School of Management and Marketing

Curtin Faculty of Business and Law

A Development Framework to Determine the Applicability of a Dry Port to Fremantle Port Supply Chains: a Case Study

Gary Ian Crockford

ORCID CODE 0000000199546748

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Declaration of Original Authorship

The work contained in this thesis has not been previously submitted to meet the requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature:

Date: 18th November 2022

Keywords

Distribution terminal, dry port, dry port development models, freight gateway, freight village, Fremantle Inner Harbour, Fremantle Outer Harbour, Fremantle Ports, Fremantle Ports Authority, hinterland terminal, inland clearance depot, inland freight depot, inland hub, inland terminal, inland port, intermodal terminal, intermodal transport, port-city, port development models, port location, transport mode selection.

Abstract

As with many seaports worldwide, Fremantle Ports Authority Inner Harbour, located in Western Australia, has experienced increasing container throughput associated with global supply chains and population growth. The land transport activity, associated with container transport, has negative environmental and social impacts on the surrounding community and, through congestion, reduces the efficiency of links with the seaport hinterland. Appropriately incorporating dry ports into supply chains can reduce these impacts and increase seaport throughput capacity and effective life. The reduction of these impacts and capacity constraints through the incorporation of a dry port applies to the Fremantle Ports Inner Harbour.

The need for and location of a future container seaport for Perth has been under consideration for a long time, first mentioned in a BP State Agreement in 1952. More recently, the 2017 Westport Strategy, a WA state Labor government project with a broad range of aims, includes planning for an Outer Harbour in Kwinana as part of an integrated transport plan for Western Australia.

This thesis explores Fremantle Port's current and future development plans for both the existing Inner Harbour and the long-planned Outer Harbour. Focusing on container freight, it examines the applicability of a dry port in improving port capacity, hinterland connectivity and maintaining control of social impacts.

Whilst the taxonomy of dry ports is not well defined in the literature, a broad definition is established and adopted in this thesis. A dry port is "an inland intermodal or transmodal hub, with direct transport links to a seaport, where some seaport and supply chain functions and facilities are duplicated".

A single case study and online survey approach are used as the Fremantle Ports Authority seaport is unique regarding its geographic location, specific actors involved, supply chain and contemporary nature.

Information and data are drawn from published literature on dry port common criteria and development models, government and port planning and policy documents and port data on container/vehicle movements, sources and destinations.

A dry port development framework is developed and validated through a hindcasting methodology.

The case study, port user survey and literature review show:

- *The common criteria identified in the literature enable the creation of a dry port development framework to identify factors that require consideration in developing a dry port.*
- *Whilst each supply chain is unique, the common criteria identified in the literature, reflected in the dry port development framework, can be used to demonstrate the suitability of a dry port in a given supply chain.*
- *The common criteria, whilst able to demonstrate the suitability of a dry port in a specific supply chain, cannot be used to predict the timing of its introduction.*
- *Fremantle Ports has developed consistent with traditional seaport and dry port development models.*
- *Surveyed Fremantle Ports Inner Harbour exporters and importers have transport mode selection determinants in broad agreement with the literature.*
- *A dry port will prolong the mature stage of the lifecycle of the Fremantle Ports Inner Harbour; and*
- *For a future Outer Harbour container port development, a dry port in conjunction with quayside rail would be a viable inclusion in the new facility's supply chains.*

The significance of this research is the use of a combination of dry port characteristics, common criteria and development theory in the literature in conjunction with a case study on Fremantle Ports and a survey of its exporters and importers to establish a dry port development framework. The framework demonstrates a dry port's role in current and future Fremantle Ports Authority operations. This approach has not been published in the literature and will add to the body of knowledge at a time when the West Australian state government actively considers the future of Fremantle Ports.

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List of Abbreviations

ABC:	Australian Broadcasting Commission.
ACCC:	Australian Competition and Consumer Commission.
ACTA:	Alameda Corridor Transportation Authority.
AGORA:	Consulting Group, KombiConsult GmbH.
AHP:	Analytical Hierarchy Process.
AMSOC:	Australian Marine Oil Spill Centre.
APB:	Associated British Ports.
ARC:	Arc Infrastructure.
AZ:	Aurizon.
BITRE:	Bureau of Infrastructure, Transport and Regional Economics.
BOOT:	Build, Own, Operate and Transfer.
BPA:	Bunbury Port Authority.
BTCE:	Bureau of Transport and Communications Economics.
CCIWA:	Chamber of Commerce & Industry Western Australia.
CCTV:	Closed Circuit Television.
DC:	Distribution centre
DoIRD:	Department of Infrastructure and Regional Development.
DoIRDC:	Department of Infrastructure, Regional Development and Cities.
DoIT:	Department of Infrastructure and Transport.
DoT:	Department of Transport.
DoTaRS:	Department of Transport and Regional Services.
DoTPI:	Department of Transport, Planning and Infrastructure.
DPI:	Department for Planning and Infrastructure.
DPW:	DP World.

DUKC: Dynamic Under Keel Clearance.

EAWAD: Engineers Australia Western Australian Division.

EFIP: European Federation of Inland Ports.

EPA: Environmental Protection Authority.

ESCAP: United Nations Economic and Social Commission for Asia and the Pacific.

EU: European Commission.

FLCWA: Freight and Logistics Council of Western Australia.

FMC: FMC Consulting.

FPA: Fremantle Ports Authority.

G&W: General & Wyoming.

GHD: GHD Consulting.

GPA: Georgia Ports Authority.

GT: Gross Tonnes.

HSA: Harbour Services Australia.

IA: Infrastructure Australia.

ICL: ICL Group.

ICT: Information communication technology.

ICS: Intermodal Container Services.

ILS: Intermodal Link Services.

IMT: Intermodal terminal.

IT: Information technology.

IV: Infrastructure Victoria.

JDCL: JD Container Logistics.

JIT: Just In Time.

LCV: Light Commercial Vehicle.

LHV:	Long Heavy Vehicle.
LOA:	Length Overall.
MRWA:	Main Roads Western Australia.
NHMRC:	National Health and Medical Research Centre.
PN:	Pacific National.
POA:	Port of Antwerp.
POLA:	Port of Los Angeles.
PTA:	Public Transport Authority WA.
PUD:	Pick-up and Delivery.
PWC:	Pricewaterhouse Coopers.
RDA:	Regional Development Australia.
RFID:	Radio Frequency Identification.
RHLP:	Roe Highway Logistics Park.
RHWA:	Rail Heritage Western Australia.
SCT:	Specialised Container Transport.
SCPA:	South Carolina Ports Authority.
Sd+D:	Strategic Design and Development consultants.
SIMTA:	Sydney Intermodal Terminal Alliance.
SKM:	Sinclair Knight Merz.
STCWA:	Sustainable Transport Coalition of Western Australia.
TEU:	Twenty-foot Equivalent Unit.
TNSW:	Transport for NSW.
UK:	United Kingdom.
UN:	United Nations.
UNCTAD:	United Nations Conference on Trade and Development.

UNESCAP:	United Nations Economic and Social Commission for Asia and the Pacific.
UoE:	University of Edinburgh.
VBS:	Vehicle booking system.
WA:	Western Australia.
WAF&LTF:	WA Freight and Logistics Task Force.
WAM:	Western Australian Museum.
WAPC:	Western Australian Planning Commission.
WAPOTF:	WA Port Operations Task Force.
WEF:	World Economic Forum.

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Chapter 1: Introduction

1.1 INTRODUCTION

As worldwide container traffic grows through growth in globally integrated supply chains, supported by the introduction of containers in the 1960s commoditising the transport of goods (Rodrigue & Notteboom, 2009a), seaport function has changed (Pettit & Beresford, 2009). Cullinane, Bergqvist, and Wilmsmeier (2012) demonstrate that seaports are increasingly capacity constrained by off-port conflicts of community and environmental impact considerations. Nguyen and Notteboom (2016a) argue that the development of dry ports offers a solution to expansion constraints and provides an increased linkage of seaports to the hinterland, enabling efficient container freight movement (Andersson & Roso, 2016).

A dry port development framework is established through this research to identify the critical factors in assessing why development is required and guide the process of developing a dry port in a given supply chain. Based on common criteria for development and development models for dry ports, the framework describes the drivers for a development and associated trigger factors, items to be considered in a development and the associated establishment mechanisms. These factors are split into streams based on the development driver and applied to Inside-Out and Outside-In dry port developments. The dry port development framework is validated using hindcasting against dry port case studies. Establishing common criteria, reasons for development and development models of dry ports provides transferability of the research results through the dry port development framework.

A Fremantle Ports Authority (FPA) case study to establish the role of a dry port in the supply chains utilising the seaport is lacking in published research. This research establishes that the Inner Harbour and contemplation of an Outer Harbour have developed following published seaport development models such as the UNCTAD seaport generations model and the seaport life cycle model.

Common criteria for dry port development, lifecycle stage, and a suitable model type to determine the suitability of a dry port in a specific supply chain are applied to the Inner Harbour and proposed Outer Harbour development. This is achieved by defining the dry port concept and identifying their different types in conjunction with a review of dry port literature. Consideration of literature (primary, secondary, tertiary and grey) information and supply chain data combined draws out common and transferable data for comparison to the Fremantle Ports supply chain's characteristics to establish the dry port's role in the current operations and future development.

Fremantle Ports represents a strategic component of Western Australia's (WA) transport infrastructure (DoT, 2016) and is the largest container handling port in the state. Currently, the seaport container trade is through the Inner Harbour located at the mouth of the Swan River. Once the Inner Harbour capacity is reached future expansion is planned for an Outer Harbour located in the general Kwinana area, approximately 20 kilometres south of the Inner Harbour.

Whilst the ultimate container handling capacity of the Inner Harbour and associated hinterland links has no exact definition, road congestion associated with seaport related freight transport and general population growth in areas surrounding the seaport is increasing, and community pressure on its operations is reported (Herald, 2017; Loopers, 2015). This congestion and community pressure will determine the practical throughput of the Inner Harbour (Westport, 2019f). The efficient incorporation of a dry port into the current Inner Harbour supply chain and future Outer Harbour development can improve hinterland linkages and reduce community and environmental impacts.

A dry port requires an efficient line haul component of sufficient capacity to move containers to and from the seaport. Road and rail transport modes compete for the line haul task. Understanding the determinants of this transport mode choice made by importers and exporters is important in considering the viability of a dry port in the supply chain. The modal choice of current Inner Harbour container importers and exporters is researched through an online survey and shown to be consistent with the literature and primarily driven by cost.

The Fremantle Ports case study provides context for the application of the dry port development framework. This is done by demonstrating that Fremantle Ports reflects the literature in its past and future development and by conducting a transport mode selection determinants survey to show consistency with the literature. These outcomes demonstrate the applicability of the dry port development framework to Inner Harbour dyads and the role of a dry port in Fremantle Ports' current and future operations.

1.2 OBJECTIVES AND RESEARCH QUESTIONS

Despite the growing significance of dry ports in container-based global supply chains, research in the field of dry ports is still relatively new, and research papers are almost exclusively narrowly focused on specific dry port issues (Rodrigues, Mota, & Santos, 2020). A partial exception to this is a conference paper by Lovric, Bartulovic, and Stieiner (2020), which presents a range of decision making factors to provide a gated pathway to dry port development. This research draws together information from a wide range of resources, not previously combined in an exploration of the Fremantle Port case study.

The overall objectives of this research are to explore and interpret a wide range of topics in the literature and use the published common criteria and development models that favour the development of a dry port to create a dry port development framework and in conjunction with a consideration of the literature review outcomes demonstrate how:

(i) A dry port may benefit the current Fremantle Ports Authority Inner Harbour operations with an emphasis on hinterland connectivity, reduction in social impact (road congestion and noise), pollution, operating life and capacity associated with current supply chain links; and

(ii) The Fremantle Ports Authority Outer Harbour development, using a dry port in conjunction with waterside infrastructure, may have benefits over a traditional waterside development.

In fulfilling the research objectives, the following research questions are answered:

(i) How can common criteria identified from the literature be combined to demonstrate the suitability of a dry port in a specific supply chain?

(ii) How do the characteristics of the current Fremantle Ports operations align with these criteria and models to indicate the role a dry port could play in these operations?

(iii) Can a dry port development be a viable inclusion in the supply chain created through development of the Fremantle Ports Outer Harbour?

In answering these questions, the research has practical application to industry.

1.3 RESEARCH PARADIGM

Saunders, Lewis, and Thornhill (2009) describe the research paradigm as the framework under which the research is conducted, reflecting the philosophy of the researcher about how knowledge is developed. The paradigm is supported by the ontological and epistemological views of the researcher.

Ontology has two worldviews:

(i) Objectivisim - social entities exist in a reality external to those involved; and

(ii) Subjectivism - the phenomenon observed comes from the perceptions and actions of those involved.

Epistemology ranges across the spectrum of:

(i) Positivisim, a natural science outlook based on observation and experiment; and

(ii) Interpretivist, a social actor approach where reality is people's subjective experience of an external world.

Pragmatism sits between these extremes and results from considering that the research question is most important in setting the epistemology and ontology.

These considerations lead to the methodology of the research. The various components must be consistent and suitable for the research undertaken. Objectivism is a relevant way of studying dry ports as the structure around them determines whether or not they will be developed.

Under a pragmatic paradigm, an inductive, exploratory single case study approach has been adopted for the research paradigm.

1.4 METHODOLOGY

For the research topic, the adoption of a single case study approach provides context for the dry port development framework. A case study approach is useful when *"A how or why question is being asked about a contemporary set of events over which the investigator has little or no control"* (Yin, 2014 p.14). The study will usually use multiple sources of information, *"Typically case study research uses a variety of evidence from different sources, such as documents, artefacts, interviews and observation, and this goes beyond the range of sources of evidence that might be* *available in historical study"* (Rowley, 2002 p.17). These case study features are relevant to the research as the future of Fremantle Port is currently actively under review, and qualitative and quantitative data are used in the study.

Primary, secondary, tertiary and grey data sources are used. Due to the physical location and support of the Fremantle Port, data is accessible.

A single case study approach is adopted as the FPA Inner Harbour seaport, and any future Outer Harbour development is unique in terms of its geographic location, specific actors involved and contemporary nature.

Given the ability of a case study approach to gather rich data in real-life situations providing a deep understanding of the nature and complex interactions of the situation, a case study method is relevant to the field of supply chain management and logistics (da Mota Pedrosa, Näslund, & Jasmand, 2012). Empirical case studies have been growing as a research method in port studies as greater efforts are expended to gather data through surveys and interviews (Woo, Pettit, Kwak, & Beresford, 2011). Most insights into dry port characteristics use case studies (Nguyen & Notteboom, 2018). A literature review conducted by Lamii et al. (2020) identifying the dominance of case study methods in the evolution of the dry port concept supports this. The accessibility of the Fremantle Port provides the opportunity to study the case in sufficient depth to support a case study approach to the research. Efficiency drivers and inhibitors for specific dry port developments vary. Case studies examine why dry ports can be developed and operate in different geographic regions, political structures, cultural and historical settings and stages of an economy's development (Rodrigue & Notteboom, 2010c).

The research is both qualitative and quantitative. The qualitative analysis contrasts aspects of conventional port waterside development with that of a dry port in conjunction with government and port planning and policy. Quantitative data is collected on Fremantle Port, transport mode selection determinants and container numbers, sources and destinations but no modelling or statistical analysis is conducted.

A survey of container importers and exporters through the Fremantle Ports Inner Harbour provides information on the ranking of transport mode selection determinants and with results from earlier Fremantle Ports surveys enables comparison to the literature. The survey adds depth to the analysis and case study.

Figure 1-1 depicts the flowchart describing the methodology and relationship between the research components in the thesis.

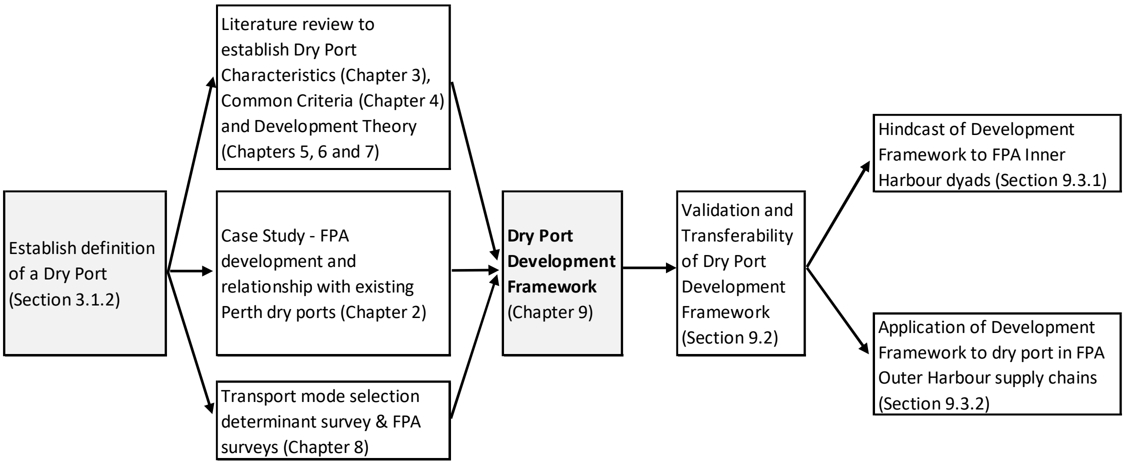


Figure 1-1 - Methodology and relationship between the research components.

A literature review is included at the start of each chapter. The research seeks to draw information from a wide range of resources, consequently, the literature review includes primary, secondary, tertiary and grey data sources.

A practical approach was taken to searching for relevant information. Initially, keywords were developed and databases relevant to seaport and dry ports were searched covering research on dry port development criteria, development theories and models. This was followed by a snowball approach using relevant references (backward snowballing) and document citing (forward snowballing) from the papers to find additional publications. This was followed until no new relevant papers were identified.

This approach was supplemented with searches of relevant government and agency websites such as Fremantle Ports, Department of Transport and BITRE to find relevant publications such as operating and planning documents associated with FPA.

General Google searches were conducted for media clips and information on individual seaports and dry ports.

Documents were reviewed for relevance to the research questions and topics before inclusion in the bibliography. The wide range of information sources required careful consideration of the bias and reliability associated with each source.

Rowley (2002) and Yin (1994) describe triangulation, the approach of using different data sources to support findings, as an important principle for data collection, and this is used in considering information sourced from various locations.

1.5 STRUCTURE AND OUTLINE OF THE THESIS

The thesis comprises three study areas to establish the dry port development framework and its applicability to Fremantle Ports operations. The literature review determines the common criteria, development models of seaports and dry ports and characteristics required for the successful inclusion of a dry port in a supply chain. The case study on the background of Fremantle Ports is used to establish that the Inner Harbour development and relationship to the dry ports that are in the supply chain developed and responded to growth pressures as described in the literature. A survey of Inner Harbour exporter and importer modal choice determinants is shown to be consistent with findings of earlier Fremantle Ports surveys and aligned with the literature.

The three study areas are self-supporting and show the literature and case study to be consistent. The findings are drawn together in a dry port development framework which is not present in the literature. The dry port development framework brings the individual research areas on dry ports together in an overarching approach to dry port development.

The dry port development framework is validated using hindcasting against dry port case studies and the literature that supports the previously identified seaport and dry port common criteria, development theory of seaports and dry ports and characteristics.

The validated dry port development framework is then applied to the Outer Harbour to determine the role a dry port could have in a future development.

The thesis is structured as follows. Chapter 2 describes FPA's background and development to this time at the Inner Harbour and potential Outer Harbour developments. Chapter 3 provides a literature review on dry ports identifying important attributes and the definition of a dry port used in the thesis. The following four chapters describe the why, how, and underlying support required for dry port development and how the FPA case study aligns with these to answer the research questions. Chapter 8 describes a survey conducted on container exporters and importers through Fremantle Ports Inner Harbour to establish the ranking of reasons for modal choice and compares this to the literature. Each of these chapters includes literature reviews relevant to the topic of discussion, as the broad range of topics discussed favours this approach over a sizeable self-contained literature review at the beginning of the thesis. Chapter 9 presents the dry port development framework and establishes its transferability. Chapter 10 details the conclusions and describes the thesis limitations and future research areas.

Chapter 2: Fremantle Ports Background

2.1 HISTORY

2.1.1 FREMANTLE PORTS CONTEXT

Fremantle Ports operates as a government trading enterprise, Fremantle Port Authority, under the Western Australian Government Port Authorities Act 1999. The Act defines the functions, area of control and management, and how Fremantle Ports operates (WA Government, 2019). Fremantle Ports represents a strategic component of the WA transport infrastructure and is the most significant container handling and general cargo port in the State (DoT, 2016; Westport, 2017). The Fremantle Ports' current operations are at the Inner Harbour in Fremantle, Figure 2-1, and the Outer Harbour in Kwinana, Figure 2-2. Both are within the Perth metropolitan area. The Inner Harbour, the focus of this study, handles container, break bulk, livestock, cruise ship and motor vehicle trade. The Outer Harbour has two Fremantle Ports operated berths, the Kwinana Bulk Jetty and Kwinana Bulk Terminal, handling mineral sands, fertiliser, sulphur, coal and other dry bulk cargo. There are also terminals operated by Alcoa (alumina), BP (petroleum) and Co-operative Bulk Handling (grain) (FPA, 2018b).

Figure 2-1 - Fremantle Ports Inner Harbour.

Source: FPA (2018a, p.147).

Figure 2-2 - Fremantle Ports Outer Harbour.

Source: FPA (2018a, p.148).

The Inner Harbour has three main operating areas. North Quay comprising of two container terminals (seven berths) and several break bulk and liquid berths. Victoria Quay comprising of two zones, the operational eastern end for general cargo, motor vehicle imports and a cruise ship passenger terminal, and the western end, under development as a community waterfront area. Rous Head is for port-related and maritime activities, including a ferry terminal servicing the Rottnest Island ferry (DoT, PTA, & MRWA, 2016b; FPA, 2000).

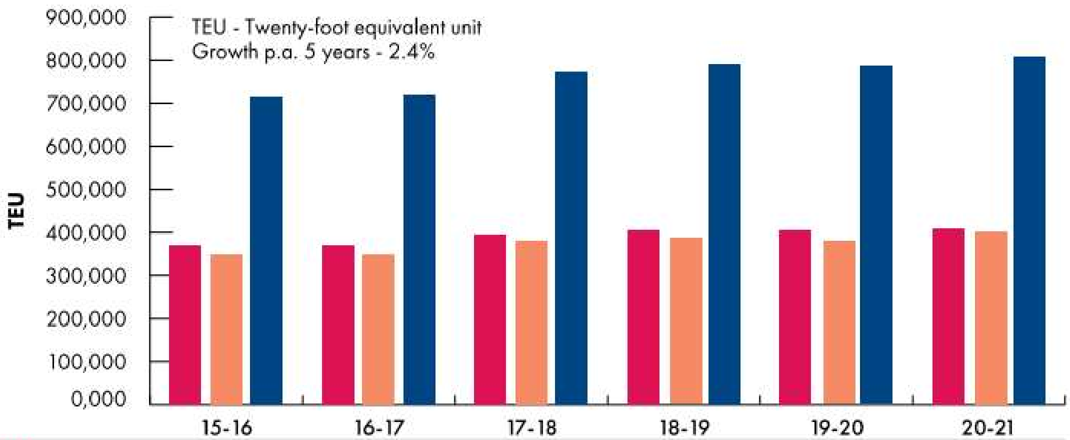
Intrastate and interstate links to rail exist for North Quay at the Inner Harbour and the Kwinana Bulk Terminal (FPA, 2018b). The North Quay Rail Terminal (NQRT) underwent an upgrade in 2014 (FPA, 2014c), and in the 2020/21 financial year, rail transported 18.4% of containers handled by Fremantle Ports (FPA, 2021a).

Currently, container trade is through the Inner Harbour but planning for the eventual development of an Outer Harbour container terminal has been considered for many years. The first mention of the concept is in the BP State Agreement Act 1952 (Westport, 2019b).

2.1.2 TRADE LEVELS

Fremantle Ports publishes annual and other reports that provide information on container and other cargo movements through the Inner Harbour. In the 2020/21 financial year, Fremantle Ports handled 807,061 (Twenty-Foot Equivalent Unit) TEU, including empty containers, as part of 31.3Mt of trade through the port. TEU full container imports (391,401 TEU) exceeded full container exports (223,404 TEU) by approximately 75%. The balance of the TEUs is empty container movements dominated by export. Over the period since 2015/16, full container imports have grown 12.7% and exports 10.4%. This disparity requires increasing the number of empty containers passing through the port (FPA, 2021a).

The FPA 2021 Annual Report (FPA, 2021a) provides a six-year snapshot of container trade levels as depicted below, Figure 2-3.



	15-16	16-17	17-18	18-19	19-20	20-21
Imports	369,072	368,670	393,639	402,703	404,635	406,454
Exports	346,035	347,277	376,583	385,563	378,802	400,607
Total	715,107	715,947	770,222	788,266	783,437	807,061

Figure 2-3 - Fremantle Ports total container trade 2015/16 to 2020/21.

Source:FPA (2021a, p.33).

