra-structure score	Interna-tional shipments score	Logistics competence and quality score	Time-liness score	Tracking and tracing score
Singapore	4.3	4.2	4.6	4.0	4.4	4.3	4.4
Finland	4.2	4.0	4.2	4.1	4.2	4.3	4.2
Denmark	4.1	4.1	4.1	3.6	4.1	4.1	4.3
Germany	4.1	3.9	4.3	3.7	4.2	4.1	4.2
Netherlands	4.1	3.9	4.2	3.7	4.2	4.0	4.2
Switzerland	4.1	4.1	4.4	3.6	4.3	4.2	4.2
Austria	4.0	3.7	3.9	3.8	4.0	4.3	4.2
Belgium	4.0	3.9	4.1	3.8	4.2	4.2	4.0
Canada	4.0	4.0	4.3	3.6	4.2	4.1	4.1
Hong Kong SAR, China	4.0	3.8	4.0	4.0	4.0	4.1	4.2
Sweden	4.0	4.0	4.2	3.4	4.2	4.2	4.1
United Arab Emirates	4.0	3.7	4.1	3.8	4.0	4.2	4.1
France	3.9	3.7	3.8	3.7	3.8	4.1	4.0
Japan	3.9	3.9	4.2	3.3	4.1	4.0	4.0
Spain	3.9	3.6	3.8	3.7	3.9	4.2	4.1

Figure 2.3 The Logistic Performance Index (World Bank, 2023)

Port Inefficiencies: Another aspect is the relatively low port efficiency, which results in longer vessel turnaround times. GCC ports often handle larger vessels as they function as transhipment hubs. Nevertheless, in the UAE and Saudi Arabia, the average duration of a

vessel's stay in the port surpasses that of other major maritime regions, including renowned transhipment hubs like Singapore and Hong Kong (KPMG, 2021).

Rising Overcapacity: Middle Eastern ports have substantially expanded their capacity. Between 2011 and 2016, they augmented their container capacity by 16 million 20-foot equivalent units (TEU), reflecting an average annual growth rate of around 7%. This expansion outpaced the growth in container throughput, which averaged 4% during the same period. As a result of this added capacity, the utilisation rate at these ports decreased by nine percentage points, dropping from 75% to 66% (Boston Consulting Group, 2018).

Given the above challenges, UAE ports must enhance their competitiveness to maintain and strengthen their position as key players in the global trade and logistics landscape. This imperative arises from the increasingly competitive nature of the shipping industry, where efficiency, cost-effectiveness, and connectivity are paramount. By improving competitiveness, UAE ports can attract more trade volume, encourage businesses to use their facilities for transhipment and distribution, and enhance their overall economic significance. This, in turn, contributes to the country's economic growth and diversification efforts while ensuring that UAE ports remain attractive and vital hubs for international trade. Container terminal performance is mainly influenced by its efficiency and competitive edge (Serebrisky et al., 2016). There is widespread agreement that a spike in terminal efficiency directly boosts its competitive nature (Chang & Tovar, 2014). Recent insights highlight that efficiency in container terminals does not just slash maritime expenses but is also crucial for the shipping industry's sustainability (Ismail & Elgazzar, 2018). As such, ports must meet global benchmarks of efficiency and competitiveness to stay relevant (Ismail, 2019). The importance of efficiency in dictating port competitiveness has been well-recognized for some time (Kammoun et al., 2018). At its core, port competitiveness means delivering goods and services as capably and promptly as rivals, mirroring the mounting competitive pressures in the port sector (Elgazzar & Ismail, 2021). Efficiency stands out as a vital factor affecting port competitiveness, which influences overall port performance, a fact highlighted by Merk and Dang (2012).

2.5 Competitiveness as a National Priority

Lee and Lam (2017) examine the concept of the "Asian Port Doctrine," which suggests that Asian economies should prioritise the development of ports and container terminals to stimulate economic growth. Consequently, countries such as Singapore, Korea, China, and Taiwan have not only established themselves as highly attractive ports in the Asian region but have also forced their economies to new heights through the competitiveness of these ports. These nations' governments actively participate in decisions related to ownership, operation, pricing, financing, and providing both landside and waterside infrastructure (Lee & Lam, 2017).

Similarly, the UAE government has adopted a strategic focus on enhancing the competitiveness and appeal of its ports to global shipping companies (Ardemagni, 2018). This endeavour aims to diversify the economy from relying on oil-related trade. The UAE serves as the epicentre of trade and economic activity in the region, making its ports among the busiest in the area. However, given the proximity of these ports, shipping companies have multiple options to choose from. In such a context, it becomes crucial to continually assess a port's competitiveness compared to other regional ports.

This research work, therefore, aims to develop a systematic approach to enhance the competitiveness of ports in the UAE.

2.6 Competitiveness

Competitiveness, at its core, refers to the ability of an entity—be it an individual, organisation, or nation—to effectively compete in a specific arena (Francis, 2023). Having reviewed many different definitions of competitiveness, Vilanova et al., (2007) summarise the five main categories of competitiveness as shown in Figure 2.4

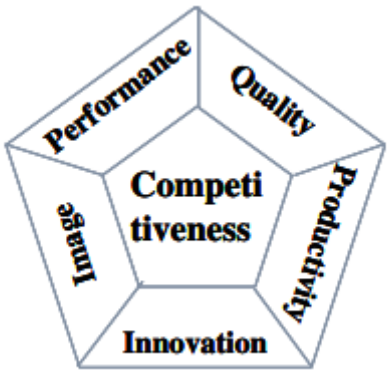

Figure 2.4: The five dimensions of the competitiveness (Vilanova et al., (2007)

Porter (1990) emphasized productivity's role in determining nations' competitive advantage. Porter argued that a nation's prosperity hinges on its firms' ability to compete, which is inextricably tied to their productivity. This productivity is affected by not just immediate factors like machinery or capital but also complex external conditions, which he called the "diamond" of national advantage, encompassing firm strategy, structure, rivalry, demand conditions, related supporting industries, and factor conditions (Stone & Ranchhod,2006).

While productivity is undoubtedly crucial, ***innovation*** also plays an undeniable role in fostering competitiveness. Schumpeter (1942) was an early proponent of the idea that economies grow and evolve through waves of innovation and creative destruction. In today's fast-paced, technology-driven world, the ability to innovate continuously is a cornerstone of competitiveness. Companies like Apple (Podolny & Hansen, 2020). Or Tesla (Kim, 2020), whose innovative products and approaches redefine markets and set them apart from competitors.

Quality, too, is central to competitiveness. As Crosby (1979) aptly stated, "quality is free". While this might seem counterintuitive initially, his argument was that the cost of doing things right the first time is invariably less than the cost of rectifying mistakes. In an age where consumers have access to many choices, the quality of products and services becomes a significant differentiator, impacting both brand perception and loyalty.

Instead of using performance and image individually, **value creation** was decided to be used as a combined indicator. Value creation is a superior measure of competitiveness compared to performance and image because it provides a comprehensive and sustainable perspective on a company's impact and success. Performance metrics often emphasise short-term operational efficiency and financial outcomes, while image focuses on brand perception and reputation. However, value creation integrates these aspects and extends further to include the long-term benefits delivered to customers, employees, shareholders, and society.. According to Prahalad and Hamel (1990), the core competencies of a firm—those things they do best—should be harnessed to create value for consumers. This aligns with the modern notion that competitiveness is not just about being the best but also about delivering the most value in terms of cost, experience, or functionality.

Competitiveness is not a monolithic idea but rather a multifaceted one embedded in productivity, innovation, quality, and value creation. Understanding and nurturing these elements will be crucial for entities aiming to stay ahead in the game as the container ports continues to evolve.

2.7 Competitiveness of UAE ports

This section attempts to assess the competitiveness of UAE ports using the four dimensions above: productivity, innovation, quality, and value creation. Table 2.1 summarises information gathered from a range of sources.

Competitiveness Dimension	Commonly used measures	Performance of UAE ports
Productivity	• Container moves per hour • Turnaround time • Dwell time	In the 2021 Global Container Port Performance Index (CPPI), in the Middle East Group, the top performer was Saudi Arabia's King Abdullah Port. Only Khalifa Port in Abu Dhabi was among the top five in the Middle East. (World Bank, 2021).
Innovation	• Technological Adoption • Digital Transformation	Although it was not possible to find academic publications

	• Green and Sustainable Initiatives	focusing on innovation in UAE ports, several commercial publications acknowledge that Khlaifa and Jabel Ali have implemented many innovative solutions (Logistics Voices, 2021),
Quality	Quality within the context of port operations refers to service quality. The most used model SERVQUAL Model (Lopez, 2018), uses five dimensions: • Tangibles • Reliability • Responsiveness • Assurance • Empathy.	Jabel Ali Port has taken a customer-centric approach, and it has been voted "Best Seaport in the Middle East" for 20 consecutive years (Bulk Distributor, 2014)
Value Creation	Value creation in ports can be measured through both tangible and intangible indicators. These indicators reflect the port's ability to generate economic value, improve operational performance, enhance stakeholder satisfaction, and contribute to the broader economic and social ecosystem. (De Martino at el.,, 2015)	Container ports in the UAE, notably Khalifa and Jebel Ali, are situated within Free Trade Zones (FTZs). This strategic positioning has amplified their ability to generate value (Chudasama & Kota, 2007).

Table 2.1 Analysis of competitiveness of UAE ports (Author)

The above brief analysis revealed a mixed picture of the competitiveness of UAE ports. Two major ports in the UAE, Khalifa and Jebel Ali, ports appear to have different strengths. It is reported that these two ports are intensifying their competition for containerised cargo. Despite no evident prospects for long-term volume growth, the mainly government-owned entities managing these ports heavily invest in increasing their capacities (Shaw-Smith, 2022). Both major ports aim to increase their competitiveness. At the same time, other smaller ports in the UAE are also gearing up

for enhancing their competitiveness. The above analysis shows the need for a framework for enhancing the competitiveness of UAE ports, but further analysis is required to identify specific needs.

2.8 Analysis using Porter's Competitive Strategy Theory

The brief analysis above provided insight into the need to improve UAE ports' competitiveness. However, it used four very broad factors considered major elements of competitiveness. In this section, further analysis of UAE container ports is carried out using Porter's Competitive Strategy Theory.

Competitive Strategy Theory (Porter, 2008) suggests that businesses exist in a competitive landscape, with success hinging on surpassing competitors. Porter identifies five fundamental forces influencing industry competition: the threat of new entrants, the bargaining power of suppliers, the bargaining power of customers, the threat of substitutes, and competitive rivalry (Figure 2.5). Porter (2008) emphasises the need for businesses to understand and evaluate these forces to formulate a strategy that ensures a lasting competitive edge.

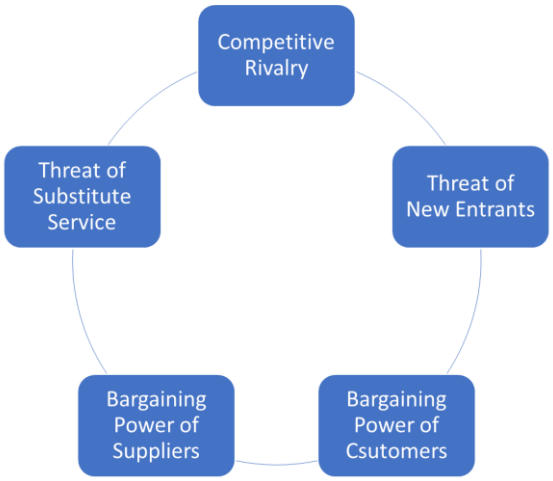

Figure 2.5: Porter's Fiver Forces of Competition (Author, after Porter, 2008)

Competitive Rivalry – As discussed above, there are competitive rivalries within and outside the UAE. Within the UAE, there are signs that Khalifa (based in Abu Dhabi) and Jabel Ali (based in Dubai) are competing with each other. Although both are within the UAE, they are owned by two different emirates. Regional rivalries are also building up, particularly in Oman and Saudi Arabia ports. The Port of Jebel Ali in Dubai is a major transhipment hub

serving the broader Middle East, Africa, and the Indian subcontinent. Therefore, it competes with ports in India and Pakistan for transhipment traffic (Notteboom & Rodrigue, 2011). There are examples from other regions of the world.

(a) *Singapore vs. Port Klang (Malaysia)*: Both ports have historically been competing to be Southeast Asia's main transhipment hub. While the Port of Singapore has often been the world's busiest in total shipping tonnage, Port Klang has made significant investments to attract more vessels and increase its container handling capacity (Yap & Lam, 2006).

(b) *Shanghai vs. Ningbo-Zhoushan (China)*: Both ports are in China and have experienced massive growth in recent decades. While Shanghai has been the world's busiest container port in terms of TEU (Twenty-foot Equivalent Units) throughput, Ningbo-Zhoushan is a close competitor and has been investing heavily to increase its capacity (Wang & Olivier, 2007).

Threat of New Entrants – Considering the numerous ports already established in the region, the chances of new ports emerging are minimal. However, mergers could give rise to new entities possessing greater bargaining strength. There are examples from other regions.

(a) *DP World & PSA International in Europe:* Global terminal operators like DP World and PSA International expanded into Europe, which increased competition among European ports. Their presence necessitated European ports to innovate, enhance service quality, and reduce turnaround times (Notteboom & Winkelmans, 2001)

(b) *Cosco in the Mediterranean:* The China COSCO Shipping Corporation has made significant inroads by acquiring stakes in major ports like Piraeus (Greece). This led to increased competition in the region and established Piraeus as a significant European gateway for Chinese goods (Pallis et al., 2010)

Bargaining Power of Customers – Shipping lines, freight forwarders, importers, exporters etc., are the typical customers of container ports. Customers' decisions are shaped by factors such as cost, efficiency, and the quality of service, among others. With numerous ports available in the region, there is a high possibility of customers switching between them. Here are two examples.

(a) Shipping Alliances and Their Impact on Ports: The formation of shipping alliances, such as 2M, THE Alliance, and Ocean Alliance, has concentrated bargaining power in the hands of a few major shipping lines. Ports often have to provide concessions, invest in infrastructure, or offer competitive rates to attract these large-volume customers (Notteboom & Yang, 2017).

(b) Shippers Pushing for Green Initiatives: With growing environmental awareness, many large shippers now demand greener supply chain solutions. Ports have responded by investing in sustainable technologies and operations to attract these environmentally conscious shippers (Acciaro et al., 2014)

Bargaining Power of Suppliers – This force has the most negligible impact since suppliers often maintain long-term contractual agreements with ports. However, other competitors may attempt to develop relationships with performing suppliers leading to loss of those suppliers in long term. There are examples.

(a) Port Equipment Suppliers: Only a few major manufacturers of specialised port equipment like quay cranes or automated guided vehicles exist. Their bargaining power can influence the price and terms of sale or lease, as well as the adoption of new technologies in ports (Cullinane & Talley, 2006)

(b) Technology and IT System Providers: The increasing importance of digitalisation and smart port technologies has had substantial influence on IT system providers. Ports rely on these providers for efficient operations, cargo tracking, and security (Lee & Yang, 2018).

Threat of Substitute Service – Since maritime is the most cost-effective choice, it lacks alternatives. Thus, this can be viewed as the least impactful force. However, there are examples.

(a) Canal Expansions and New Routes: The expansion of the Panama Canal, for example, posed a threat to ports on the US West Coast as it allowed larger ships to pass through and directly reach the East Coast, possibly bypassing transhipment through West Coast ports (Agarwal & Ergun, 2010).

(b) Development of Rail and Road Networks: Enhanced rail connectivity in continents like Asia and Europe (such as China's Belt and Road Initiative) offers an alternative to maritime transport for certain cargoes, potentially reducing the volume of containers handled by some ports (Rodrigue & Notteboom, 2017).

2.9 Using Resource Base-View (RBV) to assess the competitiveness of UAE ports

The Resource-Based View (RBV) model sees resources as key to superior firm performance. A resource exhibiting VRIO attributes (valuable, rare, inimitable, and organised to capture value) can enable a firm to gain and sustain a competitive advantage (Arbak, 2010). When applying RBV to container port competitiveness, the focus shifts to understanding how ports can achieve and maintain competitive advantage through their unique resources and capabilities (Table 2.2).

Resource Type	Description	Unique resources of UAE ports
Valuable Resources	For a container port, valuable resources might include its geographical location, infrastructure, technological advancements, and the skill level of its workforce.	Strategic Location
Rare Resources	A port might have certain unique features that are not easily replicated by other ports. This could be a natural harbour, proximity to major shipping routes, or specialised equipment and facilities.	None
Inimitable Resources	These are resources that competitors cannot easily replicate. For container ports, this could include a unique combination of efficiency, services, and relationships with shipping companies and logistics providers.	None
Organisation	This refers to how well the port is organised to leverage	None

	its resources. It includes management practices, operational efficiency, and the ability to adapt to changing market conditions.	

Table 2.2: Analysis using Resource Base View

Apart from the strategic location, no other resources can be considered unique. The strategic location is under pressure as Oman and Saudi Arabia spearhead massive investments to develop their ports (Khalid & Al-Mamery, 2019). So, factors beyond resources need to be considered when enhancing competitiveness.

2.10 Factors of Port Competitiveness

Port competitiveness is a critical determinant of a country's ability to participate effectively in international trade and logistics. A competitive port can attract more shipping traffic, reduce transportation costs, and stimulate economic growth. Several factors contribute to the competitiveness of a port, and understanding these factors is essential for this research work, as it aims to develop a framework to enhance the competitiveness of container ports. The following list was produced through an extensive review of the literature. Publications that cover the range of factors include Hales et al. (2016), Parola et al. (2017), Kaliszewski et al. (2020) and Wahyuni et al. (2020). A few specific publications are shown in Table 2.3.

Factors of Port Competitiveness	Description	Selected References
1. Location and Connectivity	**Proximity to major markets:** Ports near major consumer and production centres have a competitive advantage due to reduced transportation time and costs.	Notteboom et al.(2009), Hall & Jacobs (2010)
	Transportation infrastructure: Efficient road, rail, and inland waterway connections are	Acciaro & McKinnon (2015)

	crucial for seamless cargo movement to and from the port.	
	Connectivity to global trade routes: Ports that are well-connected to international shipping lanes can attract more vessels and cargo.	Ducruet (2022), Nguyen & Kim (2022)
2. Infrastructure and Facilities	**Modern terminals:** Ports with state-of-the-art container terminals, bulk handling facilities, and advanced cargo handling equipment are more competitive.	Heilig et al., (2017) , Kosiek et al., (2021)
	Depth and draft: Ports with adequate water depth and draft can accommodate larger vessels, increasing their attractiveness to shipping lines.	Ligteringen, & Velsink, (2012).
	Storage and warehousing: Sufficient storage and warehousing capacity ensures efficient cargo handling and reduces congestion.	
3. Customs and Regulatory Environment	**Efficient customs procedures:** Streamlined customs processes and reduced bureaucracy facilitate faster cargo clearance and lower costs.	Nyema (2014),
	Regulatory compliance: Ports that adhere to international standards and safety regulations are more attractive to international shipping companies.	Sampson et al., (2014)
4. Technological Advancements	**Port management systems:** Adopting advanced digital technologies and data analytics can enhance operational efficiency and reduce turnaround times.	Anwar et al.,(2019), Acciaro et al., (2020) Heikkilä et al., (2022),
	Port community systems: Integrated digital platforms that connect all stakeholders, including shippers, carriers, and	Carlan et al., (2016), Moros-Daza et al., (2020)

	customs, improve overall port efficiency.	
5. Labor and Workforce	**Skilled labour force:** A well-trained workforce is crucial for efficient cargo handling and terminal operations.	Satta et al., (2019), Vaggelas (2020)
	Labour relations: Stable labour relations and a history of labour harmony contribute to uninterrupted port operations.	
6. Environmental Sustainability	**Green initiatives:** Ports that implement environmentally friendly practices and reduce emissions are favoured by environmentally conscious shipping companies and customers.	Lalla-Ruiz et al., (2019), Vega-Muñoz et al., (2021)
	Sustainable infrastructure: Investments in eco-friendly infrastructure, such as electrified cranes and renewable energy sources, can enhance port competitiveness.	
7. Security	**Port security measures:** Effective protocols and surveillance systems are essential to prevent cargo theft, terrorism, and smuggling.	Scholliers et al., (2016), Aamlid (2019)
8. Pricing and Services	**Competitive pricing:** Ports that offer competitive handling fees and tariffs can attract more business.	Xing et al., (2018), Yin et al., (2019)
	Value-added services: Additional services such as logistics, distribution, and supply chain solutions can make a port more competitive.	
9. Government Policies and Investment	**Supportive policies:** Government support, including incentives, tax breaks, and infrastructure investments, can significantly boost a port's competitiveness.	Caldeirinha et al., (2017)

10. Market Demand	**Demand for specific cargo types:** Ports that cater to specific cargo types, such as bulk commodities or specialised goods, can establish niche competitiveness.	Comtoi & Lacoste (2021).

Table 2.3: Factors of Port Competitiveness

While conducting a literature review on the above exercise, it was noted that a considerable portion of recent research articles predominantly centre around the following areas.

(a) **Infrastructure and Facilities (focusing on Congestion and Capacity Management):** Many container ports worldwide experience congestion due to a surge in container traffic, particularly in crucial trade routes. This congestion can result in delays, increased shipping costs, and reduced efficiency. An up-to-date systematic examination of the literature on port capacity by Gülmez and Alpaslan (2021) provides clear evidence of this subject's increasing significance.

(b) **Technological Advancements:** Rapid technological advancements, including automation, the Internet of Things (IoT), and blockchain, transform port operations. Ports need to adapt to these changes to remain competitive. In a systematic literature review conducted by Belmoukari et al. (2023), it is asserted that the concept of intelligent ports is notably contemporary, and there is a significant upward trend in the number of related publications.

(c) **Environmental Sustainability:** Ports face increasing pressure to reduce their environmental footprint. This includes efforts to lower emissions, manage waste, and protect local ecosystems. Meeting stringent environmental regulations can be expensive. A systematic literature review by Lim et al. (2019) points to the growing interest in academia.

A relationship exists between the three developments, meaning that technological advancements can result in enhanced operational efficiencies and greater environmental sustainability. Collectively, this is known as the concept of smart concept,

2.11 Emergence of the Concept of Smart Ports

The term "smart port" is not attributed to a single inventor or individual. Instead, it emerged organically within the maritime and logistics industries as a descriptive term for ports that adopt advanced technologies and data-driven solutions to improve their efficiency, sustainability, and overall operations (Yau et al., 2020; Heikkilä et al., 2022). Mirroring the core technologies of Industry 4.0, the concept of smart ports aims to achieve transformational change in the container port industry (de la Peña Zarzuela et al., 2020). The core technologies used in Industry 4.0 are shown in Figure 2.6.

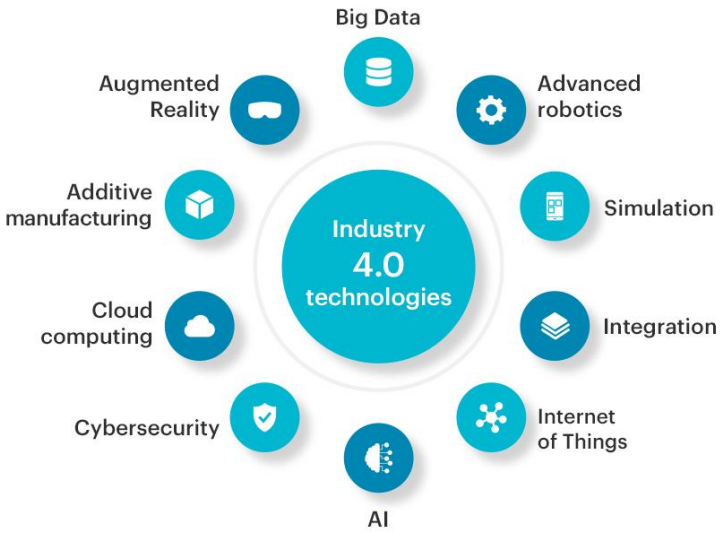

Figure 2.6: Core technologies of Industry 4.0 (Source: Business Process Incubator (n.d.))

Using digital technologies and the associated automated solutions, the concept of a smart port has the potential to make transformation impact across the entire port ecosystem (Figures 2.7 and 2.8)

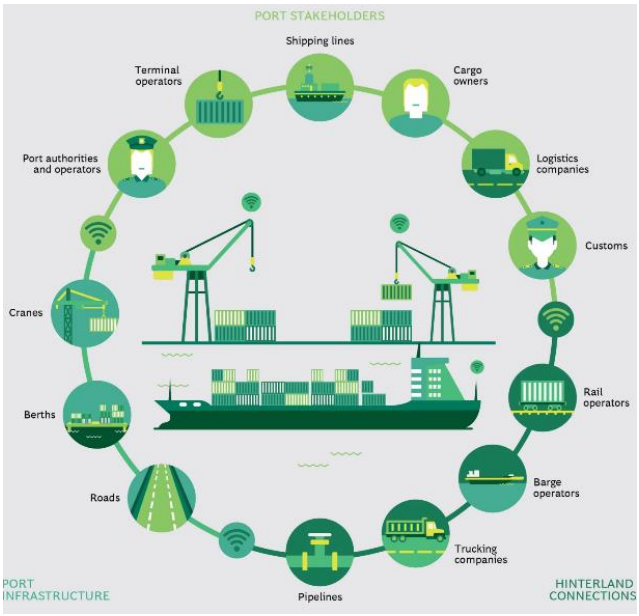

Figure 2.7: Linking the entire port ecosystem (Source: Delenclos et al., 2018)

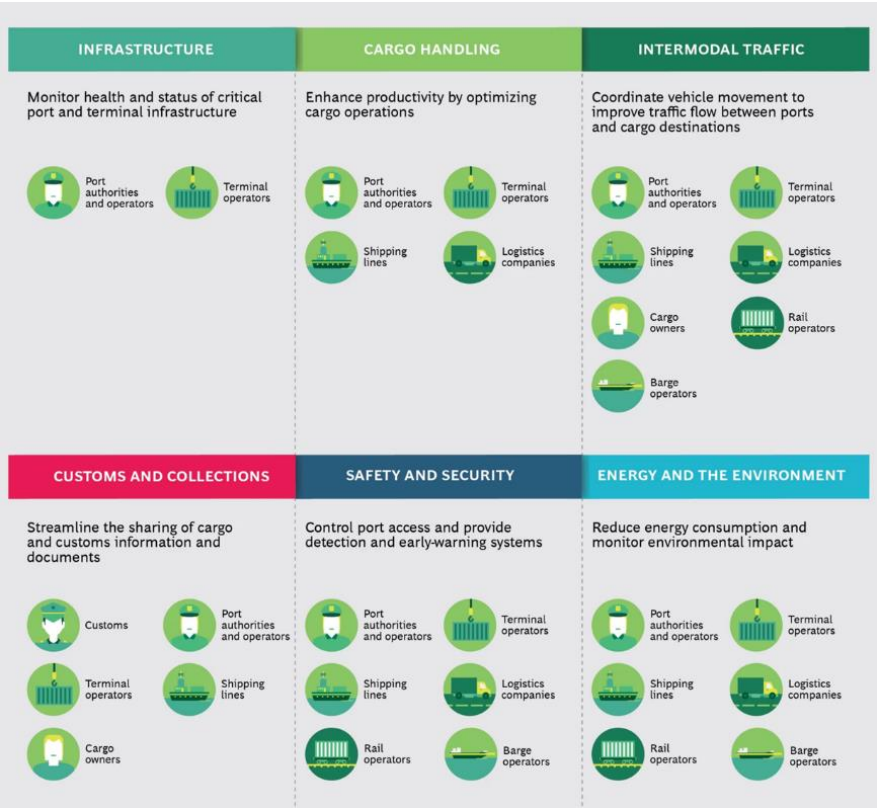

Figure 2.8: Operational and Sustainability Enhancements (Source: Delenclos et al., 2018)

2.12 Smart Port - Definitions

Belmoukari et al. (2023) lament that despite rising interest, authors could not find a clear definition of the smart port. As the concept of smart has grown organically, providing a single and comprehensive definition has been challenging. Different definitions appeared as smart ports began to embrace new technologies and adopt new international legislations (for example, sustainability). Using a blend of interviews with stakeholders and a review of 70 academic publications, Belmoukari et al. (2023) produced an inclusive definition.

> *"The smart port is a connected, sustainable, safe and automated port, which relies on smart infrastructure and equipment, skilled personnel and smart managerial practices, to ensure customer satisfaction, environmental protection and a better quality of life for the citizen."*

This definition captures three key requirements: (a) smart infrastructure and equipment, (b) skilled personnel, and (c) intelligent management practices. Definitions provided by trade organisations and industry stakeholders are often limited to smart technologies, with a few referencing sustainability. Given the inclusiveness of the above definition, it is used throughout this work.

2.13 Frameworks for Developing Smart Ports

A framework is essential for developing intelligent ports for several reasons. It provides a structured approach to integrating complex elements such as technology, operations, sustainability, and stakeholder management. To identify existing frameworks, the literature review was extended to identify academic work on developing frameworks. This effort found only a minimal number of publications.