2.1.3 TRANSPORT LINKS

Government Planning

At a national level, the land transport of freight generally, and to and from seaports, is considered critical to national prosperity (DoIRDC, 2018; DoIT, 2013; Infrastructure Australia, 2011b). The federal government planning of intermodal terminals (included in the definition of dry ports adopted for this thesis, Chapter 3 Attributes, Definition and Classification of a Dry Port) is through the Infrastructure

Investment Program as part of Infrastructure Australia (Infrastructure Australia, 2021). Whilst acknowledging social and environmental aspects of land transport, this is at a strategic rather than detailed level and includes establishing overarching principles for the planning of rail freight corridors and roads to seaports, introducing buffer policies and integrated planning for seaports at all planning levels in jurisdictions, regions and precincts. The underlying impact of population growth and associated road congestion in capital cities is recognised at this level of government, as are the negative aspects on communities caused by land freight transport (DoIT, 2013). The differing needs of freight transport compared to private commuters and the impacts of improving roads for efficient freight movement on private traffic have been recognised in the Australian context since the 1990s (BTCE, 1995). The federal government recognises the balance between adverse impacts and benefits of dry ports on local communities and understands land use planning (zoning) and expenditure above “minimum investment” in environmental controls minimise these impacts (DOTARS, 2006b). The growth in container vessel size and the impacts that this has on moving large numbers of containers away from the seaport and the importance of intermodal terminals with efficient links to the seaport in managing this are understood at a national level (DoIRD, 2017b). As national strategies are focused on a strategic level, the differences in the political agenda of the two main Australian federal political parties do not cause significant disruption to the overall freight transport approach as both parties recognise the importance of the freight task.

At a state level, political priorities have a much more direct impact on land freight transport. The WA state Liberal and Labor governments have differing approaches to improving and securing road freight transport access to the Inner Harbour. Significant planning and initial construction activity took place by the Liberal government on the Perth Freight Link as part of the Perth Freight Transport Network Plan (DoT, PTA, & MRWA, 2016a; DoT et al., 2016b; DoT, PTA, & MRWA, 2016c), with works starting on what was a controversial extension to the Roe Highway, Roe 8, just before the 2017 state election, (Barnett & Marmion, 2016). The Labor Party opposes Roe 8 (MacTiernan, 2002b) and, upon winning the state election, halted the works and rehabilitated the site (McGowan & Saffioti, 2017). The Liberal Party, now in opposition, has committed to building Roe 8 if re-elected (ABC, 2019). The Labor government commissioned the Westport study to investigate (amongst other things) options for the Outer Harbour container port and the associated road and rail links to support it (DoT, 2017b). The Labor government is undertaking some intersection upgrades of the existing road route to the Inner Harbour as part of the Metronet Plan (McGowan & Saffioti, 2018, 2019; Scaffioti, 2017, 2019) to improve safety and congestion, arguing that these replace the need for Roe 8. This work includes the replacement of the Fremantle Traffic Bridge (McGowan & Scaffioti, 2021; Scaffioti, 2019), as the bridge serves to relieve the traffic load on the Stirling bridge which is on the road freight route to the Inner Harbour.

Both state political parties support rail freight access without any significantly different approaches to maintaining and developing the infrastructure, including the replacement of the Fremantle Traffic Bridge by incorporating a rail crossing to reduce conflict between freight and passenger rail (DoT et al., 2016a; McGowan & Scaffioti, 2021; Scaffioti, 2019). Both political parties support long-term planning for intermodal (dry port) terminals in the Perth metropolitan area (discussed in Chapter 7: Dry Port Site Selection).

As transport routes converge on the Inner Harbour, concentrating truck and train movements, the environmental and community impacts of the freight transport task are also concentrated. At this local government level, transport strategy objectives favour community amenity over seaport transport needs. The City of Fremantle Integrated Transport Strategy promotes a modal shift from road to rail in daylight hours (night time operation causing adverse community impact through noise generation) and allocation of funds for lost amenity and minimising infrastructure upgrade impacts on private property and community amenity, despite recognising the importance and earlier existence of the Inner Harbour (Fremantle, 2015).

Land-based freight enters or leaves the Inner Harbour by either road or rail. The two main access roads for the Inner Harbour container terminals are Tydeman Road from the east, carrying the most port traffic, and Port Beach Road from the north, Figure 2-4. Rail comes from the Cockburn triangle to the south and links the Inner Harbour to the Kwinana and Forrestfield/Kewdale terminals along with other mainline destinations, Figure 2-5.

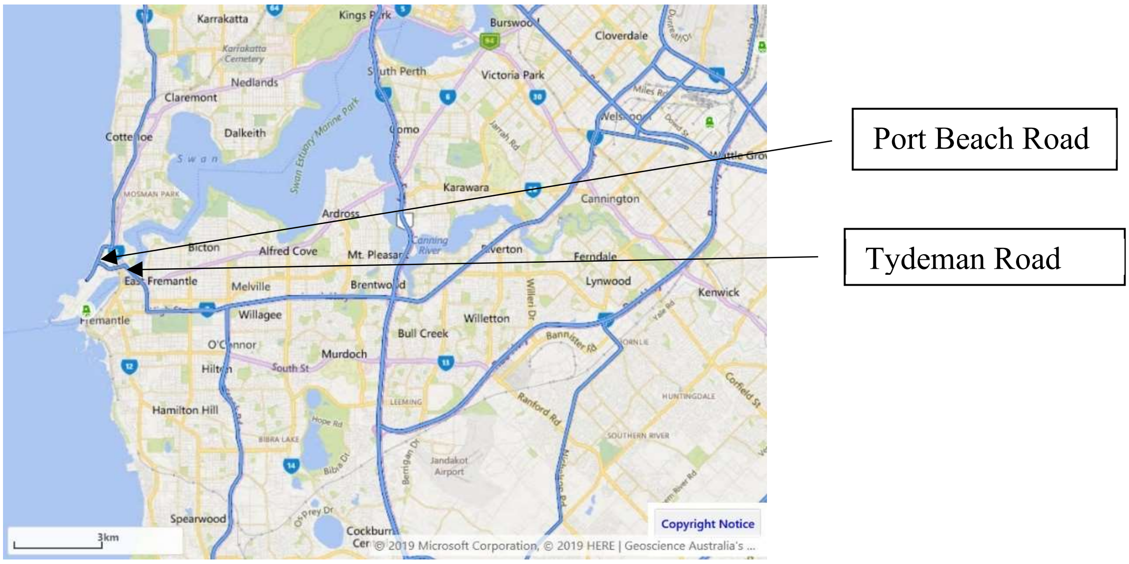


Figure 2-4 - Key Perth regional road routes.

Source: DoIRD (2019b, webpage accessed 2/09/2019).

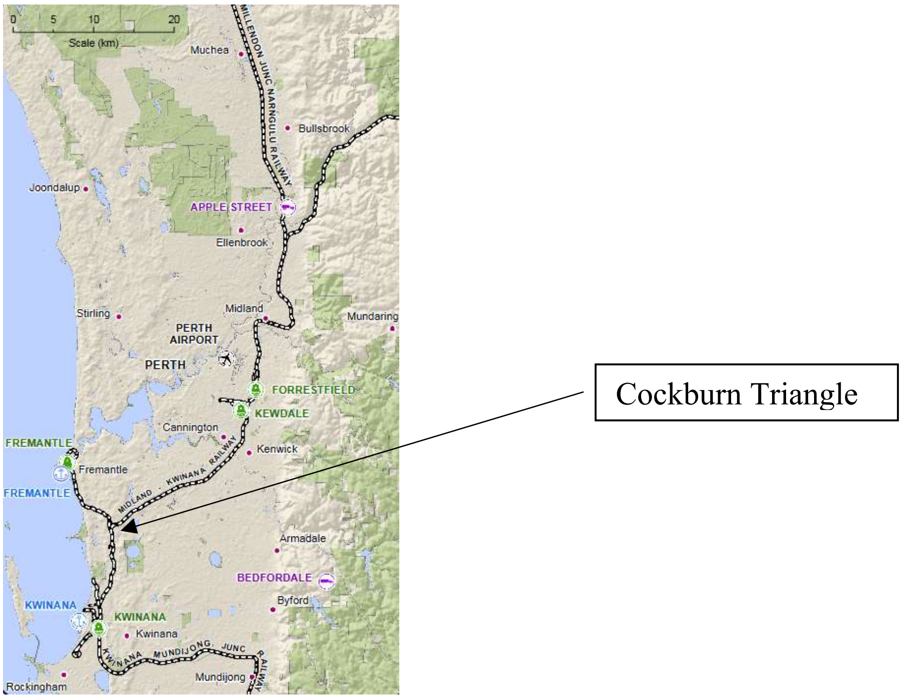


Figure 2-5 - Key Perth regional rail routes.

Source: DoIRD (2019a, webpage accessed 2/09/2019).

Road

Most containers leave and return to the Inner Harbour by road; this will continue to be the case in the future. Most containers' local sources and destinations in the Perth metropolitan area favour the flexibility and lower direct cost of road delivery over rail transport (FPA, 2017b; FPA & WAPOT, 2011). For some time, Fremantle Ports have recognised the importance of road transport for the Inner Harbour operations. Fremantle Ports is working with the Department of Main Roads WA (the government department responsible for main road planning and development) to ensure suitable road access is maintained and developed for the Inner Harbour (FPA, 2000). This road access forms an essential aspect of the Westport Study (Westport, 2017).

Despite the many studies on road access to the Inner Harbour to solve traffic congestion, general increases in private and seaport related traffic in the Fremantle and broader Perth metropolitan area have increased road congestion. Several Inner Harbour truck studies, including annual *"Truck Surveys"*, have been undertaken to establish truck numbers, destinations, origins, types of trucks, pick-up and drop-off times and areas where truck efficiency (and so overall numbers or impact on congestion) can be improved, (FPA, 2004, 2012a, 2014d). The latest annual Truck Survey provides insight into truck activity in the Inner Harbour area (FMC Consulting, 2019). The two main access roads to the container terminals are Tydeman Road and Port Beach Road. Tydeman Road links to the Kewdale-Forrestfield area via Leach Highway, Kwinana Freeway and Roe Highway and the Western Trade Coast and Kwinana industrial area from roads leading onto Stock Road (Martin, 2016). Container truck traffic as a proportion of total vehicles (between 6 a.m. and 6 p.m.) on Tydeman Road has increased since 2002 and now represents approximately 10% of all traffic whilst container traffic on Port Beach Road has remained low and is only 2% of total traffic,

Figure 2-6. These numbers have continued into 2021 (FPA, 2021a). A combination of modal shift from road to rail and other road transport factors, such as a decrease in unladen truck numbers, more multi-container trucks and an increase in 40-foot containers, has resulted in the TEU per truck movement steadily increasing from 1.31 in 2002 to 1.48 in 2019, is reflected in container trade growing at 2% per annum since 2014 with truck numbers falling 4% per annum. The loading ratio fell to 1.44 TEU per truck in 2021 (FPA, 2021a). A more recent influence on container related truck numbers is the increase in packing and unpacking of containers at Rous Head which requires truck transport to assemble or distribute cargo but does not create identifiable trucks loaded with containers, resulting in an understatement of seaport related truck movements, (FMC Consulting, 2019). The total Inner Harbour container throughput has grown from 311,000 TEU in 2001-02 (DOTARS, 2006a), to 807,061 TEU in 2020-21 (FPA, 2021a) a 260% increase.

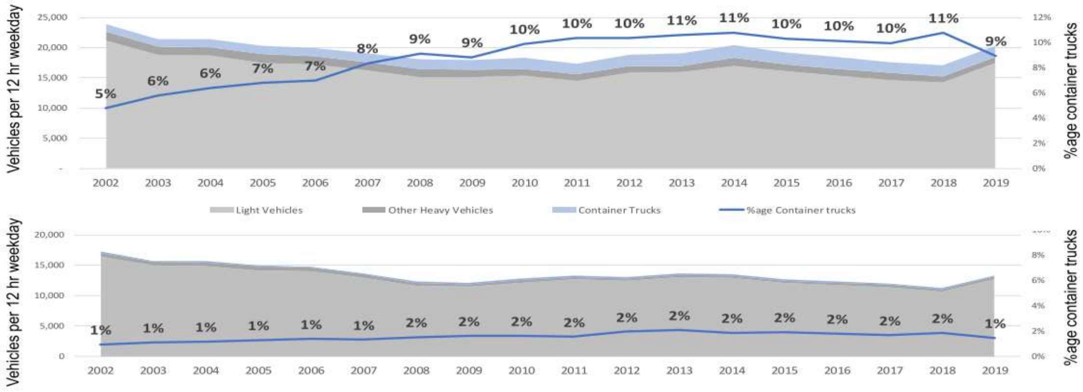


Figure 2-6 - Container vehicles as a portion of total traffic (6 a.m. to 6 p.m.).

Source: FMC Consulting (2019, slide 4).

In a study of container port landside efficiency Lubulwa, Malarz, and Wang (2011), summarise BITRE results for the proportion of travel distance of vehicle type in Australian capital cities. The study reinforces the small proportion of Fremantle truck movements,

Table 2-1, established by aggregate modelling in a BITRE 2007 traffic congestion report (BITRE, 2007). Over half the trucks in the Perth (Fremantle) classification attend the container seaport mirroring the higher truck component in the Fremantle Ports studies (despite the Fremantle Ports study being on numbers, not distance).

Table 2-1 - Percentage of truck distance travelled in Australian capital cities.

Source: Lubulwa et al. (2011, p.9).

Table 4: Base case projections for average network delay due to congestion for Australian metropolitan areas: 2005, 2010, 2015 and 2020.

Year	Melbourne		Sydney		Brisbane		Perth (Fremantle)		Adelaide	
	Min/km	Trucks VKT (%)	Min/km	Trucks VKT (%)	Min/km	Trucks VKT (%)	Min/km	Trucks VKT (%)	Min/km	Trucks VKT (%)
2005	0.335	4.0	0.350	4.7	0.286	4.6	0.261	4.1	0.283	3.2
2010	0.399	5.0	0.421	4.8	0.352	4.7	0.315	4.2	0.330	3.3
2015	0.445	5.2	0.475	4.9	0.407	4.7	0.359	4.2	0.363	3.4
2020	0.488	5.6	0.527	5.0	0.464	4.9	0.402	4.4	0.393	3.6

Min/km = minutes per vehicle kilometre travelled in the city.

Trucks VKT (%) is the sum of vehicle kilometres travelled by rigid trucks and articulated trucks as a percent of total vehicle kilometres travelled by all road vehicles in the city

Source: BITRE (2007 Tables 2.2, 2.3, 2.4, 2.5, 2.6 and 2.12)

Rail

The Western Australian state government established a 30% target for rail share of container transport to and from the Inner Harbour in 2002 (DPI, 2002; MacTiernan, 2002a; Turner, 2014; WAPC, 2006), with an expectation of achievement within ten years. However, by 2006 it was evident that the costs associated with rail transport were not commercially attractive. This unattractive cost resulted in the introduction of a rail subsidy to offset additional (direct) costs of intermodal rail transport in 2006/07 (Turner, 2014) (the role of external and direct costs on modal choice is discussed in Chapter 6 Development Criteria for Dry Ports). The uptake of rail transport, in a growing total container transport task, has steadily increased both in absolute and percentage terms, and a revised target of 20% rail share by 2018/19 was achieved (Scaffioti & MacTiernan, 2019) from a 2003/04 value of just 2% (FPA website (accessed 31/1/19)). Figure 2-7 depicts the growth in the proportion of containers transported by rail. Rail share is 18.4% in 2021 (FPA, 2021a). The rail subsidy currently stands at $50/TEU and applies to full containers transported from the NQRT to either the Forrestfield Intermodal Terminal or the Kwinana Intermodal Terminal (DOT, 2018).

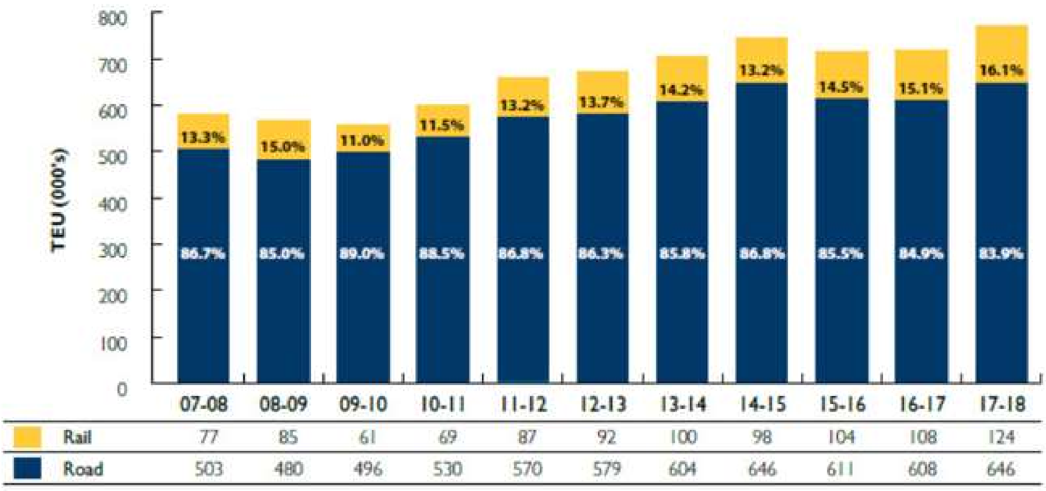


Figure 2-7 - Growth in rail share of TEU transport.

Source: FPA website https://www.fremantleports.com.au/landside/rail (accessed 31/01/2019)).

Fremantle Ports' container transport rail share is higher than the average for the five main Australian container ports (Sydney, Melbourne, Adelaide, Brisbane and Perth),

Figure 2-8 (BITRE, 2021b) and generally the highest of all (BITRE, 2021b; FPA, 2021a).

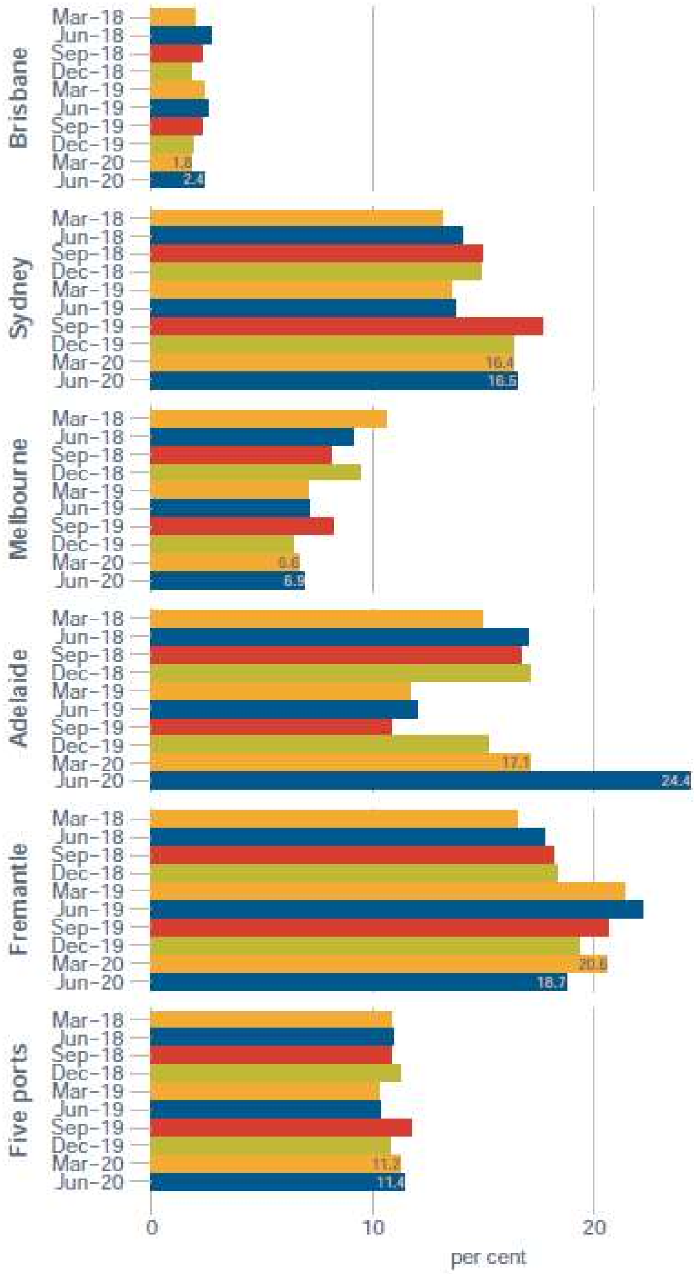


Figure 2-8 - Rail share in Australian container ports.

Source: BITRE (2021b, p.11).

The FPA has long recognised rail freight's role in realising container trade's full potential through the Inner Harbour (FPA, 2000). Deficiencies identified in the then-existing port rail terminal were poor connectivity between the seaport container terminals, with the rail terminal requiring a short road leg between the dockside and the rail terminal and no narrow gauge rail (FPA, 2004). The first stage of the NQRT (planned as a two stage project) was developed in 2005 and completed in 2006 when a 400m long terminal was built immediately behind the Inner Harbour container terminals. This track length required full length trains to be split and shunted and a rail line to facilitate connection to main rail lines (Turner, 2014). An exporter survey in 2011 identified the following barriers to rail use, the off-port rail terminals not being located in a convenient location, the cost of rail, container delivery cut-off times, especially for Just in Time (JIT) suppliers, being prohibitive and the extra handling legs in the rail supply chain (FPA & WAPOT, 2011). The second stage of the NQRT, funded by state and federal governments, increased the rail length from 400m to 690m improving turnaround times (Truss & Buswell, 2013) and providing a closer link to all the seaport container terminal activities (FPA, 2014b, 2014c). The capacity of the NQRT is 360,000TEU which is considered capable of handling a 30% rail share of the Inner Harbour container movements (Turner, 2014), and at this level would replace more than 250,000 truck movements annually (FPA, 2019e).

Rail transport between NQRT and Forrestfield/Kewdale and Kwinana suffers from the disadvantages of short-haul rail compared to road freight. The state government recognise the disparity (Boggs, 2015), reflected in the freight subsidy they pay. Currently, Intermodal Link Services operates two to three train services a day, six or seven days a week between Forrestfield and NQRT, and there are two trains per day between Kwinana and NQRT operated by Aurizon carrying freight sourced from its Malcolm and Kalgoorlie freight trains, (BITRE, 2018, 2021a). Each train can transport 90 TEU, and in 2021 rail replaced 103,000 truck movements (FPA, 2021a).

2.1.4 FORRESTFIELD/KEWDALE HUB DRY PORT

The Forrestfield and Kewdale rail terminals were developed in the 1960s as part of the standard gauge rail development between Perth and Kalgoorlie and replaced the Perth city railyards (PTA, 2010).

Intermodal Group operates both the NQRT and Forrestfield dry port through the subsidiary Intermodal Link Services. The Forrestfield facility provides the following services:

- Rail connection to FPA Inner Harbour.
- Direct access to major rail and road links (including 36.5m road train access).
- Proximity to international and domestic airports.

- Proximity to sources and destinations of Perth metropolitan cargo.
- Secure facility with CCTV and controlled exit and entry.
- Customs bonded facility.
- Fumigation facilities.
- Container lifting equipment.
- Approximately 1,000 TEU transit storage.
- Container maintenance and repair.
- Container washing.
- Web-based container tracking with the following features:
    - Connectivity with “1 Stop” and “Container Chain” FPA VBS.
    - Real-time information.
    - Document capture and storage.
    - Audit trails.
    - Alerts.

(ILS, 2020).

Kewdale incorporates a facility linked to DP World Inner Harbour terminal activities (DPW, 2020).

2.1.5 COMMUNITY INTERACTION

Recognition exists at a national level of the impact of land freight transport on metropolitan communities and identifies the disconnect between urban residents' quality of life objectives and the dependence on freight movement that supports these objectives. These conflicts often occur when urban development is allowed to encroach on existing and planned freight corridors (DoIT, 2013). This encroachment situation applies directly to the Inner Harbour. Residential development and general population growth in areas surrounding the Inner Harbour and associated transport corridors have resulted in a situation where this ultimately constrains Inner Harbour growth. The road freight transport links experience these development and growth impacts and are becoming increasingly congested with private vehicle growth, Figure 2-9. The preference given to the increasing number of passenger trains over freight trains restricting train slots on the shared rail bridge at Fremantle (Westport, 2019f) is addressed by the state government with funding allocated to eliminate this restriction which currently prohibits freight trains on the shared line for six hours a day (FPA, 2021b). This situation is consistent with population and transport conflicts at a national level (DoIRDC, 2018).

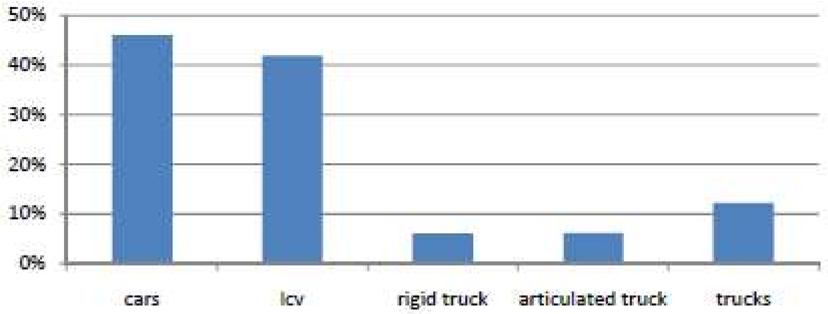


Figure 2-9 - Vehicle type contribution to traffic growth 2005 to 2020.

Source: Infrastructure Australia (2011a, p.16).

Road congestion associated with Inner Harbour activity is seen as a problem by some residents in Fremantle (ABC, 2017). Some parts of the community in the Fremantle area have lobbied for a modal shift of container transport from road to rail based on the environmental concerns of noise, air pollution and amenity loss (Herald, 2017). However, there has also been community action against rail freight based on noise (wheel squeal and crossing alarms), vibration and general amenity (Fremantle Herald Interactive, 2017), which has resulted in a voluntary halting of night trains. As in any community, views are mixed, with some individuals supporting existing uses over individuals who live in areas of urban encroachment into transport corridors (Loopers, 2016).

2.1.6 PORT-CITY RELATIONSHIP

Towards the end of the last century, as Inner Harbour trade levels and the Fremantle City population increased, the changing relationship of the seaport with the City of Fremantle was recognised by the Fremantle Ports management. This recognition resulted in the preparation of an Inner Harbour Development Plan, Buffer Studies, Strategic Freight Route Planning fact sheet and Waterfront Redevelopment Plan to protect, as far as possible, the continued functioning and growth of the Inner Harbour. This thesis focuses on containers, but the other Inner Harbour cargoes are a factor in this relationship and include cruise ship visits, motor vehicle imports, non-bulk general cargo and livestock export. Whilst livestock export is contentious, these trade areas are not the primary cause of trade growth impacts as containers represent 89.3% of Inner Harbour trade tonnage, calculated from FPA (2018a).

The Inner Harbour Development Plan recognises the potential for conflict between the seaport and the surrounding community *"Experience around the world has shown that careful planning is required if the needs of an operating port are to be reconciled with broader environmental and social goals of the community."* (FPA, 2000 p.2). The conflicts identified are light, noise and odour, and the development plan calls for ensuring *"proper controls are exercised on urban development in the vicinity of the Port"* (FPA, 2000 p.12) and announces the undertaking of a Buffer Definition Study. The development plan accepts ongoing public access to the western end of Victoria Quay.

Despite recognising the importance of Inner Harbour operations at a state and local level, the Fremantle City Council is inherently conflicted over land use and freight transport routes around the seaport (Fremantle, 2015). Fremantle Ports commissioned a Buffer Definition Study consistent with the WA State Industrial Buffer Policy. The WA Planning Commission and Department of Environmental Protection endorsed the plan in 2004. The study identified three zones around the seaport, Figure 2-10, with increasing restrictions on building uses and built forms as buffer areas closer to the seaport are entered.

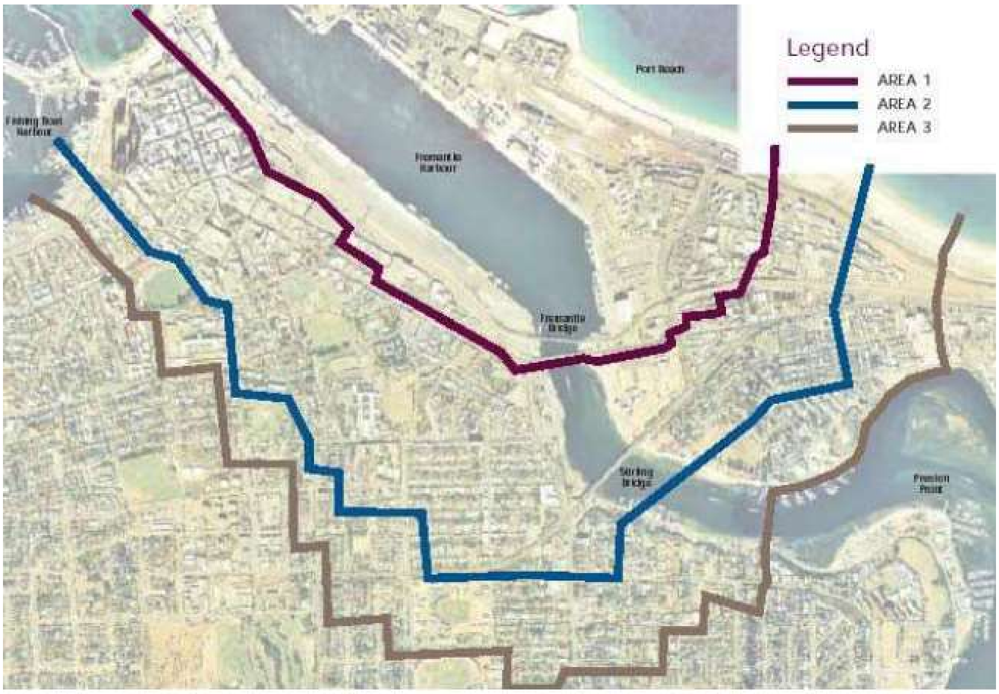


Figure 2-10 - Buffer boundaries identified in Buffer Definition Study.

Source: FPA (2002, p.12).

Fremantle Ports recognised the importance of protecting freight transport corridors (FPA, 2015b) and correctly identified issues associated with urban encroachment into freight routes, including reduced amenity of those areas compared to general residential environments and the resulting curtailment of available capacity of freight routes.

As has been the case for many seaports worldwide, changing trade patterns and technology have seen cargo activities vacate certain waterfront areas, and the surrounding city seeks redevelopment of these areas (Huddleston, 2015). In the case of the Inner Harbour, the State Government and the City of Fremantle, working with the FPA, formed a Fremantle Waterfront Steering Committee to *"revitalise the Fremantle waterfront"*. The steering committee oversaw the development of a Fremantle Waterfront Masterplan, Figure 2-11, for the western end of Victoria Quay. Whilst addressing the requirement not to conflict with the workings of the Inner Harbour, the masterplan did result in a narrowing of the rail reserve (an issue impacting its use, subsequently acknowledged by the Fremantle Council (Fremantle, 2015)), limiting it to a single track and preventing the construction of a future second track.

Figure 2-11 - Fremantle Waterfront Masterplan.

Source: Cox, Howlett, Bailey, & Woodland (2000, Fig. 01).

2.2 FUTURE

2.2.1 INNER HARBOUR CONTAINER TRADE GROWTH AND ULTIMATE CAPACITY

Container based trade growth for a particular seaport is difficult to predict, particularly over the medium (five years) to long-term, relying on factors such as world and local economic growth, container to GDP ratio, population growth and shipping patterns. Fremantle Port Inner Harbour container trade growth has averaged 5.4% over the 20 years to 2019 (Westport, 2019b), reducing to 2.4% for the five years to 2021 (FPA,–2021a). This forecasting difficulty is depicted by the total Inner Harbour container movement estimate made in 2010 of approximately 1.05M TEU movements in 2017/18 predicted by BITRE (2010) compared to the actual of 0.77M TEU (FPA, 2018a), a relative error of some 36%, a more recent BITRE report (Dolman, 2014), predicted an even higher growth rate of 5.8%. A prediction of a “3.5M population for the Perth and Peel Region by 2050” report estimates container trade to increase to 1.25M TEU by 2030 and 2.2M TEU by 2050 (DoT et al., 2016b), which is in broad agreement with the more recent Westport study. The influence of modelled growth rates is understood by Westport when looking at a 50 year time frame which results in a TEU movement (trade level) range between 3.4 and 5.5M TEU for growth rates of 2.8 and 4.0%, respectively, Figure 2-12, (Westport, 2019b).

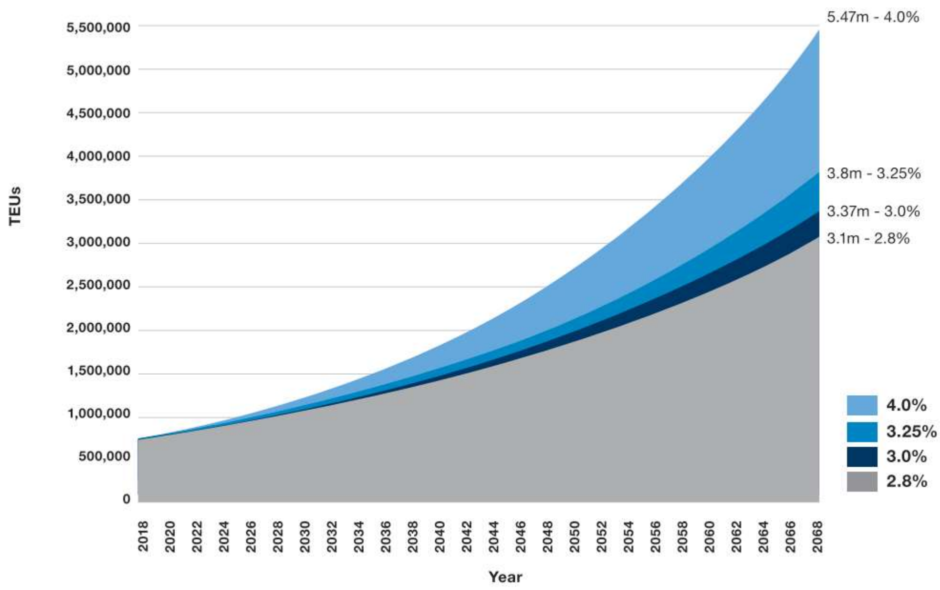


Figure 2-12 - Long-term TEU movements for Fremantle Inner Harbour, 2019.

Source: Westport (2019b, p.3).

It is beyond the scope of this thesis to model container movement growth rates. The brief exploration of the area demonstrates the difficulty in predicting the time by which a seaport capacity is reached, even with knowledge of the exact terminal capacity, solely on understanding future container handling levels. Modelling and the predicted trade levels are essential in considering at what time investment in future capacity should occur in the case of the Outer Harbour. The long lead time and high capital commitment required to develop a seaport through the planning, approval, financing and construction activities further complicate development timing.

The capacity of the Inner Harbour and its associated freight transport links and the timing of an Outer Harbour container terminal development is not established (FPA, 2000), citing a *"maximum practical capacity"* of 0.7M TEU through the Inner Harbour container terminals, some three times the previous year's throughput and currently being exceeded. A 2004 study quotes 1.2M TEU capacity with an expectation of the Inner Harbour being at capacity by 2017 (WAPC, 2004). The Perth Freight Network Plan estimates an Inner Harbour capacity of approximately 2M TEU with ongoing improvements in technology, operations and transport links (DoT et al., 2016b). The media reports the inability to predict the capacity of the Inner Harbour and associated hinterland links (Herald, 2017; Loopers, 2015), which reflects the increasing congestion and community pressure experienced.

ESCAP (2007) provides broad container terminal throughput estimates (unconstrained by external transport factors), acknowledging average vessel size, size of each port call container exchange and capacity of a seaport's equipment all impact throughputs, Table 2-2. Based on the ESCAP "major seaport" values applied to the four container berths in the Inner Harbour a theoretical capacity of 1.8M TEU results. Consideration of Inner Harbour capacity continues to the present day and forms part of a state government instigated Perth freight, logistics and defence industries study (Westport, 2017), which concludes that the current Inner Harbour berth capacity is 2.1M TEU. The capacity is still approximately triple the current throughput. This capacity and significant infrastructure upgrades will support Western Australia's forecast container trade until the mid-2030s (Westport, 2019f).

Table 2-2- Indicative container terminal throughputs.

Source: ESCAP (2007, p.57).

Port Class	Description	Throughput per berth (TEU)	Indicative cost per berth ($US m)
1	World class hub port	680,000	100
2	Major port with mainline services	460,000	80
3	Important secondary port	300,000	60
4	Feeder or regional port	230,000	40
5	Minor port using multipurpose facilities	180,000	40

The impacts the COVID-19 pandemic is having on world trade levels highlight the difficulty in predicting trade growth and associated increases in container movements. The COVID-19 pandemic outbreak resulted in lockdowns in countries around the world, and those in China have disrupted global supply chains as factories were shut (Fernandes, 2020), with an initial lowering of cargo volumes in many seaports around the world (Notteboom & Haralambides, 2020). This situation has dramatically reversed as travel restrictions saw a boom in consumer demand, leading to increased containerised trade worldwide. The vulnerability of global supply chains has also raised the spectre of returning manufacturing to a local basis, nearshoring and advancing 3D printing, which would reduce international container movements (Cullinane & Haralambides, 2021). The overall impact of COVID-19 is yet to play out as recently "opened" cities have returned to lockdowns as COVID-19 returns in the northern hemisphere winter months.

Further upgrades to the rail line linking NQRT to the broader rail network (Cockburn Triangle) are required to realise the Inner Harbour terminal capacity and improve service standards. A conflict between freight and passenger services occurs on the Fremantle Rail Bridge (with passenger trains having priority), limiting morning and afternoon container rail slots during peak commuter periods. Voluntary curtailment of rail movements at night (10 pm to 5 am) reduces impacts on residents in the Fremantle area, Figure 2-13. Both these issues require resolution to achieve the rail capacity for a 30% rail freight share needed for Inner Harbour container trade growth (DoT et al., 2016a). The construction of a separate rail bridge provides passenger and rail freight separation (FPA, 2021b; McGowan & Scaffioti, 2021).

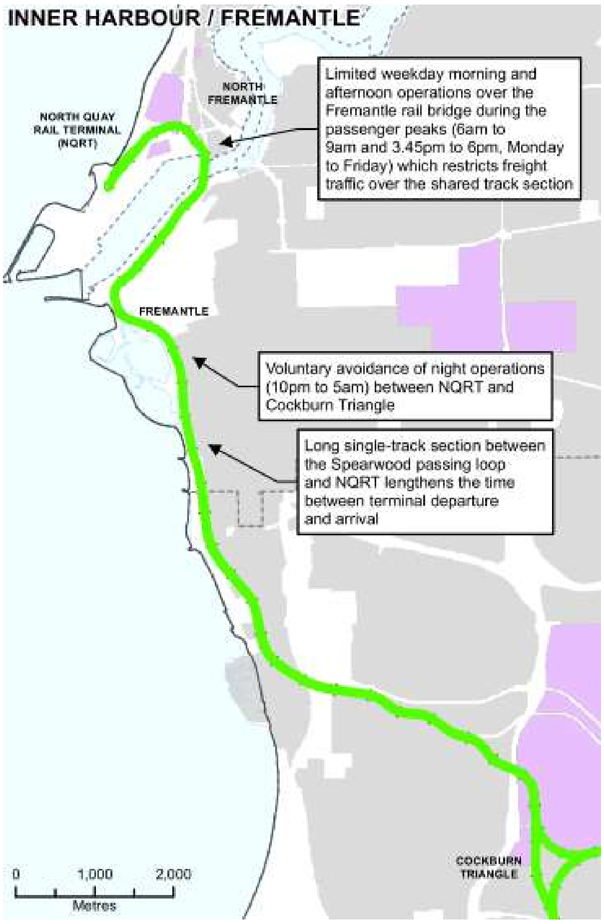


Figure 2-13 - Restrictions on the capacity of the NQRT connection.

Source: DoT et al. (2016a, p.37).

Westport studies have concluded that the ability to move freight into and out of the Inner Harbour rather than the container terminal capacity is the constraint on container throughput. These freight links will reach their limit by the mid-2030s, based on an assumed 30% of the freight task undertaken by rail transport. Whilst respective political parties may disagree over the need for the Roe 8 and subsequent Roe 9 construction, in contrast to upgrading Leach Highway, many road infrastructure upgrades are close to the Inner Harbour existing in either road freight access scenario. Road access from the north also needs an upgrade. The rail capacity to meet the rail freight transport task requires rail access improvement, and the scenario assumes the separation of passenger and freight rail lines (Westport, 2019f).

The Westport Stage 2 Report identifies passenger vehicle growth as having the most significant impact on road congestion on the Perth metropolitan roads (Westport, 2020c). It reflects the findings of the Fremantle Ports annual truck surveys, which show trucks comprise a small percentage of overall activity on roads surrounding the Inner Harbour but are still considered an unacceptable contribution to congestion by some of the local community.

The capacity of the Roe Highway project can be inferred from the summary business case for the project, which assumes a 30% rail freight task. The Inner Harbour capacity shows a long-term (from FY45) maximum throughput of approximately 1.4M TEU (MRWA, 2014). This throughput is consistent with the mid-2030s freight transport constrained value of approximately 1.3 and 1.5M TEU depending on the growth forecast (Figure 2-12) above.

The planning undertaken by both WA state government political parties includes long-term use of the Inner Harbour for containers in conjunction with a new Outer Harbour seaport (MRWA, 2014; Westport, 2019f). Whilst not directly relevant in the capacity planning horizon of 20 years, the issue of requiring extra draft (current sailing draft is 13.5m, (FPA, 2018b)) to accommodate the increasing size of container ships may ultimately lead to the Inner Harbour's relegation to a secondary seaport. This sailing draft would be tied to the ability of other Australian seaports to accommodate deeper drafts (such as consideration of the Hastings development in Victoria with Triple E container vessels and a sailing draft of 14m (Infrastructure Victoria, 2017)) and so see deeper draft container vessels servicing Australian routes. The Westport study contemplates future container vessel drafts requiring an 18m water depth (allowing for a 10% minimum of the vessel draft as under keel clearance) (Westport, 2019f), which is not unrealistic given the existence of 23,000 TEU capacity vessels with a draft of

14.5m, (MarineTraffic, 2019). This impact on the ability of the Inner Harbour to act as a primary container port is not until at least the mid-2040s when ultra-large container vessels may commence services to Australia (Westport, 2020c). The service would begin on the east coast in the first instance.

From this description of the Inner Harbour seaport, road and rail capacity, forecast container trade growth and vessel size trends, it is concluded that:

The dry port (Forrestfield/Kewdale and Kwinana Intermodal Terminals) benefits the Fremantle Port Inner Harbour operations as it extends the life of the Inner Harbour as road transport would become prohibitively congested as a result of the externalised costs associated with the transport mode, earlier and at a lower container throughput if all freight moved to and from the Inner Harbour by road.

The reasons for this conclusion and the background to the development of dry ports and their role in a supply chain in extending a seaport life are further explored in this thesis to support this early statement.

2.2.2 OUTER HARBOUR CONTAINER PORT

The need for and location of a future container port for Perth has been under consideration for a long time commencing with the first mention in a BP State Agreement in 1952 (Westport, 2019b). In 1966, the FPA identified “Southern Flats” as a potential location for a general and container cargo port; this conflicted with the federal government Navy Base on Garden Island and dropped as a concept. In 1972 Point Peron in Cockburn Sound was identified but was not supported by the then state government. Between 1982 and 1984, a Mangles Bay site was investigated, but the area was developed for residential purposes. In 1989 a broad range of options in Cockburn Sound was investigated, followed by a 1994 study of the Naval Base/Kwinana area, and this area remains the preferred location for an Outer Harbour container port to this date. The location is depicted in Figure 2-14, (Transport WA, 2019; Westport, 2017).

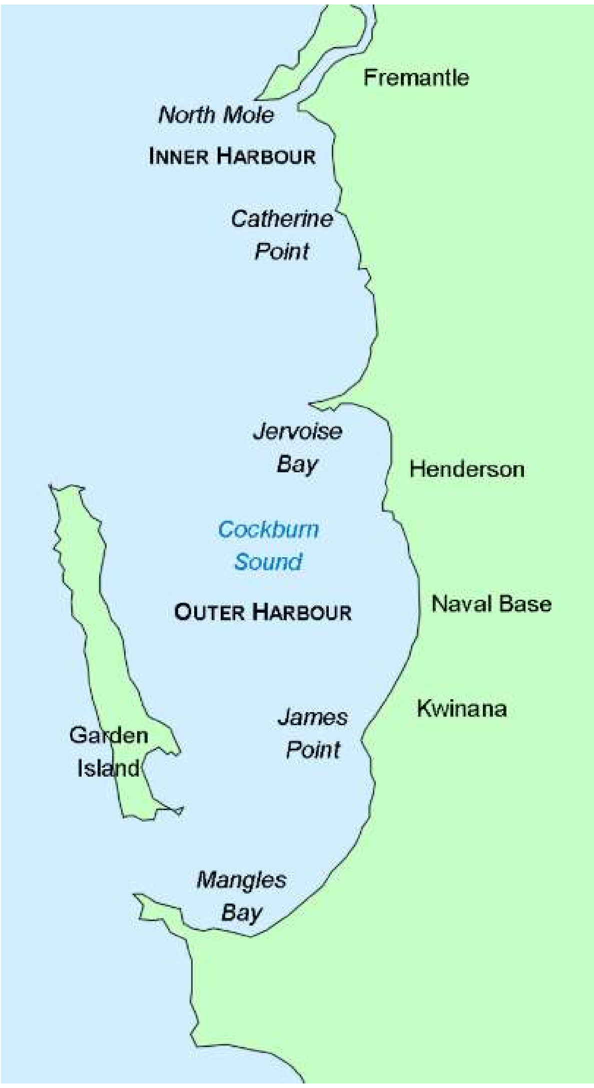


Figure 2-14 - Several locations within Cockburn Sound have been investigated for an Outer Harbour.

Source: Westport (2017, p.15)

More recent studies undertaken by both major WA state political parties have agreed that the location of a future container port would be within the *"Western Trade Coast"*, an area on Cockburn Sound between Munster and Rockingham (DoT et al., 2016b). The 2002 Fremantle Ports Outer Harbour Project considered nine potential locations, Figure 2-15, followed by a 2006 strategic assessment considering four options and progressing two of these to statutory approval processes (Westport, 2017).

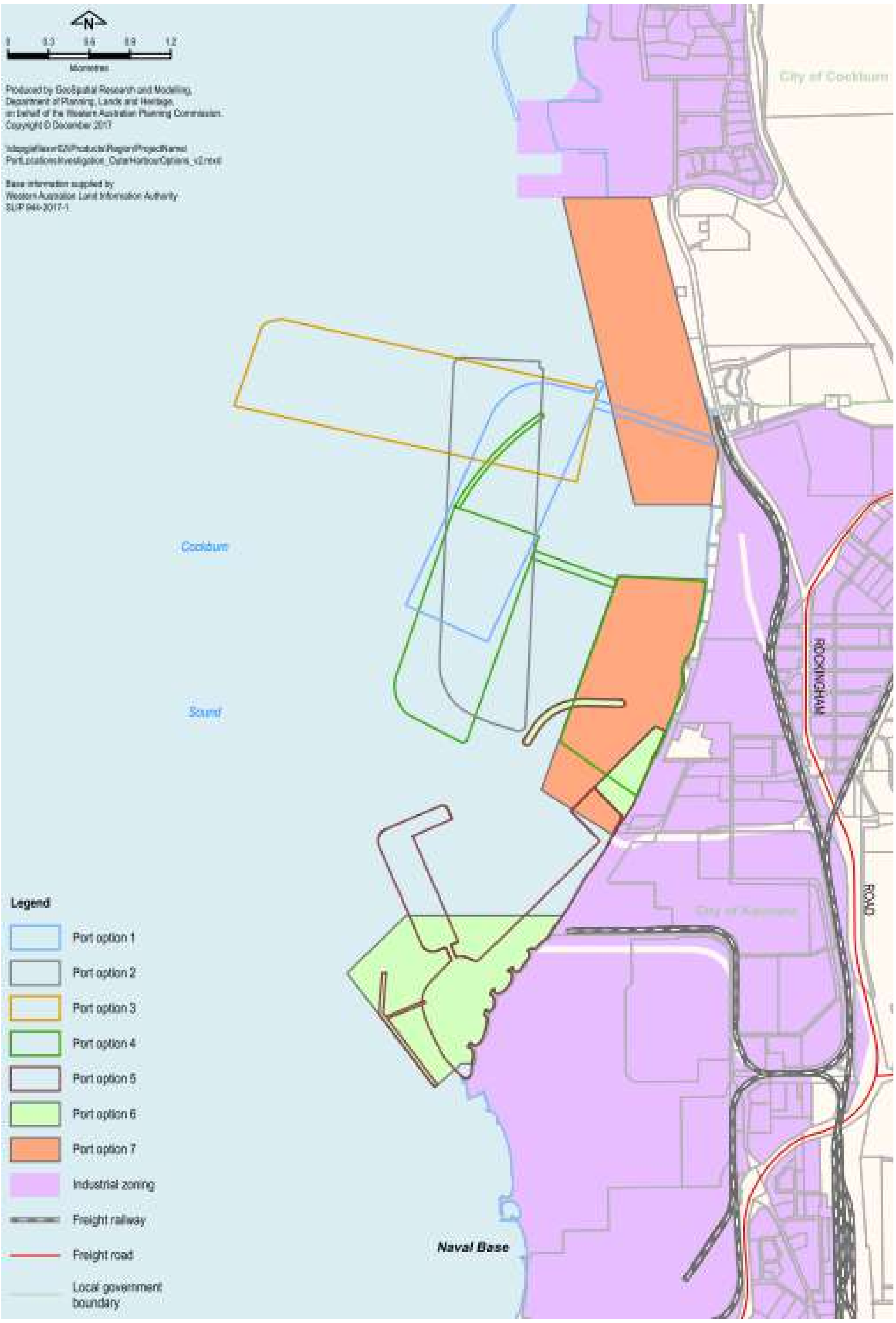


Figure 2-15 - Various port layouts have been considered for the Outer Harbour container port.

Source: Westport (2017, p.17)

Planning by a Liberal WA state government was for the development of a minimum 3M TEU per annum container seaport developed in stages, which, combined with the Inner Harbour capacity, would provide sufficient capacity until after 2050 (DoT et al., 2016b). This capacity requirement broadly aligns with the current Westport study, which predicts a need for capacity between 3.8 and 5.4M TEU capacity for Perth by 2068. Given an Inner Harbour capacity of 2.1M TEU, a new seaport will need between 1.7 and 3.3M TEU capacity (Westport, 2019f). The Westport Stage 2 Report (Westport, 2020c) identifies a location in the vicinity of Anketell Road in Kwinana (over the previously favoured Rowley Road location for the Outer Harbour, which was examined for off port facilities as discussed in Chapter 7 Dry Port Site Selection), Figure 2-16.