Year of Publication	Paper ID	Details
2023	2023(A)	Belmoukari, B., Audy, J. F., & Forget, P. (2023). Smart port: a systematic literature review. European Transport Research Review, 15(1), 1-12

	2023(B)	Pham, T. Y. (2023). A smart port development: Systematic literature and bibliometric analysis. The Asian Journal of Shipping and Logistics.
2022	2022(A)	Triska, Y., Frazzon, E. M., Silva, V. M. D., & Heilig, L. (2022). Smart port terminals: Conceptual framework, maturity modelling and research agenda. Maritime Policy & Management, 1-24.
	2022(B)	Min, H. (2022). Developing a smart port architecture and essential elements in the era of Industry 4.0. Maritime Economics & Logistics, 24(2), 189-207.
	2022(C)	Othman, A., El-gazzar, S., & Knez, M. (2022). A framework for adopting a sustainable smart sea port index. Sustainability, 14(8), 4551.
2021	2021(A)	Makkawan, K., & Muangpan, T. (2021). A conceptual model of smart port performance and smart port indicators in Thailand. Journal of International Logistics and Trade, 19(3), 133-146.
	2021(B)	Berlin, J., & Eriksson, O. (2021). Smart Port Framework study of Port of Gothenburg. Gothenburg University Library
	2021(C)	D'Amico, G., Szopik-Depczyńska, K., Dembińska, I., & Ioppolo, G. (2021). Smart and sustainable logistics of Port cities: A framework for comprehending enabling factors, domains and goals. Sustainable Cities and Society, 69, 102801.
2020	2020(A)	Molavi, Anahita, Gino J. Lim, and Bruce Race. "A framework for building a smart port and smart port index." International journal of sustainable transportation 14.9 (2020): 686-700.
	2020(B)	Philipp, R. (2020, June). Digital readiness index assessment towards smart port development. In Sustainability Management Forum| Nachhaltigkeits Management Forum (Vol. 28, No. 1-2, pp. 49-60). Berlin/Heidelberg: Springer Berlin Heidelberg.
2019	2019(A)	Chen, J., Huang, T., Xie, X., Lee, P. T. W., & Hua, C. (2019). Constructing governance framework of a green and smart port. Journal of Marine Science and Engineering, 7(4), 83.
2018	2018(A)	Tan, K. W., Kan, M., Tan, P. J., & Schablinski, S. (2018). A framework for evaluating energy sustainability efforts for maritime smart port operations. In 2018 International Conference on ICT for Smart Society (ICISS) (pp. 1-5). IEEE.
2017	2017(A)	Botti, A., Monda, A., Pellicano, M., & Torre, C. (2017). The re-conceptualization of the port supply chain as a smart port service system: The case of the port of Salerno. Systems, 5(2), 35.
2016	2016(A)	Heilig, L., & Voß, S. (2016, May). A holistic framework for security and privacy management in cloud-based smart ports. In 15th International Conference on Computer and IT Applications in the Maritime Industries-COMPIT '16, Lecce Italy.

Table 2.4: Proposed Framework from Researchers

These publications were further reviewed to classify under four (4) categories.

Category 1: A generic framework proposed
This category focuses on publications that have developed a partial or full structure for a framework that encompasses all dimensions under the definition presented in section 2.10.

Category 2: Characteristics of the generic framework proposed
The primary emphasis of these publications is to identify dimensions (features) which contribute the definition of Smart Poort Indexes

Category 3: Domain-specific characteristics/frameworks proposed
These publications address the needs of specific ports.

Category 4: Domain Specific Frameworks proposed
These developments converge on developing a framework for a specific aspect of smart ports (for example, sustainability, security, etc.)

A generic framework proposed	Characteristics of the generic framework proposed	*Country/Port specific characteristics frameworks proposed*	Domain-specific characteristics/frameworks proposed
2021(C)	2023(A) 2023(B) 2022(A) 2022(B) 2020(A)	2021(A) 2021(B) 2020(B) 2017(A)	2022(C) 2019(A) 2018(A) 2016(A)

Table 2.5: Analysis of Frameworks (Author)

As evident from this analysis, only one publication, 2021(C), attempted to develop a framework covering all essential domains of smart ports. Table 2.6 summarises the critical outcomes reported in each publication.

Category 1	A generic framework proposed
2021(C)	The key outcome of this work is a high-level framework (Figure 2.8), which encompasses a range of domains. This work also highlights the role of digital and disruptive technologies in developing smart ports.

Category 2	Characteristics of the generic framework proposed
2023(A)	A new definition encompassing seven (7) domains is proposed. Domain include operations, social, environment, energy, human resources, safety and security, as well as smart infrastructure, equipment, and technologies.
2023(B)	This systematic literature and bibliometric analysis conclude that there are underlying research themes (1) exploring the applications and consequences of digital transformation technologies in various areas like operations, environment, energy, safety, and security, incorporating both qualitative and quantitative evaluations; (2) assessing smart port performance through various indices; and (3) tackling the challenges and obstacles in the development of smart ports.
2022(A)	By establishing answers to three (3) research questions, "RQ1—How to conceptualise the smart port terminal aligning with the conceptualisation of intelligent systems?" "Q2—How to assess the current maturity level of a smart port terminal, considering the smart port terminal concept proposed in RQ1?" "RQ3—What research recommendations can be proposed for developing the smart port field?" This research proposes a maturity model that can be used to assess the readiness for the transition to smart ports and directions for future research.
2022(B)	This paper focuses on the technological aspects of the smart port framework and proposes the potential strategies to embed (a) The Internet of Things, (B) Cyber-Physical Systems, (c) Edge Computing, (d) Mass servitisation. and (d) Intelligent automation which are elements of Industry 4.0
2020(A)	This application first identifies domains of operations of smart ports and then using the data collected from 14 ports in the top 100, the research establishes relationships between port performance and factors such as GDP, R&D expenditure, and energy intensity of the economy.
Category 3	Country/Port specific characteristics frameworks proposed
2021(A)	This work presents a conceptual model which includes a range of indices relating to three domains of smart ports: (a) Smart port operation, (b) Smart port environment and energy, and (c) Smart port safety and security.
2021(B)	Using four(4) domains: (a) operations, (b) energy and environment, (c) digitalisation, and (d) cybersecurity, this compares the smart port status of Gothenburg port against ports in Rotterdam, Hamburg and Antwerpen.

2020(B)	Using Digital Auditing Tool for Ports developed by Philipp et al. (2020), the author presents an extended list of indices to compare smart port features. It also suggests that technologies such as blockchain and artificial intelligence have been hardly used in smart ports.
2017(A)	Considering various aspects of service science and the emerging trends in port supply chain management, this study presents the concept of the port as an intelligent service system using the theories of service science. By applying this viewpoint to the management of port supply chains, the paper offers a detailed framework for devising and establishing innovative and competitive port supply chains.
Category 4	Domain-specific characteristics/frameworks proposed.
2022(C)	Drawing from an extensive review of prior studies, the research found that five distinct domains—operations, environment, energy, safety and security, and human resources—are individually incorporated in smart ports. Additionally, it was observed that various ports encounter numerous challenges in achieving an appropriate level of digitalisation, influenced by these domains. Consequently, the study suggests the creation of an integrated smart port index, which is connected to sustainability performance.
2019(A)	This paper exclusively focuses on the governance structure of smart ports. Using Interpretative Structural Modeling as a tool, this paper reviewed pertinent literature and expert recommendations to identify factors that influence the development of green and smart ports and established a comprehensive governance framework for these ports.
2018(A)	Focusing exclusively on energy sustainability, the paper proposes a framework to analyse and evaluate sustainability initiatives for the land-side of ports. It uses a process-driven approach to develop a hierarchical framework from business units for accountability and to rolling up for management reporting.
2016(A)	This study introduces a comprehensive framework for managing security and privacy in smart ports. It is connected to a universal system architecture that facilitates merging physical objects, mobile devices, and external IT systems within a scalable cloud infrastructure. This integration supports the exchange of information and decision analytics in the context of smart port environments. So, this is a domain-specific framework.

Table 2.6: Detailed Analysis of Frameworks

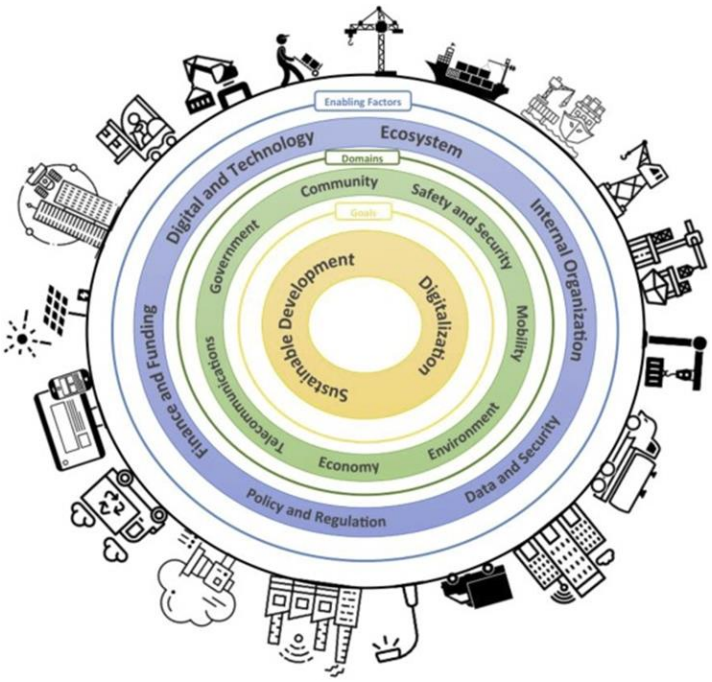

Figure 2.9: Smart and sustainable logistics in port cities framework (Source: D'Amico et al., 2021)

The above analysis concludes that most studies on smart ports have focused on identifying indices relating to a range of operating domains of smart ports. A high-level framework is reported by D'Amico et al. (2021). Whilst it highlights the key areas of smart ports, further work is required to generate a framework that port stakeholders can use

2.14 Models used by leading smart ports

The evolution of port operations has been shaped by the gradual integration of various technologies over time, highlighting continuous advancements and incremental improvements. For example, the Port of Singapore has progressively adopted automation, IoT, and AI, with initiatives like the Tuas Megaport (Lee, 2021) and digitalPORT@SG (Clemente et al., 2023) focusing on enhancing efficiency and sustainability. Similarly, the Port of Rotterdam has implemented IoT sensors and AI to optimize logistics and environmental management. (Laas, 2020).

In its journey towards becoming a smart port, the Port of Barcelona has developed a comprehensive model that integrates multiple dimensions of smart city concepts, resulting in a holistic approach to port management. This model incorporates six key dimensions: logistics, mobility, environment, economy, people, and governance, each adapted to the port's specific needs and operations (Figure 2.10).

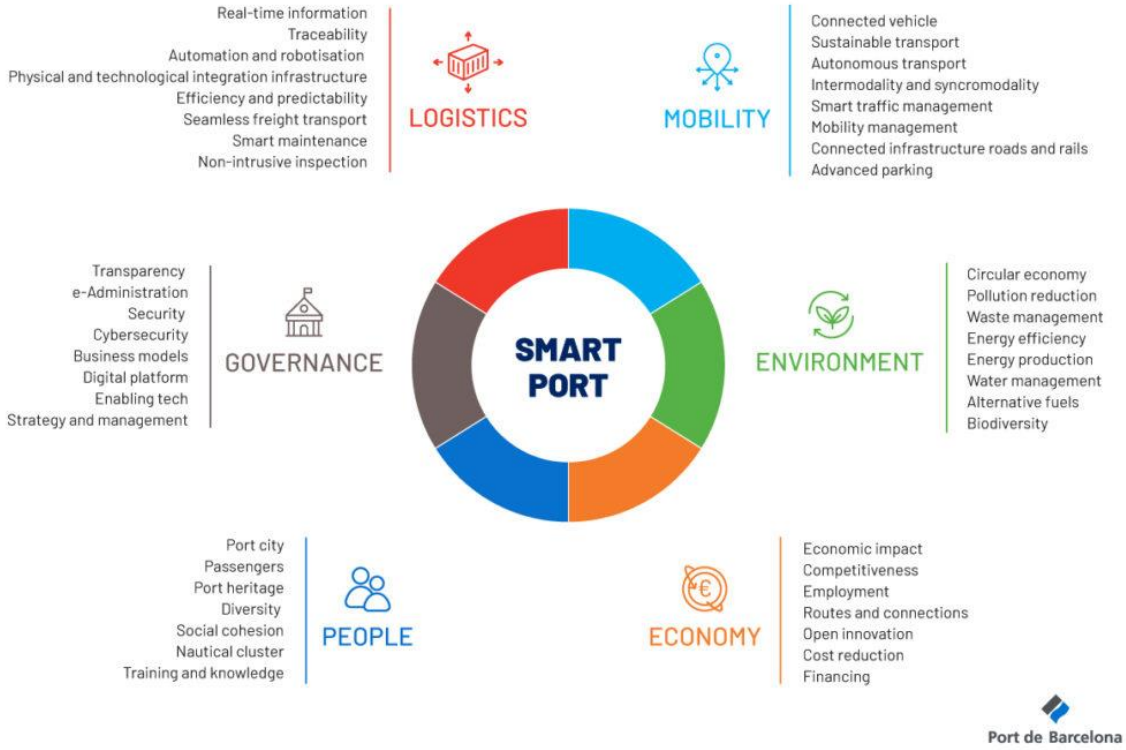

Figure 2.10: Smart Port Model – The Port of Barcelona (Grimalt, 2019)

These developments demonstrate that smart ports have emerged through technological adoptions and improvements, each building on previous innovations to create increasingly sophisticated and efficient port systems. This gradual integration highlights the evolutionary nature of smart port development, where each new technology incrementally enhances the capabilities and performance of port operations.

2.15 Conclusions and Research Gap

In the maritime industry, container ports are experiencing intense competition. The competition between all ports has become global. Within this challenging environment, these ports are struggling more than ever to remain competitive and sustainable. Given the competitive pressures on the UAE ports, there is a clear need to continuously improve competitiveness. Analysis conducted using Porter's Competitive Strategy Theory and Resource-Based View led to the same conclusion.

The concept of smart ports has emerged as a promising solution to enhance competitiveness in the maritime industry. Driven primarily by technological advancements, smart ports seek to automate operations, enhance sustainability, and fulfil corporate social responsibilities. Despite the growing interest, a review of existing publications on smart ports reveals a significant gap: no comprehensive and holistic framework currently exists for port stakeholders. Most existing studies focus on identifying the indices and characteristics related to smart ports without offering an integrated approach.

D'Amico et al. (2021) provide a high-level framework that outlines the key domains and their interconnections within the smart port ecosystem. However, this framework lacks the detailed, all-encompassing structure necessary for stakeholders' practical application.

Therefore, this research aims to address the existing gap by developing a comprehensive and holistic framework for smart ports. The objective is to create a robust, actionable model that integrates various aspects of port operations, sustainability measures, and technological innovations. This framework will serve as a valuable tool for port authorities, operators, and policymakers, enabling them to navigate the complexities of modern port management and drive the transformation towards smarter, more efficient, and sustainable ports.

Chapter 3 – Research Methodology

3.1 Introduction

Research methodology is a crucial aspect of any academic or professional study, as it lays the foundation for understanding how the research was conducted and the rationale behind the chosen methods. This chapter aims to provide a comprehensive overview of the methodologies employed in this study, offering insights into the systematic approach used to gather, analyse, and interpret data. The choice of methodology is pivotal in ensuring the reliability and validity of the research findings. This chapter uses a generic model developed by (Saunders et al., 2020) to identify the appropriate strategies and techniques to be deployed in this research work.

3.2 Research Methodology

Research methodology refers to the systematic, theoretical analysis of the methods applied to a field of study (Saunders et al., 2020). It essentially involves the principles, procedures, and techniques used to collect, analyse, interpret, and present data. This methodology is crucial in all research undertakings, as it underpins the entire research process and ensures that the findings are robust, credible, and reliable. Critical aspects of the research methodology include (Table 3.1):

Research Design	This is the overall strategy that outlines how the research will be conducted. It includes the choice between qualitative, quantitative, or mixed-methods approaches. The research design sets the data collection, analysis, and interpretation framework.
Data Collection Methods	This involves selecting the appropriate tools and techniques for gathering data. Standard methods include surveys, interviews, focus groups, observations, and experiments. The choice of data collection method depends on the research question, objectives, and the nature of the subject being studied.
Sampling	This relates to selecting individuals or groups to participate in the study. Sampling can be random, stratified, or purposive, among other types, and the choice of sampling method affects the generalizability of the research findings.
Data Analysis	Once data is collected, it needs to be analysed to draw meaningful conclusions. Depending on the nature of the data and the research objectives, this can involve statistical analysis, thematic analysis, content analysis, etc.
Ethical Considerations	Research methodology also involves adhering to ethical standards. This includes obtaining informed consent from

	participants, ensuring confidentiality and privacy, and avoiding harm or discomfort to the participants.
Validity and Reliability	Methodology is crucial in ensuring that the research is valid (accurately measures its intended measure) and reliable (can be consistently replicated).
Limitations	A sound research methodology also acknowledges the study's limitations, including potential biases, errors in data collection, and constraints in the research design.
Interpretation and Presentation	Finally, the methodology guides how the research results are interpreted and presented, ensuring that the data support the conclusions drawn.

Table 3.1: Key Aspects of Research Methodology

3.3 Research Design Models and Framework

Several models and frameworks are used in research design across various disciplines (Anfara & Mertz. 2014). These models help researchers systematically approach their studies, ensuring their research is well-structured and methodologically sound. Some of the well-known models include (Table 3.2).

Model/Framework	Description
Saunders Research Onion	This model provides a systematic approach to developing a research methodology, guiding researchers through layers that include research philosophy, approaches, strategies, choices, time horizons, and data collection and analysis methods.
Crotty's Framework	Michael Crotty's framework outlines four critical components of research methodology: epistemology, theoretical perspective, methodology, and methods. This framework is beneficial in clarifying the underlying assumptions of a research study.
The Research Process Model	A generic model that outlines the sequential steps in conducting research, including identifying the problem, reviewing the literature, formulating hypotheses or research questions, designing the study, collecting and analysing data, and reporting results.
Mixed Methods Research (MMR) Models	These models are specific to mixed methods research and provide frameworks for integrating qualitative and quantitative

	methods. Examples include Sequential Exploratory Design, Sequential Explanatory Design, and Concurrent Triangulation Design.

Table 3.2 Well-known Research Design Models and Frameworks

In order to select the most appropriate research, the above models/frameworks were further analysed. Table 3.3 compares their key features.

Aspect	Saunders Research Onion	Crotty's Framework	The Research Process Model	Mixed Methods Research (MMR) Models
Focus	Methodology development in research	Underlying assumptions of research	Sequential steps in conducting research	Integration of qualitative and quantitative methods in research
Key Components	Research philosophy, approaches, strategies, choices, time horizons, data collection methods	Epistemology, theoretical perspective, methodology, methods	Problem identification, literature review, hypothesis formulation, study design, data collection	Sequential, concurrent, and transformative designs
Application	Broad, suitable for various research types	Broad, beneficial for clarifying philosophical and theoretical underpinnings of a study	Generic, applicable across disciplines	Broad, suitable for research requiring comprehensive perspectives
Strengths	Comprehensive, systematic, and user-friendly for novice researchers	Clarifies the philosophical depth of research, aiding in rigorous methodology development	Clear, step-by-step guidance, easy to follow	Offers a comprehensive view by combining the strengths of both qualitative and quantitative research

Table 3.3 Comparison of Research Design Frameworks/Models

Since this research work requires a comprehensive and systematic approach, Saunders Research Onion was selected as the framework for the research design. It is comprehensive, systematic, and user-friendly for novice researchers.

3.4 Saunders Research Onion

The Saunders Research Onion (Figure 3.1) is highly regarded in academic circles, particularly for its comprehensive and structured approach to research methodology (Sahay, 2016). Its layered format intuitively guides researchers through the complex process of designing a research project, ensuring that every critical aspect is methodically addressed. It offers a clear, sequential roadmap, starting from the outermost layer of research philosophy and moving inward through approaches, strategies, choices, time horizons, and data collection and analysis techniques. This systematic progression ensures coherence and alignment in research design, making it particularly beneficial for novice researchers.

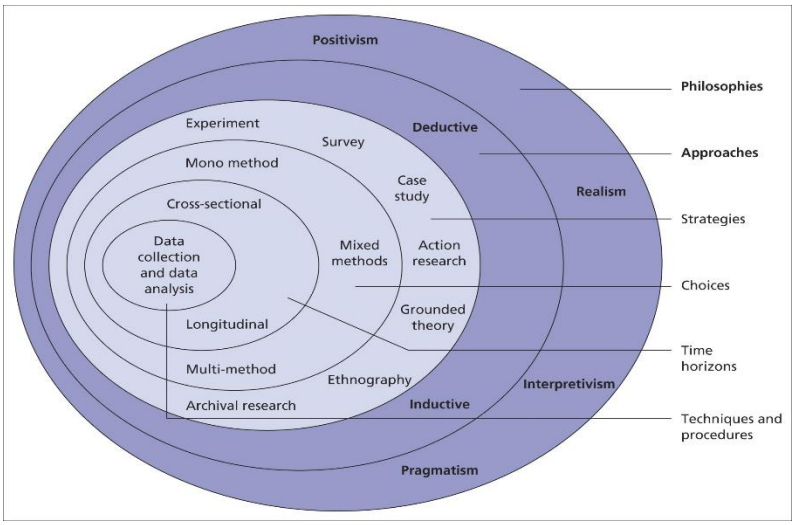

Figure 3.1: Saunders Research Onion (Source: Sahay, 2016)

Each layer is dissected to identify the most appropriate option for this research work.

3.4.1 Philosophies

The philosophy layer of the Saunders Research Onion model represents the outermost layer and forms the foundation of any research methodology. This layer is crucial as it incorporates the underlying beliefs and assumptions about *the nature of knowledge*

(epistemology) and *the nature of reality (ontology)* that guide the entire research process. Five key philosophies are shown in Table 3.4.

Philosophy	Description
Positivism	Positivism is associated with the scientific study and objective quantification of observable phenomena. Researchers adopting this philosophy rely on quantifiable data and statistical methods to test hypotheses and theories.
Interpretivism	This philosophy is more aligned with qualitative research. Interpretivists believe that reality is subjective and constructed by social actors. Therefore, research focuses on understanding the meanings and interpretations individuals or groups assign to social phenomena.
Realism	Realism is a philosophy that acknowledges the existence of a reality independent of human thoughts and beliefs. However, it recognises that the understanding of this reality is inevitably influenced by human interpretation.
Pragmatism	Pragmatism is a flexible philosophy that allows for using both qualitative and quantitative methods. It focuses on 'what works' and sees the research method as a tool to help answer the research question.
Constructivism	Often associated with qualitative research, constructivism posits that people construct their understanding and knowledge of the world through experiencing things and reflecting on those experiences.

Table 3.4: Philosophies Layer Options

Given that this research aims to develop a novel framework to improve the competitiveness of container ports, *pragmatism* is the most appropriate research philosophy as it offers an efficient and adaptable framework, making it particularly valuable in addressing complex, real-world problems.

3.4.2 Approaches

The "approaches" layer of the Saunders Research Onion model is a critical component that sits just beneath the outermost layer of research philosophy. This layer concerns the

fundamental approach researchers take in conducting their study, primarily focusing on conceptualising the relationship between theory and research. The two primary approaches in this layer are deductive and inductive, each representing a distinct pathway in research development.

Deductive Approach: This approach is often associated with a scientific and positivist philosophy. It involves developing a hypothesis based on existing theory and then designing a research strategy to test this hypothesis. It is a top-down approach where the researcher tests a theory by collecting and examining empirical data.

Inductive Approach: Unlike the deductive approach, the inductive approach is more exploratory and often associated with interpretivism. It involves collecting data and developing theory because of data analysis. This bottom-up approach starts with observations and moves towards broader generalisations and theories.

Given that the ultimate aim is to produce a framework, this research work leans towards the *inductive* approach. It is expected to identify the best elements from existing models/frameworks and use them to create a novel framework.

3.4.3 Strategies

In the Saunders Research Onion model, the "strategies" layer is a pivotal component that follows the research philosophy and approach layers. This layer involves selecting the overall plan or strategy to guide the research process. The research questions or objectives influence the choice of strategy, the chosen approach (deductive or inductive), and the underlying philosophical assumptions.

Key research strategies in the Saunders Research Onion include (Table 3.5):

Strategy	Description
Experiment	This strategy is often used in deductive approaches and is characterised by manipulating variables to observe effects on other variables. It is commonly used in scientific and psychological studies.
Survey	Surveys are popular in business and social sciences for collecting data. They are helpful for descriptive, exploratory, or explanatory research.
Case Study	This strategy involves an in-depth investigation of a single case or several cases. Case studies are useful for gaining detailed insights and understanding complex phenomena in real-life contexts.

Action Research	Action research is a participatory study where the researcher works with participants to address a problem or improve a situation. It is iterative and involves planning, acting, observing, and reflecting cycles.
Grounded Theory	This strategy is used to generate theory from data. Starting with data collection, the researcher looks for patterns and themes to develop a theory grounded in the data.
Ethnography	Originating in anthropology, ethnography involves the detailed and systematic study of people and cultures. It is characterised by immersive observation and often qualitative data collection.

Table 3.5: Options for Strategies

The choice of research strategy is crucial as it determines how the research will be conducted. It impacts the type of data collected, how it is collected, and the potential insights that can be gained.

In this work, the survey was chosen as the main strategy. One of the primary strengths of survey research within the Saunders framework is its compatibility with deductive and inductive approaches, allowing for flexibility in research design. In a deductive context, surveys are often used to test hypotheses or theories by gathering quantifiable data that can be statistically analysed. Conversely, in an inductive approach, they can help identify patterns or trends that inform the development of new theories. In this work, a survey is used to gather data about the competitiveness of UAE container ports.

3.4.4 Choices

In the Saunders Research Onion model, the "choices" layer refers to the decision-making process regarding mono-method, mixed methods, or multi-method research designs. This layer is crucial as it determines how data will be collected, analysed, and interpreted, directly impacting the research's effectiveness in answering the research questions.

Mono-method: This choice involves using either qualitative or quantitative methods exclusively. A mono-method quantitative design might use statistical tools to analyse numerical data, suitable for testing hypotheses or measuring variables. Conversely, a mono-method qualitative design would focus on textual or observational data, ideal for exploring perceptions, meanings, or experiences in depth.

Mixed Methods: This approach combines qualitative and quantitative methods within a single study. The rationale is that using both methods can provide a more comprehensive understanding of the research problem than alone.

Multi-method: This involves using multiple qualitative or quantitative methods within the same study. Unlike mixed methods, multi-method research does not necessarily integrate qualitative and quantitative data but uses different methods of the same type to enrich the research.

The multi-method is preferred as the research involves several different methods to analyse data,

3.4.5 Time Horizons

In the Saunders Research Onion model, the "time horizons" layer addresses the chronological dimension of the research, focusing on how the researcher plans to study the phenomena over time. This layer is crucial as it influences the design and execution of the research, particularly in terms of data collection and analysis. This model has two primary types of time horizons: cross-sectional and longitudinal.

Cross-Sectional Studies: These studies are observational and are conducted at a specific point in time. They provide a 'snapshot' view, capturing data at a single moment or over a short period. Cross-sectional studies are beneficial for descriptive research, where the goal is to assess the current state of the studied phenomena.

Longitudinal Studies: In contrast, longitudinal studies involve repeated observations of the same variables over an extended period. This approach allows researchers to detect developments or changes over time, making it particularly valuable for understanding long-term trends, cause-and-effect relationships, or behavioural changes.

A *cross-sectional study* is required in this research to identify the current competitive status of UAE ports.

3.4.6 Techniques and Procedures

In the Saunders Research Onion model, the innermost layer concerns "techniques and procedures," which focuses on the specific methods and tools used for data collection and analysis. This layer is critical as it directly impacts the quality and integrity of the research findings.

Data Collection Techniques: Various techniques can be employed depending on the chosen research strategy and method. For quantitative research, standard techniques include structured surveys and questionnaires, experiments, and observation with predefined variables. In qualitative research, data collection might involve semi-structured or unstructured interviews, focus groups, participant observation, and document analysis.

Data Analysis Procedures: This involves selecting appropriate methods to process and interpret the data collected. Quantitative research often involves statistical analysis, ranging from basic descriptive statistics to more complex inferential analyses. For qualitative data, the analysis might include thematic analysis, content analysis, narrative analysis, or grounded theory methodology, where data are coded and themes are identified and interpreted.

The techniques and procedures used in this research are explained in detail in the corresponding chapters.

3.5 Chosen Options from Saunders Onion Model

Table 3.6 below presents the chosen options from the analysis in section 3.5

Layer	Option
Philosophies	Pragmatism
Approaches	Inductive
Strategies	Survey
Choices	Multi-Method
Time-Horizon	Cross-sectional
Techniques and Procedures	Various (details in chapters)

Table 3.6 Chosen Options from Saunders Onion Model (also highlighted in Figure 3.2)

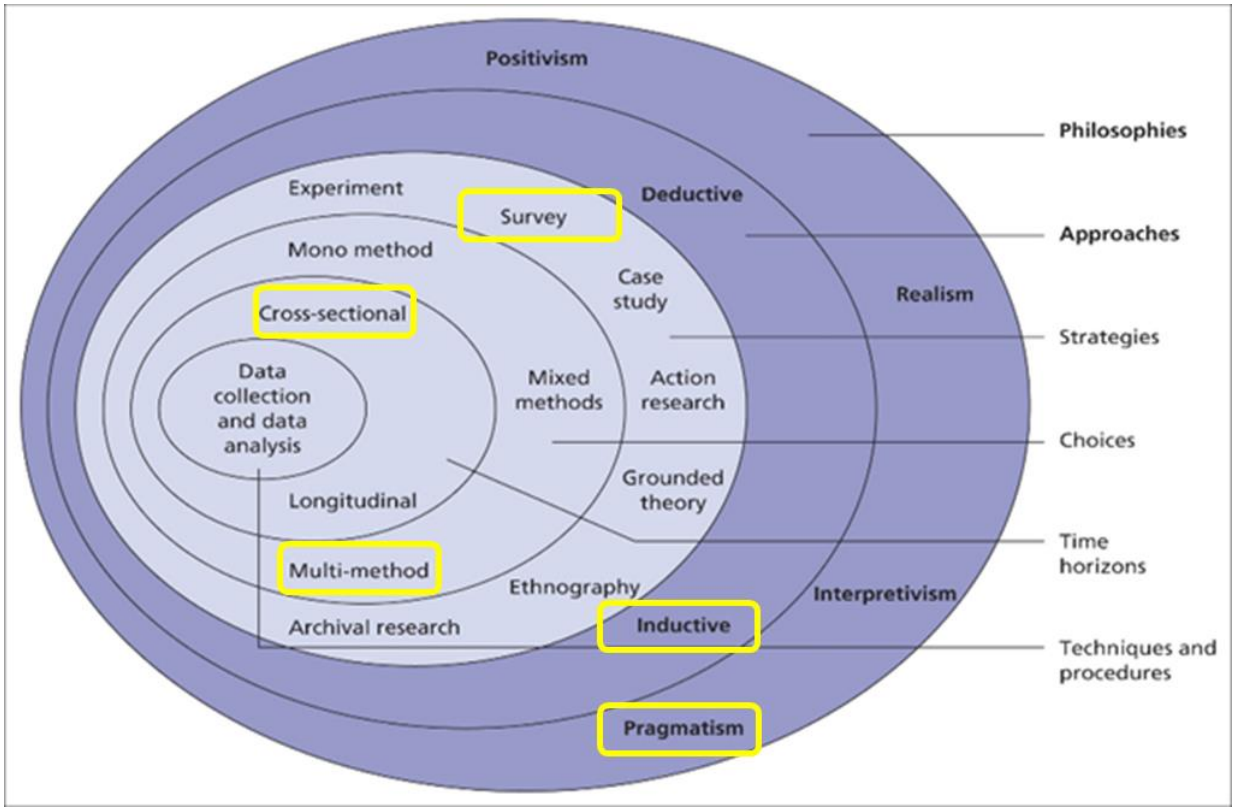

Figure 3.2: Chosen Options from Saunders Onion Model (Author, after Sahay, 2016)

3.6 Research Process

Figure 3.3 shows phases of this study.