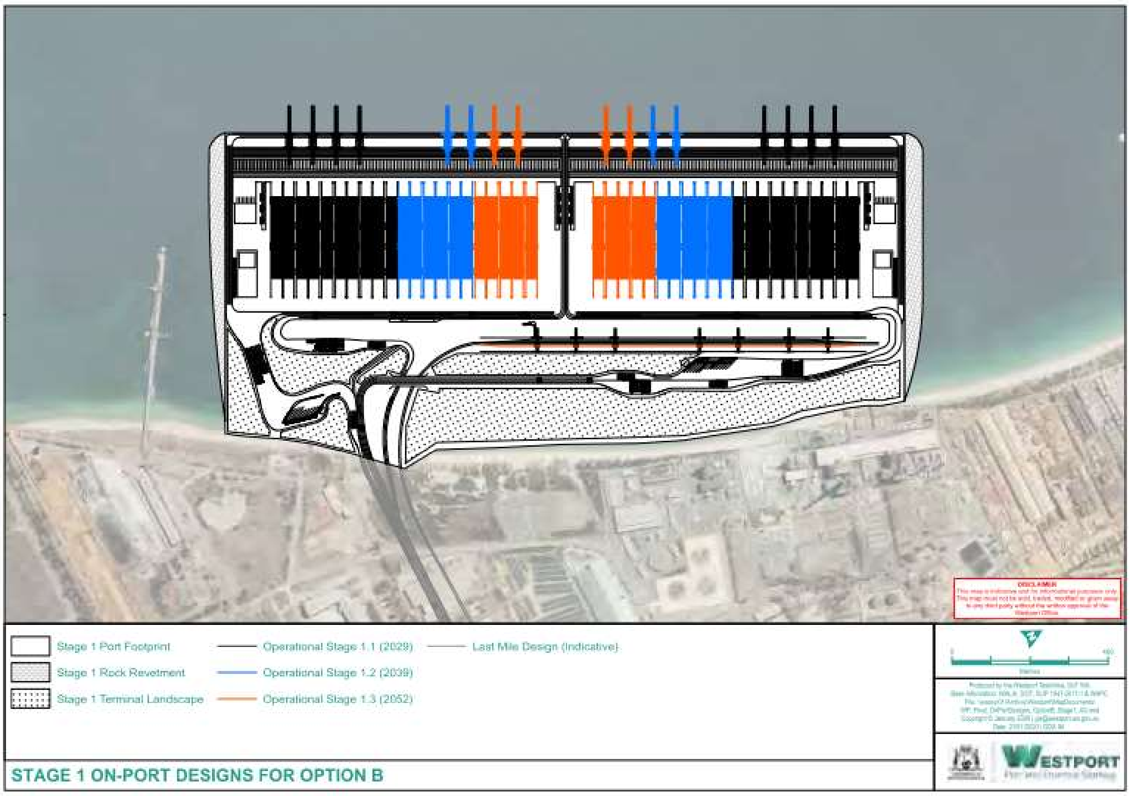


Figure 2-16 - Outer Harbour location in the vicinity of Anketell Road.

Source: Westport (2020c, p.12).

Transport Links

Road

The Outer Harbour location selection determined by the Westport study demonstrates the importance of hinterland transport links. Previously the Rowley Road transport corridor was considered an essential link for the Outer Harbour and would be upgraded as part of the Outer Harbour development; this is north of the Westport recommendation for the Outer Harbour location. Rowley Road would be upgraded to a four-lane dual carriageway road and be put forward for inclusion in the National Land Transport Network (DoT et al., 2016b). With the completion of the second stage of the Westport study, Anketell Road has been selected as the primary road transport linkage back to the Tonkin Highway, but Rowley Road is acknowledged as an important east-west transport link in future freight tasks, Figure 2-17, this selection moves the Outer Harbour to the south.

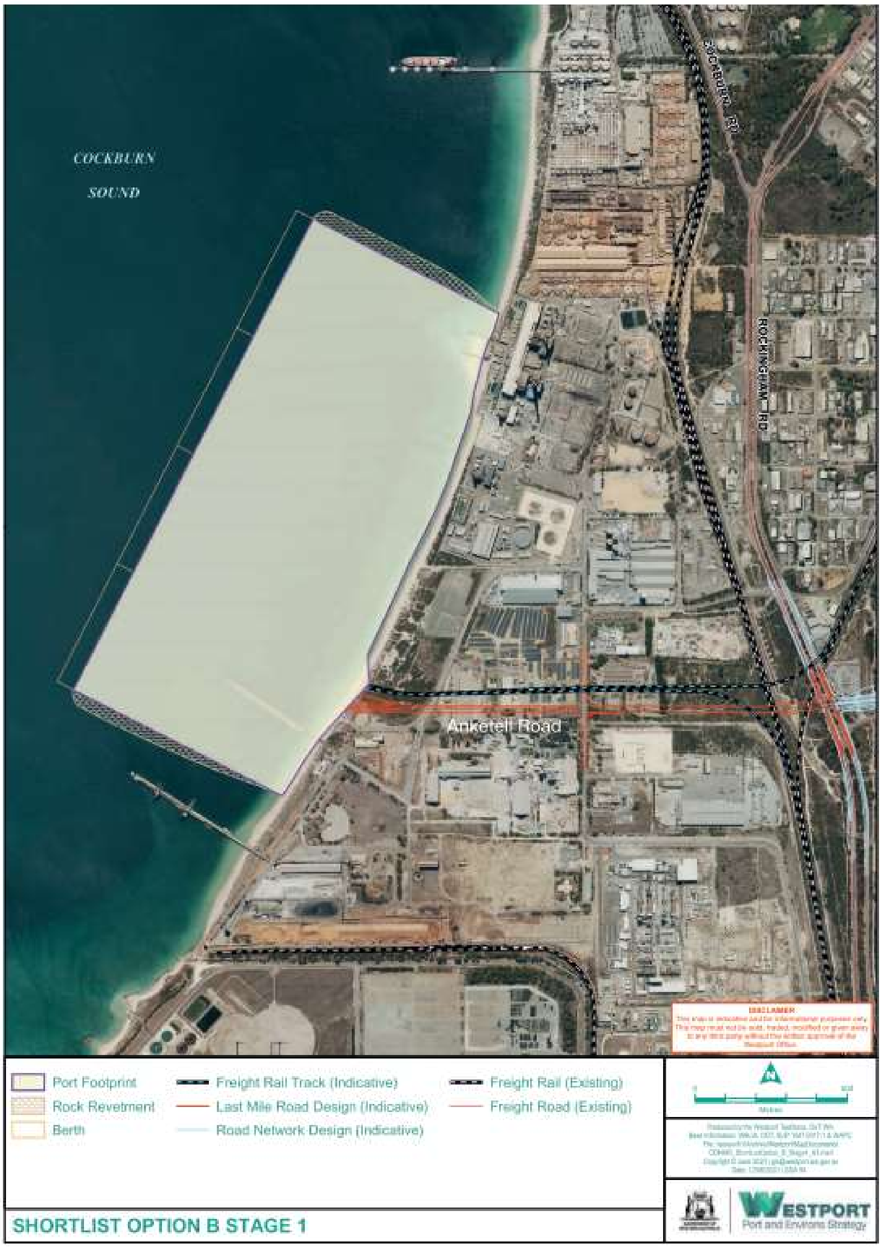


Figure 2-17 - An extension of Anketell Road services the proposed Outer Harbour location.

Source:(Westport (2020b, p.4).

Anketell Road is considered a superior road link as it provides a higher transport capacity and operating speed of 100km/h compared to 70 to 90km/h on Rowley Road and results in less impact on residents and other heritage items (Westport, 2020c). Figure 2-18 presents the outcome of the Westport transport link analysis, reflecting the increasing importance of environmental and community considerations in selecting the location of supply chain infrastructure.

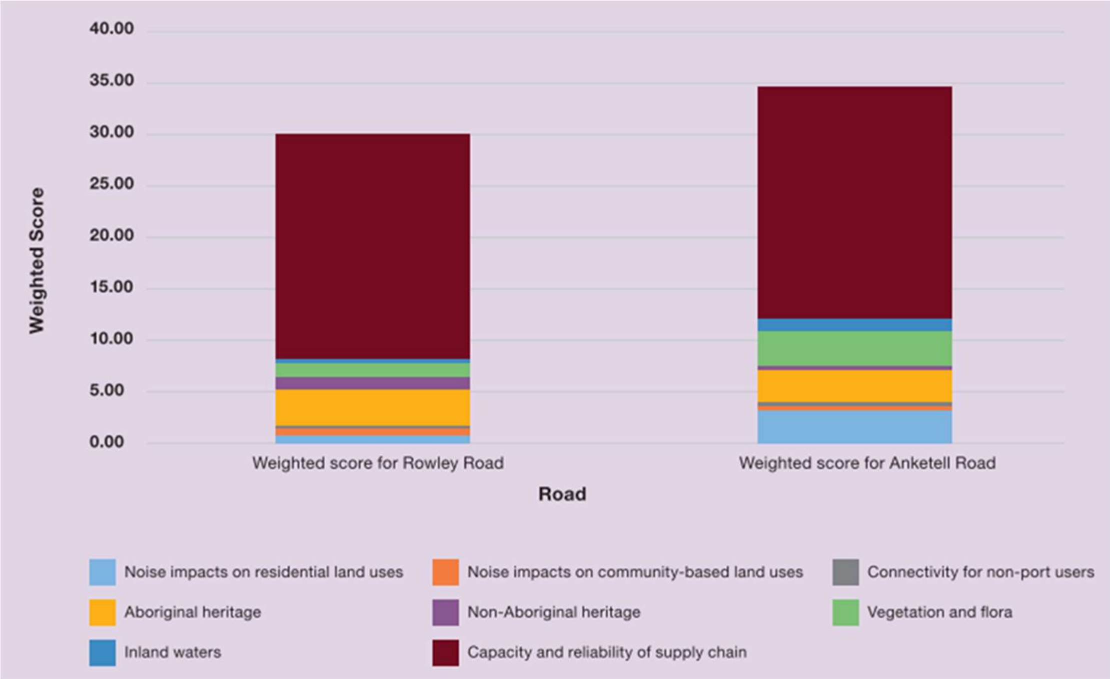


Figure 2-18 - Graphical representation of MCA for Outer Harbour road selection.

Source: Westport (2020c, p.133).

Rail

As with the road links, the previous rail transport Outer Harbor solution in the Rowley Road transport corridor connection to the existing Cockburn to Kwinana rail freight line has been updated to the Anketell Road corridor.

The Rowley Road rail is capable of double stacking containers to increase efficiency (and to make this possible in the broader network all new or replacement structures over relevant rail lines will provide the necessary 7.3m clearance, (DoT et al., 2016b)). Double stacking containers has been considered a rail efficiency factor for a significant period (FPA, 2000); this is not necessarily the case for short-haul rail, with a relatively low ratio of travel time to load time. Service frequency may be more important than single train capacity, so the selection of train configuration needs to be tailored to the specific freight task (DoIRD, 2017a; PWC, 2016).

The Westport Stage 2 report nominates a rail connection to the mainline adjacent to the Anketell Road extension, Figure 2-19.

Figure 2-19 - The rail connection to the Outer Harbour will be adjacent to the Anketell Road extension.

Source: Westport (2020b, p.7).

2.2.3 HINTERLAND COMPETITION FROM BUNBURY PORT

Early port hinterlands were captive to seaports because of the relatively few transport options available to suppliers to move their goods to remote markets, restricting the choice of viable seaports available for import or export activity. As land-based transport systems become more efficient and competitive, the physical distance to a seaport is no longer the primary determinant of a hinterland (Wilmsmeier, Monios, & Lambert, 2011).

Van Klink and van den Berg (1998) observe the introduction of containers into logistics chains have commoditised the seaborne container market, resulting in seaports becoming exposed to being subordinated to the supply chain objectives of global carriers. Seaports can change this power balance by influencing the area of their hinterland by taking an active view of the landside components of the supply chain and setting out to shape transport corridors. Port Authorities can enhance this through a unique position between government and the "market". This active approach can establish the seaport as a "gateway" with links to the hinterland that they can capture. Hinterlands for a seaport vary for different commodities and come under threat by other seaports as technology, transport infrastructure, cost structures and government policy changes. In a study of U.K. ports, Hoare (1986) finds substantial overlapping hinterlands and concluded that the concept of relatively exclusive port hinterlands no longer applies as well as it once did over 30 years previously. The consolidation of shipping lines and the introduction of containers were primary contributors to the change.

Fremantle Ports recognises the threat posed by hinterland competition (FPA, 2000). Regional locations for expanding container handling, Bunbury and Geraldton, have been previously considered and deemed unsuitable because most containers handled through the Inner Harbour have destinations or sources from the Perth metropolitan area (WAPC, 2004). The predominance of container freight sources and destinations within the Perth metropolitan area remains the case, and Fremantle Ports regularly explore these (FPA, 2012a, 2017b; FPA & WAPOT, 2011).

Following the development of the Outer Harbour, or in competition to its development, Bunbury presents an alternative location for container import and export from the Perth metropolitan area. This competition is consistent with the seaport regionalisation concept discussed in Chapter 5: Development Models for Seaports and Dry Ports.

The Westport investigation studies this hinterland competition (Westport, 2017). The study includes four potential options (in a “long-list” of 25 options) for Bunbury Port in the future container trade based on either being the state’s gateway port or sharing the task with the Fremantle Inner Harbour (Westport, 2019d). Based on a multi-criteria analysis, the “long list” options are narrowed to five for consideration, with all Bunbury options being dropped (Westport, 2019e).

As a state government trading enterprise, the removal of Bunbury Port from the options list effectively eliminates a container terminal development as part of the expanding container freight task related to the Outer Harbour development, as the state government controls capital expenditure approvals for the level of infrastructure development required. This demonstrates the importance of government and associated transport policy in both seaport and dry port development.

Hinterland competition and changes to catchments are evident in the broader Australian context. The east coast of Australia has seen export catchments change with the deregulation of rail in NSW, competition policy reform in the late 1990s, changing products and significantly the port of call order for international container vessels. This competition has seen Sydney seaports lose market share to Brisbane and Melbourne seaports, Figure 2-20 (Sd+D, 2004).

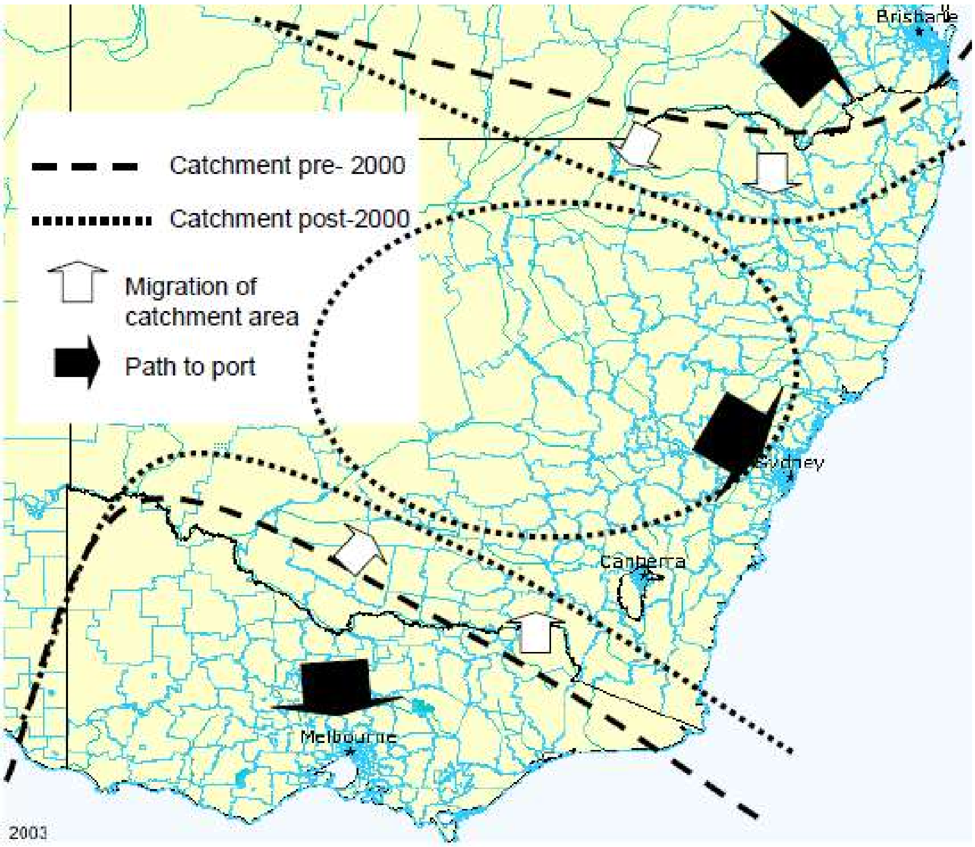


Figure 2-20 - Changing hinterlands for east coast seaports, pre and post 2000.

Source: Sd+D (2004, p.19).

If the supply chain through the Port of Bunbury was more efficient than that of the Fremantle Ports Inner Harbour, even for a selected share of the container trade, then importers and exporters are provided with a choice of seaports to use, and the Port of Bunbury could threaten the market share of Fremantle Ports (Hintjens, 2018). The supply chain efficiencies provided by the dry ports in the Perth metropolitan area support the efficiency of the Inner Harbour by improving hinterland connectivity by lowering road congestion through a modal shift, which also reduces social impacts in the same area resulting in lower CO_2 emissions from the freight task. This efficiency protects the Inner Harbour's hinterland.

On the same basis, the existing dry ports in the Perth metropolitan area provide a connectivity and supply chain link for containers landed at Bunbury.

Westport Study

The Westport Strategy is a WA state Labor government project with a task force made up of *"state and local government agencies and representatives from industry,* *academic, environment and community organisations"* (DoT, 2017b p.20) with an overarching vision as follows:

"The Westport Vision

To provide a globally responsive, environmentally responsible and market competitive plan for Western Australia's freight network to meet the South West region's trade and growth objectives, supporting the needs of a growing population and creating sustainable jobs for future generations."

With the following aims and objectives:

"Aims: The Westport Strategy will:

- *plan for the Outer Harbour at Kwinana as part of a long term integrated transport plan for the State.*
- *position Western Australia as an attractive international investment opportunity, capable of capturing trade globally but particularly between Australia and the expanding economies in South East Asia and around the Indian Ocean.*
- *protect, as far as possible, our environmental and cultural heritage and amenity.*
- *make the best use of Fremantle, Kwinana and Bunbury ports and their environs to support a growing population and create jobs; and*
- *provide for efficient transport connections and intermodal hubs between port facilities and users.*

Objectives

The objectives of the Westport Taskforce are to:

- *engage with stakeholders and the community at all stages of the planning process.*
- *plan for a modern port in Cockburn Sound to meet Perth and the surrounding regions' future growth for the next 50 to 100 years.*
- *provide land use and transport plans that support port operations, compatible land uses, port users, the community and local economy.*

- *assess the commercial implications and logistics opportunities of future port infrastructure.*
- *maximise compatibility of port and landside development with the environment, and*
- *identify the expansion and preservation of industrial areas and technology parks to support economic development and future employment opportunities."* (DoT, 2017b p.18).

The Westport strategy's premise is the eventual development of an Outer Harbour in the Kwinana area of Cockburn Sound. The Westport study is primarily a planning document to address the Perth area's long-term freight and population needs at a state and local planning and policy level. To this extent, when using the study for reference information the objectives of the author must be considered as the study's aim is to plan for the Outer Harbour at Kwinana.

Whilst aspects of the Westport Strategy consider similar factors to this thesis; it is not grounded in exploration and inclusion of the academic literature. However, the various publications of the task force provide a valuable source of information and reflect the concepts in the academic literature in a practical setting.

The Westport strategy illustrates the broad range of views of the stakeholders in the container supply chain, which includes the Inner Harbour. The opinions range from opposition to the concept on environmental and supply chain needs grounds (McKay, 2018; Myles, 2019), presentation of alternative Outer Harbour locations (Kwinana, 2015), to a strong promotion of the development. The range of views shows the many actor interests within a supply chain, some of which have competing objectives, foreshadowing the opening paragraph of Chapter 7: Dry Port Site Selection, in attempting to locate a dry port in a metropolitan environment.

The Westport study is broader ranging than this thesis, and the public documents do not serve to answer the research questions using an academic approach.

Chapter 3: Attributes, Definition and Classification of a Dry Port

3.1 LITERATURE REVIEW

3.1.1 ATTRIBUTES OF A DRY PORT

Seaports have evolved with the advent of global supply chains to handle the increased freight movement in containers. Container transport dominates the movement of goods worldwide, with some 70% of world trade being seaborne and more than 50% of this being container based trade (Song, 2021). The evolution and development of global supply chains are reflected in increased container vessel size, corresponding harbour and channel drafts and berth size, improved port handling methods, and changes in port governance. The seaport land-based infrastructure inside the seaport gate has generally coped with the changes. However, seaside access to the berth (navigation channel and berth side depth, not considered as part of this thesis) and landside delivery to and from hinterlands and container storage capacity have lagged the seaport's landside actions (Cullinane & Wilmsmeier, 2011a), with the transport link to the hinterland being the "*weakest link*" in the landside system (Behdani, Wiegmans, Roso, & Haralambides, 2020).

Merk and Notteboom (2015) provide plausible reasons for this lag, outside the seaport gate, in landside development:

- Availability of land due to population density.
- Higher evaluation requirements of the environment and social impacts of developments.
- Increasing stakeholder role in assessments and planning processes.
- Overlap and complexity in forming public policy.

Seaports have become a part of the more extensive transport system in global supply chains. Garnwa, Beresford, and Pettit (2009) show that the shift away from a focus on seaport to seaport transportation of containerised cargo has seen the introduction of dry ports into supply chains to improve overall logistics efficiency. They nominate three principal reasons for the development of dry ports;

- The requirement to improve inland transport efficiency.
- Ongoing transport route congestion in areas surrounding major container seaports.
- The move to global supply chains rather than a transport activity from seaport to seaport.

Other researchers support these reasons, noting that dry ports are used in supply chains to increase seaport capacity, relieve local congestion and address environmental and community issues (Cullinane et al., 2012; Cullinane & Wilmsmeier, 2011a; Do, Nam, & Le, 2011; Notteboom & Rodrigue, 2009).

Khaslavskaya and Roso (2019) provide insight into the necessity of dry ports providing benefits to a supply chain, observing that whilst a seaport is a necessary node in a supply chain involving a sea leg, a dry port is not. Whilst this observation identifies the need for a dry port to add value to a supply chain for its existence, it is necessary to realise that any given seaport is not guaranteed a role in a supply chain and the benefits a dry port can bring to a supply chain also support the seaport.

A comparison of dry port development in different countries contrasts the success or otherwise of dry ports in supply chains.

Garnwa et al. (2009) highlight differences between the United Kingdom (UK) and Nigeria, providing insight into the attributes that make a dry port successful.

In the UK, a reliable rail transport system linking seaports and other modes of transport enables multimodal transport to be efficient. The extensive road system in the UK promotes competition between road and rail freight transport but enables modal change for first and last mile transport. Privatisation of seaports and rail, relaxation of labour regulations and a supportive customs agency introduced improved work practices and efficiencies to the UK supply chains. Information Technology (IT) supports communications between dry ports and seaports and, combined with RFID, enables container tracking. Dry port container security is enhanced through CCTV and container X-Ray facilities. Environment impacts are crucial in allowing dry port development in the UK; noise, dust, habitat loss, pollution and community impacts are considered in any development proposal.

As with many developing economies, Nigeria has few of the attributes nominated above. Two privately funded dry port developments commenced in 1979 to service the landlocked countries of Niger and Chad. They link directly to seaports and function under Nigerian Ports Authority guidelines with inland customs clearance and were successful. This success was stifled in 1996 when customs inspections were mandated at seaports. Garnwa et al. (2009) do not describe the success or otherwise of a new generation of concessions granted as BOOT projects under the control of the Federal Ministry of Transport. The authors describe the system's weaknesses as attributed to government “interference”, inadequate infrastructure, pressure on road transport, poor IT and no transport integration.

The comparison between European and North American dry ports by Rodrigue and Notteboom (2012) shows other attributes in considering dry port success. Whilst dry ports in both locations have been successful; the transport networks are quite different due to the difference in the railway operations and transport distances involved in the two areas. Europe is a passenger dominated ex-government owned rail network crossing international boundaries over distances of between 300 and 1,500km with train shuttles carrying 40 to 95 TEU. This passenger focus is in contrast to North America, with a freight dominated rail network transporting freight over longer distances, up to 3,000km, on double stack trains with 300 to 500 TEU capacity. The historical European freight network gradually changed from a meshed to a hub and spoke and finally point to point network, with the financial viability of many direct shuttles being questionable. In northwest Europe, rail competes with barge services. Seaport terminal operators (DP World and Maersk) offer *“extended gate”* services. The deregulation of North American rail via *The Staggers Act (1980)* resulted in significant consolidation and efficiencies. With a long rail freight history, the North American dry ports are generally larger and service a more extensive area than in Europe. Developments are often a partnership between a rail operator and a real estate developer or a public authority developer looking to develop a logistics zone to underwrite the capital investment required. In Europe, port authorities and terminal operators more often develop dry ports (Wiegmans, Witte, & Spit, 2014).

Seaport developments tend to be governed by local and regional pressures and come in a discontinuous fashion. This discontinuity contrasts with the continuous evolution of freight transport requirements. The lack of alignment leads to an imbalance between the two, moving from periods of scarcity to excess capacity in the seaport. Provision of sufficient storage space for containers is critical for seaport efficiency, and in traditional seaport locations close to or within suburban/urban areas is not likely to be achieved. The dry port is put forward to solve this problem (Cullinane & Wilmsmeier, 2011a; Pettit & Beresford, 2009).

Early dry port concepts were associated with relieving congestion around seaports, and an early dry port definition is *"an inland terminal to which shipping companies issue their own import bills of lading for import cargoes assuming full responsibility of costs and conditions and from which shipping companies issue their own bill of lading for export cargoes"* (UNCTAD, 1991 p2). Importantly the future role of container trade and the hinterland links in supply chains is recognised. UNCTAD (1991) describes the attributes of a dry port as follows, dry ports:

- Are located inland with direct transport links to the seaport.
- Cater for import, export or both.
- Provide intermodal transport.
- Provide secure storage and handling of containers.
- Distribute and/or consolidate cargoes.

These attributes remain relevant in 2022, included in attributes described by many authors (Garnwa et al., 2009; Roso & Lumsden, 2009; Rozic, Rogic, & Bajor, 2016; Woxenius, Roso, & Lumsden, 2004), reflecting the significance and insight of this early publication. Rodrigue, Debrie, Fremont, and Gouvernal (2010) argue the need for three fundamental attributes in what they nominate as an inland port (they believe the term is more suitable as it encompasses relationships between terminals, logistics activities, and the hinterland served) all of which are in the above list:

- Containerisation - container handling must occur, including consolidation and/or deconsolidation, transloading and even light manufacturing.
- Dedicated link - a high capacity transport link of any mode must exist between the inland port and the seaport, with dedicated links considered the best type.
- Massification - the inland port must offer the benefit of handling larger volumes at a lower unit cost to overcome the transport of containers directly between the seaport and destination or vice versa.

The final attribute must be considered in the broadest context, as the simple transport cost between the sites may not be the lowest, but considering the total supply chain and seaport sustainability may make it a lower cost overall.

Notteboom and Nguyen (2019) nominate similar characteristics but associate them with a dry port rather than an inland port on the basis that a dry port seeks to develop a close integration of the seaport and its hinterland:

- The facility must be intermodal as it results from the unitisation (containerisation) of cargoes.
- There must be strong transport links between the dry port and the seaport.
- It must provide services that are interchangeable with a seaport, such as customs service, storage and value-adding services.

The objective of the dry port to relieve constraints on the seaport is present in the initial dry port concept but did not define the transport mode. Recently, the promotion of a modal shift away from road transport and improving hinterland connection, particularly for developed economies, has come to the fore (Wang, Monios, & Zhang, 2020).

The United Nations, in an intergovernmental agreement, provided a broad definition of a dry port (of international significance), *"an inland location as a logistics centre connected to one or more modes of transport for the handling, storage and regulatory inspection of goods moving in international trade and the execution of applicable customs control and formalities"* (UN, 2013 p. 2). The dry ports may have the following additional functions:

- Receipt and dispatch of goods.
- The consolidation and distribution of goods.
- Warehousing of goods.
- Trans-shipment of goods.

As container trade has grown and container ships increased in capacity (to achieve marine side economies of scale), seaport capacity trigger points occur when congestion starts to cause diseconomies of scale (Rodrigue & Notteboom, 2010b). The landside logistics of buffer storage and handling of containers are necessary for continuing growth (Garnwa et al., 2009; Notteboom & Rodrigue, 2008; Rodrigue & Notteboom, 2012). Dry ports facilitate this growth by enabling seaports to increase capacity and improve economies of scale (Notteboom & Rodrigue, 2009; Roso & Lumsden, 2009), and is the sixth stage of the spatial port system development model, *"regionalisation"*

(Notteboom & Rodrigue, 2005), as described in Chapter 5: Development Models for Seaports and Dry Ports.

The role of dry ports in facilitating a modal shift from road to rail transport and reducing environmental and social impacts is important (Aregall, Bergqvist, & Monios, 2018; Henttu, 2010; Henttu, Lättilä, & Hilmola, 2011; Lättilä, Henttu, & Hilmola, 2013; Roso & Lumsden, 2009; Roso, Woxenius, & Lumsden, 2009).

Protic, Fikar, Voegl, and Gronalt (2020) use semi-structured interviews in a European study of value-added services a dry port may offer to identify currently used services, those considered novel, and others that may be a future provision. The ability to offer services is necessary for differentiating a dry port in the decision making process of selecting a facility for use in a supply chain. The services are presented in Table 3-1.

Table 3-1 - Value-added service attributes of a dry port.

Source: Protic et al. (2020, p.168).

Value Added Service	Novelty
Gate-in / Gate-out process	
Automated weighing	1
Customs	1
Fast lane for trucks at gate-in	2
Pre-gate damage inspection/identification	2
Storage area	
Empty container depot	1
Reefer maintenance and repair	2
Reefer plug and socket	1
Special warehouses	1
Stuffing and stripping	1
Accompanying character	
Access to wagon load information	2
After-sale service	2
Collecting point for reverse logistics activities	3
Dynamic pricing of transhipment or VAS booking	3
Energy supply from renewable sources	2
(Fast) charging of electric trucks/battery swapping	3
Flexible/extended opening hours	2
Fumigation and de-fumigation	1
Guided tours for visitors	2
Industrial siding and process integration	2
Kitting and assembly	2
Labelling/tagging/removal of barcodes or tags	2
Online pre-announcement of truck arrival	2
Online service portal	2
Order picking	2
Packing and repacking of goods	2
Phytosanitary or veterinary controls	1
Regular truck inspection	3
Renting or leasing of trucks	1
Repair/maintenance linked to future rail freight wagons	3
Repair of damaged goods	2
Secure truck parking facilities	2
Shunting (Ueberstellservice)	2
Start-up area	2
Testing and quality control of goods	2
Trucking	1

Legend 1 = Known service, 2 = Forerunner service, 3 = Potential future or rare service

3.1.2 DEFINITION OF A DRY PORT

Differing characteristics, activities undertaken, geographical settings and supply chain actors involved lead to many terms for dry ports, often used interchangeably (Andersson & Roso, 2016; ESCAP, 2012; Higgins, Ferguson, & Kanaroglou, 2012; Marigo, Varese, & Lombardi, 2020; Nguyen & Notteboom, 2018; Rozic et al., 2016). These variations cause confusion about the function and role of a dry port and contention regarding the inclusion of terminals utilising barges for transport connections as these are not "dry" (Rodrigue et al., 2010). There is no *"exact or univocal definition for an inland terminal"* (Marigo et al., 2020 p.2). Terms include inland port, inland hub, inland terminal, inland clearance depot, inland freight depot, freight village, freight gateway, distribution terminal and hinterland terminal (Cullinane & Wilmsmeier, 2011a; ESCAP, 2012, 2015; Higgins et al., 2012; Notteboom & Rodrigue, 2009; Rodrigue et al., 2010; Wilmsmeier, Monios, et al., 2011). Notably, the availability of a range of services, not just modal change, distinguishes a dry port from an intermodal terminal (Henttu, 2010). Jeevan, Chen, and Cahoon (2019) nominate the requirement for the ability to handle all cargo types, not just containers; however, this is not a widely described requirement.

The taxonomy of inland terminals remains widely debated, and concerning dry ports is *"rather vague"* (Cullinane et al., 2012 p.2). To ensure the examination of all potential facilities for relevance to the Fremantle Port situation and to provide a sound basis for the research in this thesis by selecting a single definition (Higgins et al., 2012), the dry port definition is ***"an inland intermodal hub with direct transport links to a seaport, where some seaport and supply chain functions and facilities are duplicated"***.

3.1.3 CLASSIFICATION OF DRY PORTS

Higgins et al. (2012) note various researchers' different ways and lack of consistency in classifying dry ports in a literature review to define a typology of logistics centres. These classifications include *"function and scope of activity", "transport mode", "cargo volume and network characteristics" ("point to point, hub and spoke, line network and trunk network")* and *"role and function in the supply chain"*. Interestingly the paper does not explicitly include the commonly used classification of distance from the seaport, explored below.

The location of dry ports relative to the seaport enables categorisation as close, mid-range and distant; the main function they perform reflects their distance from the seaport (Roso et al., 2009; Woxenius et al., 2004).

Roso et al. (2009) describe distant dry ports as having the longest history and having the "conventional" role of a long-distance rail transport leg linking the seaport to the hinterland driven by the favourable economics of long-distance rail haulage. With the intermodal services offered by the distant dry port, the hinterland served by the seaport expands around the distant dry port. An example of a distant dry port is the Isaka facility in Tanzania, linked to the Dar es Salaam Port some 800km away. Distant dry ports enable greater hinterland access (Rodrigue & Notteboom, 2010b; Wilmsmeier, Monios, et al., 2011), and longer transport distances promote a modal shift from road to rail (Henttu, 2010; Woxenius et al., 2004).

Mid-range dry ports compete for hinterlands traditionally serviced by road and, through serving as cargo consolidation terminals, reduce landside seaport requirements. BITRE (2016) cite a range of distances from 350 to 1,500km as the line-haul distance over which rail becomes competitive with road transport, with various factors influencing this distance. In the continental European context, (Roso et al., 2009) nominate 500km as the distance above which rail freight is directly competitive with road transport. The services offered by the dry port combined with an efficient intermodal transfer must offer a lower overall landside transport cost than direct road freight to remain competitive. The ability to consolidate cargo on a single train for transport to a specific vessel enables mid-range dry ports to act as a buffer for seaport container yards. The Virginia Inland Port, some 330km from the Port of Virginia, is an example of moving containers by train.

Close dry ports are located on the outskirts of the seaport city and consolidate truck transport onto rail shuttles, and advanced terminals can consolidate train consists to synchronise directly with loading a vessel in the seaport, providing an effective container buffering service (Roso et al., 2009). Close dry port examples are the Los Angeles intermodal terminals (BNFS Railway Hobart and Union Pacific Los Angeles) connected to the Port of Los Angeles and Port of Long Beach by the Alameda corridor (ACTA, 2021b). The Enfield Intermodal Terminal for Port Botany in Sydney is a close dry port (L&MH, 2018; NSW Ports, 2017). The dry ports relieve seaport storage constraints (Woxenius et al., 2004) and link to the seaport through a drayage operation

(Rodrigue et al., 2010). This link can be a truck-based freight transport and can include specialised vehicles. They are a potential solution to road traffic problems associated with city seaports, particularly when the seaport is a government-controlled entity (Roso et al., 2009).

Dry port categories based on the distance between the seaport and the dry port are depicted below, Figure 3-1.

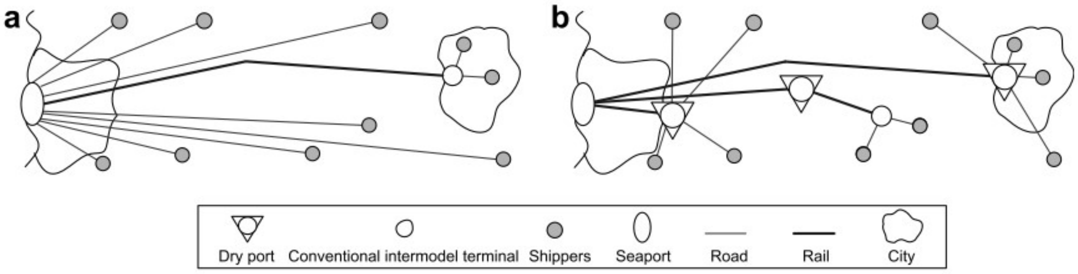


Figure 3-1 - Conventional hinterland linkage (a), close, mid-range and distant dry ports (b).

Source Roso (2007, p.524).

In a study of Dutch dry ports, Wiegmans et al. (2014) conclude that distance from the seaport to the dry port did not consistently indicate the level or growth in transhipment activity. The conclusion indicates that distance from the seaport is not a primary factor in the success or otherwise of the dry port. This result must consider the context of a large amount of barge transport (which includes bulk materials) in Europe, with the results based on total cargo movements, not just containers.

The economics of transport modes, particularly short-haul rail and intermodal handling, are important aspects discussed in Chapter 6: Development Criteria for Dry Ports.

Rodrigue et al. (2010) classify dry ports on their functional basis in a three tier description of the dry port and its hinterland (which is also part of the hinterland of the seaport that the dry port services). The first tier is the dry port itself, described as an inland terminal and its capacity, performance and freight volume handled. The second tier function is the logistics activities related to the dry port. The third tier comprises the surrounding industry that generates the inputs or consumes the outputs handled by the logistics activity of the second tier. The sum of these movements represents the hinterland. These functions are presented in Figure 3-2.

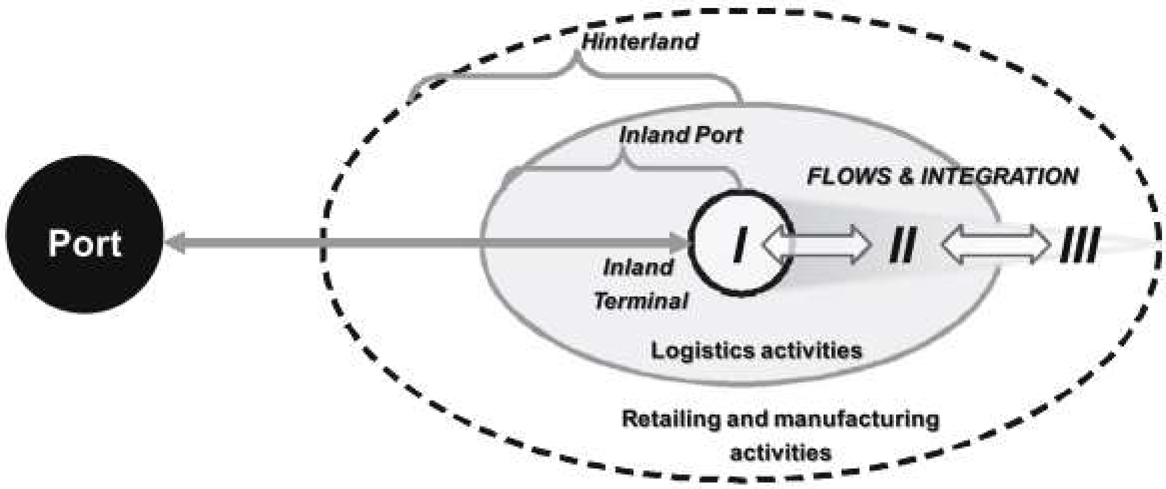


Figure 3-2 - The three tier dry port and seaport hinterland.

Source: Rodrigue et al. (2010, p.521).

The transport functions occurring in Tier I (the physical terminal) are a satellite terminal, load centre or a transmodal centre based upon differing transport functions, Figure 3-3, expanded upon by (Notteboom & Rodrigue, 2009; Rodrigue, 2010). The satellite terminal is close to the seaport (generally less than 100km) with similar functions to a close dry port. They provide additional port *"real estate"* when seaport storage and other activities have become too expensive or require too much space, or as a container depot and transloading functions (in the USA, moving from 40ft maritime containers to 53ft domestic containers) for freight distribution or consolidation. These terminals are often linked to the seaport through drayage, truck or short-haul rail services and are sited in less congested areas than the seaport. A load centre where the intermodal activity takes place, typically linking to rail, handling massified containers linking the seaport to the hinterland production and consumption market. The facility may have other logistical activity capabilities such as warehousing, distribution and logistics functions. A transmodal centre links large freight circulation systems through transloading (rail to rail) or intermodalism, sometimes with value-add functions to the seaport and connecting with distant hinterlands.

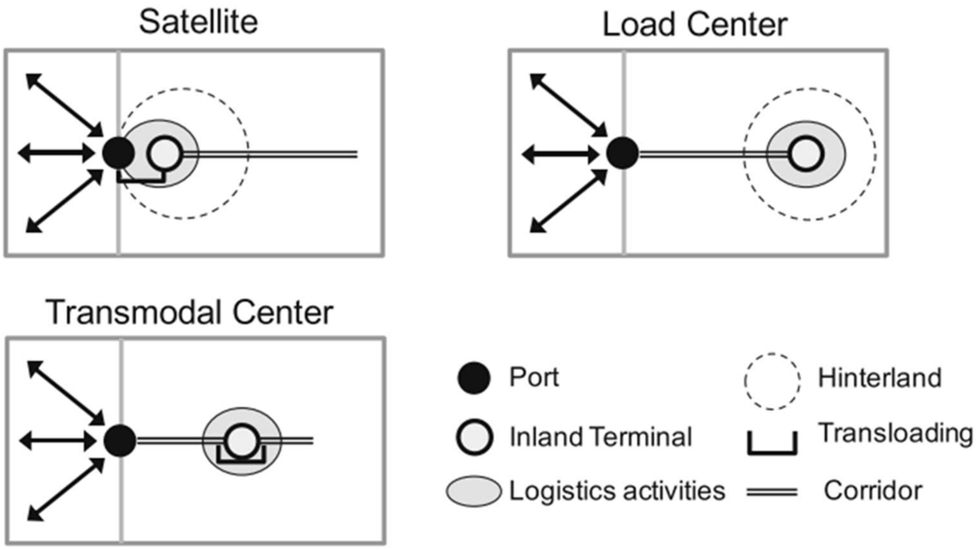


Figure 3-3 - Dry port types based on transport function.

Source: Rodrigue et al. (2010, p.521).

Underlying these transport functions are supply chain functions, Tier II, which provide a value add to the system. Rodrigue et al. (2010) nominate significant functions such as consolidation/deconsolidation, where cargo is fitted into or removed from containers or the containers are batched for massified transport or broken down for loading onto trucks from a train. Transloading, whereby land-based containers move to maritime containers or vice versa. Postponement, when the dwell time at a terminal, is used to buffer the supply chain and allow performance of last minute or last mile requirements, such as light transformations where local market packaging or labelling requirements can be applied close to the customer base.

Tier III activities interact with Tier II and generate or consume the material flows. The retail sector generally consumes incoming goods whilst causing a container imbalance (empty containers) that the second tier must manage. A manufacturing sector that consumes resources from the second tier or surrounding area and exports product containers is more balanced.

Beresford, Pettit, Xu, and Williams (2012), in a study of dry port development in China, classify Chinese dry ports as sea-port based, city-based or border dry ports with the function and location of the dry port along with the local economy establishing the type. The seaport based dry ports are located on the coast of China and focus on pre-customs clearance and cargo consolidation from inland cargo sources. City based dry ports are in central China, usually within a logistics cluster servicing both the production and consumption of goods. They are located remote from seaports and adjacent transport routes. These develop through a government driven mode in which local government plays an essential role in their establishment (Zheng, Zhang, van Blokland, & Negenborn, 2020). The border dry ports are a long distance from the seaport, greater than 2,000km, and serve as transhipment and custom clearance centres for the inland location (Beresford et al., 2012). These develop through a "*Corridor Effect"* resulting from large trade volumes crossing the border (Zheng et al., 2020).

The classifications provided by Rosso, Rodrigue and Beresford can be grouped into three types with similar characteristics, Table 3-2.

Table 3-2 - Classification of dry ports.

Author	Rosso	Rodrigue	Beresford
Type 1 • In close proximity to the seaport, possibly on the urban fringe. • Provides container storage and consolidation.	Close	Satellite	Seaport based
Type 2 • Somewhat remote from the seaport. • It is located near the production/consumption base. • Typically rail/road intermodal.	Mid-range	Load center	City based
Type 3 • Remote from the seaport, linking the distant hinterland. • Able to take advantage of rail linehaul costs to expand seaport hinterland.	Distant	Transmodal	Boarder

3.1.4 PORT-CENTRIC LOGISTICS

The concept of port-centric logistics, in which seaports offer value-adding and distribution services at the seaport (Mangan, Lalwani, & Fynes, 2008), is an important aspect of this research. It represents a supply chain approach that could be counter to the development of dry ports as in the case of Falköping (Sweden), where some port-centric activities have or may shift to the dry port (Bergqvist & Monios, 2021). Mangan et al. (2008) observe that port-centric logistics is not counter to "Port Regionalisation" (discussed in Chapter 5: Development Models for Seaports and Dry Ports), and as with dry ports, the specific attributes of the supply chain determine the suitability of port-centric logistics. In a review of the strategies related to distribution centres adopted by southern European ports, Ferrari, Parola, and Morchio (2006), describe the reasons needed to locate them within the seaport, giving rise to port-centric logistics, as effective integration of terminal and distribution centre activities, ability to "re-export" without leaving the seaport and removing congestion and environmental impacts from distant distribution centres. This translocation of congestion impacts away from the seaport is a recognised result of introducing a dry port into a supply chain. Monios, Notteboom, Wilmsmeier, and Rodrigue (2016) describe this re-emergence of seaport activities as a *"dualism"* of distribution locations. Monios, Bergqvist, and Woxenius (2018) observe that many seaports have retained distribution activities at or near the seaport. The port-centric logistics concept is depicted in Figure 3-4.

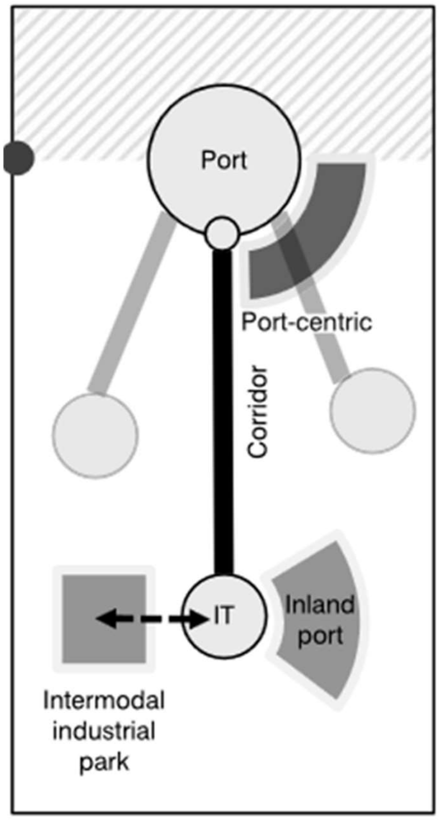


Figure 3-4 - The port-centric concept.

Source: Rodrigue & Notteboom (2011, p.12)

There is some blurring of what constitutes a port-centric location as distinct from a close or seaport-based dry port or, in the European context, a distripark. *"A truly port-centric location, meaning within the port perimeter", "but many "port-centric" developments in reality mean locations a few kms from the port"* (Monios et al., 2018 p. 58) and *"if port-centric logistics is to define anything new, then it should be defined as locating the full distribution centre (DC) in the port and distributing direct to customers from there, or basing a first-tier DC in the port and then transporting goods to a second-tier DC"* (Monios et al., 2016 p. 29). Further broadening of the port-centric concept comes from Mason, Pettit, and Beresford (2015), who describe early port-centric approaches to include dry ports in the guise of inland container depots. This is at odds with being inside or close to the seaport gate. Valantasis-Kanellos (2018) offers a reason for these differences contrasting the differing development of British seaports and trade flows to that of Europe and North America, which maintained the practice of value-adding at seaports as distinct from a straight ship and cargo handling approach adopted in the UK during the 1980s and 1990s. In the early 2000s, seaport operators realised that benefits could be gained from on-port value-adding and port-centric logistics came into being. The disconnect from within the seaport boundary is identified, in Figure 3-5, showing the different distribution approaches for port-centric and dry port distribution.

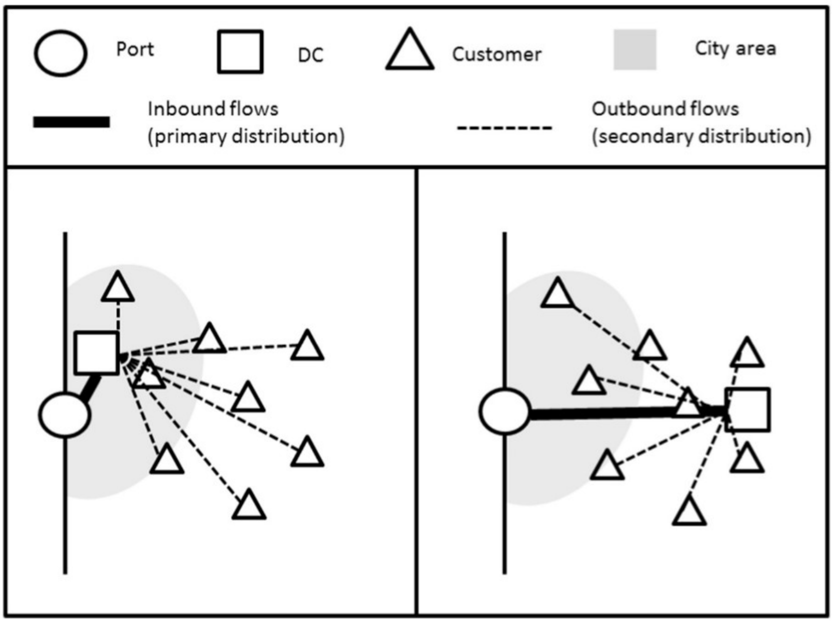


Figure 3-5 - Distribution approaches for port-centric and dry port distribution.

Source: Monios et al. (2018, p.59).