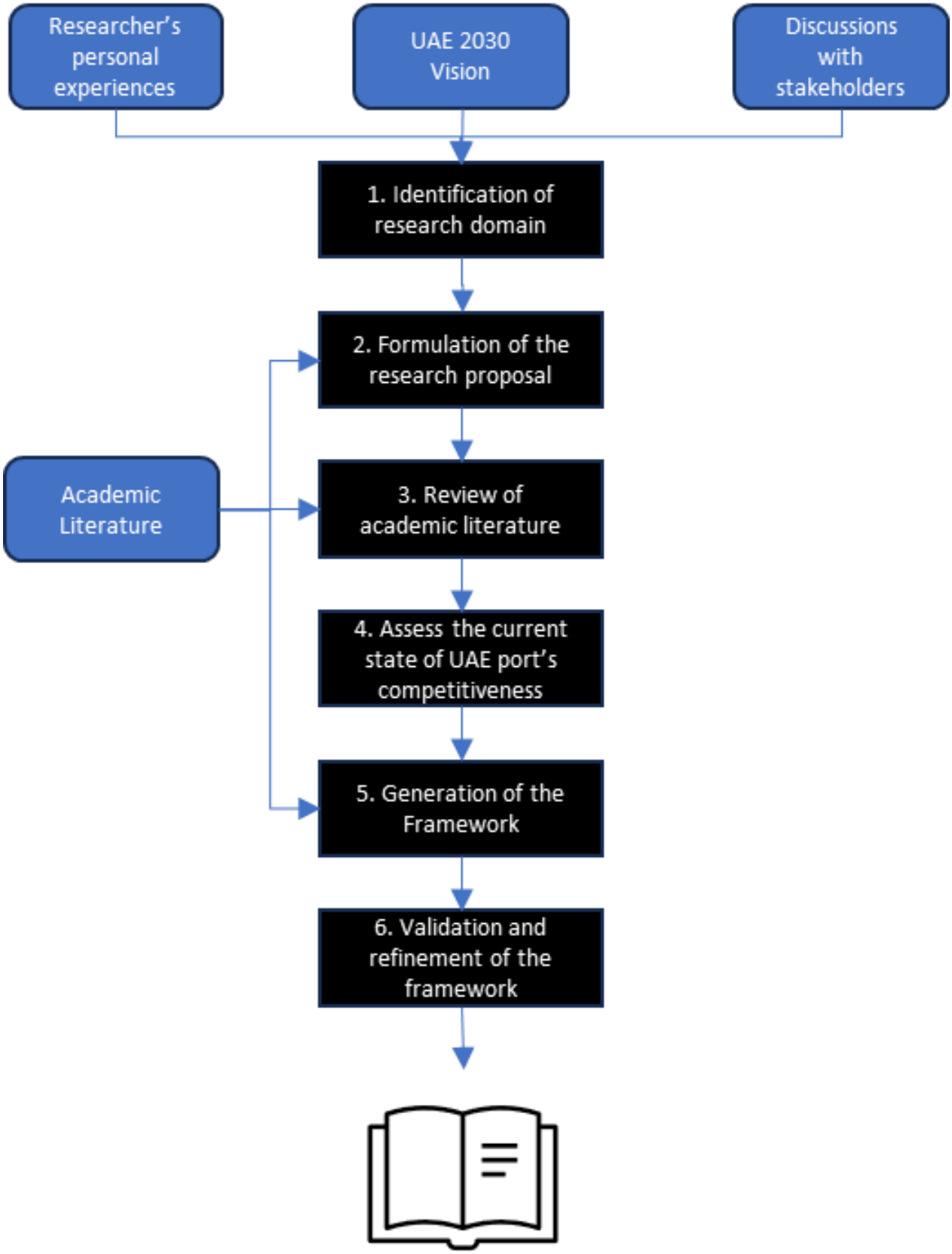

Figure 3.3 – Key stages of the research process

Process 1: Identification of the research domain

This research was inspired by the researcher's firsthand experiences working within the UAE port sector. The formulation of the UAE 2030 strategy, a visionary plan for the nation's future, further fueled this interest. Engaging in conversations with key stakeholders in the sector revealed a consensus on the necessity to enhance the competitiveness of the UAE's container port industry. This insight laid the groundwork for the study, underscoring the importance of exploring and addressing the challenges and opportunities within this vital sector.

Process 2: Formulation of the research proposal

Formulating a research proposal is a critical step in the research process, serving as a blueprint for the study. It outlines the research objectives, methodology, and significance of the study.

Process 3: Review of academic literature

A review of academic literature is a critical component of any research project, serving multiple vital functions in the research process. It involves systematically examining, summarising, and evaluating existing scholarly articles, books, and other sources relevant to a specific research question or topic.

Process 4: Assess the current status of UAE port competitiveness

A survey and further data collection channels are used to assess the current status of UAE port competitiveness

Process 5: Generation of the framework

The best constructs from the existing models/framework are synthesised with other elements to create the framework.

Process 6: Validation of the framework

The final process involves validating the framework and enhancing the framework based on the feedback received from the focus group. Using a focus group to validate a framework involves gathering a diverse group of stakeholders to discuss and provide feedback on the proposed model.

3.7 Summary

The primary objective of this chapter is to detail the selection process of research philosophies and approaches adopted for this research program. Employing Saunders' Research Onion Model as a guiding framework, suitable options were selected for each model layer to ensure a robust and coherent research design. Table 3.6 summarises these selections concisely, offering a clear overview of the methodologies and approaches employed. Additionally, Figure 3.3 visually represents the critical processes involved in the research programme. To provide a deeper understanding and comprehensive insight into these methodologies, subsequent chapters will investigate more detailed discussions of the tools and techniques utilised, explaining their relevance and application in the scope of this study. This thorough discussion aims to clarify the methodological underpinnings of the research, ensuring transparency and rigour in the research process.

Chapter 4: Interview and Survey Analysis -The Perspectives from UAE Port Operators

4.1 Introduction

Including stakeholders' perspectives in research is beneficial and essential, as it significantly enriches the overall value of the study. Their active participation plays a crucial role in elevating the quality of the research. This is primarily because stakeholders, closely associated with the subject matter, bring a deep understanding of the existing challenges and their aspirations and expectations. Their insights offer a practical view of the issues at hand, which can guide the direction and focus of the research.

In this context, the chapter presents the results obtained from two distinct types of surveys specifically designed to gather and understand the viewpoints of these stakeholders. These surveys were instrumental in capturing a wide range of perspectives, providing a comprehensive understanding of the stakeholders' views. By analysing these survey results, the chapter aims to highlight how stakeholder input has shaped the research and the importance of their contributions to the development of the research process.

4.2 Selecting container ports for the analysis

As outlined in Section 1.5, the UAE has a total of eight (8) container ports. Excluding Ajman and Umm Al-Quwain, each of the other five emirates hosts one or more container ports, as outlined in Table 4.1.

Emirate	Ports (TEU Capacity)	Global Ranking (The Container Port Performance Index, 2022, World Bank, a total of 348 ports)
Abu Dhabi	Khalifa Port (7.8), Mina Zayed (0.15)	3 -
Dubai	Jebel Ali Port (19.3) Port Rashid (1.5)	38
Sharjah	Mina Khalid (1.7), Sharjah Container Terminal (0.69)	- -
Ajman		
Umm Al-Quwain		
Fujairah	Fujairah Port (2.50)	-
Ras Al Khaimah	Mina Saqr (0.35)	-

Table 4.1: Container ports in the UAE -

Regarding TEU capacity, Khalifa Port and Jebel Ali Port stand out significantly. They excel in capacity and are the sole two ports in the World Bank's Global Ranking (World Bank Group (Transport), 2023). This distinction creates a clear binary division. Consequently, the analysis has been narrowed down to concentrate on these two globally leading ports: Khalifa Port and Jebel Ali Port.

It is essential to acknowledge that Khalifa Port and Jebel Ali Port are not immune to competition. Regional contenders, especially the Port of Salalah in Oman, which ranks 2nd, and Dammam Port in Saudi Arabia, positioned 31st in the above ranking, present significant challenges. Therefore, further improvement is needed in the competitiveness of those two ports. Some other ports in the UAE are also working towards becoming leading players in the region; for example, Ras Al Khaimah is investing to expand and upgrade its main port, Mina Saqr (Nuttall, 2023).

4.3 Interviews

Interviews are a fundamental research method used across various disciplines. The primary aim of interviews in research is to gather detailed information, insights, and personal experiences from participants. There are different types of interviews (Low et al., 2019).

Structured Interviews: These are highly formalised and follow a predetermined set of questions. The interviewer does not deviate from the script, ensuring consistency across all interviews.

Semi-Structured Interviews: These interviews have a framework of themes and questions, but the interviewer is free to explore new topics or ask follow-up questions based on the interviewee's responses.

Unstructured Interviews: Often resembling a conversation, these interviews are flexible with no predetermined questions. They are helpful in exploring complex or sensitive topics where the interviewee's perspective is central.

Group Interviews or Focus Groups: Involves interviewing multiple people simultaneously. This format is handy for understanding the dynamics of a group and how opinions are formed and expressed in a social setting.

Like any research method, interviews have advantages and disadvantages (Alamri, 2019). Table 4.2 summarises the advantages and disadvantages.

Advantages	Disadvantages
Depth and Detail: Interviews allow for in-depth exploration of topics, providing rich, detailed data often unattainable through other methods like surveys.	**Time-Consuming:** Conducting interviews and analysing the data can be time-intensive.
Flexibility: In semi-structured and unstructured formats, interviews can adapt to the flow of conversation, allowing researchers to explore unexpected topics or insights.	**Subjectivity:** The presence and manner of the interviewer can influence responses, and personal biases can affect interpretation.
Personal Touch: Interviews enable researchers to build rapport with participants, often leading to more honest and comprehensive responses	**Limited Generalisation:** Due to typically smaller sample sizes, the interview findings may not be generalised to a larger population.
Contextual Understanding: Interviews provide context to the responses, helping researchers understand the underlying reasons, motivations, and emotion	**Potential for Misinterpretation:** Non-verbal cues and the subtleties of spoken language can lead to misinterpretation of responses

Table 4.2: Advantages and disadvantages of interviews

Effectively conducting Interviews is essential to ensure that the gathered information is valid and valuable (McGrath et al., 2019).

Preparation: Develop a clear set of objectives and questions while being prepared to adapt as needed.

Building Rapport: Creating a comfortable environment for the interviewee, ensuring confidentiality, and establishing trust.

Active Listening: Being attentive, showing interest, and responding appropriately to encourage detailed responses.

Recording and Transcription: Accurately recording the interviews for thorough analysis, often involving transcription.

Ethical Considerations: Ensuring informed consent, respecting privacy, and maintaining confidentiality.

Reliability and Validity: Steps have been taken to improve validity by carefully selecting research questions. However, the potential biases of interviewees pose an issue, affecting reliability. These biases need to be managed during the interviews based on the researcher's experience in the sector and evidence gathered from the literature review.

The above considerations were noted when conducting the interviews.

4.4 Developing interview questions

The research questions focused on five (5) key areas: (a) recent developments, (b) ranking, (c) challenges, (d) competitiveness, and (e) technologies. Table 4.3 lists key questions. Roberts (2020) provides valuable insights into the process of developing research questions.

Focus	Questions
Recent Developments	Q1: What were the main changes in the port's organisational structure over the past five years? What were the impacts of those changes?
	Q2: What strategic and operational measures were adopted to attract container traffic? What were the impacts of those measures?
Ranking	Q3: Does your port management emphasise your port's ranking in terms of the volume of container traffic it handles?
	Q4: What factors have changed your port's standing in the global rankings?
Challenges	Q5: What have been the impacts of regional dynamics on your port's strategic and operational planning? What types of challenges are you currently encountering?
Competitiveness	Q6: What measures has your organisation implemented to preserve and enhance the competitive edge of your port?
	Q7: What are your strategies to maintain or improve your port's competitive standing over the next 5 to 10 years?
Technologies	Q8: What technologies, including smart technologies, have you used to transform port operations?

Table 4.3: Interview Questions

As explained above, only Port A and Port B were chosen for this analysis. The following abstracts of the interviews are presented. Interviews were conducted in bi-lingual (Arabic and English). Interviews were not recorded, but the participants checked the transcripts for accuracy and completeness. Both ports requested anonymous analysis of interview abstracts and questionnaire surveys.

4.3 Port A

Date: 05 November 2019

Interviewee: Senior Executive

Q1: What were the main changes in the port's organisational structure over the past five years? What were the impacts of those changes?

Over the past five years, we have expanded our business scope by acquiring several entities (names of entities were removed to make the transcript anonymous). This expansion has led us into new sectors, including defence, aerospace, and medical devices. We have also undergone restructuring, which involved consolidating our subsidiaries and shedding non-essential assets. Our financial trajectory during this period has been inconsistent, marked by phases of both growth and decline. We have encountered financial hurdles, including net losses in certain quarters and the need for debt restructuring. In summary, we have experienced considerable transformation in the past half-decade, focusing on diversification and restructuring to enhance our financial standing.

The outcomes of our transformations in the last five years have been varied. While we have made strides in diversifying our portfolio, streamlining our operations, and aiming to bolster our financial health, these changes have also brought about specific challenges and adverse effects.

Q2: What strategic and operational measures were adopted to attract container traffic? What were the impacts of those measures?

We have significantly invested in enhancing port infrastructure to manage the growing container traffic volumes. This development includes expanding container terminals,

deepening channels for larger ships, and boosting intermodal connections for efficient cargo movement to and from ports. We have focused on providing exceptional service to container shipping lines and other supply chain stakeholders. This involves optimising operational efficiency, reducing vessel turnaround times, and offering additional services like customs clearance and warehousing.

We have developed robust marketing and branding strategies to market our ports, engaging in industry events, advertising in trade publications, and utilising social media and digital platforms for broader outreach. Embracing technological advancements, we have improved operational efficiency and customer experience by implementing advanced terminal operating systems, incorporating automation and AI for cargo handling, and offering digital shipment tracking and management platforms.

Over the past five years, our strategies for attracting container traffic have evolved significantly. We have expanded our global presence through mergers, acquisitions, joint ventures, and new developments in emerging markets, diversifying our port portfolio and better catering to customer needs. We have increasingly adopted technologies like automation, AI, and IoT to optimise port operations and enhance customer experiences, leading to greater efficiency, productivity, and supply chain transparency. Recently, we have focused on sustainability, employing green technologies and practices to minimise our environmental impact. This includes using renewable energy, eco-friendly design standards, and investing in recycling and waste reduction initiatives.

In summary, we have continually adapted our strategies and operations to meet changing market demands, customer needs, and technological advancements. While the core objective of attracting container traffic remains, the methods have become more sophisticated and varied over time.

Q3: Does your port management emphasise your port's ranking in terms of the volume of container traffic it handles?

Container traffic serves as a vital revenue stream for ports, generating income through services like cargo handling, storage, and transportation. Ports handling larger volumes of container traffic are typically perceived as more economically robust and successful than those with lesser volumes. Beyond financial gains, high container traffic can offer additional

benefits to ports, including creating more job opportunities and the potential to draw new businesses and industries to the region.

Consequently, it is understandable that port authorities pay close attention to their standings in container traffic volumes, which can greatly influence their economic prosperity and competitive edge. They often focus on upgrading their infrastructure, services, and operational efficiency to attract more container traffic and enhance their rankings. However, it is important to recognise that container traffic is just one facet of a port's overall performance and success. Other critical aspects, such as operational efficiency, reliability, and commitment to environmental sustainability, also play significant roles in defining a port's standing and effectiveness.

Q4: What factors have changed your port's standing in the global rankings?

Since our foundation, we have seen remarkable changes and growth. Initially, in the mid-1980s, we held a lower position in global port rankings based on container traffic. However, we have grown significantly, achieving a consistently higher ranking in subsequent years.

We have significantly invested in upgrading our port infrastructure, including constructing new terminals and acquiring ports globally, enabling us to handle an increased volume of container traffic and improve our ranking. Benefiting from the country’s substantial economic growth since the 1980s, which has boosted trade and demand for container shipping, we have successfully harnessed this upsurge, leading to a rise in container traffic volume. We have also formed strategic partnerships and alliances with shipping companies and port operators, expanding our international reach and enhancing our container traffic volume. Crucially, the government has played a pivotal role in our growth and expansion, providing essential financial support and fostering a favourable regulatory environment, facilitating our ability to invest in our infrastructure and expand our operation.

In summary, the shift in our standing in the world rankings since the mid-1980s results from a multifaceted approach, encompassing infrastructure investment, leveraging economic growth, forming strategic partnerships, and receiving government support.

Q5: What have been the impacts of regional dynamics on your port's strategic and operational planning? What types of challenges are you currently encountering?

The influence of regional dynamics on port operations and planning is substantial, as ports are often shaped by the economic and political climate of their locality and the competitive landscape of nearby ports. For instance, shifts in regional trade policies or economic conditions can affect the quantity and nature of cargo a port handles. Additionally, regional factors often dictate the availability of critical resources like labour, fuel, and raw materials.

Moreover, the competitive strategies of adjacent ports play a crucial role in a port's strategic and operational decisions. Ports must be mindful of the services and incentives their neighbouring ports offer to attract clientele and maintain competitiveness. Consequently, port operators must stay attuned to these regional dynamics and adapt their strategic and operational plans to keep pace. This adaptation could involve introducing new services or facilities to draw customers or altering operational processes to enhance efficiency and cut costs.

Port operators might also find it necessary to collaborate with supply chain stakeholders and local communities to address challenges posed by regional dynamics effectively. Such proactive engagement and adaptation are crucial to navigating the complexities of regional influences on port operations.

Q6: What measures has your organisation implemented to preserve and enhance the competitive edge of your port?

Indeed, we have initiated several strategies to sustain our competitive edge in the international port sector. Our primary focus has been adopting advanced IT systems to enhance efficiency and minimise costs. For instance, we have introduced a comprehensive digital platform called the "Global Supply Chain Platform." This platform consolidates all our terminal and logistics services into a unified system, allowing customers to access real-time cargo information and manage their shipments across the supply chain. It also enables us to streamline our operations, enhancing the speed and precision of cargo handling. Beyond IT advancements, we have also significantly invested in infrastructure and superstructure

enhancements. Additionally, we have expanded existing facilities to accommodate larger vessels and handle increased cargo volumes.

Addressing environmental sustainability is another critical area where we have been proactive. In 2019, we launched our sustainability program, aiming to reduce our carbon footprint and enhance the sustainability of our operations. This program encompasses investments in renewable energy, electrification of port equipment, and efforts to lower emissions from port activities.

Our initiatives reflect a dedication to innovation, sustainability, and ongoing enhancement, which are crucial for maintaining our competitive position in the global port industry.

Q7: What are your strategies to maintain or improve your port's competitive standing over the next 5 to 10 years?

We have outlined a comprehensive plan to maintain and enhance our competitive edge in the global port industry over the next 5-10 years.

We are actively pursuing a digital transformation agenda to enhance efficiency and reduce costs, incorporating advanced technologies such as AI, automation, and IoT alongside developing digital platforms to elevate customer experiences and optimise operations. Committed to achieving carbon neutrality by 2050, we are focusing on sustainability, investing in renewable energy, electrifying port equipment, and cutting emissions from port activities while planning to introduce sustainable logistics solutions to reduce the carbon footprint of supply chain operations. In our bid to expand globally, we are investing in new port developments and acquisitions, mainly targeting emerging markets in Africa and Asia. We are developing logistics and warehousing facilities to support the growing e-commerce sector. Moving beyond traditional port operations, we are diversifying into logistics, supply chain management, and value-added services, developing integrated logistics solutions like warehousing and transportation, and acquiring companies with complementary services. Additionally, we are emphasising customer-centricity more, developing digital platforms for real-time cargo tracking and visibility, and implementing customer feedback mechanisms to improve service quality.

Overall, these strategies are designed to secure our position as a global port industry leader and capitalise on new growth opportunities in emerging markets and sectors.

Q8: What technologies, including smart technologies, have you used to transform port operations?

We have strategically implemented various technologies across our global port network to enhance efficiency, lower operational costs, and improve customer service. Our container terminals have embraced automation technologies like automated stacking cranes, automated guided vehicles, and automated terminal tractor-trailers. These advancements streamline cargo handling processes and reduce the necessity for manual labour. Additionally, we have integrated Internet of Things (IoT) technology to advance the tracking and monitoring of cargo, utilising sensors and RFID tags for real-time location and condition monitoring throughout the supply chain. We have also collaborated with blockchain technology firms to create platforms that bolster the transparency and security of cargo transactions, facilitating real-time cargo tracking, reducing paperwork, and ensuring secure, unalterable transaction records.

In our pursuit of operational excellence, we employ AI-powered systems, including AI-based vessel scheduling, to optimize vessel timings considering cargo volume, capacity, and weather conditions. The development of digital platforms allows customers to access up-to-the-minute information about their cargo and track shipments across the supply chain, offering enhanced visibility and transparency. Furthermore, we have implemented port community systems (PCS) in several ports, creating a unified platform for stakeholder communication and operational streamlining. Terminal Operating Systems (TOS) use in port terminals further optimizes container handling and boosts efficiency, aiding in reducing vessel turnaround times and enhancing berth productivity. Our investment in automated container handling systems underscores our commitment to efficiency and reduced manual labour reliance. Overall, these technological initiatives underscore our dedication to maintaining our competitive edge in the global port industry while delivering value to our customers.

4.4 Port B

Date: 07 January 2020

Interviewee: Senior Executive

Q1: What were the main changes in the port's organisational structure over the past five years? What were the impacts of those changes?

During the past five years, there have been many changes in several important aspects of the company; in terms of the significant growth in the number of employees and the trend towards mergers and acquisitions that occurred during the previous years, the growth in profits and the transformation into several sectors and subsidiaries under the umbrella of the parent company.

Moreover, focus on the human element as one of the most critical assets, training hand, development and well-being of the employee, and the leadership's conviction of the employee's role in achieving long-term strategic goals.

From my point of view, growth in net profits, excellence awards, talent search, creating opportunities to build a clear career path, developing long-term strategies, and spreading work culture to create added value. In addition to signing long-term agreements and contracts with external parties.

Q2: What strategic and operational measures were adopted to attract container traffic? What were the impacts of those measures?

Our impressive performance in recent years demonstrates our dedication to evolving from a traditional port operator into a key player in facilitating and enabling industrial and global trade. This strategic shift has led us to forge long-term local and global partnerships, enhancing trade routes across Asia, Africa, Europe, and beyond. These collaborations attract new global customers and solidify our significant international trade hub status.

A primary strategic and operational focus has been on continuously improving process efficiency year after year. This is evident in our overall Customer Satisfaction Survey Results, efforts to improve and attract customers, increase volumes, and reduce vessel turnaround times. Furthermore, we are committed to fostering excellence and innovation, gaining recognition, and establishing our port as a distinguished brand while embracing a sustainable future for everyone.

Our strategic objectives are cascaded from the top down, linked with scorecards and KPIs. Each member contributes to their functional capacity, enhancing revenue and fostering productivity development with a lean approach. In line with supporting the UAE's diversification agenda, we play a crucial role as a business enabler, providing essential infrastructure for the global maritime industry. We promote the Emirate as a leading regional and international hub through our comprehensive commercial, community, logistics, and leisure port portfolio.

Our growth is remarkable in the container, general cargo, bulk, and RoRo services, tapping into the immense potential of the 90% of world trade transported by sea. We maintain an unwavering commitment to the safety and security of operations across our ports and industrial zones. Our business unit rigorously follows a systematic approach to responsibly minimise HSE (Health, Safety, and Environment) risks to a level that is as low as reasonably practicable.

Q3: Does your port management emphasise your port's ranking in terms of the volume of container traffic it handles?

Indeed, we have a dedicated management team focused on assessing our progress and standing among international companies. This is achieved through performance indicators that inform our leadership about our position in the global corporate landscape. There's no cause for concern regarding the clarity of our vision, our rapid growth, the establishment of new overseas concessions, and the signing of agreements that are poised to place us in a leadership position.

Currently, our capacity stands at 5 million TEUs, split evenly with two operators. One is set to expand its capacity to 5 million TEUs. Consequently, other's capacity could escalate to 9 million TEUs in the next five years.

Q4: What factors have changed your port's standing in the global rankings?

The leadership team at our port is committed to fostering a sustainable, diverse economy with a high value-add, promoting enterprise, entrepreneurship, and innovation. This aligns with their goal of seamlessly integrating our ports into the global economy. Notably, the port has made a significant leap from the 90-100 range to the 70-80 range, recognised for

achieving the most significant percentage increase in container throughput among all contenders. This remarkable achievement has led to it being acclaimed as the fastest-growing port in the world.

Q5: What have been the impacts of regional dynamics on your port's strategic and operational planning? What types of challenges are you currently encountering?

Our vision is to be a Beacon for Maritime Trade. Since its inception, our port has consistently aligned with the long-term vision of the local government. It has played a crucial role in the emirate's development, contributing 3.6% to non-oil GDP growth.

I believe the primary challenges lie in attracting and nurturing talent across various organisational levels in this unique sector, particularly in addressing the shortage of leaders. Additionally, a significant focus is on attracting new business volumes and clients while maintaining and enhancing business revenue through expanding our portfolio.

Q6: What measures has your organisation implemented to preserve and enhance the competitive edge of your port?

Over the past decade, our port has realised numerous successes through well-defined strategies, with several changes contributing to achieving many strategic objectives.

A significant investment has been made in technology and world-class infrastructure. In alignment with the government's long-term vision, we are committed to accelerating development and trade by offering smart and innovative digital solutions to the trade and port communities. Our services are tailored to enhance the efficiency and productivity of maritime business interactions. This is achieved by fostering transparency and providing access to real-time information through cutting-edge port automation and seamless, integrated solutions. Additionally, we have adopted a new organisational structure model, forming various clusters, each led by its own CEO and board of members.

Q7: What are your strategies to maintain or improve your port's competitive standing over the next 5 to 10 years?

A primary objective of our port is to extend its role beyond traditional port operations, aiming to complement, support, and contribute to the government's long-term vision. This

vision focuses on creating a diversified, sustainable, integrated economy driven by innovation and knowledge. Technology plays a crucial role in the future plans of the ports.

In the past decade, the efforts of the port to transform the UAE's trade, logistics, and industrial sectors have reached an exciting juncture. We are now ushering in a new digital transformation era, introducing innovative solutions for all stakeholders and consumers involved. A vital component of this strategy is X (name removed to make it anonymous) Gateway, the digital arm of our port. Our team has developed and managed the UAE's first Port Community System.

Q8: What technologies, including smart technologies, have you used to transform port operations?

Yes, we use (a) orts Community System, (b) blockchain technology Integrated Services and (c) Terminal Operating system. Our dedicated management team has expertise in assessing our development and benchmarking our standing among international companies. They utilise performance indicators to give our leadership insights into our position within the global corporate landscape.

4.5 Analysis of Interviews

Interview analysis is a crucial process in qualitative research, where data collected from interviews are systematically examined to derive meaningful insights (Mattimoe et al., 2021). The most common techniques are shown in Table 4.4.

Technique	Description	Suitability
Thematic Analysis	This involves identifying patterns or themes within interview data. It is a flexible approach. The process typically involves familiarisation with the data, generating initial codes, searching for themes, reviewing, and defining and naming themes.	Yes
Content Analysis	This method focuses on the content of the interviews, often quantifying the frequency of	Yes

	certain words or phrases. It can be used to systematically describe the meaning of qualitative material and make inferences about the messages within the data.	
Narrative Analysis	This technique is used to interpret the stories that people tell during interviews. It involves examining the structure and content of the narrative to understand how individuals perceive and make sense of their experiences.	No
Discourse Analysis	This approach analyses the language used in the interviews to understand how it reflects and shapes social realities and power dynamics. It goes beyond the content of speech or writing, considering the context and manner of communication.	No
Grounded Theory	This is a systematic methodology that involves the construction of theories through methodical gathering and analysis of data. It is a standard method in social sciences for analysing qualitative data, such as interview transcripts.	No

Table 4.4: Qualitative Data Analysis Techniques

Thematic analysis was chosen as it enables the identification of key themes and the comparison of two ports (Humble & Mozelius, 2022). Having reviewed the interview transcripts, the following were chosen as themes: (a) the port's organisational structure, (b) strategic measures, (c) operational changes, (d) global standing, (e) regional dynamics, (f) competitive strategies, (g) plans, and (h) technological advancements.

Table 4.5 below summarises the results from the thematic analysis of the two ports.

Port A	**Port B**
(a) Organizational Changes and Impacts: • **Expansion and Diversification**: The port has expanded into new sectors like defence, aerospace, and medical devices, indicating a diversification strategy.	**(a) Organizational Changes and Impacts**: • **Employee Growth and Development**: Significant increase in employee numbers and emphasis on training, development, and well-being.

• **Restructuring**: Consolidation of subsidiaries and shedding non-essential assets point towards a focus on streamlining operations. • **Financial Trajectory**: The port experienced growth and decline, highlighting financial volatility. • **Challenges**: Financial hurdles and net losses in certain quarters suggest ongoing challenges in financial management.	• **Mergers and Acquisitions**: Expansion through mergers and acquisitions, indicating growth and diversification. • **Profit Growth and Sector Expansion**: Increase profits and expansion into various sectors and subsidiaries. • **Focus on Human Element**: Recognition of employees as vital assets for achieving strategic goals.
(b) Strategies to Attract Container Traffic: • **Infrastructure Enhancement**: Investment in expanding terminals, deepening channels, and improving intermodal connections. • **Service Optimization**: Focus on operational efficiency, reducing turnaround times, and offering additional services. • **Marketing and Branding**: Use social media, digital platforms, and participation in industry events. • **Technological Advancements**: Implementation of automation, AI, and digital shipment tracking. • **Sustainability Focus**: Adoption of green technologies and practices.	**(b) Strategies to Attract Container Traffic**: • **Strategic Partnerships**: Forging local and global partnerships to enhance trade routes and attract global customers. • **Operational Efficiency**: Continuous improvement in process efficiency, customer satisfaction, and reduction in vessel turnaround times. • **Brand Recognition and Sustainability**: Establishing the port as a distinguished brand and embracing sustainable practices. • **Supporting National Diversification Agenda**: Contributing to the UAE's diversification and promoting the emirate as a critical hub.
(c) Emphasis on Container Traffic Volume: • **Economic Significance**: Container traffic is a significant revenue stream influencing the port's economic prosperity. • **Competitive Edge**: High container traffic volume is linked to the port's competitive standing.	**(c) Emphasis on Container Traffic Volume**: • **Performance Monitoring**: Dedicated management team assessing progress and standing in the global corporate landscape. • **Capacity Expansion**: Plans to expand capacity significantly in the coming years.
(d) Factors Influencing Global Ranking: • **Infrastructure Investment**: Construction of new terminals and global port acquisitions.	**(d) Factors Influencing Global Ranking**: • **Economic Diversification and Innovation**: Commitment to fostering a

• **Economic Growth Leverage**: Benefiting from the country's economic growth to boost trade. • **Strategic Partnerships**: Alliances with shipping companies and port operators. • **Government Support**: Financial and regulatory assistance from the government.	diverse, innovative economy and integrating into the global economy. • **Significant Growth in Container Throughput**: Recognized as the fastest-growing port in container throughput.
(e) Impact of Regional Dynamics: • **Adaptation to Regional Factors**: Adjusting strategies based on regional trade policies and economic conditions. • **Competitive Strategies**: Responding to neighbouring ports' services and incentives.	**(e) Impact of Regional Dynamics**: • **Alignment with Local Government Vision**: Consistent alignment with the long-term vision of the local government. • **Talent Attraction and Business Expansion**: Challenges in attracting talent and expanding business volumes and clients.
(f) Measures to Maintain Competitive Edge: • **Advanced IT Systems**: Introduction of digital platforms for cargo management. • **Infrastructure and Sustainability Investments**: Enhancements to accommodate larger vessels and reduce carbon footprint.	**(f) Measures to Maintain Competitive Edge**: • **Technology and Infrastructure Investment**: Significant investment in technology and world-class infrastructure. • **Digital and Innovative Solutions**: Offering smart digital solutions to enhance maritime business interactions. • **Organizational Restructuring**: Adopting a new organisational structure with various clusters led by CEOs and boards.
(g) Future Strategies for Competitive Standing: • **Digital Transformation**: Embracing AI, automation, and IoT. • **Sustainability Goals**: Aiming for carbon neutrality and sustainable logistics solutions.	**(g) Future Strategies for Competitive Standing**: • **Role Expansion Beyond Traditional Operations**: Aiming to support and contribute to the government's vision of a diversified, sustainable economy. • **Digital Transformation**: Introduction of innovative digital solutions, including developing the UAE's first Port Community System.

• **Global Expansion**: Targeting emerging markets and diversifying into logistics and supply chain management.	
(h) Use of Smart Technologies: • **Automation and IoT**: Automated cranes, vehicles, and IoT for cargo tracking. • **Blockchain and AI**: Enhancing transaction security and optimising vessel scheduling. • **Digital Platforms and PCS**: Improving customer service and operational efficiency.	**(h) Use of Smart Technologies**: • **Port Community System**: A comprehensive system for enhancing port operations is implemented. • **Blockchain Technology**: Integration of blockchain for secure and transparent operations. • **Terminal Operating System**: Utilization of advanced systems for optimising terminal operations.

Table 4.5: Comparison of two ports using thematic analysis

The above analysis identified similarities and differences (Table 4.6).

	Similarities	Differences
(a) Organizational Changes and Impacts:	Highlight expansion, diversification, and restructuring as fundamental organisational changes.	The first interview emphasises financial challenges and transformation, while the second focuses on employee growth, training, and development.
(b) Strategies to Attract Container Traffic:	Discuss improving infrastructure, operational efficiency, and strategic partnerships.	The first interview details technological advancements and sustainability efforts, whereas the second emphasises brand recognition and aligning with national diversification agendas.
(c) Emphasis on Container Traffic Volume:	Acknowledge the importance of container traffic volume for economic prosperity and competitive edge.	The second interview provides specific details on capacity expansion and performance monitoring.
(d) Factors Influencing Global Ranking	Mention infrastructure investment and strategic partnerships as critical factors.	The first interview includes government support as a factor, while the second highlights the port's leap in

		global rankings and its recognition as the fastest-growing port.
(e) Impact of Regional Dynamics	Recognise the influence of regional dynamics on port operations and planning.	The second interview more explicitly discusses the alignment with the local government vision and the challenges in talent attraction.
(f) Measures to Maintain Competitive Edge	Focus on technological advancements and infrastructure improvements.	The second interview also discusses organisational restructuring and the formation of clusters led by CEOs.
(g) Future Strategies for Competitive Standing	Emphasise digital transformation and sustainability.	The second interview mentions explicitly the role of technology in supporting the government's long-term vision and the development of a digital arm.
(h) Use of Smart Technologies	Mention the adoption of advanced technologies like automation, AI, and IoT.	The second interview provides more specific examples, such as the Port Community System and blockchain technology.

Table 4.6: Similarities and differences of interview responses

In summary, while both interviews cover similar thematic ground regarding the port's development and strategies, they differ in their specific focus areas: the first interview leans more towards financial aspects and technological advancements, while the second interview places greater emphasis on employee development, brand recognition, and specific technological implementations. Both ports are continually taking steps to improve competitiveness. A comprehensive and holistic framework would be helpful to guide their journey towards achieving the highest levels of competitiveness.

According to Chen et al. (2019) and Molavi et al. (2020), smart ports encompass five key aspects: smart infrastructure, well-educated personnel, automation, skilled workers, and environmental awareness. Smart infrastructure involves advanced hardware and software for real-time data management, such as sensors and monitoring systems. Well-educated

personnel are crucial for managing these systems and responding to market changes. Automation reduces labour inefficiencies and safety issues. Skilled workers are necessary to operate the advanced automated facilities. Finally, environmental awareness is integral to fifth-generation ports, focusing on green and low-carbon technologies, unlike the earlier port generations. The above analysis shows that the two ports have used different combinations of the above aspects.

4.6 Questionnaire Survey

Questionnaire surveys add value to interviews by providing a structured and consistent approach to gathering data (Murphy, 2023). This ensures that all respondents are asked the same questions, allowing for a more straightforward comparison of responses. Combined with interviews, which offer depth and context, questionnaires contribute breadth and quantifiable data, making for a more comprehensive understanding of the current state and challenges. The following presents the key steps (Gulnoza & Niginabonu, 2022) in designing and implementing the questionnaire survey.

Step 1: Define Objectives

The main objectives of the questionnaire survey are to understand the current infrastructure, port performance, and technology deployment.

Step 2: Design the questionnaire.
The questionnaire was designed on six (6) dimensions: Infrastructure, Capacity, Performance, Technology, Sustainability and Competitiveness.

Step 3: Pilot Test
Pilot testing a survey is an essential step in the survey design process for several important reasons. It helps to ensure the survey's reliability, validity, and effectiveness before it is administered on a larger scale. The pilot test involved three participants: a senior executive and two senior managers. The following adjustments were made based on their feedback. Statements suggested by the pilot testers are shown in green, and statements removed in red (Table 4.7). The pilot testers indicated that survey respondents might not offer dependable opinions because they might lack access to information about the eliminated questions.

D1: Infrastructure
S1.01: The port has sufficient berth length to accommodate large container ships.
S1.02: The docking facilities are well-maintained and equipped with modern amenities.
S1.03: The port is equipped with high-capacity cranes suitable for container handling.
S1.04: The cargo handling equipment at the port is regularly updated and maintained.
S1.05: The port has ample and secure storage facilities for containers.
S1.06: There are enough container freight stations for efficient handling and storage.
S1.07: The port is well-connected to road networks for easy container transport.
S1.08 Intermodal transport facilities are efficient and reduce cargo handling times.
S1.09: The port employs advanced technology for container tracking and management.
D2: Capacity
S2.01: The port can handle a high volume of container traffic without significant delays.
S2.02: The turnaround time for container ships at the port is optimal.
S2.03: There is sufficient space and planning for expanding container facilities.
S2.04: The port has a strategic plan for scaling up its container handling capacity.
S2.05: The port's container handling processes are streamlined for maximum efficiency.
S2.06: The average container dwell time at the port is within acceptable industry standards.
D3: Performance
S3.01: The turnaround time for container ships at this port is consistently efficient.
S3.02: The port effectively manages peak-time congestion to minimise delays.
S3.03: The speed of loading and unloading containers meets or exceeds industry standards.
S3.04: The port has adequate workforce and machinery to handle cargo efficiently.
S3.05: Customs clearance processes for containers are quick and efficient.
S3.06: Documentation procedures for container handling are streamlined and user-friendly.
S3.07: The port staff are knowledgeable and provide excellent customer service.

S3.08: Queries and complaints about container operations are addressed promptly and effectively.
S3.09: Communication between the port, shipping lines, and freight forwarders is clear and compelling.
S3.10: The port adheres to high container handling and storage safety standards.
S3.11 Security measures for container cargo at the port are robust and reliable.
S3.12: The port's infrastructure is well-suited to handle current container volumes.
S3.13: The port continuously invests in upgrading its infrastructure to improve container handling.
S3:14: The costs associated with container handling at the port are competitive and reasonable.
S3.15: The port provides good value for money regarding container handling services.
S3.16: The port has robust security measures in place for container cargo.
S3.17: Safety protocols for container handling are regularly reviewed and updated.
D4: Technology
S4.01: The port has implemented state-of-the-art container tracking and management technology systems.
S4.02: Automated systems are widely used for container handling and operations.
S4.03: The port utilises advanced digital platforms for communication and data exchange.
S4.04: Real-time tracking and monitoring of containers are effectively implemented at the port.
S4.05: The port's technology systems are well-integrated with global shipping and logistics networks.
S4.06: The port supports electronic data interchange (EDI) for efficient document handling.
S4.07:The adoption of modern technology has significantly improved operational efficiency.
S4.08: Technology has reduced the time required for container loading, unloading, and turnaround.
S4.09: The technological systems ensure high accuracy in container handling operations.
S4.10: The port's technology is reliable and seldom experiences significant downtimes or failures.
S4.11:The technology used at the port is user-friendly and easy to navigate.
S4.12: Staff training for new technologies is adequate and effective.
S4.13: The use of technology has resulted in cost savings for the port and its users.
S4.14: Investments in technology have shown a clear return on investment.
S4.15: Modern technology gives the port a competitive advantage in the industry.
S4.16: The port's technological advancements meet international shipping companies' expectations.
S4.17: The port offers advanced digital solutions for tracking and managing container shipments.
S4.18: Automation is effectively used in container handling and operations.
D5: Sustainability
S5.01: Technology has made the port's operations more environmentally sustainable.
S5.02: The port uses technology to monitor and reduce its environmental impact.
S5.03: The port implements eco-friendly practices in its container operations.
D6: Competitiveness
D6.01: The port ranks favourably in global comparisons of container ports.
D6.02: The port has a strong and positive reputation in the international shipping community.
D6.03: The port has successfully increased its market share in container handling.
D6.04: The port demonstrates consistent growth in container throughput.
D6.05: The port's operational efficiency is par with leading global container ports.
D6.06: The port has short waiting times and quick container turnaround.
D6.07: The port offers a wide range of services that meet the diverse needs of its users.
D6.08: The quality of services provided at the port is superior to that of competing ports.
D6.09: The port's pricing for container handling is competitive and offers good value.
D6.10: The cost structure of the port is transparent and predictable

D6.11: The port's infrastructure is modern and well-maintained. (repetition)
D6.12: The port continuously invests in upgrading its infrastructure to stay competitive.
D6.13: The port employs advanced technology to enhance its operational efficiency.
D6.14: The technological solutions at the port are innovative and industry-leading.
D6.15: The port's location is strategically advantageous for international shipping routes.
D6.16: The port is well-connected to major inland transportation networks.
D6.17: Customers are generally satisfied with the services provided at the port.
D6.18: The port has a high rate of customer retention and loyalty.

Table 4.7: Survey Questions

Step 4: Determine the Target Audience
Survey participants are junior and senior managers of two ports.

Step 5: Choose the Survey Method
Google Forms was used to design the online survey.

Step 6: Administer the Survey
The survey was open for three weeks.

Step 7: Analysis
Analysis of the survey is presented in section 4.7 below.

4.7 Survey Analysis

This section presents the analysis for each dimension, and where possible, evidence from external sources is used to qualify the analysis. The weighted score (1 to 5) is provided to show the overall strength of the responses. A graded colour scheme was used to colour code the weighted scores (Figure 4.1)

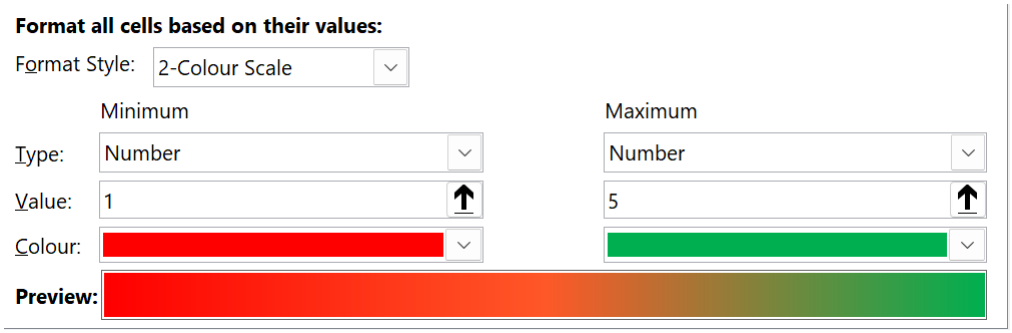

Figure 4.1: Graded colour scheme for weighted scores

4.7.1 Infrastructure

Table 4.8 shows the analysis of the responses for the statements under infrastructure.

	Port-A							Port-B					
D1: Infrastructure	**SD**	**D**	**N**	**A**	**SA**	**WS**		**SD**	**D**	**N**	**A**	**SA**	**WS**
	(%)	**(%)**	**(%)**	**(%)**	**(%)**			**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	
S1.01: The port has sufficient berth length to accommodate large container ships.	0%	0%	0%	43%	57%	**4.6**		0%	0%	26%	74%	0%	**3.7**
S1.02: The docking facilities are well-maintained and equipped with modern amenities.	0%	0%	0%	21%	79%	**4.8**		0%	13%	43%	22%	22%	**3.5**
S1.03: The port is equipped with high-capacity cranes suitable for container handling.	0%	0%	0%	7%	93%	**4.9**		0%	0%	0%	61%	39%	**4.4**
S1.04: The cargo handling equipment at the port is regularly updated and maintained.	0%	0%	21%	43%	36%	**4.1**		0%	13%	13%	43%	30%	**3.9**
S1.05: The port has ample and secure storage facilities for containers.	0%	0%	18%	36%	46%	**4.3**		0%	0%	0%	30%	70%	**4.7**
S1.06: There are enough container freight stations for efficient handling and storage.	0%	7%	21%	36%	36%	**4.0**		9%	22%	35%	35%	0%	**3.0**
S1.07: The port is well-connected to road networks for easy container transport.	0%	0%	0%	14%	86%	**4.9**		0%	0%	0%	13%	87%	**4.9**
S1.08 Intermodal transport facilities are efficient and reduce cargo handling times.	0%	11%	11%	43%	36%	**4.0**		0%	8%	32%	52%	8%	**3.6**
S1.09: The port employs advanced technology for container tracking and management.	0%	0%	0%	0%	100%	**5.0**		0%	0%	0%	17%	83%	**4.8**

Table 4.8: Comparison of Survey Results – Infrastructure

(SD-Strongly Disagree, D–Disagree, N–Neutral, A-Agree, SA-Strongly Agree, WS – Weighted Score)

Port-A generally scores higher in most infrastructure aspects, indicating a well-maintained and modern facility, particularly in terms of berth length, docking facilities, crane capacity, and advanced technology for container tracking.

Port-B, while scoring well in several areas like storage facilities and technology, shows room for improvement in docking facilities, cargo handling equipment, and container freight stations. It matches Port-A in road network connectivity and nearly in container tracking technology.

Port infrastructure is critically critical for its success as it is a vital gateway for international trade and economic growth. Efficient ports facilitate the swift and cost-effective movement of goods, significantly impacting a nation's ability to participate in global trade. They also play a crucial role in attracting investments, boosting local economies, and creating employment opportunities. Moreover, a well-developed port infrastructure can enhance a country's competitive edge by improving supply chain efficiency, reducing transportation costs, and ensuring the timely delivery of goods (Wang et al., 2021). This is essential in today's interconnected global economy, where the efficiency of ports can directly influence trade volumes, economic stability, and a nation's overall prosperity.

4.7.2 Capacity

Table 4.9 shows survey results for capacity-related statements.

	Port-A							Port-B					
D2: Capacity	**SD**	**D**	**N**	**A**	**SA**	**WS**		**SD**	**D**	**N**	**A**	**SA**	**WS**
	(%)	**(%)**	**(%)**	**(%)**	**(%)**			**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	
S2.01: The port can handle a high volume of container traffic without significant delays.	0%	7%	57%	36%	0%	**3.3**		13%	35%	35%	17%	0%	**2.6**
S2.02: The turnaround time for container ships at the port is optimal.	21%	25%	43%	11%	0%	**2.4**		23%	23%	50%	4%	0%	**2.3**
S2.03: There is sufficient space and planning for expanding container facilities.	0%	0%	14%	36%	50%	**4.4**		0%	0%	26%	52%	22%	**4.0**
S2.04: The port has a strategic plan for scaling up its container handling capacity.	0%	0%	0%	36%	64%	**4.6**		0%	9%	35%	35%	22%	**3.7**
S2.05: The port's container handling processes are streamlined for maximum efficiency.	4%	21%	25%	21%	29%	**3.5**		26%	26%	17%	30%	0%	**2.5**
S2.06: The average container dwell time at the	0%	11%	61%	25%	4%	**3.2**		26%	26%	30%	17%	0%	**2.4**

port is within acceptable industry standards.												

Table 4.9: Comparison of Survey Results – Capacity

(SD-Strongly Disagree, D–Disagree, N–Neutral, A-Agree, SA-Strongly Agree, WS – Weighted Score)

Port-A generally scores higher in capacity-related aspects, indicating better performance in handling container traffic, planning for future expansion, and strategically scaling capacity. However, it faces challenges in turnaround times and streamlining processes.

Port-B shows lower scores across all aspects, indicating more significant challenges in handling container traffic efficiently, turnaround times, and streamlining processes. However, it shows potential in planning for future expansion and strategic scaling, albeit less than Port-A.

Port capacity is critical to its success as it directly influences the ability to handle large cargo volumes efficiently and effectively (Cong et al., 2020). Higher capacity ensures that ports can accommodate more ships and more diverse types of cargo, leading to reduced waiting times and faster turnaround. This efficiency is vital in a global economy where timely delivery is crucial. Ports with higher capacities are better equipped to manage peak demand periods and can adapt more readily to changes in trade patterns or shipping technologies. Consequently, ports with ample capacity are more attractive to global shipping lines, fostering increased trade, economic growth, and competitiveness on the international stage.

4.7.3 Performance

The table below (Table 4.10) analyses responses to performance-related statements.

	Port-A							Port-B					
D3: Performance	**SD**	**D**	**N**	**A**	**SA**	**WS**		**SD**	**D**	**N**	**A**	**SA**	**WS**
	(%)	**(%)**	**(%)**	**(%)**	**(%)**			**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	
S3.01: The turnaround time for container ships at this port is consistently efficient.	7%	14%	21%	21%	36%	**3.6**		22%	26%	30%	22%	0%	**2.5**

S3.02: The port effectively manages peak-time congestion to minimise delays.	0%	14%	29%	21%	36%	**3.8**	17%	26%	35%	22%	0%	**2.6**
S3.03: The speed of loading and unloading containers meets or exceeds industry standards.	0%	0%	0%	21%	79%	**4.8**	9%	9%	26%	30%	26%	**3.6**
S3.04: The port has adequate workforce and machinery to handle cargo efficiently.	0%	0%	0%	18%	82%	**4.8**	0%	0%	0%	30%	70%	**4.7**
S3.05: Customs clearance processes for containers are quick and efficient.	14%	29%	29%	14%	14%	**2.9**	30%	35%	30%	4%	0%	**2.1**
S3.06: Documentation procedures for container handling are streamlined and user-friendly.	0%	0%	21%	43%	36%	**4.1**	17%	17%	22%	43%	0%	**2.9**
S3.07: The port staff are knowledgeable and provide excellent customer service.	0%	14%	25%	36%	25%	**3.7**	0%	26%	35%	39%	0%	**3.1**
S3.08: Queries and complaints about container operations are addressed promptly and effectively.	0%	21%	29%	36%	14%	**3.4**	0%	26%	26%	43%	4%	**3.3**
S3.09: Communication between the port, shipping lines, and freight forwarders is clear and compelling.	4%	14%	29%	36%	18%	**3.5**	0%	43%	26%	30%	0%	**2.9**
S3.10: The port adheres to high container handling and storage safety standards.	0%	0%	0%	29%	71%	**4.7**	0%	0%	17%	22%	61%	**4.4**
S3.11 Security measures for container cargo at the port are robust and reliable.	0%	0%	0%	21%	79%	**4.8**	0%	0%	4%	43%	52%	**4.5**
S3.12: The port's infrastructure is well-suited to handle current container volumes.	0%	7%	21%	29%	43%	**4.1**	8%	13%	25%	50%	4%	**3.3**
S3.13: The port continuously invests in upgrading its infrastructure to improve container handling.	0%	0%	0%	14%	86%	**4.9**	0%	0%	0%	35%	65%	**4.7**
S3:14: The costs associated with container handling at the port are competitive and reasonable.	0%	7%	14%	21%	57%	**4.3**	13%	13%	13%	26%	35%	**3.6**
S3.15: The port provides good value for money regarding container handling services.	0%	11%	25%	29%	36%	**3.9**	0%	17%	26%	35%	22%	**3.6**

S3.16: The port has robust security measures in place for container cargo.	0%	0%	0%	14%	86%	**4.9**		0%	0%	0%	26%	74%	**4.7**
S3.17: Safety protocols for container handling are regularly reviewed and updated.	0%	0%	29%	29%	43%	**4.1**		0%	17%	22%	26%	35%	**3.8**

Table 4.10: Comparison of Survey Results – Performance

(SD-Strongly Disagree, D–Disagree, N–Neutral, A-Agree, SA-Strongly Agree, WS – Weighted Score)

Port-A generally scores higher across most performance metrics, indicating more efficient operations, better handling of peak-time congestion, faster loading/unloading times, and strong safety and security measures.

Port-B, while also performing well in certain areas like workforce, machinery, and security, shows significant room for improvement in turnaround times, congestion management, customs processes, and communication effectiveness.

Port performance is vital to its success for several reasons (Ha et al., 2019). Firstly, efficient port operations ensure the swift movement of goods, reducing delays and costs associated with long waiting times. This efficiency is crucial in a global economy where timely delivery is a critical competitive factor. Secondly, high port performance attracts more shipping lines and cargo, increasing revenue and economic growth for the surrounding region. Efficient ports also contribute to better supply chain management, as they are critical nodes in the logistics network. Furthermore, ports that consistently demonstrate high performance can invest in advanced technologies and infrastructure, further enhancing their competitiveness.

4.7.4 Technology

Table 4.11 presents the survey results for statements related to technology.

	Port-A							Port-B					
D4: Technology	**SD**	**D**	**N**	**A**	**SA**	**WS**		**SD**	**D**	**N**	**A**	**SA**	**WS**
	(%)	**(%)**	**(%)**	**(%)**	**(%)**			**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	
S4.01: The port has implemented state-of-the-	0%	0%	0%	0%	100%	**5.0**		0%	0%	0%	26%	74%	**4.7**

art technology systems for container tracking.												
S4.02: Automated systems are widely used for container handling and operations.	0%	0%	0%	14%	86%	**4.9**	0%	26%	26%	26%	22%	**3.4**
S4.03: The port utilises advanced digital platforms for communication and data exchange.	0%	0%	0%	7%	93%	**4.9**	0%	13%	35%	17%	35%	**3.7**
S4.04: Real-time tracking and monitoring of containers are effectively implemented at the port.	0%	0%	0%	7%	93%	**4.9**	0%	0%	30%	35%	35%	**4.0**
S4.05: The port's technology systems are well-integrated with global shipping and logistics networks.	0%	14%	29%	14%	43%	**3.9**	17%	22%	26%	30%	4%	**2.8**
S4.06: The port supports electronic data interchange (EDI) for efficient document handling.	0%	0%	18%	36%	46%	**4.3**	0%	22%	22%	22%	35%	**3.7**
S4.07:The adoption of modern technology has significantly improved operational efficiency.	0%	0%	0%	14%	86%	**4.9**	0%	0%	17%	17%	65%	**4.5**
S4.08: Technology has reduced the time required for container loading, unloading, and turnaround.	0%	0%	11%	14%	75%	**4.6**	0%	22%	22%	22%	35%	**3.7**
S4.09: The technological systems ensure high accuracy in container handling operations.	0%	0%	0%	18%	82%	**4.8**	0%	0%	26%	30%	43%	**4.2**
S4.10: The port's technology is reliable and seldom experiences significant downtimes or failures.	0%	0%	14%	29%	57%	**4.4**	0%	17%	26%	22%	35%	**3.7**
S4.11:The technology used at the port is user-friendly and easy to navigate.	0%	0%	11%	25%	64%	**4.5**	0%	17%	30%	35%	17%	**3.5**
S4.12: Staff training for new technologies is adequate and effective.	0%	0%	11%	36%	54%	**4.4**	0%	13%	22%	30%	35%	**3.9**
S4.13: The use of technology has resulted in cost savings for the port and its users.	7%	14%	18%	25%	36%	**3.7**	17%	13%	26%	26%	17%	**3.1**
S4.14: Investments in technology have shown a clear return on investment.	0%	11%	36%	14%	39%	**3.8**	13%	13%	30%	35%	9%	**3.1**

S4.15: Modern technology gives the port a competitive advantage in the industry.	0%	0%	0%	11%	89%	4.9		0%	0%	0%	13%	87%	4.9
S4.16: The port's technological advancements meet international shipping companies' expectations.	0%	0%	7%	21%	71%	4.6		0%	0%	0%	35%	65%	4.7
S4.17: Automation is effectively used in container handling and operations.	0%	0%	0%	18%	82%	4.8		0%	13%	26%	43%	17%	3.7

Table 4.11: Comparison of Survey Results – Technology

(SD-Strongly Disagree, D–Disagree, N–Neutral, A-Agree, SA-Strongly Agree, WS – Weighted Score)

Port-A excels in technology implementation, particularly in container tracking, automation, digital communication, and operational efficiency. It is highly rated across most technology aspects.

While also strong in certain areas like container tracking and meeting international expectations, Port-B shows room for improvement in automation, integration with global networks, and reliability of technology systems.

Technology is crucial in modern port operations, significantly enhancing efficiency, safety, and sustainability. Advanced technologies like automation, AI, and IoT enable ports to handle cargo more quickly and accurately, reducing ship turnaround times and improving overall supply chain efficiency (Hirata et al., 2022). Shipping digitalisation and automation for the intelligent port. The supply chain has recent advances and new perspectives in the industry 4.0 era. For instance, automated cranes and self-driving vehicles can move containers with precision and speed, while digital platforms facilitate seamless communication and real-time tracking of goods (Anwar et al., 2019). This technological integration boosts productivity and minimises human error, enhancing safety in an environment where even small mistakes can have significant consequences.

4.7.5 Sustainability

The survey results for sustainability-related statements are displayed in Table 4.12.

	Port-A							Port-B					
D5: Sustainability	**SD**	**D**	**N**	**A**	**SA**	**WS**		**SD**	**D**	**N**	**A**	**SA**	**WS**

	(%)	(%)	(%)	(%)	(%)			(%)	(%)	(%)	(%)	(%)	
S5.01: Technology has made the port's operations more environmentally sustainable.	0%	0%	29%	43%	29%	**4.0**		0%	17%	22%	22%	39%	**3.8**
S5.02: The port uses technology to monitor and reduce its environmental impact.	0%	0%	21%	50%	29%	**4.1**		0%	13%	35%	35%	17%	**3.6**
S5.03: The port implements eco-friendly practices in its container operations.	0%	0%	25%	43%	32%	**4.1**		0%	9%	17%	22%	52%	**4.2**

Table 4.12: Comparison of Survey Results – Sustainability

(SD-Strongly Disagree, D–Disagree, N–Neutral, A-Agree, SA-Strongly Agree, WS – Weighted Score)

Port-A is perceived as moderately successful in integrating technology for environmental sustainability and implementing eco-friendly practices, with weighted scores consistently above 4.0.

Port-B, while also viewed positively in these aspects, shows a slightly more varied response, particularly in using technology to monitor and reduce environmental impact. However, it scores slightly higher in implementing eco-friendly practices.

Sustainability is critical in port operations due to the significant environmental impact ports can have and the growing global emphasis on environmental stewardship. Ports, as pivotal hubs in global trade, are often associated with high levels of air and water pollution, noise, and habitat disruption (Lalla-Ruiz et al., 2019). By adopting sustainable practices, ports can mitigate these negative impacts. This includes implementing cleaner fuel technologies, reducing emissions from docked ships, and managing waste effectively. Sustainable practices also make ports more resilient to the effects of climate change, such as rising sea levels and extreme weather events, ensuring long-term operational viability. Furthermore, sustainable ports can meet the increasing regulatory requirements and societal expectations for environmental responsibility, enhancing their public image and community relations (Tang & Gekara, (2020), Lim et al., (2019)).