Monios and Wilmsmeier (2012b), considering the UK hinterland distribution, argue that port-centric logistics is a return of UK seaports to traditional warehousing roles warranted due to the focus on dry ports, which may be overlooking the role of seaport-based logistics in supply chains that have been established in a period when different economics applied.

The development of *"Maritime Clusters"* (de Langen, 2002) can evolve from the establishment of the value-adding activities at the seaport node through a geographically constrained *"inter-linkage"* of companies and organisations which create complementing and common processes (Dwivedi, Singh, Chhetri, & Padhaye, 2016). This clustering improves efficiencies through economies of scale, building an exchangeable knowledge base, establishing a supplier source, resource sharing and reduced transport costs (de Langen, 2002; Dwivedi et al., 2016). These clusters not only relate to direct logistics activities but also ancillary services. The same factors that promote the introduction of dry ports control the ability to establish port-centric logistics. These factors are the type of cargo, where the goods are travelling to or from, the availability of sufficient land at the seaport and congestion surrounding the seaport, reducing transport efficiency and adversely impacting the local community (Monios & Wilmsmeier, 2012b).

Expanding on specific supply chain characteristics that support port-centric logistics, Mangan et al. (2008) elaborate on why UK seaports promoted distribution centres to be at the seaport on the premise that all the goods pass through the seaport, providing the opportunity for colocation of the distribution centre. The presence of specific factors, such as load limits restricting road transport to part containers or a container imbalance in which large numbers must be returned empty to the seaport, may allow these port-centric distribution centres to have a role. The authors conclude that depending on the specific circumstances, either approach or a combination of the two may be viable. The importance of these specific circumstances is recognised in the literature when a seaport views a close dry port as threatening some of the seaport business then reclaiming this activity when situations such as the availability of more land at the seaport or technologies, change.

Monios et al. (2016) provide reasons for a return to port-centric activity. Firstly, the distribution function and those related to the *"unit of cargo"* handled. In the case of containers, this may be stuffing and stripping activities in customised facilities or transferring cargo from maritime to domestic land-based containers (continental containers). The second function relates to production and distribution, where value-adding functions occur at the seaport, such as consolidating cargoes for distribution or export cargo warehousing and consolidation for export.

Guerrero (2019) argues both positive and negative attributes of port-centric logistics, with the negative aspects dominating. The positive aspect is cost savings associated with not having to return empty containers to the seaport. Negative aspects include sub-optimal locations relative to the hinterland and increased volume of transported goods due to breaking up and palletising import container loads, outweighing the cost savings. Some European seaports (Le Havre and Gothenburg) are developing seaport-based warehouses and intermodal terminals (Bouchery, Woxenius, & Fransoo, 2020). In the case of Falköping, the presence of a container park at the dry port is beneficial to the balance of container movements and provides cost savings in the supply chain (Bergqvist & Monios, 2021).

Ultimately the choice between port-centric and dry port-based supply chains is a consideration of the same reasons as to the value of developing a dry port. Bouchery et al. (2020), through modelling from a logistics service provider's perspective, identify that port-centric logistics, direct trucking and intermodal hinterland transport will generally compete. The modelling incorporates time cost in the form of container detention charges and includes competition from direct trucking from the seaport to the destination and the introduction of "continental" containers into the transport chain. The competitive position of both direct trucking and port-centric logistics is reduced, not unexpectedly, for high cargo volumes transported to a large hinterland distant from the seaport. The authors recognise that other actors will have different positions, such as the environmental and social impacts that road transport can have on communities surrounding the seaport. As situations change, the balance between port-centric and dry port systems may also change, and a return to the seaport of previously removed activity, port-centric logistics, may be warranted.

3.2 FREMANTLE PORTS

3.2.1 INNER HARBOUR

The various studies conducted by Fremantle Ports relating to truck movements, improving rail share and provision of infrastructure for both marine and landside operations demonstrate the need for the seaport to satisfy issues associated with the following attributes of a dry port development:

- Improved inland transport efficiency.
- Reduction of congestion in the surrounding suburbs and road links.
- A recognition the Fremantle Ports Inner Harbour is part of a global supply chain.

The FPA 2011 Exporter Survey on Off-Port facilities (Hall, 2012) provides information on exporter's views of the benefits and obstacles of using an “Off-Port Hub/Inland Port” with the rankings presented in Table 3-3. The factors align closely with the literature on the benefits of dry ports in a supply chain. The obstacles nominated indicate factors that must be satisfied for a dry port to be successful as discussed in the literature. The nomination of the cost being the highest ranking obstacle along with other cost incurring items such as double handling of containers and dead running is consistent with transport mode selection discussed further in Chapter 8: Freight Transport Modal Choice Survey.

Table 3-3 - Benefits and obstacles for a dry port in the Inner Harbour supply chain.

Source: Adapted from Hall (2012).

Benefit	**Obstacle**
Less congestion at Inner Harbour.	Could be cost prohibitive.
One point to do all activities.	Cut-off times could be prohibitive.
Proximity to customers.	Double handling of boxes.
Cost benefit.	Liability/insurance for getting boxes to wharf must be addressed.
Reduced time in whole supply chain.	Must have all facilities to avoid dead running.
No requirement to deal directly with wharf.	Must have right infrastructure (road access, rail link to Port).
Flow of trucks/trains more efficient	Reliant on shipping companies for stocking the right equipment.
	Location critical to success (to transport, customers etc).

The physical evidence of transport improvements is the construction of the NQRT and its ongoing commercial development (Milne, 2019) and the development of the Kenwick (ARC, 2020) and Forrestfield/Kewdale dry port, which offers a range of services described in Chapter 2: Case Study-Fremantle Ports.

Forrestfield/Kewdale is a close dry port, approximately 39km by rail or 23km straight line from the Inner Harbour (GoogleMaps, 2020) and is within the Perth metropolitan area.

Rous Head offers port-centric logistics, however, its impact on congestion is not identifiable as disaggregated cargo on trucks is not accounted for in the Fremantle Ports truck surveys (FMC Consulting, 2019). Various logistics and marine-related services are available at Rous Head in Fremantle Port (GoogleMaps, 2021), such as warehousing and quarantine services, container packing/unpacking, oil spill training and response, marine services (vessel charter), dive services and stevedoring container handling and storage (AMOSC, 2021; DP World, 2021; HSA, 2021; ICL, 2021; JDCL, 2021; Lionfish, 2021; Patrick, 2021; Qube, 2021; Stevenson, 2021; TAMS, 2021; TYNE, 2021) representing a maritime cluster.

3.2.2 OUTER HARBOUR

The future Outer Harbour facility can develop with the support of long-term planning decisions. This planning allows for establishing road and rail links to the seaport from the existing metropolitan transport network, see Chapter 7: Dry Port Site Selection.

The land in the proposed development location will allow for quayside rail infrastructure and potentially port-centric logistics activity. The close-by Latitude 32 industry zone allows the development of substantive storage and distribution facilities. The significance of this area for port-related activities is demonstrated by the Latitude 32 Development Area 4 undergoing a structure plan review arising from Westport Study implications (Landcorp, 2019). Quayside rail will allow the Outer Harbour to link with the existing dry ports in the metropolitan area in a close dry port system.

Chapter 4: Common Reasons for Dry Port Development

4.1 LITERATURE REVIEW

4.1.1 INTRODUCTION

Seaports fundamentally develop in response to transport demand. Dry port developments are also a response to transport demand where their presence leads to improvement of the transport network. This improvement is generally accompanied by maintaining or improving the competitiveness of the seaport(s) in that supply chain and the overall supply chain itself.

The introduction of containers into the transportation of goods facilitated land-based intermodal transport and enabled the exploitation of high-capacity transport systems reliant on consolidating or distributing cargoes via intermodal terminals (dry ports) (Basallo-Triana, Vidal-Holguín, & Bravo-Bastidas, 2021).

As dry ports do not exist in every supply chain which includes a seaport there must be specific circumstances that promote the dry port development over and above solely a transport demand. Nguyen, Thai, Nguyen, and Tran (2021) correctly identify that understanding the contribution that a dry port makes to the seaport hinterland (both economic and non-economic) is essential in understanding if it will be a success and the different actors in the supply chain will have differing views on this as discussed in Chapter 6: Development Criteria for Dry Ports. Along with transport demand, the remainder of this section explores these reasons.

4.1.2 TRANSPORT DEMAND

Seaports are traditionally described as relying on the derived demand for transport as a driver of their growth. This demand results from the interaction between the economic, shipping and port systems with the exogenous economic system initiating transport flows (Cullinane & Wilmsmeier, 2011a).

Seaport function has changed as container traffic has grown through globally integrated supply chains. Seaports moved from a monopolistic transport position (in respect of both forelands and hinterlands) to a supply chain node, albeit an important one (Notteboom & Haralambides, 2020). This changed position requires the development of strategies by seaports to survive increasing competition with competitiveness becoming increasingly dependent on the seaports' ability to synchronise and integrate their operations with the hinterland transport modes and nodes and other actors in the logistics networks (Iannone, 2013; Monios, 2011; Pettit & Beresford, 2009).

Changing supply chain management approaches, global production networks and commodity chains lead Hesse and Rodrigue (2004) and Rodrigue (2006) to challenge the view that freight transport is a derived demand and introduce the concept of "*integrated demand*". They argue at a high level of transport flows, and physical distribution, the derived demand concept holds, however, integrated demand occurs at the materials management, freight distribution level. This freight distribution level change occurs from globalisation changing the operational scale, supply and demand relationships, functional integration, role and function of distribution centres and accounting for time in supply chains. Physical distribution comprises all the activities to move goods from the point of production to the point of sale. Whilst materials management comprises the activities associated with tasks in the manufacturing process along a supply chain such as inventory management, assembly and packaging. The relationship between these is the integrated demand.

For dry port development factors, whilst it may determine the approach to or location of the development, the source of the transport demand, derived or integrated, does not require resolution. Rather, factors associated with materials management, such as space and transport equipment movement, influence dry port development. The integrated demand concept reflects the attributes of changing supply chains and globalisation, supported by container freight movements.

4.1.3 REMAINING COMPETITIVE AND HINTERLAND COMPETITION

The introduction of containers into the transport system, technological advances that provide timely information flows, and reduced transport costs, initially obtained by introducing increasingly larger container vessels, have facilitated the globalisation of supply chains. The importance of these global supply chains and the role of dry ports in them has become evident in the unfolding COVID-19 pandemic (EFIP, 2020). Globalisation has led to supply chains, including the seaports within them, competing against each other rather than the historical situation of seaports existing in relative isolation with captive hinterlands. This change was recognised by Slack (1985), observing that seaport competition is no longer related to dominating a primary hinterland, but freight levels through the seaport are influenced by "*cost and service"* factors. Further consideration of these changes by Rodrigue and Notteboom (2009b) lead to the concept of *"buffer terminalisation"* of supply chains. Seaports, particularly seaport terminals, depending on the economics of a supply chain, move from being considered efficient (by supply chain controllers) when quickly moving containers between marine and land transport activity to a position where the supply chain is attempting to take advantage of the dwell time at the seaport terminal. This dwell time uses seaports as "*buffers"* and *"in transit inventory"*, replacing a portion of inventory holdings in warehouses. Seaport terminal operators are introducing various charges and booking systems to prevent this use of dwell time due to the expensive and potentially scarce quayside land resource. Dry ports find a role in this situation, providing an opportunity to store containers on less expensive land and supporting the regionalisation concept as logistics poles, and ultimately a regional load network is established in the hinterland.

The concentration of container trade to hub seaports, Figure 4-1, and consolidation of the shipping and port terminal sector have led to *"footloose"* global carriers that can readily move from one seaport to another (Merk, 2013), requiring seaports to take action to remain competitive.

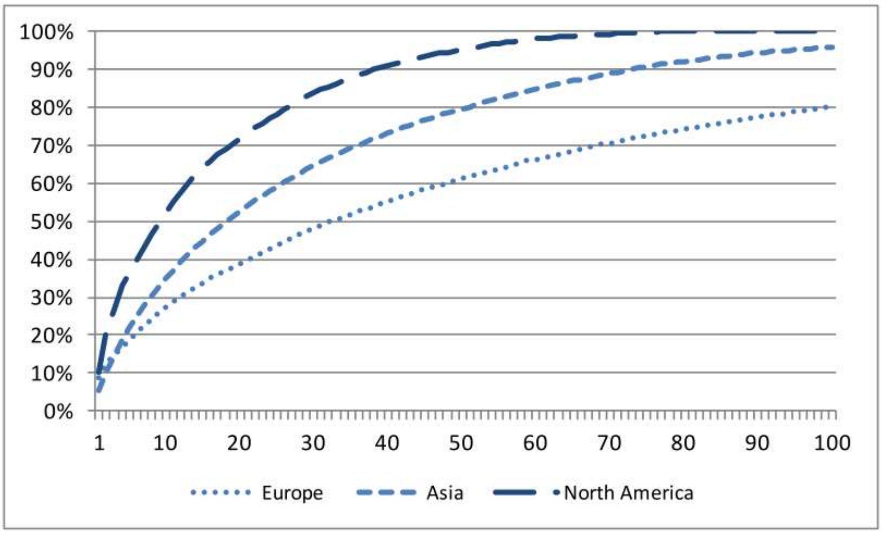


Figure 4-1 - Port concentration (2009), top 100 seaports and the cumulative traffic share.

Source: Merk (2013, p.45).

In a literature review of seaport competitiveness Parola, Risitano, Ferretti, and Panetti (2017), provide a “top ten” listing of competitiveness drivers in which the dry port enhancing factors of hinterland proximity and connectivity are nominated just behind the primary selection criteria of cost. The authors note a shift in competitiveness measures from marine factors to *“hinterland drivers”* as providing a competitive advantage over time, and *“Overall, it can be stated that maritime-related factors, despite their importance, exert a comparatively lower influence in the definition of port competitiveness.”* (Parola et al., 2017 p.125). Drawing upon recent developments to recast priorities, regionalisation (Chapter 5.1.3: Spatial and Functional Models) further supports dry ports' role in seaport competitiveness. Dry ports' role in supporting modal change (from road to rail transport) satisfies *“green and sustainability”* factors that are increasingly important in modern competitive seaports.

In a literature review focussing on container seaport choice, Moya and Valero (2017) demonstrate differing priorities of actors when deciding on a seaport's competitiveness and differentiate between the competitive aspects a seaport can control and those beyond that control. The authors observe that the development of Inland Container Depots (dry ports) by a seaport is not well researched but do note that *“port connectivity”* and the *“quantity and quality of connections with the hinterland and hinterland intermodality have become key determinants of the decision-makers competitiveness*” (Moya & Valero, 2017 p.313).

The drivers of competitiveness moving away from a straight cost basis reflect the move from supply chains being cost driven to outcome focussed (Khaslavskaya & Roso, 2019) and the need for seaports to position themselves as “*value add”* nodes, not “*cost centres”* in the supply chain. Dry ports allow seaports to participate in supply chains that achieve this with value add activities such as cargo consolidation, container maintenance (Nguyen & Notteboom, 2016b; Talley & Ng, 2017), container storage (Andersson & Roso, 2016), and market customisation, which are ideally performed along hinterland transport routes occurring, (Notteboom & Rodrigue, 2007). Interestingly Andersson and Roso (2016) conclude that value-adding services do not attract new customers but expand volumes with and improve the satisfaction of established customers; this is further explored in Chapter 5: Development Models for Seaports and Dry Ports.

Table 4-1 derived from Khaslavskaya and Roso (2019) presents a summary from the literature of supply chain benefits related to the integration of dry ports. These findings are confirmed as relevant during an interview process of actors using the Skaraborg dry port in Sweden.

Table 4-1 - Literature findings on dry ports in supply chains.

Source: adapted from Khaslavskaya & Roso (2019, p.4).

Supply Chain Factor	Possible Improvements
Cost	• Increase combined seaport dry port throughput. • Decrease transport cost. • Lower container storage costs. • Reduce road accidents (and associated costs). • Reduce transport fees (tolls).
Responsiveness	• Reliable and frequent transport service. • Able to accommodate changing customer needs. • Avoid congestion and use intermodal services.
Security	• Improved safety and security of freight. • Consolidation enables capital purchase e.g., X-Ray equipment.
Environment	• Reduction in CO2 emissions. • Green transport for last-mile handling.
Resilience	• Supports a supply chain during "constant change" such as technology. • Reduces the impact of seaport labour unrest.
Innovation	• Promotes new ways of doing things.

Dry ports are increasingly important in facilitating seaport capacity, enabling efficient intermodal transfers and enlarging hinterlands (Iannone, 2013). Roso et al. (2009) contend that dry ports provide efficiency in seaport container handling and improved hinterland logistics resulting in a better service to shippers and supporting the competitiveness of seaports.

The changing landscape of seaport hinterlands, following the introduction of containers and improved transport corridors, has been evident for over 70 years. The German term hinterland from *"the land behind"* first appeared in English research documents in 1908 (Sdoukopoulos & Boile, 2020). Weigend (1956), citing earlier papers by F.W. Morgan, notes the *"simple parcelling out of the country behind ports is an inadequate interpretation of the concept "hinterland""* (Weigend, 1956 p.1), and seaports have many hinterlands with varying structure and physical extent. Morgan observes that there are *"primary" and "secondary"* hinterlands. Primary hinterlands are an area over which the seaport has firm control, whilst secondary hinterlands are not well defined and *"rivalry among ports is a "free-for all""* (Weigend, 1956 p.2). This description is arguably a general reflection of the current situation, whereby some locations close to or with efficient and expensive to replicate direct links to a seaport render it a primary hinterland. Hoare (1986), in a paper on a Bristol Port development, references a White Paper as stating, *"Old fashioned ideas on the extent of a port's hinterland put it at 25 miles. Now, because of vastly improved transport communications, the limits of the hinterland are said to extend to a radius of 100 miles or more"* (Hoare, 1986 p.30). During this time, industry consolidation and vertical integration were concentrating trade through fewer seaports which changed the dynamics of the seaport hinterland interactions. Land freight flows crossed traditional regional (hinterland) boundaries to seaports concentrating marine trade, Figure 4-2.

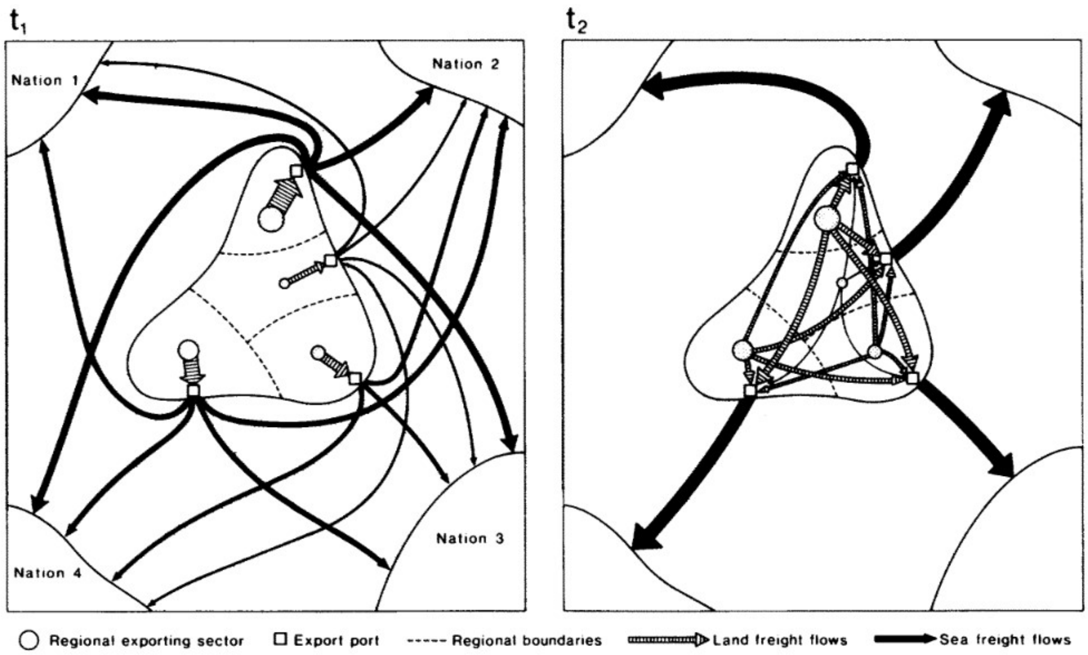


Figure 4-2 - Changing dynamics of seaport-hinterland relations (exports) over time, t_1 to t_2.

Source: Hoare (1986, p.33).

As previously discussed, this relationship has continued to evolve and resulted in globalised supply chains that fundamentally changed the generation of transport demand and the concept of hinterlands. Distance is no longer the prime determinant of hinterlands. Functional relationships play a key role in supply chains. However, the "*distance-decay*" approach to hinterlands should not be dismissed, as evidenced by the selection of additional seaports in the modelling performed by Cabelle Valls, deLangen, Garcia, and Vallejo-Pinto (2020). They included distant ports and those with tightly held hinterlands to expand the suite of Spanish Ports in their modelling of port selection factors. A reflection of the need to combine distance with other factors such as the types of goods ((Cabelle Valls et al., 2020) observing that hinterlands are commodity-specific), the behaviour of actors, efficiencies, types of transport available, environmental constraints and method by which "*distance*" is determined (Sdoukopoulos & Boile, 2020). This reduction in the determinate of the hinterland by distance represents the regionalisation and disconnected hinterlands discussed in Chapter 5.1.3: Spatial and Functional Models.

In recognition of these changes, Notteboom and Rodrigue (2007) consider hinterlands generated at three levels: macro-economic, physical and logistical.

Macro-economic hinterlands - relate to the general derived demand concept for transport as freight moves from origins to destinations. Whilst they are forces exogenic to the seaport, they impact seaports through traffic volumes and flow direction.

Physical hinterlands - relate to the network of transport infrastructure, types of transport and terminals that link it. These systems may be quite small as in the Chinese ports' coastal hinterlands or over a considerable distance as found in the USA inland rail corridors.

Logistical hinterlands - have regard to actual freight flows within the macro-economic and physical settings, and these logistics networks directly influence the supply chain's competitiveness. The move from a direct transport link to a network is driven by the global supply chains and reflects the previously described integrated demand.

The ability of the physical and logistical hinterlands to cope with the massification of container flows has led to the breakdown of traditional hinterlands and the fragmented situation of direct and distant hinterlands described in Chapter 5: Development Models for Seaports and Dry Ports.

In the Australian context, the choice of a seaport for imports to Australia is influenced by the spatial characteristics of the continent, especially the east and west, meaning overseas shipper ports of destination and shipping line ports of call will generally include Fremantle for Western Australian imports. This reflects the high landside cost of transporting goods from east to west and serves to protect the Fremantle port hinterland (Ng, Sun, & Bhattacharjya, 2013). The increasing population level in Perth supports the hinterland by increasing consumer demand promoting liner service calls reducing interstate rail transport from east coast seaports to Perth, this is discussed further in Chapter 7: Dry Port Site Selection.

4.1.4 STORAGE SPACE

To gain economies of scale, shipping companies increased the carrying capacity of container vessels, massification, Figure 4-3, requiring additional draft, larger portainers (quayside container cranes) and larger container storage yards and transport equipment in seaports to handle the arrival of large numbers of containers on a single vessel. This infrastructure improves maritime economics and direct loading, handling and unloading of containers (Notteboom & Rodrigue, 2008). Once unloaded, the provision of increased storage space for containers can be physically constrained and is a potentially significant issue for seaports in traditional city locations aligned with the *"maturity"* phase of the port lifecycle model (Cullinane et al., 2012; Jeevan et al., 2019), discussed in Chapter 5: Development Models for Seaports and Dry Ports.

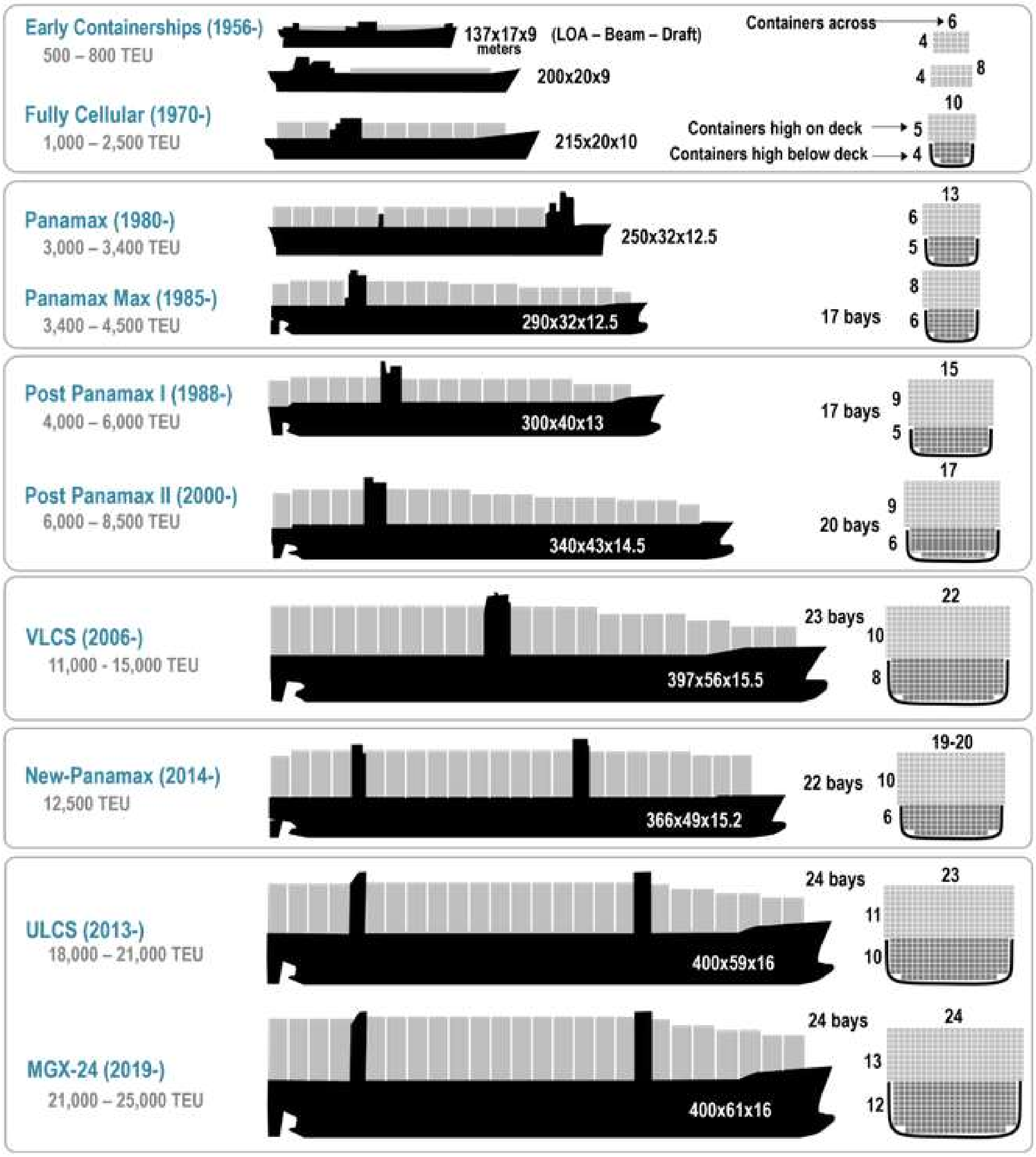


Figure 4-3 - Increasing container vessel size over time.

Source: Rodrigue (2020, no page number).

The restriction on storage space expansion, along with consideration of environmental and community impacts and changes to the supply chain, gives rise to the emergence of dry ports as a solution to storage constraints (Cullinane et al., 2012; Cullinane & Wilmsmeier, 2011b; Lovric et al., 2020; Nguyen & Notteboom, 2016a).

4.1.5 COMMUNITY, CONGESTION AND ENVIRONMENT

Dry port development aspects behind community, congestion and environmental factors are closely interrelated and arise from the "*externalised costs*" of seaport operation and associated transport of goods. These externalised costs are evidenced in the Australian context as a result of urban encroachment into transport corridors and port operational areas and are expressed most obviously through road congestion (Ernst & Young, 2014).

In a review of *"green port"* hinterland activities, Aregall et al. (2018) observe the close link between seaport performance and hinterland connectivity. However, seaport activity relating to implementing green strategies in these links is not widely studied. They identified four areas for setting impact reduction goals:

- Air emissions.
- Noise.
- Landside congestion.
- Modal shift and intermodality.

The authors identify seaports in port cities are more likely to take green action in hinterlands and reasonably hypothesise that congestion and community impacts are most likely in these city locations. Separately these action areas are put forward in the literature as reasons for the development of dry ports.

Port cities benefit from seaports through the economic activity and the direct employment they create. During the early stages of seaport operations and growth, road transport provides a viable sole hinterland link, but at some point, it becomes inefficient as a sole transport means (Notteboom & Rodrigue, 2009), with the cities adversely impacted by congestion and exhaust pollution. Heightened community concern over these impacts occurs as many of the economic benefits associated with the movement of the goods are regionalised whilst the negative aspects are local (Merk & Dang, 2013). Local residents are essential stakeholders in seaports, and through influencing local governments can deliver policy, planning, rules and other restrictions on seaport operations that adversely impact freight movement (Lubulwa et al., 2011).

Cullinane et al. (2012) argue that seaports are increasingly capacity constrained by off-port conflicts of community and environmental considerations. Congestion adversely impacts the community and acts as a diseconomy of scale for the seaport (Merk, 2013; Nguyen & Notteboom, 2016a), with the off-port impacts creating pressure to restrict seaport activities (Starr, Liu, & Cassey, 2000). Roso et al. (2009) argue that dry ports relieve port cities from some congestion through a modal shift from road to rail, reducing accidents and road maintenance and creating less traffic pollution (Roso, Black, & Marušić, 2017). Acciaro and McKinnon (2013) identify *"port gate"* controls such as vehicle booking systems as methods of reducing queueing and hence congestion and emissions. Implementation of these controls is not straightforward, as discussed in Chapter 6: Development Criteria for Dry Ports.

The contribution to traffic congestion of seaports is documented in the Australian context by Lubulwa et al. (2011). Talley and Ng (2017) nominate dry ports as a practical method of reducing seaport (outside gate) traffic congestion. In an empirical study of US ports, Wan, Zhang, and Yuen (2013) determine a correlation between increasing congestion around a seaport and a reduction in container traffic, whilst an increase in congestion around a nearby seaport leads to an increase in container throughput through the less congested seaport. The study relates only to container movements associated with road transport (including drayage to near seaport rail terminals). This correlation is consistent with the cost of transport increasing due to congestion and decisions to move to nearby seaports with lower costs and the associated "*peripheral port challenge"* (Hayuth, 1981).

In a study of *"transferia"*, Meers, Vermeiren, and Macharis (2018) consider both local community and global advantages of the concept in a Belgian case study. They conclude local impacts such as noise, congestion, traffic accidents, air pollution and infrastructure degradation are improved, especially when transport moves out of peak congestion periods. This amelioration may not counter local community resistance to locating a dry port in their area as the overall impact is still increased compared to no facility in the area. Overall impacts such as CO_2 emissions can increase if the hinterland leg is swapped to road transport from rail or barge by use of the facility.

Other community impact factors are light and noise (Starr et al., 2000; Valentine, 2014) and particulate pollution from diesel exhaust emissions (Liedtke, Guillermo, & Murillo, 2012). Noise from trucks and trains can cause general annoyance and sleep impacts (Merk, 2013). This aspect is aggravated by the redevelopment of vacated seaport areas and facilities, with urban encroachment becoming a significant issue around many seaports (Witte, Wiegmans, van Oort, & Spit, 2014). Health impacts on communities around seaports arising from noise and air pollution are established (Merk, 2013).

4.1.6 ECONOMIC DEVELOPMENT

Dry port development can promote or support economic development in a region. This development enables access to a market through economies of scale for a region and its business that would not have been achievable as individual entities; this is particularly important in developing nations (Rodrigue & Notteboom, 2012). Favourable planning or granting of subsidies or operating concessions in an attempt by governments to support economic growth in a particular region, such as "*economic zone facilitation*" supports dry port development (Do et al., 2011; Nguyen & Notteboom, 2016a) or the Grand Western Development (Go West) programme in China (Beresford et al., 2012), in conjunction with a general approach of using dry ports as economic development drivers, (Monios & Wilmsmeier, 2012a; Notteboom & Yang, 2017; Zeng, Maloni, Paul, & Yang, 2013).

In contrast to this generally accepted concept, Wiegmans et al. (2014), in a study of Dutch dry ports, could not find a statistically significant relationship between regional employment levels and transhipment levels for a dry port in the same area. The authors prophesize that this may be due to the relationship being too indirect to correlate. It may also reflect the narrow study area or concerning this thesis that the activity level includes not only containers but all commodities moving through the dry port, bulk products having less employment growth for increased throughput than containerised goods.

4.2 FREMANTLE PORTS

4.2.1 INNER HARBOUR AND EXISTING DRY PORTS

Transport Demand

As described in Chapter 2: Case Study- Fremantle Ports, the Inner Harbour has an annual total container throughput of 807,061 TEU, including empty containers (FPA, 2021a). From various estimates, growth is between 2.8 to 5.8% per annum for the forecastable future. The proportion of the containers transported by rail is 18.4% (FPA, 2021a), (a 1% shift to rail equating to removing approximately 5,000 truck movements per annum) (FPA, 2019c), with a target of 30% (DPI, 2002; MacTiernan, 2002a; Turner, 2014; WAPC, 2006). Each loaded train consist removes up to 60 truck movements (FPA, 2021a). The rail share target level allows the Inner Harbour to have the capacity to meet transport demand until the mid-2030s without significant further road congestion impact (Westport, 2019f). This capacity is contested with industry presenting an argument that the Inner Harbour is already capacity constrained and will continue to be so by rail and road transport links, harbour characteristics and land use competition (Edwards, 2018a).

Demand for both import and export capacity is forecast to grow through the Inner Harbour, though the Kwinana industry argues that growth rates, particularly for exports, could be increased by the Outer Harbour development. Regardless, design, approvals and construction periods will require the Inner Harbour to serve as the primary West Australian container port until the 2030s.

Remaining competitive and hinterland competition

The Fremantle Ports Inner Harbour is the fourth largest (capital city) container seaport in Australia, behind Melbourne, Sydney and Brisbane. The Inner Harbour has the fastest landside container turnaround time of the Australian container seaports meaning that Fremantle Ports has the best combination of truck utilisation (containers per truck) and truck processing time combined. For January to June 2020, the Australian seaport average was 19.2 minutes compared to the Inner Harbour of 13.3 minutes (BITRE, 2021b). The Inner Harbour is below the national average for port interface costs (a measure of the landside cost of container handling) as presented in Table 4-2. Fremantle Ports is competitive in cost and landside container movement time in the Australian context. This position supports the Westport argument that the Inner Harbour operates under a throughput that hampers efficiency rather than already reaching or exceeding capacity.

Table 4-2- Australian container seaport port interface costs for January to June 2020.

Source: BITRE (2021b).

Vessel size, GT		National $/TEU	Fremantle $/TEU
5,000 to 20,000	Import	973	941
	Export	942	876
35,000 to 50,000	Import	992	944
	Export	940	905
65,000 to 80,000	Import	985	933
	Export	925	894

Whilst not an overall indicator of landside transport efficiency, Australian seaports have a similar crane, labour and ship productivity to international container seaports of comparable size and attributes. The remoteness and distance between Australian container seaports reduce inter-port competition, potentially reducing productivity improvement (ACCC, 2019). WEF (2019) supports this, ranking the Australian "*efficiency of seaport services*" as 37th in the world, a position highlighted by Edwards (2018b) in an argument to change the Outer Harbour development study approach, as discussed in economic development factors in the Outer Harbour section of this chapter.

Fremantle Ports does not have a captive hinterland when considering existing west coast seaports. Despite the significant distance from Australian east coast container seaports, there is competition between them and Fremantle Ports as discussed further in Chapter 7: Dry Port Site Selection. At a state level, the Southwest of the state including Perth is a captive hinterland. This situation will largely remain until the Inner Harbour reaches capacity, at which time the high capital investment required for establishing a new container seaport and the potential of the growing local population to support the direct import of goods will open competition for funding of a new container terminal (Outer Harbour) with a potential competitor seaport in Bunbury.

Several shipping lines have commenced direct container services into the Pilbara Ports. Whilst relying on break bulk cargo and container freight to make the service viable, it competes with Fremantle Ports Inner Harbour due to the long land transport leg between Perth and the Pilbara (SAL, 2020; Shipping Australia, 2021). Whilst only a small number of containers will be lost to Fremantle Ports, the services demonstrate that seaport hinterlands are not captive.

The Inner Harbour relies on a WA state government subsidy of $50 per TEU for containers moved by rail for the transport mode to be attractive to users. This reliance shows the Inner Harbour rail link to be uncompetitive on a direct cost basis with road transport. However, paying the subsidy could provide a net benefit over the externalised costs of road transport such as road repair, accidents and cost of congestion to other road users and deferring significant capital expenditure on a new seaport and road infrastructure.

Given space constraints, the Inner Harbour is even now potentially threatened by regional seaports, particularly Bunbury, in vehicle imports and livestock export. These trades require near quayside space which is scarce at Fremantle but readily available at Bunbury Port.

A changing export base with battery precursors and other significant processed mine products promotes competition for container export through Bunbury. The WAPC (2004) Outer Harbour report recognises regional seaports could offer a container service for regionally sourced containers even if not those moved with sources and destinations in the Perth metropolitan area. The Western Australian Regional Freight Transport Network Plan (DoT, 2012) identified Bunbury Port expansion, Bunbury to Perth rail upgrades, and a Bunbury Port access road as a priority in the 2020 timeframe. Whilst road upgrades have commenced, port and rail works have not; these priorities support a container trade for regional and even Perth metropolitan container trades to be opened in Bunbury through improvement to the hinterland connections that Bunbury Port could potentially serve.

With the lack of specialised container facilities at Bunbury and the relatively small regional hinterland, liner services will not divert from Fremantle Ports Inner Harbour to Bunbury. A container trade commencing from Bunbury would likely be of a boutique nature, using ships gear or a harbour crane for loading vessels that call on a weekly or fortnightly basis, potentially as a feeder service to an Asian hub such as

Singapore. On this basis, Bunbury port potentially threatens Fremantle Ports Inner Harbour container trade at the margins, with the threat growing with additional infrastructure funding at Bunbury port. The Westport study acknowledges this, reporting a similar local source of containers supporting Port of Bunbury container operations (Westport, 2019a).

Storage space

The ability to increase the land area available for port activities, including container storage space at the Inner Harbour, is restricted. The southern side of the Inner Harbour, Victoria Quay, is the interface with the urban area of Fremantle and is the subject of redevelopment for community use. The interface prevents land expansion in this direction.

Further land reclamation to the north is possible at Rous Head, extending along the North Mole. Studies undertaken as part of the Fremantle Port 2009 dredging program resulted in a reduced reclamation over what was thought possible. The reduction was due to a lack of fill and compliance with approved structure plans for the area's development. Further reclamation is possible, but this would require a significant source of fill, $3.75Mm^3$ above the Option 3 expansion that was completed (possibly sourced from future dredging, the port deepening campaign in 2010 generated approximately $3.1Mm^3$ in total, split between landside and sea disposal) and various environmental and planning approvals (SKM, 2009), Figure 4-4. The economics of such a dredging campaign requires the need to accommodate deeper draft vessels, such as the Emma Class with a 15.5m draft, at Inner Harbour berths. A need of this type may trigger the development of the Outer Harbour if the capacity constraints outside the Inner Harbour port gate limit the benefit of berthing larger vessels, eliminating the source of fill for an Inner Harbour reclamation program.

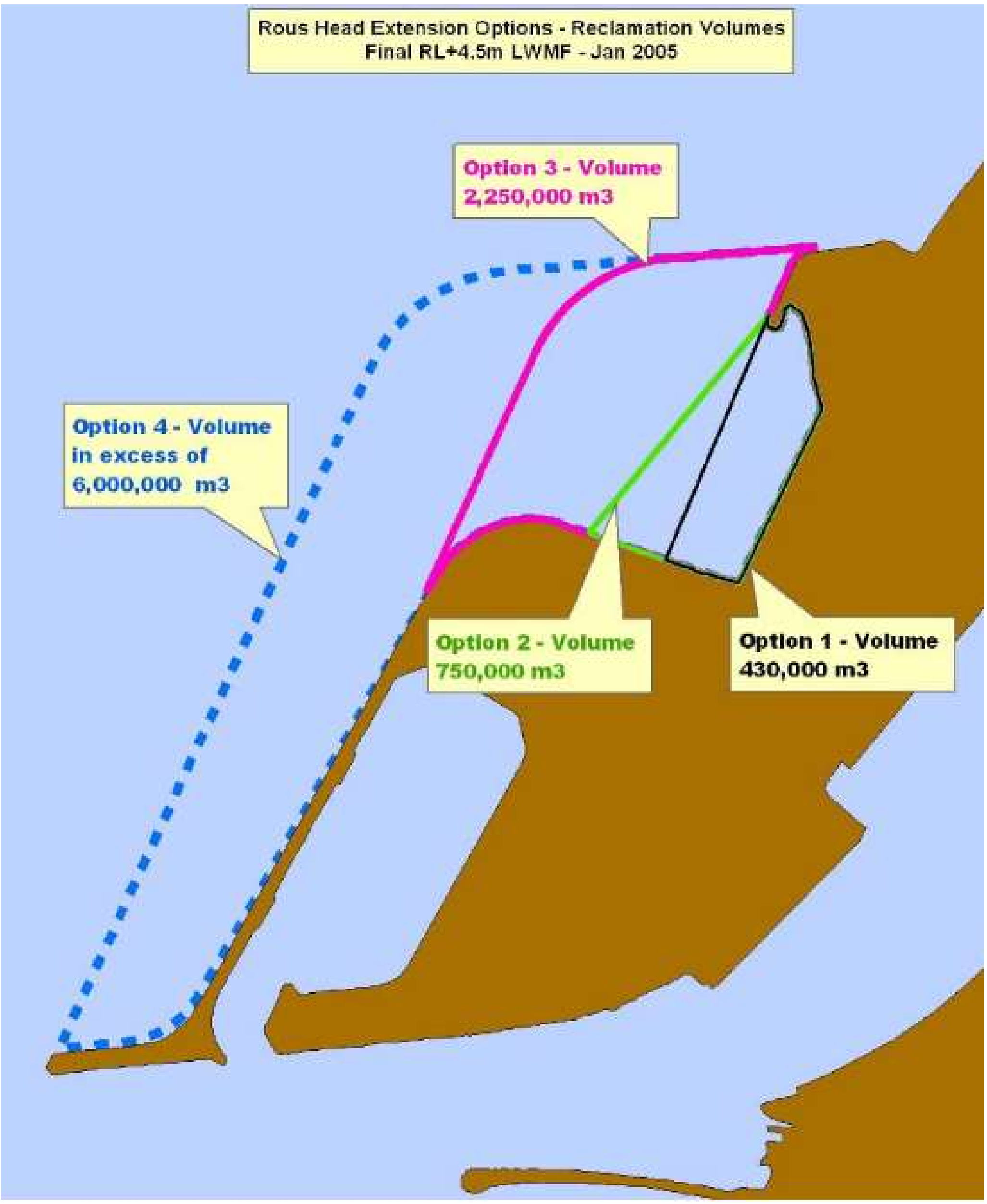


Figure 4-4 - Potential reclamation areas.

Source SKM (2009, p.2-7).

The Westport study (Westport, 2019f) provides an alternative viewpoint, concluding that further Inner Harbour river dredging is not feasible, and additional land can be developed by constructing deep-water berths outside the river mouth. The dredge spoil used to reclaim the existing small boat harbour to provide land, berths and space capacity for 3.8M TEU, Figure 4-5. Costs for this, even without consideration of hinterland links, could trigger the development of the Outer Harbour.

Figure 4-5 - Reclaimed land and deep-water berths for 3.8M TEU capacity.

Source: Westport (2019f, p.3).

Community, Congestion and Environment

As evidenced in the exporter survey (Hall, 2011), Fremantle Ports recognises road congestion caused by container trade and the role of rail and "inland facilities" in reducing this. Supported by the WA state government, Fremantle Ports has taken measures to mitigate the impacts on the community surrounding the Inner Harbour and congestion of Fremantle and hinterland connecting roads. These measures reduce the environmental impacts of the land transport leg of the Inner Harbour supply chain.

Most of these actions relate to the dry port hub at Forrestfield/Kewdale. The activities include efforts in four of the ten green port activity areas nominated by Aregall et al. (2018):

- Dedicated infrastructure – North Quay Rail Terminal.
- Intermodal service development – Fremantle Ports actively engage with industry to promote intermodal services and management agreements for the NQRT operation.
- Port dues and subsidy funds – State government subsidy for container movements on rail transport.
- Technology – electronic vehicle booking system (VBS) and cloud based information systems.

As previously discussed, Fremantle Ports recognise the community impacts and potential threats to Inner Harbour operations and undertook a Buffer Definition Study to understand and define community impacts (FPA, 2002). The study accounted for all Inner Harbour activities focusing on noise, explosion risk and odour but not road congestion.

Container truck surveys have been performed for 19 years on the two main approach roads to the Inner Harbour, Tydeman Road and Port Beach Road, to assess the number of trucks, contribution to overall traffic and time of activity and indirectly the road transport efficiency gains and intermodal transport (rail) impacts on road congestion due to the Inner Harbour activities. General traffic level rose by some 20% in 2019 from a general downward trend reducing the proportion of container trucks from a generally stable proportion since 2010 (FMC Consulting, 2019).

Despite these efforts, the Westport study concludes that Inner Harbour capacity will be limited by external rather than inside the gate seaport factors; Chapter 2: Case Study- Fremantle Port.

Economic Development

In the broad economic picture, the efficiency of the Fremantle Ports Inner Harbour directly influences the state of Western Australia's industry competitiveness and living standards (Starr et al., 2000; Westport, 2017). Road congestion impacts the transport of containers in and out of the Inner Harbour, so improved efficiencies afforded by the modal shift to rail act to maintain the operational efficiency of the supply chain. This efficiency assists WA exporters in remaining competitive in overseas markets and supports local industries with inputs not unnecessarily burdened by supply chain charges.

The sources for export and destinations of import containers moving through the Inner Harbour are understood through studies conducted by Fremantle Ports, Chapter 7: Dry Port Site Selection. The planned dry ports in the Perth metropolitan area are sited to support growth in the Perth greater metropolitan region rather than being developed in advance to promote the development in a *"build it and they will come"* approach. The siting of the new Kenwick intermodal terminal is immediately adjacent to the Roe Highway Logistics Park, Chapter 7: Dry Port Site Selection, and serves to promote the development of this area in the context of providing transport capacity into an established industrial zone rather than establishing a new development area away from existing facilities initiating a regional development program.

4.2.2 OUTER HARBOUR

An FPA Outer Harbour development has been considered in several concept studies over the last 20 years (DPI, 2004; FPA, 2000; WAPC, 2004) and is a primary consideration in the workings of the Westport taskforce (DoT, 2017b). The studies seek to solve issues impacting the operation of the Inner Harbour when the study is written and rely on trade forecasts for container movements in establishing a timeframe for an Outer Harbour development. Many of these issues support the development of a dry port, aside from the complex problem of vessel draft requirements at the Inner Harbour location.

Remaining competitive and hinterland competition

The location of the Outer Harbour seeks to reduce the adverse hinterland link issues that have developed over time at the Inner Harbour. This location does not eliminate the need to transport containers to the light industrial areas within the Perth metropolitan area and so means that new or existing dry ports have a role in the supply chain of which the Outer Harbour will form a node.

The Port of Bunbury is a competitor to an Outer Harbour expansion through its inclusion as an option for consideration in planning future freight tasks servicing the Perth metropolitan region (DoT, 2017b), though dismissed in the current Westport study (Westport, 2019a). The Westport study demonstrates the potential of Bunbury port acknowledging the current 33,000 TEU of exports sourced in the Bunbury hinterland (15% of current exports) and the forecast of up to an additional 50,000 TEU in future years, representing 15 years of export growth at 3%.

Storage space

The location of the Outer Harbour near the Latitude 32 and Kwinana industrial zones and the availability of dredged material from the seaport development allow planning for storage space and integration with the surrounding industry. The heavy industrial area will inhibit urban encroachment into the seaport location, reducing the land available for incompatible land use development.

Community, Congestion and Environment

Transport links to the seaport must integrate with the existing metropolitan infrastructure. This integration will require a rail link to be developed and the existing major east-west road, an extension of Anketell Road, to the seaport. Infrastructure can be developed or planned by establishing freight route corridors to a scale appropriate to satisfy forecast transport demands to reduce freight transport congestion.

The industrial setting of the Outer Harbour seaport removes the pressure placed on transport routes immediately surrounding seaports by congestion impacting local communities. The lower community impact of using Anketell rather than Rowley Road corridor as the road and rail connection to the existing Perth freight network influenced the location of the Outer Harbour.

Employing rail transport in an integrated fashion utilising a quayside rail terminal and existing metropolitan dry ports provides the environmental benefits of rail transport.

Economic Development

The Outer Harbour will be in the "Western Coast Trade Region", comprising heavy industrial areas in the Latitude 32, Rockingham and Kwinana zones and the Australian Maritime Complex. As with the dry port for the Inner Harbour, the Outer Harbour and any associated dry port or port-centric development would support economic growth in an area already partially developed (DoT, 2017b) rather than be the seed for the initial development. Edwards (2018a) promotes, from an industry perspective, the economic development the Outer Harbour can offer and considers the requirement to reach the congestion-based capacity at the Inner Harbour before developing the Outer Harbour as being a sub-optimal outcome for the promotion of industry. Edwards argues that by some measures, the Inner Harbour is already at capacity and that the uncertainty of future development timeframes inhibits private investment in the Inner Harbour, reducing the efficiency of the existing supply chain. This conclusion reflects the actor's viewpoint of the situation as the Inner Harbour operates more efficiently than other Australian container seaports.

Outer Harbour Dry Port Development

The Outer Harbour location, land availability and opportunity to link with existing rail and terminal networks do not support a further dry port development close to the site. A quayside rail terminal eliminates the cost associated with drayage to a rail terminal, making the intermodal short-haul rail approach more cost competitive.

4.2.3 SUMMARY OF COMMON REASONS FOR DEVELOPMENT RELATING TO FREMANTLE PORTS

Table 4-3 presents the common reasons for dry port development in the literature and the corresponding status of the Fremantle Ports Inner and Outer Harbour consideration.

Table 4-3 - Summary of development reasons Fremantle Ports.