4.7.6 Competitiveness

Table 4.13 provides the survey results pertaining to competitiveness-related statements.

	Port-A		Port-B

D6: Competitiveness	SD	D	N	A	SA	WS		SD	D	N	A	SA	WS
	(%)	(%)	(%)	(%)	(%)			(%)	(%)	(%)	(%)	(%)	
D6.01: The port ranks favourably in global comparisons of container ports.	0%	0%	0%	18%	82%	4.8		17%	22%	26%	26%	9%	2.9
D6.02: The port has a strong and positive reputation in the international shipping community.	0%	0%	0%	14%	86%	4.9		13%	26%	39%	9%	13%	2.8
D6.03: The port demonstrates consistent growth in container throughput.	0%	0%	11%	25%	64%	4.5		0%	9%	13%	35%	43%	4.1
D6.04: The port's operational efficiency is on par with leading global container ports.	0%	0%	0%	18%	82%	4.8		17%	22%	26%	22%	13%	2.9
D6.05: The port has short waiting times and quick container turnaround.	0%	11%	18%	29%	43%	4.0		0%	0%	22%	43%	35%	4.1
D6.06: The port offers a wide range of services that meet the diverse needs of its users.	0%	0%	0%	14%	86%	4.9		0%	0%	17%	35%	48%	4.3
D6.07: The quality of services provided at the port is superior to that of competing ports.	0%	0%	28%	32%	40%	4.1		0%	0%	35%	43%	22%	3.9
D6.08: The port continuously invests in upgrading its infrastructure to stay competitive.	0%	0%	18%	36%	46%	4.3		0%	0%	35%	17%	48%	4.1
D6.09: The technological solutions at the port are innovative and industry-leading.	0%	0%	11%	36%	54%	4.4		0%	22%	35%	43%	0%	3.2
D6.10: The port's location is strategically advantageous for international shipping routes.	0%	0%	0%	21%	79%	4.8		0%	22%	13%	30%	35%	3.8
D6.11: Customers are generally satisfied with the services provided at the port.	0%	0%	0%	14%	86%	4.9		0%	0%	0%	17%	83%	4.8

Table 4.13: Comparison of Survey Results – Competitiveness

(SD-Strongly Disagree, D–Disagree, N–Neutral, A-Agree, SA-Strongly Agree, WS – Weighted Score)

Port-A excels in most aspects of competitiveness, particularly in global ranking, reputation, operational efficiency, range of services, and customer satisfaction. It is perceived as a

leading port with consistent growth and strategic investments in infrastructure and technology.

While competitive in specific areas like customer satisfaction and container turnaround times, Port-B shows room for improvement in global ranking, reputation, operational efficiency, and technological innovation. It maintains a good position in terms of service diversity and infrastructure investment.

Due to maritime trade's highly globalised and competitive nature, improving competitiveness is critical for ports. Ports are essential nodes in the global supply chain, and their ability to attract shipping lines and cargo directly impacts their success and profitability (Luo et al., 2022). A competitive port is also more likely to invest in advanced technologies and infrastructure, further enhancing its appeal to global shipping companies and traders. Moreover, a competitive port can significantly contribute to the economic development of its surrounding region by creating jobs, fostering trade, and attracting related industries. In an environment where shipping routes and alliances are constantly evolving, a port's competitiveness ensures its relevance and sustainability in the dynamic world of maritime trade (Kaliszewski et al., 2020)

4.8 Addressing Research Question 1

As stated in Chapter 1, the first research question to be addressed is:

RQ1: What are the underlying causes and key factors driving the need to enhance the competitiveness of UAE container ports, and how do these elements influence the strategic positioning of the UAE in the global maritime and logistics industry?

Through interviews and a survey, this research investigates the underlying causes and key factors driving the need to enhance the competitiveness of UAE container ports, specifically focusing on two major ports. Several critical themes emerge through detailed interviews and surveys with senior executives and stakeholders. One of the primary drivers for enhancing competitiveness is the need for substantial infrastructure investment, which includes expanding terminal capacities, deepening channels to accommodate larger vessels, and integrating advanced technologies like automation and AI. These measures aim to optimise operational efficiency, reduce vessel turnaround times, and provide superior

services to shipping lines and other supply chain stakeholders. The emphasis on these strategies highlights the importance of maintaining a competitive edge in global maritime, where regional rivals such as the Port of Salalah in Oman and Dammam Port in Saudi Arabia pose significant challenges.

Additionally, the interviews highlight the critical role of strategic partnerships, government support, and economic diversification in driving the ports' competitiveness. Both ports leveraged strategic alliances with global shipping companies and operators to enhance their international reach and container traffic volumes. Governmental support through favourable regulatory environments and financial assistance has enabled these ports to undertake significant infrastructure projects and expand their operations. The research also points to the impact of regional dynamics, such as shifts in trade policies and economic conditions, which necessitate continuous adaptation and strategic planning by port operators. These insights reveal a multifaceted approach to improving competitiveness, encompassing infrastructure development, strategic partnerships, technological advancements, and responsive operational strategies.

4.9 Summary and Conclusions

Using questionnaire surveys and interviews is invaluable in assessing the competitiveness of ports, as these methods provide a multifaceted view of operational strengths and areas needing improvement. Interviews, on the other hand, offer qualitative insights. Through detailed discussions with port managers, interviews can uncover more profound issues that surveys might not reveal, such as organisational challenges, technological adoption, or strategic planning insights. These conversations also provide context to the data collected through surveys, offering a more comprehensive understanding of the port's competitive position. Together, these tools enable a thorough assessment of a port's strengths and weaknesses.

One of the significant findings from the interviews is the emphasis on diversification and restructuring within Port A, which has experienced financial volatility due to expansion into new sectors and the consolidation of subsidiaries. On the other hand, Port B has focused on

employee growth, development, and well-being alongside mergers and acquisitions to drive growth and profitability. Both ports have adopted advanced technologies and infrastructure improvements to attract container traffic, but their approaches differ; Port A has a stronger focus on technological advancements and sustainability, while Port B emphasises brand recognition and alignment with national diversification agendas.

The survey results further highlight the strengths and areas for improvement in both ports. Port A excels in infrastructure, technology implementation, and operational efficiency, particularly in container tracking, automation, and digital communication. It is perceived as a leading port with consistent growth and strategic investments. In contrast, Port B, while competitive in areas such as customer satisfaction and container turnaround times, shows room for improvement in global ranking, reputation, and technological innovation. The focus on sustainability is evident in both ports, with Port A scoring consistently high in integrating technology for environmental sustainability and implementing eco-friendly practices, whereas Port B has slightly more varied responses but performs well in eco-friendly practices.

The above analysis revealed that UAE ports must continue to embark on a journey to enhance their competitiveness. A comprehensive and holistic framework is required to guide ports to achieve high competitiveness. This will fortify their position in the global maritime industry and contribute significantly to the economic growth of the UAE.

Chapter 5: Framework Repository for Enhancing Competitiveness of Container Ports

5.1 Introduction

The findings presented in Chapter 4 of this study emphasise the necessity for a comprehensive and holistic framework to enhance the competitiveness of container ports. However, as detailed in Chapter 2, an extensive literature review on smart ports reveals a noteworthy gap. There is a lack of a fully developed, comprehensive, and holistic framework that stakeholders in the port industry can reliably adopt. While numerous studies have investigated various frameworks, these primarily focus on identifying specific indices or characteristics related to smart ports rather than offering a complete, actionable framework.

Within this context, the work of D'Amico et al. (2021) stands out for its attempt to provide a more structured approach. Their research presents a high-level framework outlining the key domains essential to innovative port development and the interconnections between them. This framework is valuable for its clear description of the primary focus areas and their interrelationships, offering a high-level view of the intelligent port ecosystem. However, despite its merits, D'Amico et al.'s (2021) framework stops short of being a fully comprehensive guide. It lays down a crucial foundational structure but does not present practical steps and strategies necessary for implementation. Therefore, while it contributes significantly to the area of research, there is a need for a more detailed and step-by-step framework.

This chapter is, therefore, dedicated to designing and developing a *framework repository*. It is intended to encompass several frameworks, each designed to support smart ports' comprehensive and holistic design and operation.

5.2 Frameworks

Generally, a framework is a basic structure underlying a system or concept. In management and other disciplines, a framework is a set of guidelines, tools, or models that provide a structured approach to understanding complex issues, solving problems, or implementing strategies (Budler & Trkman, 2023). Frameworks are designed to help users systematically

approach a topic, often breaking down more significant issues into more manageable components. Key characteristics of a framework include:

***Structure*:** Frameworks provide an organised way of thinking about and analysing specific problems or tasks. This structure often includes a set of principles, stages, or components that guide the user through a process.

Flexibility: While offering structure, frameworks are typically adaptable to different situations or contexts. They provide a general guideline but can be customised based on specific needs or challenges (Rogers & Salas, 1999).

Guidance: Frameworks guide thinking and action. They help users focus on the most critical aspects of a problem or task and provide a pathway for analysis or implementation.

Efficiency: By providing a tried and tested structure, frameworks can make problem-solving or planning more efficient. They allow users to leverage existing knowledge and methodologies instead of starting from scratch.

Standardisation: Frameworks can standardise processes across an organisation or industry, ensuring consistency and making comparing and benchmarking performance easier (Edwin, 2014).

Learning and Communication: They facilitate learning and communication by providing a common language and approach to discussing and tackling issues (Schneider-Marin & Abualdenien, 2019)

5.3 Development of the framework

Both deductive and inductive approaches were used to generate the framework. Figure 5.1 shows how these two approaches were used to generate the framework.

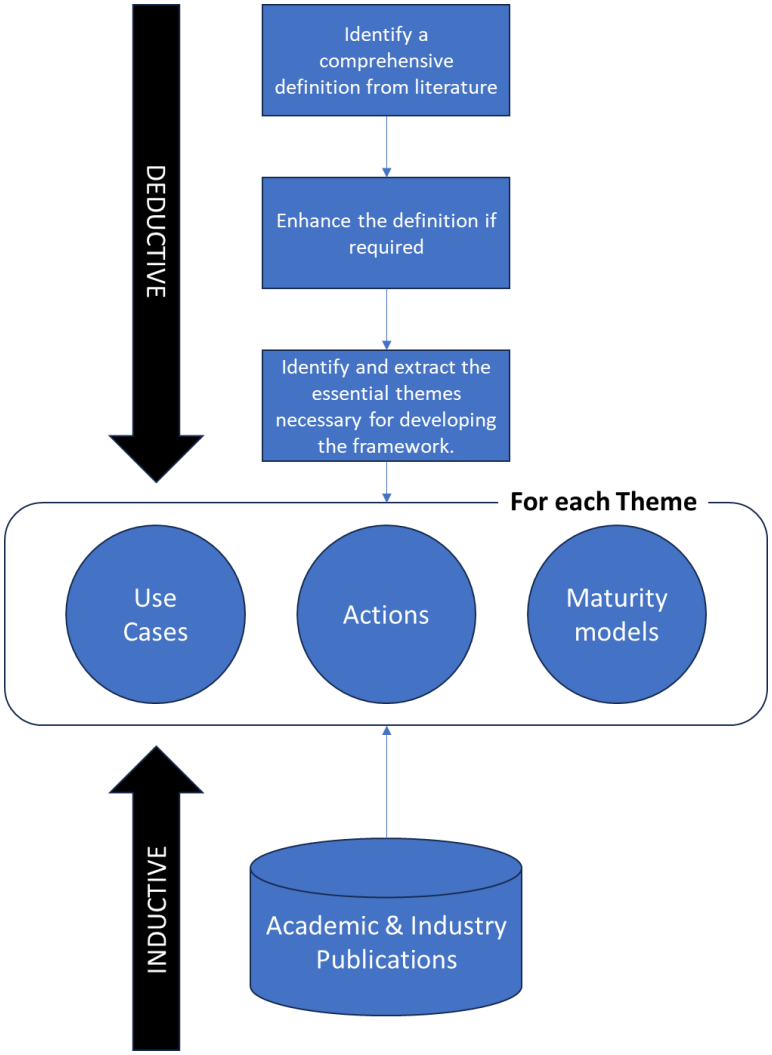

Figure 5.1: Generating use cases, actions, and maturity models using deductive and inductive processes.

In the deductive phase, the process began by identifying a broad definition, which was then refined and expanded to ensure comprehensiveness. This enhanced definition was meticulously analysed to extract the key themes of the framework. Subsequently, an extensive range of academic and industry publications was employed to inductively generate practical use cases, specific actions, and detailed maturity models.

5.3 Enhancing the definition of smart ports

As presented in Section 2.13, a blend of interviews with stakeholders and a review of 70 academic publications, Belmoukari et al. (2023) produced an inclusive definition.

"The smart port is a connected, sustainable, safe and automated port, which relies on smart infrastructure and equipment, skilled personnel and smart managerial practices, to ensure customer satisfaction, environmental protection and a better quality of life for the citizen."

As shown in Figure 5.2, this definition can be dissected to identify a range of frameworks necessary to design and operate smart ports.

Figure 5.2: Smart port definition by Belmoukari et al. (2023) and potential themes for

Further review of the literature on smart ports revealed that the above definition has not captured other critical imperatives.

Regulatory and compliance ensure that smart ports operate within legal boundaries and adhere to international standards, which are crucial for maintaining safety, security, and environmental integrity. Additionally, given the global nature of shipping and trade, compliance with international maritime laws and trade regulations is vital to facilitate smooth cross-border operations (Ignaccolo et al., 2020). Thus, regulatory and compliance frameworks provide a structured approach to managing these diverse and critical aspects (Saruchera, 2020).

Stakeholder engagement is imperative in smart port operations as it ensures the alignment of the port's activities with the interests and needs of all parties involved. This includes local

communities, government bodies, shipping companies, and environmental groups (Ashrafi et al., 2020). Engaging stakeholders allows for sharing insights and feedback, crucial for addressing concerns, fostering collaboration, and building trust. It also helps navigate regulatory landscapes and environmental considerations (Osobajo et al., 2021). Effective stakeholder engagement leads to more sustainable and community-friendly port operations.

Innovation and research are critical in smart port operations as they drive the continuous improvement and modernisation essential for meeting the evolving demands of global trade (Koukaki & Tei,2020). With the rapid advancement of technologies like AI, IoT, and automation, research and innovation enable ports to enhance efficiency, reduce operational costs, and increase throughput. By staying at the forefront of technological and operational advancements, smart ports can maintain competitiveness, adapt to changing market dynamics, and offer better services to their users, thereby securing their position as critical nodes in the global supply chain.

By considering the above three imperatives, this research proposes an enhanced definition for intelligent ports.

> *The smart port is a connected, sustainable, safe, and automated port which relies on smart infrastructure and equipment, skilled personnel, and smart managerial practices to ensure customer satisfaction, environmental protection, and a better quality of life for the citizens while adhering to stringent regulatory standards, actively engaging with diverse stakeholders, and fostering a culture of continuous research and innovation.*

This definition extended the number of frameworks by one (1) as the customers and citizens are included in the stakeholder category (Figure 5.3).

Figure 5.3: Enhanced definition for smart ports and related frameworks

The proposed Smart Port Framework Repository (SaPFaR) is shown in Figure 5.4.

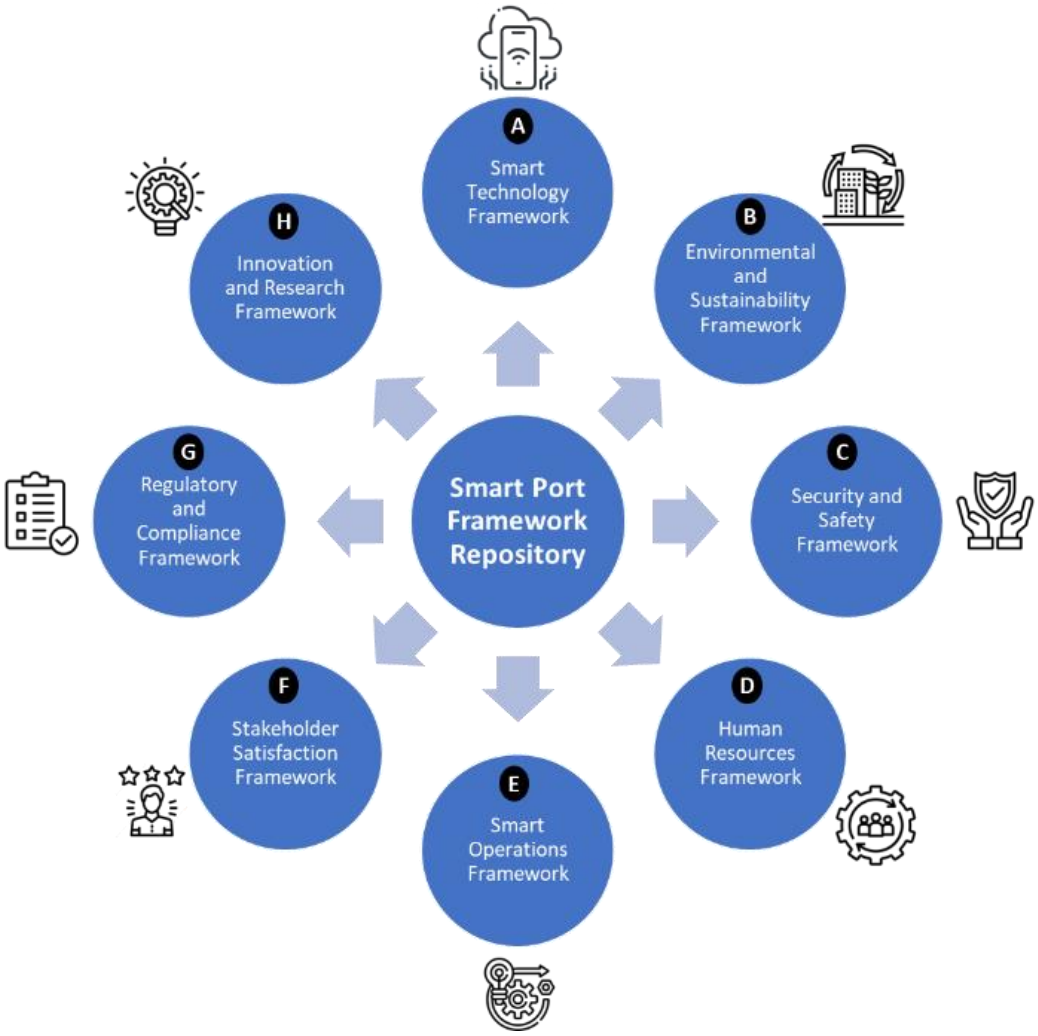

Figure 5.4: Smart Port Framework Repository (SaPFaR)

Having developed the foundational structure of the framework repository, the next crucial step involves detailing each node within this repository. This detailed explanation is vital to assist port operators in identifying the most effective practices and strategies tailored to their needs. Moreover, it is essential to construct a maturity model for each node. Such a model will serve as a guide for port operators, enabling them to consistently identify areas for improvement and implement necessary measures to enhance the efficiency and effectiveness of port operations (Khoshgoftar & Osman, 2009).

In the following section, each node is expanded to provide further insights and guidance.

5.3 Smart Technology Framework

Smart technologies are the cornerstone of developing and operating smart ports because they significantly enhance efficiency, safety, and sustainability (Yang et al., 2018). These technologies enable real-time monitoring and data analysis, leading to optimised cargo handling and streamlined logistics (Bouhlal et al., 2022). They also play a crucial role in predictive maintenance, reducing downtime and extending the lifespan of port infrastructure (Vlasov et al., 2018). Furthermore, smart technologies contribute to environmental sustainability by reducing carbon emissions and improving energy management (Nižetić et al., 2019). Smart technologies are, therefore, at the heart of smart ports.

When evaluating smart technologies, it is essential to regard Industry 4.0 as the foremost framework (Salkin et al., 2018). This perspective is crucial because Industry 4.0 encapsulates a comprehensive range of modern technological innovations. Nonetheless, the existing literature on the application of Industry 4.0 in smart ports has not sufficiently highlighted the comprehensive value of the Industry 4.0 framework. Instead, they concentrate on the individual technologies within this framework (de la Peña Zarzuela et al., 2020; Min, 2022). Therefore, the research suggests that the Industry 4.0 framework (Figure 5.5) should be the cornerstone of smart ports.

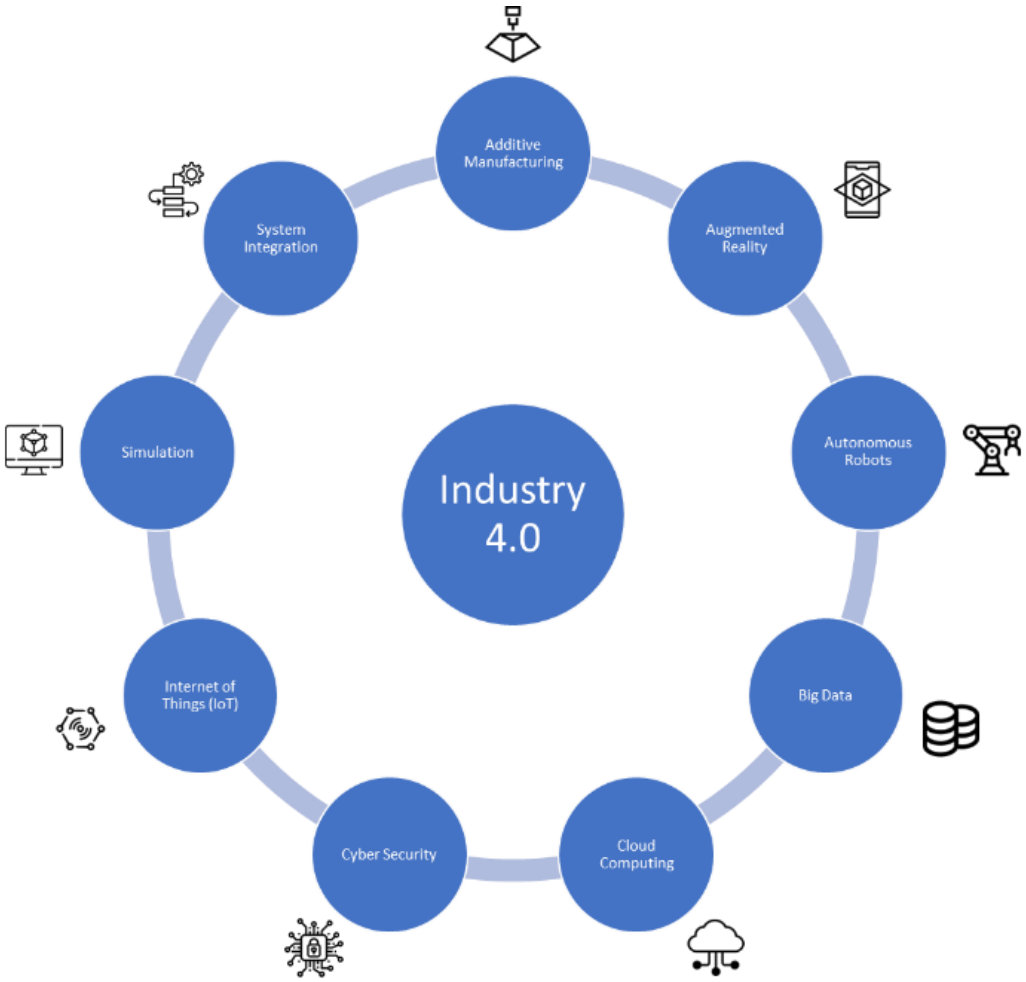

Figure 5.5 Industry 4.0 Framework (Author, developed using technologies identified by Salkin et el., 2018)

Although the origins of Industry 4.0 relate to the manufacturing industry, it has been adapted in many other sectors, for example, the service sector (Sony et al., 2021) and healthcare (da Silveira et al., 2019). When the adaptation of Industry 4.0 is considered for smart ports, a collection of ***use cases*** for each smart technology adds immense value. For example, Zhang et al. (2018) cite a range of use cases to stress the potential applications of blockchain technology in healthcare. Therefore, the following sections present a selection of use cases for each Industry 4.0 technology, enabling port operators to identify potential applications.

5.3.1 Additive Manufacturing – Use Cases

Additive manufacturing, commonly known as 3D printing, allows for the direct fabrication of objects from digital models, enabling rapid prototyping, reducing material waste, and offering significant flexibility in design. It also enables on-demand production, leading to

shorter lead times and reduced inventory costs. Table 5.1 presents use cases of additive manufacturing in smart ports (Moshiri et al., 2020; Ribeiro Cunha et al., 2023).

	Additive Manufacturing Use Cases
Use Case	Details
Spare Parts Production	One of the most immediate applications is the on-demand production of spare parts for machinery and equipment. This reduces the need for extensive inventories and allows quick parts replacement, minimising downtime.
Customised Tools and Equipment	Additive manufacturing enables the creation of customised tools and equipment tailored to specific tasks or machinery in the port. This can lead to more efficient operations and help address unique challenges that standard tools may not solve.
Repair and Maintenance	Additive manufacturing can be used for the repair of components and equipment. Techniques like 3D metal printing can refurbish parts, extending their service life and reducing the need for complete replacements.

Table 5.1: Additive Manufacturing – Use Cases

5.3.2 Augmented Reality – Use Cases

The main benefit of Augmented Reality (AR) is its ability to enhance the real world by overlaying digital information, thereby enriching user experience and interaction. Table 5.2 presents potential use cases of AR (Sakar & Surucu, 2018; Wang et al., 2021).

	Augmented Reality Use Cases
Use Case	Details
Enhanced Visualisation	AR can provide real-time data overlays on physical objects in the port. This can include information about cargo content, destination, handling instructions, and more, making it easier for workers to manage and process shipments efficiently.
Training and Safety	AR can be used for training, allowing new workers to experience realistic scenarios in a controlled, virtual environment. This can improve safety by preparing them for real-world situations without the associated risks.
Maintenance and Repairs	AR can assist maintenance staff by directly overlaying repair instructions and diagrams onto the equipment needing service. This can speed up repair times and reduce errors, minimising equipment downtime.
Navigation and Logistics	In extensive port facilities, AR can help guide workers to specific locations and help them navigate through the complex layout. It can also optimise the movement of goods by providing the best routes for transportation within the port.
Remote Assistance	Experts located remotely can use AR to provide real-time assistance and guidance to workers on the ground. This can be particularly useful for complex tasks or when specialised knowledge is required.

Environmental Monitoring	AR can display real-time environmental data, such as air and water quality, which is crucial for ports adhering to environmental regulations and sustainability goals.
Emergency Response	In emergencies, AR can provide vital information to responders, like the quickest routes to an incident, the location of hazardous materials, and the nearest emergency equipment.
Customer Interaction	AR can offer an interactive experience for clients visiting the port, providing them insights into the port operations, cargo tracking, and other relevant information.

Table 5.2: Augmented Reality – Use Cases

5.3.3 Autonomous Robots – Use Cases

The main benefit of autonomous robots is their ability to operate independently, without human intervention, which significantly enhances efficiency, safety, and productivity in various applications. These robots can perform repetitive, dangerous, or complex tasks with high precision and consistency, reducing the risk of human error and injury, especially in hazardous environments. Table 5.3 shows vital use cases (Topping, 2023; Min, 2022).

	Autonomous Robots Use Cases
Use Case	**Details**
Container Handling and Movement	Autonomous robots, often automated guided vehicles (AGVs) or autonomous straddle carriers, transport containers within the port. They can move containers between ships, storage areas, and transportation links more efficiently and with less human intervention.
Loading and Unloading Ships	Autonomous robotic cranes can load and unload containers from ships. These cranes often have advanced sensors and AI algorithms to optimise their movements and handle containers safely and efficiently.
Inspection and Maintenance	Robots equipped with cameras and sensors can inspect infrastructure and equipment for maintenance needs. They can access hard-to-reach areas and provide detailed, real-time data to maintenance teams.
Surveillance and Security	Autonomous drones and underwater robots can monitor the port's perimeter and inspect underwater infrastructure. This enhances security and safety within the port area.
Inventory Management and Tracking	Robots integrated with RFID and GPS technology can assist in tracking containers and inventory within the port. This improves the accuracy of inventory management and reduces the chances of lost or misplaced items.
Environmental Monitoring	Autonomous robots can also be used for environmental monitoring, such as checking water quality or detecting spills. This is crucial for maintaining sustainability standards in port operations.
Rescue and Emergency Response	In emergencies, such as fires or accidents, specialised robots can be deployed for rescue operations or to handle hazardous materials, minimising the risk to human life.

Customs and Border Protection	Robots can assist in scanning and inspecting containers for customs and border protection purposes, speeding up the process while ensuring compliance with regulations.

Table 5.3: Autonomous Robots – Use Cases

5.3.4 Big Data – Use Cases

The main benefit of big data lies in its immense potential to provide deep insights and informed decision-making across various sectors. By analysing large and complex data sets, big data enables organisations to identify patterns, trends, and correlations that would otherwise be invisible. Table 5.4 lists use cases of Big Data within the context of smart port operations (Lee et al., 2022; Rajabi et al., 2018).

	Big Data Use Cases
Use Case	**Details**
Optimising Operations	Big Data analytics can process vast amounts of data from various sources like cargo handling, vessel movements, and weather conditions. This information helps optimise port operations, reduce turnaround times, and improve efficiency.
Predictive Maintenance	By analysing data from sensors on equipment and infrastructure, ports can predict when maintenance is needed, reducing downtime and extending the life of their assets.
Enhanced Security	Big Data tools can analyse patterns and detect anomalies in port operations, which helps in enhancing security measures against potential threats or illegal activities.
Traffic Management	Big Data can manage and streamline vessel traffic, reducing congestion and improving the turnaround time of ships.
Environmental Monitoring	Smart ports use Big Data to monitor environmental factors like air and water quality. This helps in minimising the environmental impact of port activities.
Energy Management	Big Data enables better monitoring and management of energy usage, helping ports to reduce their carbon footprint and operate more sustainably.
Customer Service Improvement	Analysing data from various touchpoints, ports can improve their services and tailor them to the specific needs of their customers.
Real-time Decision Making	With real-time data analysis, port operators can make informed decisions quickly, adapting to changing conditions and demands.
Collaboration and Integration	Big Data facilitates better collaboration between stakeholders in the port ecosystem, leading to more integrated and cohesive operations.

Table 5.4: Big Data – Use Cases

5.3.5 Cloud Computing – Use Cases

The main benefit of cloud computing is its ability to provide scalable, flexible, and cost-effective access to computing resources and data storage without substantial upfront

investment in hardware and infrastructure. Table 5.5 presents potential use cases for smart ports (Heilig & Voß, 2016; Yau et al., 2020).

	Cloud Computing Use Cases
Use Case	**Description**
Data Management and Analysis	Smart ports generate vast amounts of data from various sources, such as cargo handling, vessel movements, logistics, and environmental sensors. Cloud computing provides the necessary infrastructure to store, manage, and analyse this data efficiently. This enables port authorities and operators to make informed decisions based on real-time data analysis.
Enhanced Operational Efficiency	Cloud computing allows for integrating various port operations, leading to improved efficiency. Processes like cargo handling, logistics management, and vessel traffic services can be optimised using cloud-based solutions, reducing turnaround times and increasing throughput.
Scalability and Flexibility	Cloud computing offers scalable solutions that can adapt to the changing needs of a port. As the volume of cargo and the size of vessels increase, cloud solutions can be scaled up to meet these demands without significant infrastructure investments.
Improved Collaboration and Communication	Cloud platforms facilitate better collaboration between different stakeholders in the port ecosystem, including shipping companies, logistics providers, customs, and port authorities. This improved communication leads to more efficient operations and better coordination.
Cost-Effectiveness	Ports can reduce their capital expenditure on IT infrastructure by using cloud services. Cloud solutions often operate on a pay-as-you-go model, which can be more cost-effective than maintaining in-house IT systems.
Enhanced Security and Compliance	Cloud providers typically offer advanced security features that can help protect sensitive data related to port operations. Additionally, cloud solutions can help ports comply with various international regulations and standards by providing necessary tools and frameworks.
Innovation and Future-Proofing	Cloud platforms can easily integrate with emerging technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain. This integration paves the way for innovative solutions in port operations and ensures that ports remain competitive and efficient despite technological advancements.

Table 5.5: Cloud Computing – Use Cases

5.3.6 Cyber Security – Use Cases

Cybersecurity in smart ports is crucial due to the increasing reliance on digital technologies and automation in port operations. Smart ports, which integrate advanced technologies such as IoT (Internet of Things), AI (Artificial Intelligence), and big data analytics, are

particularly vulnerable to cyber threats. Use Cases for cyber security are presented in Table 5.6 (Ahokas et al., 2017; de la Peña Zarzuelo, 2021).

	Cyber Security Use Cases
Use Case	**Details**
Protection of Operational Technology (OT) Systems	Smart ports rely heavily on OT systems to control and monitor physical processes. Cybersecurity measures are essential to protect these systems from attacks that could disrupt port operations.
Securing Data Communication	As smart ports involve extensive data exchange between ships, port authorities, logistics companies, and other stakeholders, ensuring the security of these communications is vital to prevent data breaches and espionage.
Supply Chain Security	Ports are critical nodes in global supply chains. Cybersecurity measures help safeguard the integrity of supply chain information and prevent disruptions caused by cyber-attacks.
Preventing Unauthorized Access	Implementing robust access control systems is crucial to prevent unauthorised access to critical port infrastructure and information systems.
IoT Device Security	Smart ports use many IoT devices for various functions, such as monitoring, tracking, and automation. Securing these devices is essential to prevent them from becoming entry points for cyber attacks.
Compliance and Regulatory Requirements	Ports often need to comply with national and international cybersecurity regulations. Implementing cybersecurity measures helps in meeting these regulatory requirements.
Incident Response and Recovery:	Developing and maintaining effective incident response and recovery plans is a crucial cybersecurity use case, ensuring that ports can quickly respond to and recover from cyber incidents.
Integration with National and Global Cybersecurity Initiatives	Ports, being critical infrastructure, need to align their cybersecurity practices with broader national and international cybersecurity strategies and frameworks.
Real-time Monitoring and Threat Detection	Implementing systems for real-time monitoring and threat detection helps identify and mitigate cyber threats promptly.
Protecting Against Ransomware and Malware	Ports are attractive targets for ransomware and other malware attacks. Robust cybersecurity measures are required to protect against such threats.
Securing Automated and Autonomous Systems	As ports adopt more automated and autonomous systems, ensuring the security of these systems becomes a critical cybersecurity concern.
Vendor Risk Management	Managing the cybersecurity risks associated with third-party vendors and service providers is important to a smart port's overall cybersecurity strategy.

Table 5.6: Cyber Security – Use Cases

5.3.7 – Simulation -Use Cases

The main benefit of simulation lies in its ability to model complex systems and scenarios, allowing for experimentation and analysis without the risks and costs associated with real-world testing. By creating virtual replicas of processes, environments, or products, simulations enable individuals and organisations to gain insights into behaviour under various conditions, test hypotheses, and make predictions. Table 5.7 lists potential use cases in smart ports (Lakhmas & Sedqui, 2020).

	Simulation Use Cases
Use Case	**Details**
Traffic Management and Logistics Optimisation	Simulations can model the movement of ships, trucks, and cargo within the port. This helps optimise routes, reduce congestion, and improve overall logistics efficiency.
Capacity Planning and Infrastructure Development	Port authorities can better understand how to expand or modify infrastructure to meet future demands by simulating different scenarios.
Safety and Security	Simulations can be used to train staff in emergency procedures and test the effectiveness of security measures. They can also predict the impacts of various security threats.
Environmental Impact Assessment	Smart ports can use simulations to assess the environmental impact of their operations, including air and water pollution, and develop strategies to minimise these impacts.
Energy Management	Simulating energy use can help optimise the energy consumption of port operations, including using renewable energy sources.
Automation and Robotics	Simulation is crucial for testing and implementing automated systems, such as automated guided vehicles (AGVs) and robotic cranes, ensuring they integrate smoothly into port operations.
Training and Skill Development	Virtual simulations provide a risk-free environment for training port staff in various operations, enhancing their skills without disrupting actual port activities.
Disaster Preparedness and Response	Simulating disaster scenarios (like oil spills, fires, or extreme weather events) helps plan and prepare for effective emergency responses.
Supply Chain Integration	Simulation can be used to understand and optimise the port's role within broader supply chains, ensuring efficient integration with inland transportation and logistics networks.
Predictive Maintenance	By simulating equipment operations, ports can predict when maintenance is needed, reducing downtime and extending the life of their assets.
Stakeholder Engagement and Policy Development	Simulations can help visualise proposed changes and engage with stakeholders, including local communities and regulatory bodies, for policy development and consensus building.
Research and Development	Simulations provide a cost-effective and low-risk environment for testing new technologies or operational strategies.

Table 5.7: Simulation – Use Cases

5.3.8 – System Integration - Use Cases

There is only one use case for this technology, i.e., ***integration***. System integration is critical in smart port operations due to modern port activities' complex and interconnected nature. System integration enables a more cohesive and efficient operation by seamlessly connecting various technologies and systems, such as cargo handling equipment, traffic management tools, security systems, and data analytics platforms. The integration of systems ensures that ports can respond swiftly to changing conditions, maintain a competitive edge, and meet the increasing demands of global trade (Jović et al., 2019; Morgan et al., 2021).

5.3.9 Comprehensive and Holistic Use Cases – Industry 4.0 and Smart Ports

The preceding analysis methodically examined use cases associated with eight (8) distinct smart technologies offered by Industry 4.0. This approach is unique in its breadth and depth, as no other research has compiled such an inclusive and collective viewpoint on this topic to date. The analysis stands out for its comprehensive coverage and holistic understanding of the applications and implications of Industry 4.0 technologies. Doing so significantly contributes to the existing body of knowledge, filling a gap in research that had not been addressed before.

This collection of use cases is beneficial for ports that aim to embark on a smart port development journey.

5.3.10 Towards Digital Twins

The ever-increasing use of smart technologies in smart ports enables port operators to explore the use of digital twins, further enhancing automation. A digital twin is a virtual model designed to reflect a physical object, system, or process accurately. This concept is widely used in various industries for simulation, analysis, and control.

However, the implementation of digital twins in smart ports is not without challenges (Wang et al., 2021). The high initial investment in technology and infrastructure can be a significant barrier, especially for smaller ports. Additionally, the complexity of integrating various systems and ensuring data accuracy and security poses considerable challenges. There is also the need for skilled personnel to manage and interpret the vast amount of data generated. Despite these challenges, the potential benefits of digital twins in enhancing the

efficiency and sustainability of smart ports make them invaluable tools in the future of maritime logistics (Lind et al., 2020; Yao et al., 2021).

5.3.11 Maturity Model for Industry 4.0 Technologies in Smart Ports

Maturity models are frameworks used by organisations to assess, evaluate, and improve their processes, systems, or skills (Khoshgoftar & Osman, 2009) . These models typically consist of a series of levels representing how well the activities in a particular area are managed.

Alshamsi (2022) thoroughly examines various maturity models applicable to Industry 4.0 implementations, presenting a comprehensive analysis of these frameworks. Among the models evaluated, the VDMA IMPULS model is highlighted as the most comprehensive and detailed maturity model for Industry 4.0 applications. Alshamsi (2022) discusses this model in depth and introduces a simplified adaptation of the VDMA maturity model. This adapted version is particularly useful for its compatibility and relevance to the context of smart ports, demonstrating its practical applicability in this specific sector. Therefore, it is proposed that Alshamsi's (2022) model be adapted for this work (Figure 5.6).

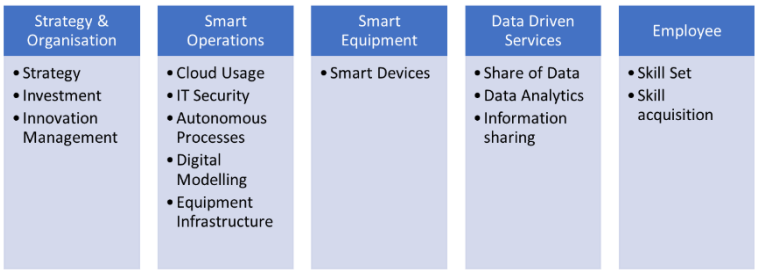

Figure 5.6: Dimensions and Sub-Dimensions of Alshamsi's (2022) Maturity Model (Alshamsi, 2022))

Alashamsi (2022)provides a detailed breakdown of sub-dimensions for four (4) levels of maturity: Beginner, Intermediate, Experienced and Expert. The tables below present modified maturity models for each dimension. Most entries remain largely intact, but changes (highlighted in bold) were made to show that these tables are for smart ports instead of the emergency management domain (Tables 5.8, 5.9, 5.10,5.11, 5.12 and Figure 5.7).

Dimension: **Strategy and Organisation**				
Sub-Dimensions	**Level 1 (Beginner)**	**Level 2 (Intermediate)**	**Level 3 (Experienced)**	**Level 4 (Expert)**
Strategy (to recognise Industry 4.0 as a critical technology platform)	Industry 4.0 is recognised by individuals or by departments but is not an integral element of the strategy	Industry 4.0 is included in the strategy, but stakeholders are not aware of the strategy	Industry 4.0 is included in the strategy and is widely communicated to stakeholders	Industry 4.0 is recognised as a core technology, and senior executives take responsibility for leading the implementation
Investments (on Industry 4.0 technologies)	Limited investments in a specific area	Investments in a few areas but lack a coherent approach	Investments in many areas but lack a clear strategy	A clear investment strategy is in place, and it is communicated
Innovation Management (to develop innovative applications of Industry 4.0)	There is no culture of innovation management	Innovation is encouraged at the department level	Innovation is encouraged at all levels, but there is no clear strategy	An explicit innovation strategy is in place, and it is actively encouraged at all levels

Table 5.8: Strategy and Organisation Dimension (, Alshasmsi, 2022)

Dimension: **Smart Operations**				
Sub-Dimensions	**Level 1 (Beginner)**	**Level 2 (Intermediate)**	**Level 3 (Experienced)**	**Level 4 (Expert)**
Cloud Usage (use of Cloud Computing)	Ad hoc use of Cloud Computing and limited awareness	Opportunistic use of Cloud Computing driven by the vendors	A systematic approach to using Cloud Computing is in place.	Cloud Computing is a strategic priority and is well-understood by all stakeholders.
IT Security	No coherent strategy and the use of traditional IT security methods	Strategy is based on traditional IT security methods	Mix use of traditional methods and blockchain technology	Blockchain as the primary cyber security approach
Autonomous Processes (Includes Equipment infrastructure)	Limited awareness of autonomous technologies and ad hoc use of autonomous processes and equipment **in smart ports**	Department-level awareness of applications in their areas	Awareness across stakeholders involved **in smart port** but disparate applications	Strategy to embed autonomous technologies and ensure connected systems and applications
Digital Modelling	No use of digital modelling.	Ad hoc use of digital modelling	Digital modelling as a core competency	Digital modelling as a strategic tool and embodiment of the

			across **smart port** operations	digital twins concept
IT Systems	Bespoke IT systems for local processes with little or no integration	Islands of automated systems	Corporate-level IT systems integrated with essential bespoke systems	Cloud-enabled fully integrated systems with Edge Computing capabilities for fast responses

Table 5.9: Smart Operation Dimensions (Alshamsi, 2022)

Dimension: **Smart Equipment**				
Sub-Dimensions	**Level 1** (Beginner)	**Level 2** (Intermediate)	**Level 3** (Experienced)	**Level 4** (Expert)
Smart Devices (Use of smart devices)	Smart devices are used but are not connected to other systems	Smart devices are used and partly connected with other systems.	Smart devices are used and fully integrated with other systems, but the integration is limited to the exchange of information	Smart devices are used and integrated with other systems, and the integration ensures the optimal use.

Table 5.10: Smart Equipment (After Alshamsi 2022)

Dimension: **Data-Driven Services**				
Sub-Dimensions	**Level 1** (Beginner)	**Level 2** (Intermediate)	**Level 3** (Experienced)	**Level 4** (Expert)
Data-driven services	Data is collected but not used to improve **smart port operations and services.**	Ad hoc use of data to **smart port operations and services.**	Data is identified as a strategic asset and used to improve services	Data-driver services are a strategic priority
Data analytics in **smart port operations**	Descriptive analysis to provide insights into **past performance**	Descriptive and diagnostics analysis of **past performance**	Predictive analytics to assess **future performance**	Predictive analytics as a strategic tool in **smart port management**
Information Sharing	Information sharing in a few selected areas	Information sharing with trusted stakeholders and partners	Information sharing with all stakeholders and partners but limited to non-sensitive information	Information sharing involving both sensitive and non-sensitive data using cloud and blockchain technologies

Table 5.11: Data-Driven Services Dimensions (Alshamsi, 2022)

Dimension: Employees				
Sub-Dimensions	**Level 1** (Beginner)	**Level 2** (Intermediate)	**Level 3** (Experienced)	**Level 4** (Expert)
Employee skill sets	Little understanding of digital technologies	Digital technology skills in technology-focused areas	Digital technology and analytics skills across all areas	Deep knowledge of digital technologies and analytics
Skill acquisition	Self-learning on Industry 4.0 technologies	Organised events in local areas on Industry 4.0 technologies	Corporate-level training for Industry 4.0	Strategy to develop Industry 4.0 technology competencies in all relevant areas

Table 5.12: Employee Dimensions (, After Alshamsi 2022)

The above tables are integral parts of the SaPFaR framework in relation to the adaptation of Industry 4.0 in smart port operations.

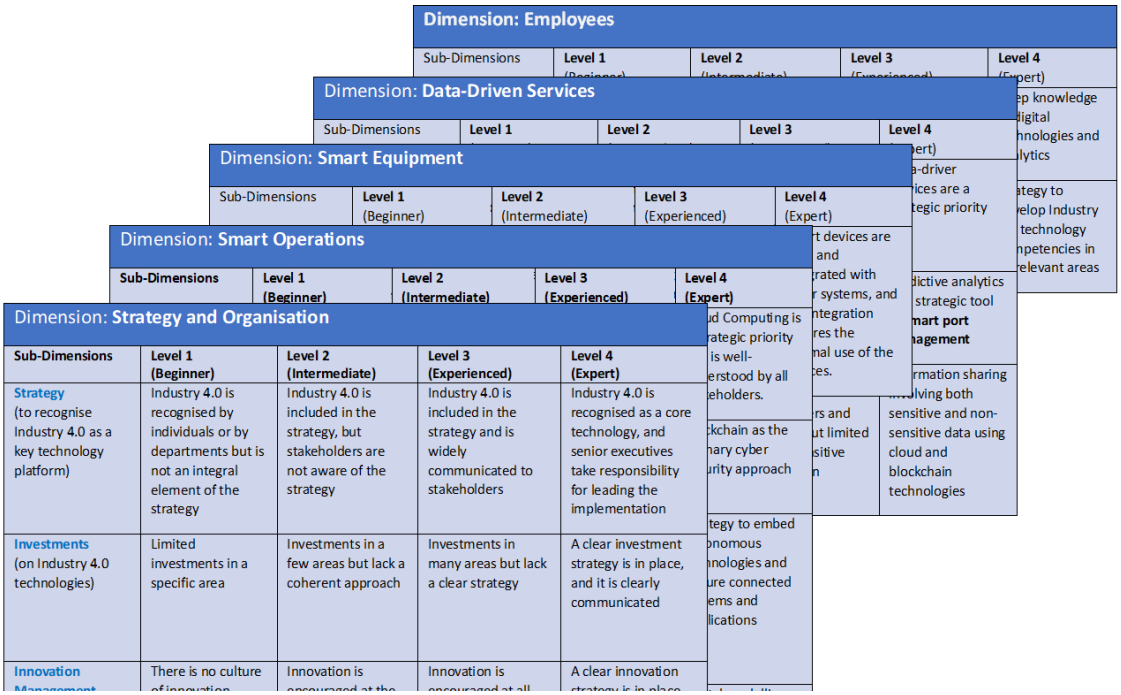

Figure 5.7: Maturity Model for Industry 4.0 in Smart Ports

5.3.12 Summary of Smart Technology Framework

Section 5.3 of the document offers extensive use case examples for various technologies specifically tailored to enhance smart port operations. This section presents a unique effort to assemble a detailed and all-encompassing perspective of use cases applicable to Industry 4.0 technologies within this context. It represents the first instance where such a comprehensive approach has been undertaken to systematically outline the potential

applications of these technologies in smart port environments. Additionally, the section introduces a modified version of Alashamsi's (2022) maturity model. This adaptation was developed, incorporating slight changes to better align with the specific requirements of smart port operations. Together, these elements form a robust and holistic framework designed to seamlessly integrate Industry 4.0 into the operations of smart ports, thereby optimising their efficiency and effectiveness.

5.4 Developing frameworks and maturity models for remaining areas of SaPFaR Framework Repository

Section 5.3 and its sub-sections provide a detailed description of the development of a smart technology framework. As smart technologies form the foundation of smart ports a such detailed analysis is required.

Two building blocks are developed for each of the remaining repository frameworks.

(a) **key domains and actions** required to implement the framework. These domains represent the critical areas or components within the framework essential for achieving its objectives. For each domain, specific actions must be planned and executed.

(b) **Maturity model,** which allows ports to assess their current stage in the innovation journey and plan their progression towards becoming a fully integrated, efficient, and sustainable smart port. It emphasises the importance of gradual development, from initial awareness and strategy formulation to full-scale implementation and industry leadership.

5.5 Environmental and Sustainability Framework

Implementing an environmental and sustainability framework in smart port operations is critical for balancing economic growth and ecological preservation. A practical framework ensures that smart ports operate with minimal environmental footprint, reducing emissions, managing waste effectively, and conserving natural resources. It also promotes sustainable practices like green energy usage and eco-friendly infrastructure development. This helps mitigate the adverse effects of climate change and aligns port operations with global sustainability goals. Moreover, such a framework can enhance the port's reputation, making it more attractive to eco-conscious stakeholders and customers, fostering a new era of responsible and sustainable maritime commerce (Tan et al., 2018; Molavi et al., 2020; D'Amico et al., 2021; Othman et al., 2022). Table 5.13 and Table 5.14 show domain actions and characteristics of the maturity model respectively.

Domain	Actions
1. Vision and Objectives	**Define Vision:** Articulate a clear vision for environmental sustainability in the context of smart port operations. **Set Objectives:** Establish specific, measurable, achievable, relevant, and time-bound (SMART) objectives for environmental performance and sustainability.
2. Stakeholder Engagement	**Identify Stakeholders:** Port authorities, shipping companies, local communities, environmental groups, and government agencies. **Engagement Strategies:** Develop strategies for regular communication, consultation, and collaboration with stakeholders.
3. Environmental Assessment	**Baseline Study:** Conduct an environmental impact assessment to understand the current state. **Continuous Monitoring:** Implement systems for ongoing monitoring of environmental indicators.
4. Sustainability Pillars	**Emission Reduction:** Strategies for reducing greenhouse gas emissions, including using renewable energy sources. **Waste Management:** Implement waste reduction, recycling, and responsible disposal practices. **Water Management:** Ensure efficient use of water resources and prevent water pollution. **Biodiversity Conservation:** Protect local ecosystems and marine biodiversity.
5. Technology and Innovation	**Smart Technologies:** Leverage IoT, AI, and other smart technologies for efficient resource management and environmental monitoring. **Innovation Incubation:** Encourage the development and testing of new sustainable technologies.
6. Regulatory Compliance and Standards	**Legal Framework:** Ensure compliance with national and international environmental regulations. **Adopt Standards:** Embrace international standards like ISO 14001 for environmental management.
7. Sustainability Reporting and Transparency	**Reporting Mechanism:** Develop a system for regular reporting on environmental performance. **Transparency:** Maintain transparency in operations and environmental initiatives.
8. Training and Capacity Building	**Employee Training:** Regular training programs for staff on environmental practices and sustainability. **Community Education:** Engage with local communities to raise awareness about environmental issues.
9. Risk Management	**Identify Risks:** Assess environmental risks associated with port operations. **Mitigation Strategies:** Develop strategies to mitigate identified risks.
10. Continuous Improvement	**Feedback Loops:** Establish mechanisms for feedback and continuous improvement.

	Periodic Review: Regularly review and update the framework to reflect new challenges and opportunities.

Table 5.13: Environmental and Sustainability Framework – Domains & Actions

Level	Characteristics
Level 1: Basic	Essential awareness of environmental issues and compliance with minimum legal requirements. Environmental practices are unstructured and reactive. Minimal interaction with stakeholders regarding environmental issues.
Level 2: Developing	Development of formal environmental policies and objectives. Beginning of regular communication with stakeholders on environmental matters. Implementation of essential environmental monitoring and reporting systems.
Level 3: Defined	Introduction of integrated environmental management systems (e.g., ISO 14001). Active engagement with all relevant stakeholders, including community outreach and education. Establishment of key performance indicators (KPIs) for environmental and sustainability performance.
Level 4: Managed	Comprehensive environmental monitoring and transparent reporting practices. Proactive and preventive environmental practices are in place. Effective use of smart technologies for environmental management and sustainability.
Level 5: Optimising	Ongoing efforts to improve environmental performance based on data and stakeholder feedback. Leading in the adoption of innovative sustainable technologies and practices. Full integration of sustainability into the port's strategic planning and operations.
Level 6: Leading	Recognised leader in environmental and sustainability practices in the port industry. Play an active role in setting international standards and best practices. Advocacy for environmental sustainability in the wider maritime and transportation industry

Table 5.14: Environmental and Sustainability Framework – Maturity Model

This maturity model provides a roadmap for smart ports to systematically enhance their environmental and sustainability practices. It encourages continuous improvement and adaptation to emerging challenges and technologies in sustainable port operations.

5.6 Safety and Security Framework

The necessity for a robust safety and security framework in smart ports is driven by the increasing complexity and interconnection of port operations due to the integration of smart technologies. While enhancing efficiency and productivity, these technologies also introduce new vulnerabilities, particularly cybersecurity. Smart ports, critical nodes in global supply chains, face threats ranging from cyber-attacks that can disrupt operations and compromise sensitive data to traditional physical security challenges such as unauthorised access and theft. Additionally, the dense concentration of goods, machinery, and personnel necessitates stringent safety protocols to prevent accidents and ensure smooth operations. A comprehensive safety and security framework is essential not only to protect against these diverse risks but also to ensure compliance with international regulations, maintain operational continuity, and uphold the port's reputation as a secure and reliable node in the global trade network. Therefore, this framework plays a pivotal role in safeguarding the assets, data, and personnel involved in port operations while ensuring that the port remains a resilient and efficient hub for global commerce (de la Peña Zarzuelo, 2021; Gunes et al., 2021; Pöyhönen, 2023; Progoulakis et al., 2023). Table 5.15 and Table 5.16 show domain actions and characteristics of the maturity model respectively.

Domain	Actions
1. Risk Assessment	**Identify Threats:** Understand potential threats, including cyber-attacks, physical intrusions, operational hazards, and natural disasters. **Vulnerability Analysis:** Assess the vulnerability of port infrastructure and IT systems. **Impact Analysis:** Evaluate the potential impact of identified risks on operations, safety, and compliance.
2. Physical Security	**Access Control:** Implement advanced access control systems using biometrics or RFID. **Surveillance:** Deploy CCTV and drone surveillance for real-time monitoring. **Perimeter Security:** Secure the port perimeter by using fencing, sensors, and alarms.

3. Cybersecurity	**Network Security:** Secure the port's network with firewalls, intrusion detection systems, and regular penetration testing. **Data Protection:** Implement strong encryption for data at rest and in transit. **Incident Response Plan:** Develop a robust plan for responding to cyber incidents.
4. Operational Safety	**Automated Systems:** Implement automated systems for container handling and vehicle movements to reduce human error. **Safety Training:** Regular training on safety practices and emergency procedures for staff. **Emergency Preparedness:** Establish clear procedures for dealing with accidents, spills, or other emergencies
5. Technology Integration	**IoT Devices:** Use IoT for real-time tracking of goods and equipment monitoring. **AI and Analytics:** Leverage AI for predictive maintenance, traffic management, and threat detection. **Blockchain:** Utilize blockchain for secure and transparent supply chain management.
6. Regulatory Compliance	**International Standards:** Ensure compliance with International Maritime Organisation (Halff et al., 2019) guidelines and the International Ship and Port Facility Security Code (Tam & Jones, 2018). **Environmental Regulations:** Adhere to environmental regulations for waste management and emissions control. **Regular Audits:** Conduct regular audits to ensure adherence to international and local regulations
7. Stakeholder Collaboration	**Partnerships:** Collaborate with law enforcement, government agencies, and other ports for information sharing and best practices. **Community Engagement:** Engage with the local community for support and awareness.
8. Continuous Improvement	**Feedback Mechanisms:** Implement systems for feedback from staff and port users. **Technology Upgrades:** Regularly update technology to keep up with advancements and emerging threats. **Training and Development:** Continuous training programs for staff to stay updated with new security and safety protocols.
9. Documentation and Reporting	**Policy Documentation:** Document all policies and procedures. **Incident Reporting:** Have a system for reporting and documenting security and safety incidents.
10. Resilience Planning	**Backup Systems:** Ensure backup systems are in place for critical operations. **Disaster Recovery Plan:** Develop a comprehensive disaster recovery plan for significant incidents.

Table 5.15: Safety and Security Framework – Domains & Actions

Level	Characteristics
Level 1: Basic	Reactive approach with no formalised policies or procedures. Safety and security measures are inconsistent and unorganised. Essential compliance with minimal legal requirements. Ad hoc incident response.
Level 2: Developing	Awareness of the importance of safety and security. Initial efforts to establish policies are in place, but they are not fully implemented or standardised. Developing basic safety and security policies. Initial training and awareness programs for staff.
Level 3: Defined	Established and documented safety and security procedures. Compliance with national and international regulations is achieved. Consistent implementation of defined policies. Regular training and compliance with standards.
Level 4: Managed	Proactive management and regular review of safety and security practices. The use of technology for monitoring and response is integrated. Continuous improvement based on performance metrics. Risk management strategies are in place.
Level 5: Optimising	Advanced technology integration like AI, IoT, and blockchain for safety and security. Predictive analytics are used for risk management. Leveraging technology for enhanced safety and security. Predictive and proactive risk management
Level 6: Leading	Pioneering in safety and security practices. High level of automation and predictive capabilities. The global benchmark for best practices. Continuous innovation in safety and security technologies and processes. Leadership in industry standards and practices

Table 5.16 Safety and Security Framework – Maturity Models

This six-level maturity model offers a comprehensive and progressive roadmap for smart ports to enhance their safety and security measures. By advancing through these levels, ports can safeguard against current risks and position themselves as leaders in adopting innovative practices that set new port safety and security standards.

5.7 Human Resource Framework

The Human Resource (HR) framework is crucial in developing and operating intelligent ports. Smart ports, which leverage smart technologies, require a skilled workforce to manage and utilize these technologies effectively (Sivathanu & Pillai. 2018; Avdeeva et al., 2019; Rana & Sharma, 2019). Table 5.17 and Table 5.18 show domain actions and characteristics of the maturity model respectively.

Domain	Actions
1. Strategic Alignment	**Vision and Mission Integration:** Align HR strategies with the overall vision and mission of the smart port. **Technology Emphasis:** Focus on integrating HR practices with the technological advancements of the port.
2. Talent Acquisition and Management	**Recruitment Strategy:** Develop a strategy to attract talent with specialised skills in IoT, AI, big data, and other relevant technologies. **Selection Process:** Implement a rigorous selection process that assesses technical skills and adaptability to a tech-driven environment.
3. Training and Development	**Skill Development Programs: Establish** continuous learning programs focusing on new technologies and industry developments. **Leadership Training:** Create leadership development programs for managing high-tech teams and fostering innovation.
4. Performance Management	**KPIs and Metrics**: Define clear performance metrics aligned with smart port operations and objectives. **Feedback and Appraisal Systems:** Implement regular feedback mechanisms and performance appraisal systems that encourage innovation and efficiency.
5. Change Management	**Change Facilitation:** Develop programs to assist employees in adapting to technological changes and new operational processes. **Communication Strategy:** Ensure transparent and continuous communication regarding changes and developments within the port.
6. Compensation and Benefits	**Competitive Compensation:** Design competitive compensation packages that reflect the specialised skills required. Benefits and Incentives: Offer benefits and incentives that promote employee well-being and job satisfaction.
7. Workforce Planning	**Future Skill Forecasting:** Regularly assess future skill requirements and adjust recruitment and training programs accordingly. **Succession Planning**: Implement a succession planning strategy for critical roles within the port.
8. Safety and Compliance	**Safety Training:** Provide comprehensive safety training relevant to high-tech equipment and operations. **Regulatory Compliance:** Ensure all HR practices comply with labour laws and industry regulations.
9. Employee Engagement and Culture	**Engagement Programs:** Develop initiatives to enhance employee engagement and job satisfaction. **Cultural Alignment:** Foster a culture of innovation, adaptability, and continuous improvement.

10. Diversity and Inclusion	**Inclusive Recruitment:** Promote diversity in hiring practices. **Diversity Training:** Provide training to ensure an inclusive and respectful work environment.
11. Technology Utilization	**HR Information Systems:** Implement advanced HRIS for efficient management of HR processes. **Data-Driven Decision-Making:** Use data analytics for informed decision-making in HR strategies and practices.
12. Cross-functional Collaboration	**Team Integration:** Encourage cross-functional teamwork and collaboration among different departments within the port.
13. Evaluation and Continuous Improvement	**Regular Assessments:** Conduct regular assessments of HR practices and their impact on port operations. **Feedback Mechanisms:** Establish mechanisms for employee feedback on HR policies and practices.

Table 5.17: Human Resource Framework – Domains & Actions

Level	Characteristics
Level 1: Basic	HR practices are reactive and unstructured. Limited understanding of the specific HR needs for a smart port. Essential recruitment, ad-hoc training, minimal compliance standards.
Level 2: Developing	HR practices are more consistent but still developing. Initial strategies for talent acquisition and basic training programs are in place. Establishing fundamental HR policies, essential performance management, and initial safety and compliance measures.
Level 3: Defined	HR processes are standardised and documented. There is a clear understanding of the HR requirements for smart port operations. Systematic recruitment processes, structured training and development programs, and defined performance metrics.
Level 4: Managed	HR practices are managed and monitored. There is a focus on aligning HR strategies with technology integration in the port. Advanced training in technology and leadership, effective performance management systems, and enhanced safety protocols.
Level 5: Optimising	HR practices are integrated with overall port operations. There is a strong emphasis on continuous improvement and adaptability. Cross-functional collaboration, comprehensive workforce planning, integrated safety and compliance strategies.

Level 6: Leading	HR practices are at an advanced stage of maturity, focusing on optimization and strategic foresight. Data-driven HR decision-making, advanced talent management strategies, innovation and change management leadership.

Table 5.18: Human Resource Framework – Maturity Model

This maturity model allows smart ports to systematically evaluate and enhance their HR capabilities, ensuring their workforce is well-equipped to meet the challenges and opportunities of advanced port technologies and operations.

5.8 Smart Operations Framework

The Smart Operations Framework in smart ports is pivotal in revolutionising the maritime industry. This framework integrates advanced technologies to enhance port operations' efficiency, security, and environmental sustainability. The framework significantly improves decision-making processes by leveraging real-time data analysis and predictive analytics, leading to optimised cargo handling, reduced turnaround times, and increased throughput (Ren et al., 2019; Yau et al., 2020; Dalaklis et al., 2023). Table 5.19 and Table 5.20 show domain actions and characteristics of the maturity model respectively.

Domain	Actions
1. Assessment of Current Operations	**Analysis of Existing Infrastructure:** Evaluate current port infrastructure, including cargo handling, storage facilities, and transportation links. **Operational Efficiency:** Assess current operational processes, turnaround times, and logistics management. **Environmental Impact:** Review the environmental footprint of the port, including emissions, waste management, and energy usage.
2. Technology Integration	**Automation:** Implement automated systems for cargo handling, gate operations, and container management. **IoT (Internet of Things):** Deploy sensors and IoT devices for real-time monitoring of equipment, cargo, and environmental conditions. **Data Analytics**: Utilize big data analytics for predictive maintenance, traffic management, and operational optimisation. **Cybersecurity Measures:** Ensure robust cybersecurity protocols to protect data and operational integrity.
3. Sustainability Practices	**Green Technologies:** Adopt renewable energy sources, such as solar and wind power, and electrify equipment. **Emission Control:** Implement strategies for reducing greenhouse gas emissions and controlling air pollution.

	Waste Management: Develop efficient recycling and waste reduction processes.
4. Stakeholder Engagement and Collaboration	**Port Community System:** Establish a digital platform for information sharing among port users, including shipping lines, freight forwarders, and customs. **Partnerships:** Foster collaborations with technology providers, academic institutions, and industry experts. **Regulatory Compliance:** Ensure adherence to international and local regulations and standards.
5. Smart Logistics and Supply Chain Integration	Digital Connectivity: Enhance digital integration with the global supply chain network. **Intermodal Transport Solutions**: Develop efficient connections with rail, road, and inland waterways. **Real-time Tracking**: Implement systems for real-time tracking of cargo and vessels.
6. Innovation and Continuous Improvement	**Research and Development:** Invest in R&D for continuous technological advancements. **Pilot Projects:** Test new technologies and practices through pilot projects. **Feedback Mechanisms:** Establish systems for feedback and continuous improvement.
7. Training and Skill Development	**Workforce Training:** Provide training for staff in new technologies and processes. **Talent Acquisition:** Attract skilled professionals with technology, logistics, and environmental management expertise.
8. Performance Monitoring and Reporting	**KPIs (Key Performance Indicators):** Define and monitor KPIs to measure performance improvements. **Reporting:** Regularly report on progress, challenges, and achievements.
9. Risk Management and Resilience Planning	**Risk Assessment:** Regularly assess operations, cybersecurity, and environmental impacts regularly. **Emergency Preparedness:** Develop and test emergency response plans.
10. Scalability and Future-Proofing	**Scalable Solutions:** Ensure that technologies and processes are scalable for future growth. **Adaptability:** Maintain flexibility to adapt to emerging technologies and changing market demands

Table 5.19: Smart Operations Framework – Domains & Actions

Level	Characteristics
Level 1: Basic	Basic understanding and awareness of smart port concepts.

	Limited use of digital technologies. Conventional operational practices. Minimal automation and data analytics. Basic environmental compliance.
Level 2: Developing	Laying the groundwork for smart port transformation. Initial investments in infrastructure upgrades. Introduction of basic automation in cargo handling. Initial steps towards digital documentation and data management. Early-stage environmental initiatives.
Level 3: Defined	Integrating advanced technologies and beginning automation. Increased use of IoT and automation in operations. Enhanced data analytics for operational efficiency. Improved cybersecurity measures. Greater focus on sustainable practices and energy efficiency.
Level 4: Managed	Full-scale digital transformation and process optimisation. High level of automation and smart technologies in operations. Advanced data analytics for predictive maintenance and decision-making. Strong cybersecurity infrastructure. Significant strides in sustainability and green initiatives.
Level 5: Optimising	Integrating operations with the broader logistics and supply chain ecosystem. Seamless digital connectivity with global supply chains. Intermodal transport solutions are fully integrated. Real-time tracking and advanced logistics management. Comprehensive environmental management systems.
Level 6: Leading	Pioneering new technologies and sustainability practices. Leading-edge technology adoption and innovation. Full-scale sustainable and renewable energy utilisation. Proactive in setting industry standards and practices. Strong focus on R&D, continuous improvement, and adaptability.

Table 5.20: 5.8 Smart Operations Framework – Maturity Model

This maturity model provides a structured pathway for ports to evolve into fully integrated, efficient, and sustainable smart ports. It emphasises gradual progression, allowing ports to develop at a pace that matches their capabilities and resources while aiming for continuous improvement and innovation.

5.9 Stakeholder Satisfaction Framework

The stakeholder satisfaction framework is crucial in the context of smart ports due to modern port operations' complex and interconnected nature. Smart ports, characterised by their use of advanced technologies for automation, data analytics, and interconnected logistics, involve a wide range of stakeholders, including shipping companies, port authorities, local communities, regulatory bodies, and logistics providers. A stakeholder satisfaction framework ensures that the needs and expectations of all these parties are systematically identified, understood, and addressed. By prioritising stakeholder satisfaction, smart ports can enhance collaboration, foster innovation, and balance technological advancements and human-centric approaches. This leads to improved service quality, higher operational efficiency, and a stronger competitive position in the global maritime industry, ultimately contributing to the sustainable growth and resilience of the port ecosystem (Ha et al., 2019; Lozano et al., 2020; Truong et al., 2020; Phan et al., 2021). Table 5.21 and Table 5.22 show domain actions and characteristics of the maturity model respectively.

Domain	Actions
1. Identification of Stakeholders	**Primary Stakeholders:** Shipping companies, port operators, logistics providers, customers, and regulatory bodies. **Secondary Stakeholders**: Local communities, environmental groups, suppliers, and government entities.
2. Stakeholder Needs Assessment	**Surveys and Interviews:** Conduct surveys and interviews to gather insights about stakeholder expectations and needs. **Focus Groups:** Organise focus groups with representatives from different stakeholder categories to discuss specific needs related to smart port functionalities.
3. Setting Satisfaction Metrics	**Performance Indicators:** Develop key performance indicators (KPIs) relevant to each stakeholder group, such as turnaround time for shipping companies, environmental impact for regulatory bodies, and job creation for local communities. Balanced Scorecard: Implement a balanced scorecard approach to measure financial, customer, internal business process, and learning and growth perspectives.
4. Integration of Smart Port Technologies	**Data Analytics:** Use data analytics to monitor and improve stakeholder-related processes and services.
5. Feedback Mechanisms	**Regular Surveys:** Conduct regular surveys to gather feedback on stakeholder satisfaction. **Feedback Channels:** Establish open channels for stakeholders to provide feedback and raise concerns.

6. Continuous Improvement	**Data-Driven Decisions:** Use collected data and feedback to make informed decisions. **Adaptation and Flexibility:** Be prepared to adapt strategies and operations based on stakeholder feedback and changing needs.
7. Communication and Transparency	**Regular Updates:** Provide stakeholders with regular updates on port operations, improvements, and initiatives. **Transparent Policies:** Maintain transparency in policies and decision-making processes.
8. Training and Development	**Stakeholder Education:** Offer training and educational programs to stakeholders about the benefits and use of smart port technologies. **Employee Training:** Ensure that port staff are well-trained in customer service and stakeholder engagement.
9. Sustainability and Social Responsibility	**Environmental Impact:** Focus on reducing the environmental impact of port operations. **Community Engagement:** Engage with local communities to ensure the port's operations align with their interests and contribute to local development.
10. Monitoring and Evaluation	**Regular Reviews:** Conduct regular reviews of the stakeholder satisfaction framework. **Performance Reporting:** Report on the performance against the set KPIs and make adjustments as necessary.

Table 5.21: Stakeholder Satisfaction Framework – Domains & Actions

Level	Characteristics
Level 1: Basic	Essential recognition of stakeholder groups and their general needs. Identifying primary and secondary stakeholders, initial communication channels established.
Level 2: Developing	Gathering detailed information about stakeholders' expectations and needs. Conducting surveys, interviews, and focus groups; beginning to set up feedback mechanisms.
Level 3: Defined	Integrating stakeholder needs into smart port operations and strategies. Developing specific KPIs for stakeholder satisfaction, integrating feedback into operational processes, and beginning to use smart technologies for better stakeholder engagement.
Level 4: Managed	Systematic management of stakeholder satisfaction with established processes and metrics. Regularly reviewing stakeholder feedback, making data-driven decisions, and adapting strategies based on stakeholder input.
Level 5: Optimising	Advanced use of smart port technologies to exceed stakeholder expectations.

	Leveraging AI, IoT, and data analytics for predictive insights and personalised stakeholder engagement; advanced training for staff in stakeholder relations.
Level 6: Leading	Setting industry standards in stakeholder satisfaction, influencing policies and practices beyond the port. Leading initiatives for industry-wide improvements, sharing best practices, and actively participating in policy development.

Table 5.22: Stakeholder Satisfaction Framework – Maturity Model

Each stage in this maturity model represents a step forward in the smart port's ability to understand, manage, and enhance stakeholder satisfaction. As a port progresses through these stages, it improves its operations and contributes to the broader development of sustainable and efficient maritime logistics. The model serves as a roadmap for continuous improvement and strategic development in stakeholder engagement within smart port's dynamic and technologically evolving landscape.

5.10 Regulatory and Compliance Framework

A regulatory and compliance framework is essential in smart ports to ensure the effective integration and management of smart technologies, which are pivotal in enhancing operational efficiency, security, and environmental sustainability. This framework establishes standards and guidelines that govern the deployment and use of these technologies, ensuring they are safe reliable, and do not compromise the security of the port's operations. Moreover, compliance with international and local regulations is crucial for maintaining smooth global trade operations, as ports are critical nodes in the international supply chain. A robust regulatory framework also addresses data privacy and cybersecurity concerns, which are increasingly important in an era where vast amounts of sensitive information are processed and stored. By setting clear rules and standards, a regulatory framework ensures that smart ports operate within legal boundaries, maintain high safety standards, and foster trust among stakeholders, including shipping companies, port operators, and customers (Togan, 2016; Azmi et al., 2018; Burns, 2018). Table 5.23 and Table 5.24 show domain actions and characteristics of the maturity model respectively.

Domain	Actions
1. Technology and Innovation Standards	**Integration of Emerging Technologies:** Guidelines for implementing IoT, AI, blockchain, and other digital solutions. **Innovation Encouragement:** Policies to foster continuous technological advancement while ensuring safety and efficiency.
2. Cybersecurity and Data Protection	**Data Privacy Regulations:** Compliance with global data protection laws (like GDPR) for handling personal and sensitive data. **Cybersecurity Measures:** Mandatory cybersecurity protocols to protect against cyber threats and data breaches.
3. Operational Efficiency and Safety	**Automated Systems Standards:** Regulations for the safe operation of automated cranes, vehicles, and other equipment. **Emergency Response Protocols:** Clear guidelines for handling emergencies, including technological failures
4. Environmental Compliance	**Sustainability Standards:** Regulations that minimize environmental impact include waste management and emissions control. **Green Technology Adoption:** Incentives and guidelines for using renewable energy sources and eco-friendly technologies.
5. Legal and Ethical Compliance	**International Trade Laws:** Adherence to international maritime and trade laws. **Ethical Standards:** Guidelines to ensure ethical practices in operations and labour.
6. Quality Control and Service Standards	**Performance Benchmarks:** Setting high standards for operational efficiency and service quality. **Regular Audits and Assessments:** Periodic evaluations to ensure compliance with the established standards.
7. Stakeholder Engagement and Transparency	**Collaboration with Stakeholders:** Regular engagement with shipping companies, local communities, and government bodies. **Transparency in Operations:** Policies to ensure open communication about operations, incidents, and compliance status.
8. Training and Development	**Workforce Training Programs:** Continuous training for staff on new technologies and compliance requirements. **Skill Development Initiatives:** Encouraging skill enhancement to keep pace with technological advancements.
9. Monitoring and Reporting	**Compliance Monitoring Systems:** Tools and systems to monitor compliance with regulatory requirements. **Regular Reporting Mechanisms:** Mandatory reporting on compliance, incidents, and operational efficiency.
10. Adaptability and Continuous Improvement	**Regular Framework Reviews:** Periodic reassessment and updating of the regulatory framework to adapt to new challenges and technologies. **Feedback Mechanisms:** Channels for receiving feedback from stakeholders for continuous improvement.

Table 5.23: Regulatory and Compliance Framework – Domains & Actions

Level	Characteristics
Level 1: Basic	Basic understanding of the need for a regulatory and compliance framework. : Initial identification of relevant technologies, cybersecurity needs, and environmental concerns. Minimal or ad-hoc; largely reactive.
Level 2: Developing	Recognition of specific regulations and standards required for intelligent ports. Drafting preliminary policies, starting to address cybersecurity, data privacy, and environmental standards. Developing consistent but basic compliance practices.
Level 3: Defined	Established policies and procedures for technology integration, cybersecurity, and environmental compliance. Implement standard operational procedures, initial training programs, and basic monitoring systems.
Level 4: Managed	Advanced implementation of compliance and regulatory standards with measurable outcomes. Regular training, advanced cybersecurity measures, active stakeholder engagement, and performance benchmarking. Active monitoring and reporting mechanisms are in place, with compliance being regularly reviewed and managed.
Level 5: Optimising	Full integration of compliance framework into all aspects of smart port operations. Continuous improvement processes, advanced data analytics for decision-making, and high-level stakeholder collaboration. Proactive and predictive compliance management with integrated feedback mechanisms.
Level 6: Leading	Setting industry standards, leading in innovation and compliance practices. Pioneering new technologies and practices, leading sustainability efforts, and contributing to developing global standards. Exemplary compliance record, with the port being a model for others in the industry.

Table 5.24: Regulatory and Compliance Framework – Maturity Models

This maturity model helps track progress and set clear goals and strategies for continuous improvement in regulatory and compliance practices within smart ports.

5.11 Innovation and Research Framework

Innovation and research framework is essential in developing smart ports due to the rapidly evolving nature of global trade and technology. Through systematic research and innovation, smart ports can optimise cargo handling and logistics, improve real-time decision-making, and ensure better resource management. By fostering a continuous improvement and adaptation culture, innovation and research frameworks ensure that smart ports remain at the forefront of technological advancements. (Bjerkan & Seter, 2019; Leonidou et al, 2020). Table 5.25 and Table 5.26 show domain actions and characteristics of the maturity model respectively.

Domain	Actions
1. Vision and Objectives Setting:	**Defining a clear strategy:** Define clear, long-term goals for the smart port, focusing on innovation, sustainability, efficiency, and security. **Alignment with external domains:** Align these goals with broader industry trends, environmental standards, and global trade dynamics.
2. Technology Assessment and Integration:	**Environmental scanning: Continuously** monitor emerging technologies that can be integrated into port operations. **Impact analysis:** Evaluate these technologies' feasibility, cost, and potential impact on port efficiency and sustainability.
3. Research and Development (R&D)	**Future-proofing:** Invest in R&D projects focusing on innovative solutions for cargo handling, logistics management, energy use, and waste reduction. **Developing collaborations:** Partner with academic institutions and tech companies for cutting-edge research and pilot projects
5. Pilot Testing and Scalability	**Pilot testing:** Conduct tests for new technologies and processes to evaluate their effectiveness before full-scale implementation. **Scaling up:** Plan for the scalability of successful innovations across different port operations.
6. Regulatory Compliance and Risk Management	**Compliance:** Ensure that all innovations comply with international and local regulations. **Risk minimisation:** Develop strategies for managing risks associated with new technologies and operational changes
7. Performance Monitoring and Continuous Improvement:	**Improving performance:** Establish metrics and KPIs to measure the performance of implemented innovations. **Continuous improvement:** Regularly review and adjust the innovation strategy based on performance data and changing industry trends.

Table 5.25: Innovation and Research Framework – Domain & Actions

Level	Characteristics

Level 1: Basic	Basic understanding of the need for innovation and research in port operations. Limited use of advanced technologies. A preliminary roadmap for innovation with identified stakeholders and initial goals
Level 2: Developing	Development of a structured innovation and research strategy aligned with port objectives. A comprehensive innovation and research strategy, including plans for stakeholder engagement and technology exploration.
Level 3: Defined	Initial integration of new technologies and commencement of pilot projects. Successful pilot projects and a better understanding of the practical implications of new technologies in port operations.
Level 4: Managed	Full-scale implementation of proven technologies and processes. Streamlining operations using data analytics, IoT, AI, and other technologies. Emphasis on training staff and updating processes.
Level 5: Optimising	Advanced use of technologies and data analytics. Continuous improvement, advanced training programs, and integration of cutting-edge technologies. A highly efficient, sustainable, and technologically advanced port operation
Level 6: Leading	The port becomes a leader in innovation within the maritime industry. Ongoing R&D, setting industry standards, and influencing global practices. Continuous adaptation to emerging technologies and market trends. A model smart port that not only excels in operational efficiency and sustainability but also contributes to the broader maritime industry through leadership and innovation.

Table 5.26: Innovation and Research Framework – Maturity Model

The importance of a maturity model Innovation and Research Framework in smart ports lies in its ability to provide a structured and systematic approach for assessing and enhancing the innovation capabilities and technological advancements within these complex environments.

5.12 Summary and Conclusions

This chapter stands as the cornerstone of the thesis. It undertakes a thorough and methodical analysis of data collected from various publications. This comprehensive approach has been instrumental in laying the groundwork for creating the SaPFaR. The depth and breadth of the analysis ensure a robust foundation for the framework, integrating diverse insights and perspectives from the literature. This chapter synthesises existing knowledge and contributes to the field, marking a significant milestone in the thesis. The figure 5.8 shows all the elements of SaPFaR.

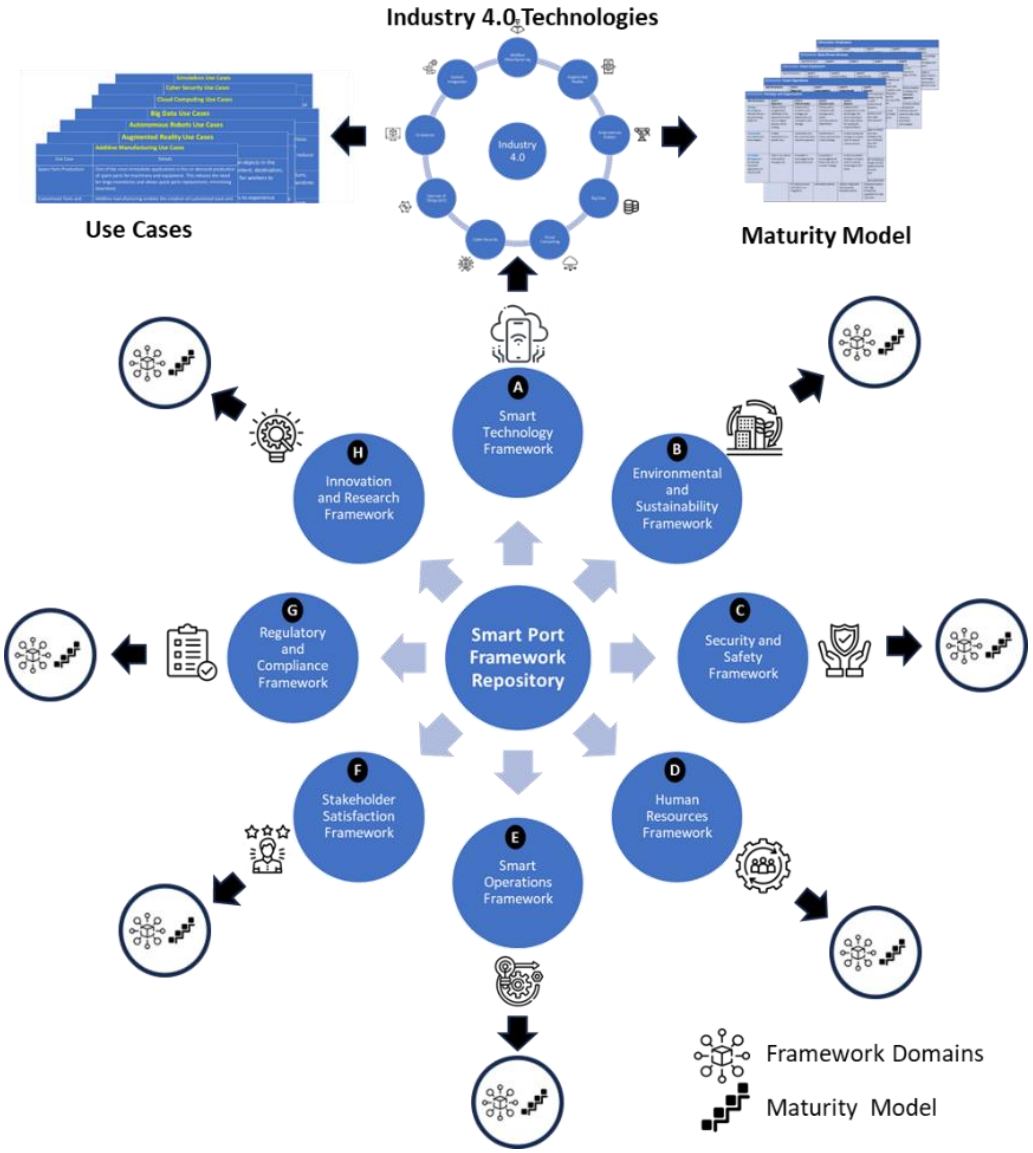

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Figure 5.8: Smart Port Framework Repository - SaPFaR

Chapter 6 – Validation of Smart Port Framework Repository (SaPFaR)

6.1 Introduction

The development of the SaPFar was carried out through a methodical and systematic research approach. However, it is crucial to thoroughly assess the framework's validity to confirm its robustness and applicability, particularly within the UAE port community. This chapter is dedicated to detailing the validation process that was implemented for the SapFar. It will cover the various steps involved in the validation, the feedback gathered from relevant stakeholders, and the subsequent modifications incorporated into SapFar based on this feedback. The aim is to provide a comprehensive overview of how SaPFar was tested and refined to ensure its effectiveness and relevance in smart ports.

6.2 Validation Approach

SaPFaR, a comprehensive repository, was developed by gathering and integrating insights from numerous publications. This repository is tailored for the design and operations of smart ports, embodying a generic approach to address the complexities in this field. Engaging in a validation process is crucial to ascertain its effectiveness and applicability, primarily through expert evaluation.

Two primary methods for this validation are (a) conducting a questionnaire survey and (b) soliciting reviews from domain experts. The questionnaire survey approach was considered unsuitable for SaPFaR, given the framework's multifaceted nature and the broad spectrum of elements it consists of. This complexity requires an expert-driven evaluation method.

Ideally, the validation process should involve a diverse group of experts, including those from academia and industry experts. Such a blend of perspectives is vital for a holistic framework assessment. Nonetheless, the UAE lacks academic specialists in smart port operations. This limitation narrows down the feasible approach for validation.

Given these circumstances, conducting in-depth interviews with industry professionals is the most viable option. These interviews aim to tap into these professionals' rich practical knowledge and experience, providing valuable insights into the practicality and relevance of the SaPFaR. Through these discussions, the framework can be critically assessed, ensuring it holds up under the scrutiny of real-world applications and industry needs.

6.3 Review by Domain Experts - Steps

The following steps were taken to gather feedback from domain experts.

Step 1: Identifying domain experts for focus group interviews

A group of senior executives from three ports, identified as Port A, Port B and Port C, were selected from three UAE ports. Two well-established ports, Port A and Port B, contributed to the work reported in Chapter 2. Port C is an expanding container port in the UAE with an ambitious plan to use smart technologies to support its growth.

Step 2: Preparing for focus group interviews

In preparation for the interviews, the following questions were drafted.

Q1: Does the framework fulfil its intended purpose (i.e., provides a comprehensive and holistic structure)?

Q2: What are your thoughts on the overall architecture of the SaPFar?

Q3: Does the framework encompass all necessary domains to facilitate the design and operation of smart ports?

Q4: How beneficial are the use cases for each smart technology introduced by Industry 4.0?

Q5: Have you previously used maturity models? Can you comment on the usefulness of the maturity models provided in SaPFaR?

Q6: What improvements or changes would you like to suggest to make SaPfaR more beneficial for your port?

6.4 Summary of responses from focus group interviews

The critical responses provided by each group are outlined below (Table 6.1)

	Port A	Port B	Port C
Number of participants	2	3	3
Questions			
Q1: Does the framework fulfil its intended purpose (i.e., provides a comprehensive and holistic structure)?	“We wish we had seen this before. It is so comprehensive. I cannot think of any area you have missed”.	“This is an excellent attempt. It gives us a birds-eye view of all essential elements of smart port operations and the details.”	“As you know, we are new players in this area. Our port has only limited smart features. So, this is incredibly helpful in planning our journey.”

Q2: What are your thoughts on the overall architecture of the SaPFaR?	"Given the details you have captured, it is difficult to think about a better structure to present them."	"On paper, navigating through different layers is a bit difficult. Maybe you can use some visualisation software to make the navigation easier."	"We like the overall structure but do not think a paper-based structure would be useful."
Q3: Does the framework encompass all necessary domains to facilitate the design and operation of smart ports?	"Certainly, yes, for operations. We may use more digital modelling tools for the initial design of a new port."	"Yes, it has captured all key domains that are essential in smart port operations. We do not have much experience designing new ports, so it is difficult to say whether it also covers the design of ports".	"Although we do not have much experience in this area. It looks detailed enough."
Q4: How beneficial are the use cases for each smart technology introduced by Industry 4.0?	"This is very useful. It is nice to see that your study has covered many application areas."	"Useful. We can use some of the examples in our training materials."	"This is incredibly helpful for us to understand the application areas".
Q5: Have you previously used maturity models? Can you comment on the usefulness of the maturity models provided in SaPFaR?	"No. This is new to us. We can see why you have supplied maturity models. "	"A few people are aware of the concept. "But we do not think we ever used them in our smart port transformation. We think it is very useful to understand where you are and decide how far you would like to go."	"Certainly not. We think this is very useful. We can use maturity models to understand where we are now. It also gives us targets".
Q6: What improvements or changes would you like to suggest to make SaPfaR more beneficial for your port?	"We certainly would like to see a roadmap for the implementation. Our port is quite high in the global ranking for smart ports. Nevertheless, the competition is hotting up. Anything that helps us to do more is always welcome".	"This is a pretty complex model. It is good to know where to start and how to progress. "	"What you have proposed is very useful to us. Any insights into how to implement this would be incredibly useful."

Table 6.1: Summary of Responses from focus group interviews

6.5 Analysis of the feedback from focus group interviews

In summary, every participant reached a consensus that the SaPFar framework has the potential to enhance their operations significantly. This enhancement is expected to be realised through various means, including applying supply use cases, integrating maturity models, and exploring different application domains within each framework. The discovery that none of the port operators had prior knowledge of maturity models was particularly unexpected. This lack of awareness suggests that the shift towards smart operations among these operators is happening organically. This organic transformation highlights a potential area for further education and structured development in adopting new technologies and operational frameworks.

In enhancing SapFaR, every port highlighted the need for an implementation plan for SaPFaR. Since smart technology integration is central to smart ports' evolution, the implementation of smart technologies can be considered a digital transformation project. It is recommended to draw upon established digital transformation models developed by industry pioneers to facilitate this transformation effectively. These models, with their proven strategies and methodologies, can provide valuable guidance and a structured approach to the ports' journey towards digitalisation. By leveraging these models, ports can navigate the complexities of integrating advanced technologies and optimise their operations. This strategic alignment with industry-leading practices enhances the implementation process and ensures a more seamless and successful transition into smart ports.

6.6 Digital Transformation Models

As indicated above, it is advisable to consider proven digital transformation models to implement the “Smart Technology Framework” of SaPFaR. Table 6.2 presents well-established digital transformation models and their key strengths and weaknesses. This list was compiled from information from The Best Digital Transformation Frameworks in 2020 (2020).

Model	Strengths	Weaknesses
McKinsey's Digital Quotient (DQ)	• Comprehensive, covering strategy, capabilities, culture, and organisation.	• Can be complex and require significant data for accurate assessment. • May be more suitable for larger organisations.

	• Well-structured for benchmarking against competitors.	
MIT Sloan & Deloitte's Digital Maturity Model	• Easy to understand stages of maturity. • Emphasises the importance of leadership and culture.	• May oversimplify the transformation process. • Less focus on specific technologies or operational aspects.
Gartner's Digital Business Transformation Model	• IT-centric, suitable for technology-focused organisations. • Strong in integrating digital technology across business areas.	• May underemphasise the human and cultural aspects of transformation. • Can be too IT-focused for some organisations.
Forrester's Digital Maturity Model 2.0	• Balances customer experience and operational excellence. • Useful for customer-centric organisations.	• May require extensive customer data for accurate assessment. • Less emphasis on internal cultural change.
Accenture's Digital Maturity Model	• Comprehensive across strategy, technology, organisation, and operations. • Flexible and adaptable to different industries.	• Complexity can be overwhelming for smaller organisations. • External consultancy may be required for full implementation.
Capgemini's Digital Transformation Framework	• Addresses complexities of digital transformation. • Includes governance, which is often overlooked.	• Can be too broad, lacking specific guidance in certain areas. • May be challenging to implement without external guidance.
Altimeter's Six Stages of Digital Transformation	• Provides a clear, staged pathway for transformation. • Emphasizes adaptability and innovation.	• Stages may not align perfectly with all organisations. • Risk of oversimplifying complex transformation processes.

Table 6.2: Digital Transformation Frameworks

6.7 Proposed Digital Transformation Framework

Given the multifaceted nature of port operations, Capgemini Digital Transformation Framework's comprehensive approach covering customer experience, operations, technology, and governance is beneficial (Figure 6.1). Ports require a balanced focus on these areas to effectively manage the digital transformation process. The inclusion of

governance is particularly relevant for ports, which often must adhere to strict regulatory standards and engage with multiple stakeholders.

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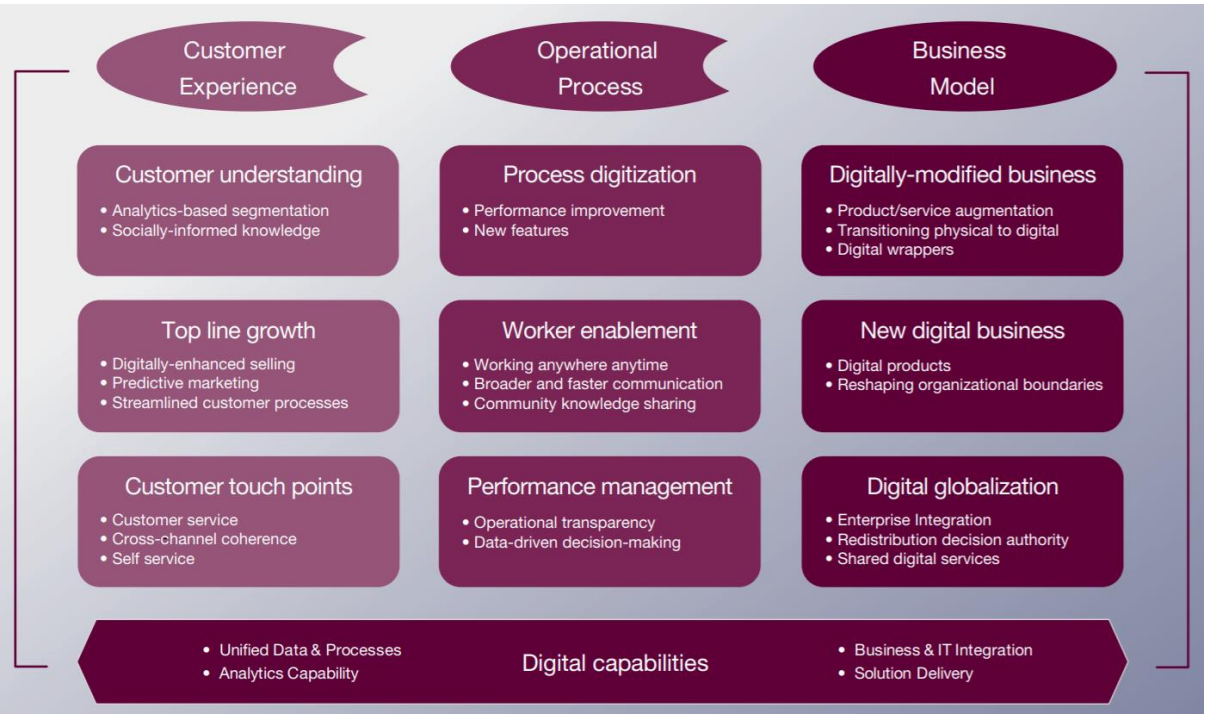

Figure 6.1: Capgemini's Digital Transformation Framework (Westerman et al., 2011)

6.8 Summary and Conclusions

This chapter presents the steps taken to validate SaPFaR. Given the complexity of the SaPFaR structure, focus group interviews were chosen as the best approach to capture views from domain experts in the UAE. Eight (8) Senior executives/managers from three (3) ports participated in focus group interviews.

There was a unanimous agreement that SaPFaR is comprehensive and holistic. All acknowledge that SaPFaR has captured all required elements of smart port operations. Focus group interviews revealed a lack of awareness of maturity models in the container port sector in the UAE. In terms of necessary enhancements, all three ports stated that an implementation framework would be helpful.

Given that smart technologies are the heart of smart ports, it is sensible to use a proven digital transform framework to implement SaPFaR. Following the review of industry-strength digital transformation models, it is suggested that Capgemini's Digital Transformation Framework be used to implement SaPFaR.

Chapter 7 – Conclusions and Contribution to Knowledge

7.1 Introduction

This chapter is dedicated to presenting findings and insights gained from this research work, articulating the significant contributions made to the existing body of knowledge, and suggesting avenues for future research. It begins with a concise overview of the underlying rationale, objectives, and aims that guided the research.

This chapter also acknowledges and explores the inherent limitations of the research work. This critical evaluation not only adds to the credibility of the research by demonstrating an understanding of its boundaries but also provides context for interpreting the results and conclusions. Lastly, the chapter proposes potential directions for future research. This forward-looking perspective is essential for the ongoing evolution and development of the subject area.

7.2 Rationale

In Chapters 1 and 2, the introductory concepts and the broader context of the container port industry were thoroughly examined, setting the stage for a deeper analysis of the specific challenges and opportunities faced by the United Arab Emirates (UAE) in this sector. Chapter 4 further enhances this discussion by presenting the perspectives of container port operators in the UAE, offering valuable insights into the ground realities and operational considerations within the region.

The collective insights from those three chapters underline the pressing need to enhance competitiveness in the UAE's container ports. The dynamic and ever-evolving nature of the global and regional container port landscape drives this necessity. As the industry undergoes rapid changes, marked by technological advancements, shifting trade patterns, and evolving customer expectations, it becomes imperative for UAE container ports to not only keep pace but also anticipate and proactively respond to these changes.

UAE container ports must adopt a systematic and proactive approach to remain relevant and competitive in this fast-paced environment. This involves embracing innovation, improving operational efficiencies, and enhancing service quality. By doing so, they can effectively respond to emerging challenges and capitalise on new opportunities, securing their position as key players in the global maritime industry.

The discussions in the initial chapters and insights from UAE container port operators as reported in Chapter 4 collectively make a compelling case for the need to boost competitiveness in the UAE's container port sector. This is essential not only for the growth and sustainability of the ports themselves but also for the broader economic development of the UAE, given the critical role these ports play in international trade and logistics.

7.3 Aim Research Questions and Objectives

This section provides a summary of outcomes for each category.

7.3.1 Aim:

The aim is to "Develop a framework for improving the strategic competitiveness of container ports in the UAE".

This has been achieved by developing a comprehensive and holistic repository of frameworks named SaPFaR (**S**m**a**rt **P**ort **F**r**a**mework **R**epository)

7.3.2 Research Questions

To achieve the above three (3) research questions were framed.

The specific research questions are:

RQ1: What are the underlying causes and key factors driving the need to enhance the competitiveness of UAE container ports, and how do these elements influence the strategic positioning of the UAE in the global maritime and logistics industry?

Chapters 1 and 2 provide background to the critical imperatives of enhancing the competitiveness of UAE ports. Global and regional competitors continue to improve competitiveness by integrating novel technologies in all areas of operations. In Chapter 4, UAE port operators reiterated similar perspectives.

RQ2: What is the most effective strategy for enhancing the competitiveness of container ports, especially considering the context of global trade dynamics and technological advancements?In Chapter 2, the concept of Smart Ports is identified as the best strategy. The emerging technologies enable all container port areas to achieve high efficiencies and significantly enhance sustainability.

RQ3: What are the elements of a comprehensive and holistic approach to implementing the best strategy for enhancing the competitiveness of container ports?

Through a systematic analysis of various academic publications, Chapter 5 presents a comprehensive and holistic framework named SaPFaR. It embodies a collection of use cases for each Industry 4.0 technology and framework and maturity models for eight (8) different operational aspects of smart ports.

The objectives of the proposed research programme are as follows:

OB1: Conduct a comprehensive literature review to identify the current challenges in the container port sector, the strategies employed to enhance competitiveness, and recent research developments.
Chapter 2 provides a detailed analysis of the research landscape concerning container and smart ports. It also identifies the concept of smart port as the way forward.

OB2: Capture the perspectives of UAE container ports regarding their challenges and opportunities Chapter 3 provides a comprehensive overview of the industrial perspectives gathered through interviews and a questionnaire survey. This chapter is structured to present a detailed analysis of the insights and opinions collected from industry professionals, offering a valuable window into current industry trends, challenges, and expectations.

OB3: Develop a detailed research methodology to effectively address the research questions
Chapter 4 details the research method's design using Saunders's Onion model. This model is a systematic approach to developing a research methodology, peeling back layers of decision-making processes similar to the layers of an onion. The chapter is structured to methodically explore each layer of the model, demonstrating how it was applied to shape the research design.

OB4: Design, develop, and validate a framework aimed at enhancing the competitiveness of UAE container ports Chapter 5 presents an in-depth exploration of developing a robust and all-encompassing framework, positioning Industry 4.0 at its heart to facilitate the adoption of smart technologies. This chapter outlines how this framework repository integrates and aligns with seven additional frameworks and maturity models. It comprehensively analyses each component, illustrating how they collectively contribute to

more efficient and technologically advanced smart ports. The chapter also examines the synergies between these frameworks and Industry 4.0, highlighting their roles in enhancing operational efficiency, innovation, and digital transformation in smart ports.
Focus group interviews were the platform for engaging eight domain experts from three different ports to validate the framework. These experts unanimously agreed that the SaPFaR offers a thorough and holistic method for advancing smart port operations. After reviewing the feedback for possible enhancements, Capgemini's Digital Transformation Model has been recommended as the ideal platform for implementing SaPFaR.

OB5: Discuss the limitations of the research and propose f.uture research directions This chapter identifies major constraints, including the limited amount of previous scholarly work on the container port sector in the UAE and the overall scarcity of research within the country. It suggests an exciting avenue for future investigation: examining how Generative Artificial Intelligence can be utilised to improve and apply SaPFaR.

7.4 Contribution to knowledge

Contributing to knowledge doctorate level research is paramount, as it represents the core objective of doctoral studies. This contribution demonstrates the researcher's ability to understand the field of research but also pushes the boundaries of existing knowledge. In the following, key contributions are highlighted.

7.4.1 Industrial perspectives of UAE container port operators

The investigation into the UAE container ports sector, marked by interviews with senior executives from leading port operators and a comprehensive questionnaire survey, represents a pioneering effort to elucidate the sector's challenges and opportunities. By capturing first-hand insights from industry leaders and systematically collecting data, this research provides a indispensable understanding of the current state of container ports in the UAE. This enhanced knowledge base is crucial for stakeholders, as it offers valuable perspectives on operational hurdles and growth potential, informing strategic decisions and fostering advancements within the sector.

7.4.2 An extended definition for smart port

Considering a range of imperatives, an enhanced definition of smart port is provided.

> *"The smart port is a connected, sustainable, safe, and automated port which relies on smart infrastructure and equipment, skilled personnel, and smart managerial practices to ensure customer satisfaction, environmental protection, and a better quality of life for the citizens while adhering to stringent regulatory standards, actively engaging with diverse stakeholders, and fostering a culture of continuous research and innovation."*

This definition informs the development of SaPFaR.

7.4.3 Use Cases Library

Having argued that Industry 4.0 technologies should be at the heart of smart ports, a comprehensive library of use cases for each technology in Industry 4.0 is provided. This library serves as a critical resource for understanding the practical applications and benefits of these advanced technologies in the port industry. By detailing specific scenarios and examples, the library offers valuable insights into how smart ports can leverage Industry 4.0 to enhance their operations, improve efficiency, and remain competitive in a rapidly evolving maritime landscape.

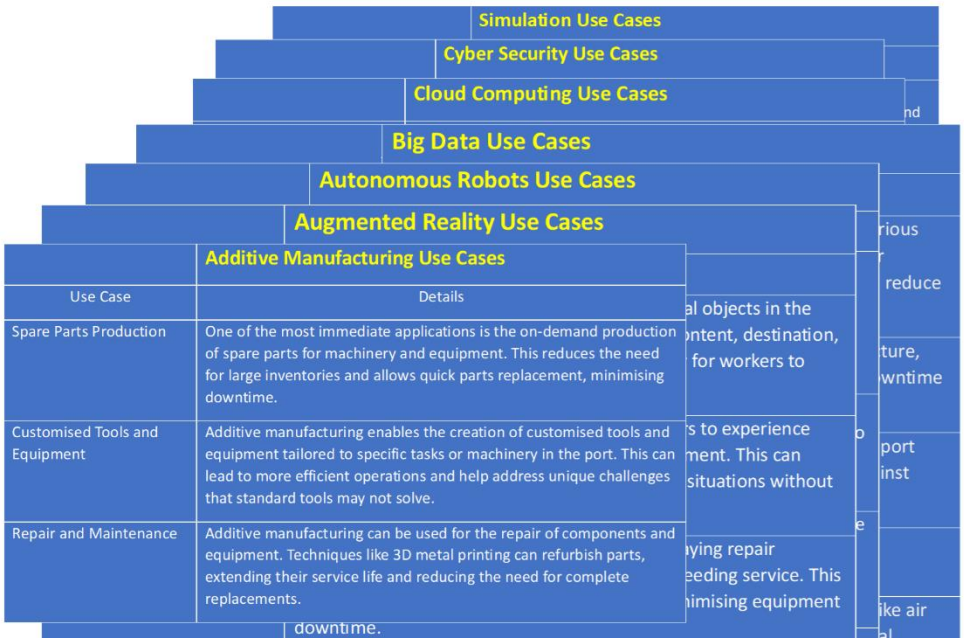

Figure 7.1: Use Case Library

7.4.3 SaPFaR

SaPFaR represents a groundbreaking advancement in the field of smart port development, making it an invaluable asset for enhancing knowledge in this domain. As the most significant contribution to date, SaPFaR offers a comprehensive and holistic repository that addresses multiple facets of smart port transformation.

Firstly, SaPFaR includes an extensive library of use cases, which serve as practical examples and benchmarks for implementing smart port technologies. These use cases provide detailed insights into various scenarios, challenges, and solutions, helping stakeholders understand the real-world applications and benefits of Industry 4.0 technologies in port operations.

Moreover, SaPFaR features an Industry 4.0 implementation framework specifically tailored for ports. This framework guides the systematic integration of advanced technologies such as IoT, AI, and big data analytics into port infrastructure and operations. By offering a structured approach, it ensures that ports can effectively transition to smarter, more efficient systems while minimizing risks and optimizing resource allocation.

In addition to the implementation framework, SaPFaR encompasses seven other frameworks and maturity models. These models assess and benchmark the readiness and progress of ports in adopting smart technologies. They provide a multi-dimensional evaluation covering aspects such as digital infrastructure, workforce skills, cybersecurity, and sustainability. By using these models, ports can identify their current maturity level, set realistic goals, and develop strategic plans to achieve higher levels of smart port maturity.

Overall, SaPFaR's comprehensive repository facilitates a deeper understanding and more effective implementation of smart port technologies. It empowers ports to leverage the

latest advancements in Industry 4.0, ultimately leading to enhanced operational efficiency, improved safety, and increased competitiveness in the global maritime industry.

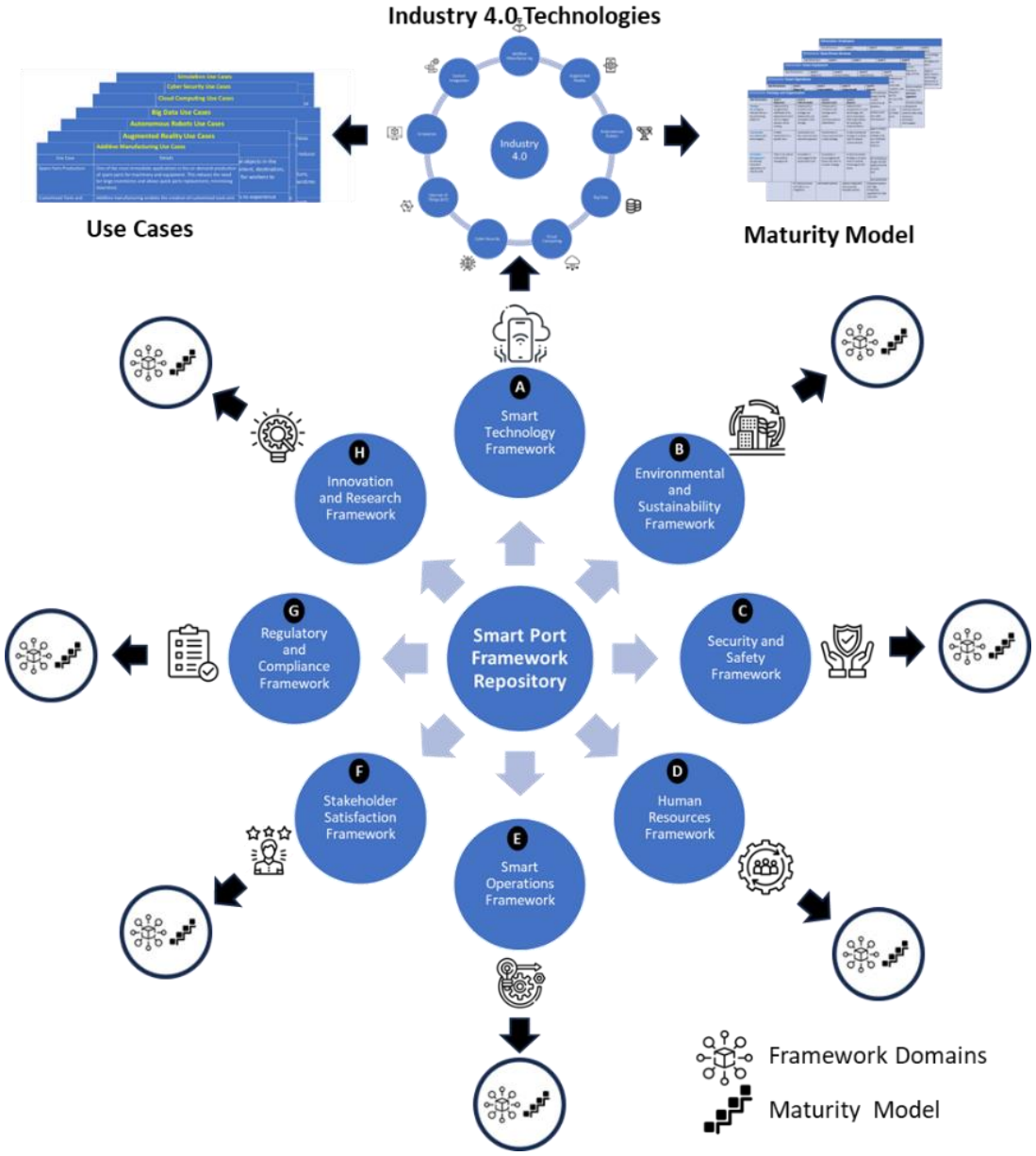

Figure 7.2 SapFaR

The above outcomes have contributed significantly to the research in designing and developing smart ports.

7.4.4 Generalisability

Although this research began with focusing on enhancing the competitiveness of container ports in the UAE, SaPFaR can be considered a general approach to enhancing the competitiveness of any container port.

7.5 Limitations of research

Research work, by its very nature, often encounters a range of limitations. These constraints can arise from various sources and impact the study's scope, depth, and findings. It is important to note that acknowledging these limitations is a critical aspect of conducting rigorous and transparent research.

(a) Limited research work on UAE ports

The container ports are pivotal to the development of the UAE. Despite their significant importance, there is a noticeable scarcity of research on these ports. This lack of academic research and study can primarily be attributed to the absence of specialised research programs in local higher education institutions. This gap in academic focus has led to a shortage of in-depth studies and analyses, which are crucial for understanding and enhancing the global competitiveness of the UAE's ports.

(b) Limited pool of domain experts and access restrictions

Among the eight (8) container ports located in the United Arab Emirates, only two of these ports have achieved recognition in the global ranking of container ports. Furthermore, within this elite group, only a single UAE container port has secured a position in the top 10. This scenario indicates a relatively narrow field of domain experts with the specialised knowledge and experience necessary to contribute significantly to this work area. The scarcity of such experts presents a challenge in conducting comprehensive research. Additionally, the process of gathering information and insights has been further complicated due to imposed restrictions.

7.6 Recommendations for future research

This is the first-ever research work focused on container ports in the UAE. In terms of future research directions, there are two distinct possibilities.

(a) Assessing the impact of Generative Artificial Intelligence (GAI)

The advent of General Artificial Intelligence (GAI) is anticipated to bring about a revolutionary transformation across all industrial sectors. Given that intelligent ports heavily depend on advanced technologies for their operations, it becomes crucial to assess the impact of GAI in this context thoroughly. Integrating GAI into smart ports promises to streamline processes and introduce innovative approaches to handling cargo, managing traffic, and maintaining security. Therefore, a detailed analysis of GAI's potential applications and implications in the innovative port sector is essential to leverage its capabilities fully,

(b) SaPFaR-based smart guidance system

Considering the comprehensive and holistic structure of the SaPFaR, it would be highly beneficial to create an advanced, intelligent guidance system that leverages its various components. This proposed system would offer an interactive platform tailored explicitly for SaPFaR users, enhancing their experience and efficiency. For instance, when a user inputs their current maturity profile into the system, it would be equipped to analyse this data and provide well-informed recommendations on the subsequent steps they should take. This level of personalised guidance would simplify the process for users and ensure that they are making the most informed decisions based on their unique position within the SaPFaR framework. By integrating such an intelligent system, users can navigate the complexities of SaPFaR with greater ease and precision, leading to more effective and successful outcomes.

7.7 Summary

This chapter presents a comprehensive overview of the significant contributions made to the field of knowledge, the most critical outcome being SaPFaR. Additionally, the chapter acknowledges the limitations inherent in the present studies, discussing the constraints and challenges encountered. Furthermore, the chapter outlines prospective research directions, suggesting pathways and opportunities for upcoming studies.

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Appendix 1: Survey Questionnaire

Introduction: You are invited to participate in a survey designed to enhance the competitiveness of container ports in the United Arab Emirates (UAE). This study is conducted as part of a PhD research program at Sheffield Hallam University, United Kingdom. Your participation will provide valuable insights to develop a framework.

Purpose of the Survey: This survey aims to gather feedback from stakeholders involved in identifying key factors and strategies that affect the competitiveness of UAE container ports.

Procedures: If you agree to participate in this survey, you will be asked to complete a questionnaire that will take approximately 30-45 mins to finish. The survey will include questions related to port operations, services, infrastructure, and other relevant aspects.

Voluntary Participation: Your participation in this survey is entirely voluntary. You may choose not to participate or to withdraw from the survey at any time without any consequences.

Confidentiality: All information collected in this survey will be kept confidential. Your responses will be anonymised, and data will be reported in aggregate form to ensure that individual responses cannot be identified.

Risks and Benefits: There are no foreseeable risks associated with participating in this survey. Your participation will contribute valuable insights that will enhance the competitiveness of UAE container ports, potentially benefiting the entire maritime and logistics industry.

Contact Information: If you have any questions or concerns about this survey, please feel free to contact Prof Terrence Perera (t.d.perera@shu.ac.uk)

Consent: By proceeding with this survey, you acknowledge that you have read and understood the information provided above and consent to participate in this study.

Thank you for your time and valuable contribution.

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I agree to participate in this survey: ☐ Yes ☐ No

Dimension	Strongly Disagree	Disagree	Neutral	Agree	Strongly Disagree
D1: Infrastructure					
S1.01: The port has sufficient berth length to accommodate large container ships.					
S1.02: The docking facilities are well-maintained and equipped with modern amenities.					
S1.03: The port is equipped with high-capacity cranes suitable for container handling.					
S1.04: The cargo handling equipment at the port is regularly updated and maintained.					
S1.05: The port has ample and secure storage facilities for containers.					
S1.06: There are enough container freight stations for efficient handling and storage.					
S1.07: The port is well-connected to road networks for easy container transport.					
S1.08 Intermodal transport facilities are efficient and reduce cargo handling times.					
S1.09: The port employs advanced technology for container tracking and management.					
D2: Capacity					
S2.01: The port can handle a high volume of container traffic without significant delays.					
S2.02: The turnaround time for container ships at the port is optimal.					
S2.03: There is sufficient space and planning for expanding container facilities.					
S2.04: The port has a strategic plan for scaling up its container handling capacity.					
S2.05: The port's container handling processes are streamlined for maximum efficiency.					
S2.06: The average container dwell time at the port is within acceptable industry standards.					
D3: Performance					
S3.01: The turnaround time for container ships at this port is consistently efficient.					

S3.02: The port effectively manages peak-time congestion to minimise delays.					
S3.03: The speed of loading and unloading containers meets or exceeds industry standards.					
S3.04: The port has adequate workforce and machinery to handle cargo efficiently.					
S3.05: Customs clearance processes for containers are quick and efficient.					
S3.06: Documentation procedures for container handling are streamlined and user-friendly.					
S3.07: The port staff are knowledgeable and provide excellent customer service.					
S3.08: Queries and complaints about container operations are addressed promptly and effectively.					
S3.09: Communication between the port, shipping lines, and freight forwarders is clear and compelling.					
S3.10: The port adheres to high container handling and storage safety standards.					
S3.11 Security measures for container cargo at the port are robust and reliable.					
S3.12: The port's infrastructure is well-suited to handle current container volumes.					
S3.13: The port continuously invests in upgrading its infrastructure to improve container handling.					
S3:14: The costs associated with container handling at the port are competitive and reasonable.					
S3.15: The port provides good value for money regarding container handling services.					
S3.16: The port has robust security measures in place for container cargo.					
S3.17: Safety protocols for container handling are regularly reviewed and updated.					
D4: Technology					
S4.01: The port has implemented state-of-the-art container tracking and management technology systems.					
S4.02: Automated systems are widely used for container handling and operations.					
S4.03: The port utilises advanced digital platforms for communication and data exchange.					

S4.04: Real-time tracking and monitoring of containers are effectively implemented at the port.					
S4.05: The port's technology systems are well-integrated with global shipping and logistics networks.					
S4.06: The port supports electronic data interchange (EDI) for efficient document handling.					
S4.07:The adoption of modern technology has significantly improved operational efficiency.					
S4.08: Technology has reduced the time required for container loading, unloading, and turnaround.					
S4.09: The technological systems ensure high accuracy in container handling operations.					
S4.10: The port's technology is reliable and seldom experiences significant downtimes or failures.					
S4.11:The technology used at the port is user-friendly and easy to navigate.					
S4.12: Staff training for new technologies is adequate and effective.					
S4.13: The use of technology has resulted in cost savings for the port and its users.					
S4.14: Investments in technology have shown a clear return on investment.					
S4.15: Modern technology gives the port a competitive advantage in the industry.					
S4.16: The port offers advanced digital solutions for tracking and managing container shipments.					
S4.17: Automation is effectively used in container handling and operations.					
D5: Sustainability					
S5.01: Technology has made the port's operations more environmentally sustainable.					
S5.02: The port uses technology to monitor and reduce its environmental impact.					
S5.03: The port implements eco-friendly practices in its container operations.					
D6: Competitiveness					
D6.01: The port ranks favourably in global comparisons of container ports.					

D6.02: The port has a strong and positive reputation in the international shipping community.					
D6.03: The port has short waiting times and quick container turnaround.					
D6.04: The port offers a wide range of services that meet the diverse needs of its users.					
D6.05: The quality of services provided at the port is superior to that of competing ports.					
D6.06: The port continuously invests in upgrading its infrastructure to stay competitive.					
D6.07: The port employs advanced technology to enhance its operational efficiency.					
D6.08: The technological solutions at the port are innovative and industry-leading.					
D6.09: The port's location is strategically advantageous for international shipping routes.					
D6.10: The port is well-connected to major inland transportation networks.					
D6.11: Customers are generally satisfied with the services provided at the port.					
D6.12: The port has a high rate of customer retention and loyalty.					