Source: Author

Reason for development	**Inner Harbour**	**Outer Harbour**
Transport demand	Already present with forecast container trade growth of between 2.8 and 5.8%. These estimates were made before the COVID-19 pandemic.	The growth required to reach capacity at Inner Harbour before Outer Harbour development.
Remaining competitive and hinterland competition	Targeted modal shift allows throughput expansion without growth in truck congestion and builds on Forrestfield/Kewdale value add capability.	Transport links and storage areas must compete with potential developments at the Port of Bunbury.
Storage Space	Restricted land availability and the difficulty/expense of reclaiming further land. Requiring an efficient means of moving containers from container terminals.	Depending on the development approach land can be made available at the seaport location or in the closely adjacent Latitude 32 industrial area.
Community, congestion and environment	A dry port is currently in the supply chain, but transport links place a limit on capacity with road congestion being the limiting factor. Modal shift to rail reduces road congestion. Seaport life and capacity are extended by dry port use.	The movement of road transport to industrialised areas reduces impacts on the surrounding community, but transport links must still be able to access the sources and destinations of containers in the Perth metropolitan area.

Chapter 5: Development Models for Seaports and Dry Ports

5.1 LITERATURE REVIEW

5.1.1 INTRODUCTION

Dry port development models have emerged from seaport models and concepts imported from other research areas.

Understanding the various development models provides insight into the suitability of a dry port for a given seaport and the likely development approach and justification. This understanding demonstrates the need to use spatial development of seaports in conjunction with knowledge of how the functional role of a seaport must change in providing insight into the role and suitability of a dry port in the supply chain.

Overarching these factors is the approach of the seaport management to the changes occurring in world trade transport systems. Unless the controlling body reacts to ensure that the seaport infrastructure and services align with the needs of the actors in the supply chain, the seaport will decline in importance, reflected in reduced cargo volumes. Mangan et al. (2008 p.38) support the changing role of seaports, noting the need to *"embrace the activities and strategies relevant to their context and customers"*. Pettit and Beresford (2009 p. 255) observe that *"an overall improvement in port performance therefore requires ports to see their operations both as individual logistics systems in their own right and part of the overall supply chain"*.

The development models for seaports and dry ports reflect the various reasons for dry port development. The dry port's development location and the associated political and legislative structure, culture, history and economic situation determine the most appropriate model.

The models included in this chapter were sourced following the search methodology described in Section 1.4 Methodology and were selected as they are widely cited providing support for their application and validity. Models that were applied to the Australian seaports in the literature were of particular interest. The models are consistent with and explain the development of the Fremantle Inner Harbour and future expansion in the Outer Harbour. The readiness of a seaport to be involved with a dry port operation or development is an important consideration in the dry port development framework.

5.1.2 SEAPORT MANAGEMENT MODELS

UNCTAD (1994, 1999) discuss the changing role of seaports by describing four port *"generations",* reflecting the move of seaports from the traditional function of loading and unloading cargo from vessels in isolation from other transport activity to being a node in globally integrated supply chains. UNCTAD cites this as requiring a change in the *"attitude and policy regarding port management"* (UNCTAD, 1994 p.2) as the fundamental response to a changing exogenous world transport system. Building on this, customer-centric fifth generation seaports are discussed in the literature (Flynn, Lee, & Notteboom, 2011; Lee & Lam, 2016; Lee, Lam, Lin, Hu & Chong, 2018). Finally, a sixth (future) generation seaport is postulated by Kaliszewski (2018).

First generation seaports focus solely on the interface between land and sea. This narrow focus isolated the seaport from the rest of the transport activity, and the surrounding community and treats port users and functions independently of each other. This representation is typical of a pre-1960s organisation from which seaports have advanced at differing rates.

Second generation seaports emerge through the recognition of the seaport having a role in a broader area of the supply chain, expanding to contribute to transport, industrial and commercial services. This requires governments and port authorities to embrace a broader view of the port functions. This phase results in developments close to the seaport and closer community and customer relationships as the seaport reaches into its hinterland.

Third generation seaports, developed in the 1980s from increased globalisation promoted by the introduction of container transport and associated intermodal activities and volatility of container cargo movements. Seaports could no longer rely on captive hinterlands to prosper but had to promote trade through the seaport as they became a node in a global supply chain. This involved offering value-adding services such as packaging, distribution and warehousing facilities. As discussed in Chapter 3: Attributes, Definition and Classification and Classification of a Dry Port, some seaports, particularly in the UK, moved away from these activities in subsequent generations. There is now a revival of the activity under port-centric logistics.

Fourth generation seaports, developed in the 2000s, are associated with container terminals and see increased private sector involvement in infrastructure development, with port authority management focusing on policy, planning and port promotion. Paixao and Marlow (2003) state the necessity of seaports to add value, not cost, to the supply chain as in the European seaport-based WORKPORT model. Naniopoulos (2000) considers industrial business management techniques to apply to fourth generation seaport management. This generation aligns with the Monios and Wilmsmeier (2012a) observation that seaports can only maintain efficient hinterland links if they do not distinguish between core and supporting activities.

Fifth generation seaports are customer-centric community ports. The focus of this generation is to attract and keep clients and serve community stakeholders in a structured way, reflecting a much more complex operating environment for seaports (Flynn, Lee & Notteboom, 2011; Lee & Lam, 2016; Lee, Lam, Lin, Hu & Chong, 2018). The evolution of technology has enabled this service to be provided in a *"globalized e-port"* or smart port (Henríquez, R., Martínez de Osés, F. & Martínez Marín, J, 2022 p.3). A fifth generation seaport must have the following attributes, *service*, featuring service quality, *technology*, with efficient IT and communications systems, *sustainable development*, including green credentials and *high port-city co-ordination*, clustering in areas of maritime cluster management and seaport cluster management and be a *hub* with global linkages and high quality inland connections (Lee, Lam, Lin, Hu & Chong, 2018).

Sixth generation seaports are postulated based on the ability to accommodate 50,000 TEU containerships, no sixth generation seaports currently exist. Building on the IT capability of fifth generation seaports a sixth generation seaport would have fully automated terminal operations and hinterland connections to handle a 50,000 TEU vessel of up to 20m draft (Kaliszewski, 2018).The characteristics of the existing five seaport generations are depicted in Figure 5-1.

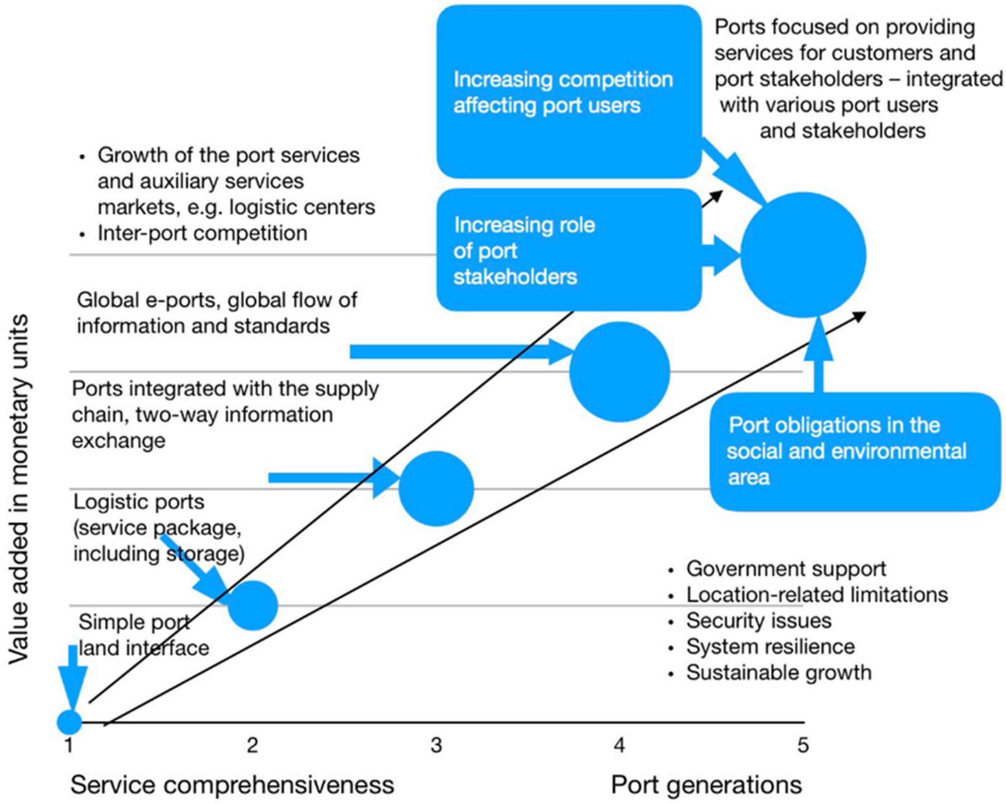


Figure 5-1 - Characteristics of the existing five seaport generations.

Source: Kaliszewski (2018, p.17).

The WORKPORT project developed a schematic model describing the evolution of the European seaport industry starting in the 1960s to promote the growth and efficiency of seaports. This was done by considering the impacts of new technology and consideration of new organisational and management concepts to meet the changing demands on seaports. The WORKPORT model describes changes in the areas of:

- Ownership, increasing private sector involvement, particularly in superstructure and cargo operations.
- Cargo form, substitution of unitised for break bulk cargo, introduction of containers.
- Cargo handling processes, increasing automation and mechanisation in quay and stacking operations.
- Cargo support processes and information provision, proliferation of methods through increasing use of IT and increasing complexity of communications network.

- Working culture, decreasing workforce numbers as cargo operations become more capital intensive.
- Port function/port development processes, increasing diversity of port related activities.
- Health and safety aspects of the working environment, introduction of formal health and safety policies and decreasing accident and absenteeism rates.
- Environment increasing environmental awareness and introduction of environmental management systems.

(adapted from Naniopoulos, 2000 p.74).

The introduction of a *"port ladder"* concept (Flynn et al., 2011 p.500) overcomes the deficiency of discrete level changes postulated by the UNCTAD generations. The concept allows seaports to respond to the specific conditions in which they operate, matching the "generation" along a spectrum. This response may differ for different aspects of the seaport operation, terminals in the seaport, and external demands (commercial, social and legislative) placed upon the seaport. Beresford, Gardner, Pettit, Naniopoulos, and Wooldridge (2004) support this concept based on the WORKPORT project and conclude that the UNCTAD generational approach is fundamentally flawed by not recognising a continuous evolution of seaports rather than discrete steps. Tempering the criticism is the recognition of changing technology and supply chains in the intervening years, whereby the WORKPORT study had a broader set of criteria in the model.

Pettit and Beresford (2009) broadened the WORKPORT model concept by considering the changing seaport role in supply chains,

Figure 5-2.

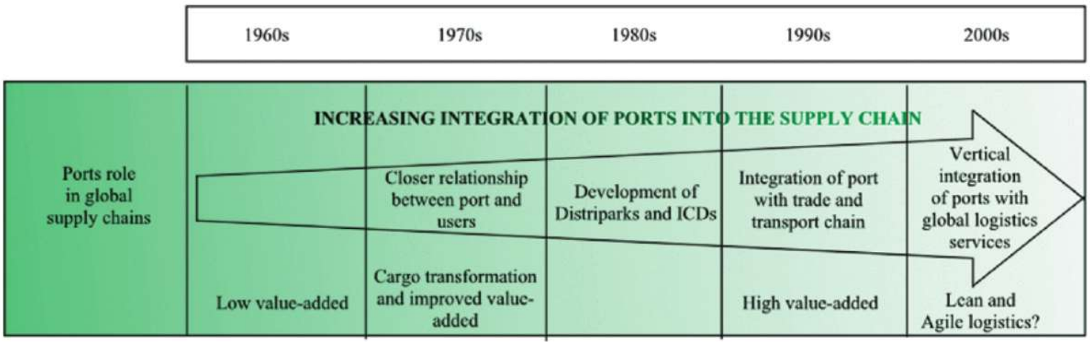


Figure 5-2 - The integration of seaports into supply chains.

Source:Pettit & Beresford (2009, p.256).

Additionally, Cullinane and Wilmsmeier (2011b) identify that physical seaport developments do occur in step changes as significant infrastructure spending is by its very nature a discrete, not continuous process. Both models accommodate these steps with separate consideration of the different aspects and terminals within a seaport, allowing them to be at different stages of development simultaneously. Bichou and Gray (2005) express the deficiency relating to a single generation, arguing the model's focus on the sea to shore interface lacks insight into the shore to landside expansion providing little guidance on dry port development.

The UNCTAD and WORKPORT models focus on changes within the seaport from a managerial perspective in response to changing technology and supply chain. It reflects the "mindset" of the seaport to respond, rather than a model that relates the spatial and functional changes around seaports that require them to change.

5.1.3 SPATIAL AND FUNCTIONAL MODELS

The Anyport model based on British seaport development postulated by Bird (1980) is a fundamental port model (Monios & Wilmsmeier, 2012a; Notteboom & Rodrigue, 2005), Figure 5-3. It provides a development model that can be adapted to reflect the different geographic (spatial) settings in which seaport concentration occurs. It is focused on the changes within the seaport itself as it adapts to changing cargo handling and vessel advances (Hilling, 1977) by moving away from the original townsite seaport location to provide specialised deep-water berths and cargo handling infrastructure such as container handling. This movement is not necessarily a steady advancement of the seaport as different areas may be at different stages of development due to capital considerations (Monios & Wilmsmeier, 2012a). Notteboom and Rodrigue (2005) build upon the Anyport model and propose a fourth stage of seaport development, *"regionalisation",* depicted below, Figure 5-3. Notteboom and Rodrigue (2004) characterise this stage of development as one in which the distribution of cargo inland becomes the most significant factor for a seaport to remain competitive. During this phase, transport corridors and logistics poles are promoted along with a transport mode shift away from road transport. This modal change addresses the issues of local traffic congestion around and limited land availability faced in growing seaports.

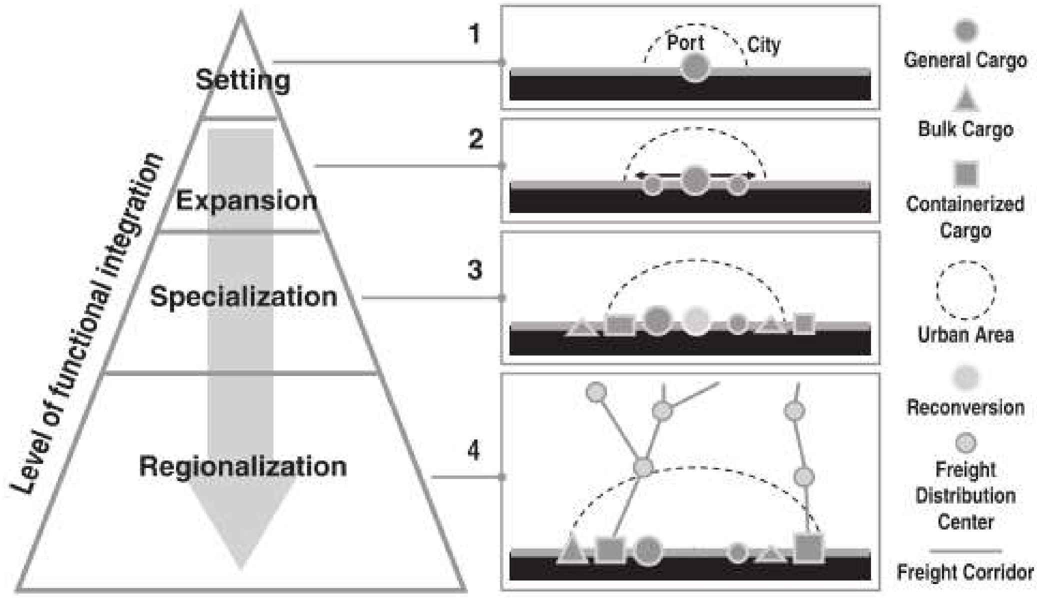


Figure 5-3 - Evolution of a seaport according to Bird.

Source: Notteboom & Rodrigue (2005, p.298).

An earlier model postulated by Taaffe, Morrill, and Gould (1963), is based on the expanding transport networks in developing economies (Ghana and Nigeria), with a greater focus on landside links than Bird. The development phases are depicted in Figure 5-4 and are described below.

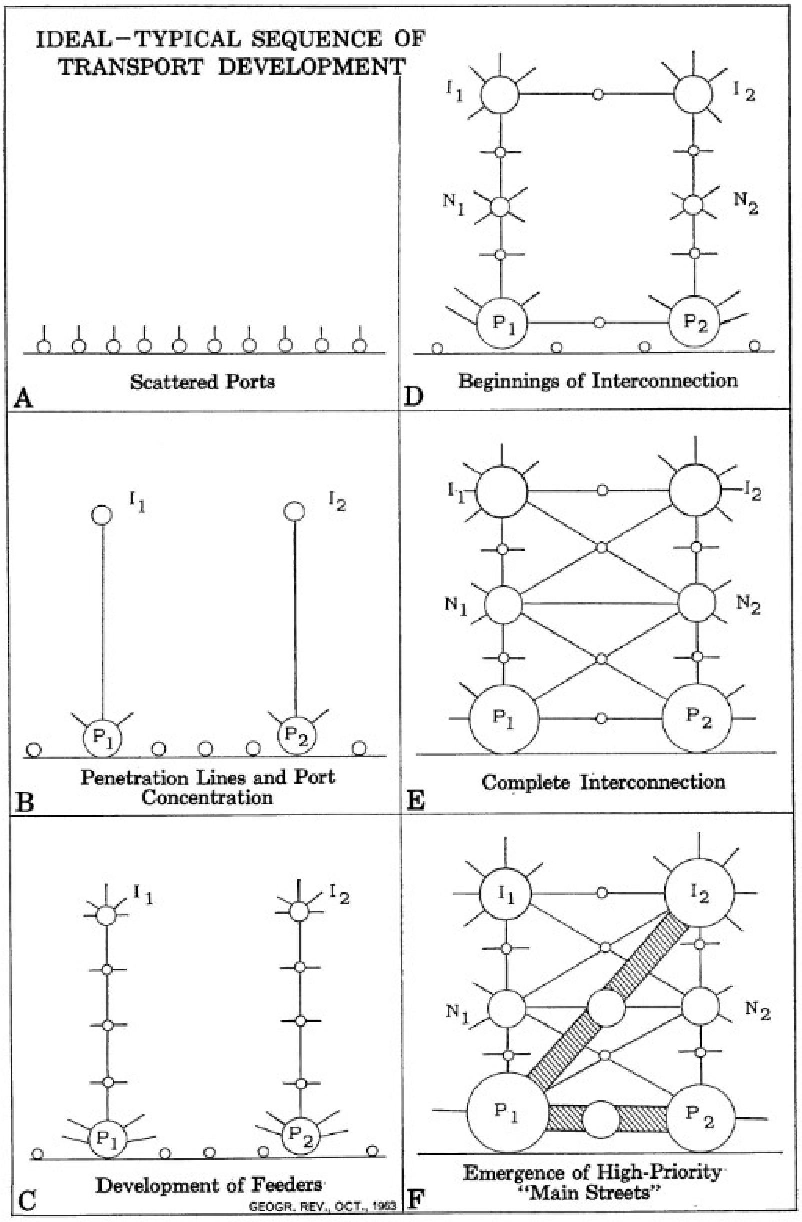


Figure 5-4 - Evolution of idealised transport network according to Taaffe.

Source: Taaffe et al. (1963, p.500).

The first phase (A) of the transport network, scattered ports, is small, long established unconnected ports distributed along a coastline where restricted and poorly connected hinterlands exist.

The second phase (B) of port concentration begins as *"lines of penetration"* into the hinterland develop. This advancement results in the development of feeder routes allowing some seaports to grow their hinterland at the expense of others as they attract more cargo and reduce costs. The inland penetration development's drivers are the connection of administrative areas, mineral fields and agricultural areas to the coast.

The third phase (C) arises as the feeder routes grow and develop internal transport nodes, attracting cargo and creating greater seaport concentration as the larger seaports *"pirate"* cargo from smaller seaports.

The fourth phase (D) occurs where larger feeder networks form and link up through lateral interconnection.

The fifth phase (E) is the increasing interconnection until all seaports and inland nodes are linked.

The sixth phase (F) is a higher-level concentration with priority linkages, such as national highways and trunk train lines forming "*main streets*".

Rimmer (1967) builds upon the models of Bird and Taaffe, Morrill and Gould using the seaport development in Australia between 1861 and 1962 with the addition of a phase of decentralisation and accounting for changes to the maritime organisation as a factor in seaport development. The model is depicted in Figure 5-5. Rimmer importantly recognises that the developments are not necessarily distinct phases, and seaports can have aspects of all present, with the step approach being for clarity of understanding.

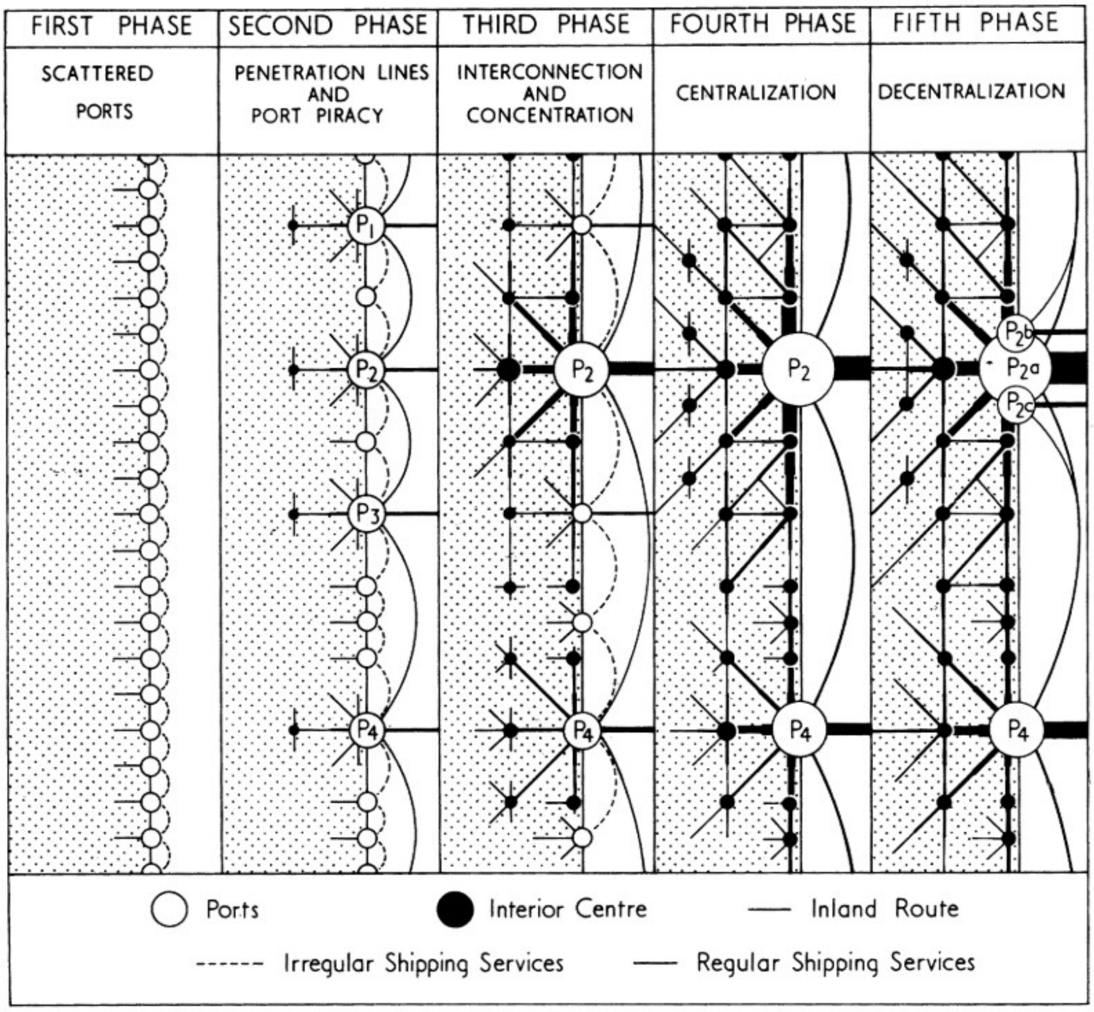


Figure 5-5 - Idealised seaport development stages.

Source: Rimmer (1967, p.43).

As with the earlier models, seaports progressed from being scattered along the coastline with little hinterland penetration and trade between them to a second stage of "*penetration lines and port piracy",* during which seaports with the most favourable conditions, initially Melbourne and Sydney, develop hinterland connections and expand, robbing trade from other seaports. As these seaports become more closely linked by landside connections, further concentration occurs, and a hierarchy of major and minor seaports emerges. The smaller seaports survive due to poorer connectivity of the major seaports to the more extensive landside network or the offer of specialised services. Newcastle represents one such seaport serving the local industry. The centralisation phase occurs as the dominant seaports continue to grow at the expense of others. This growth occurs until the dominant seaport reaches "capacity" and decentralisation occurs. In the Australian context, this resulted in the development of

Port Botany when Sydney could not handle the high tonnage low-value bulk cargoes and Geelong when Melbourne diverted oil and fertilizer shipments.

The model was developed on the eve of containers becoming an established part of Australian trade, and Rimmer correctly recognises they may alter future seaport development and postulates the possible emergence of *"super ports"* capturing vast amounts of trade. This change occurred when European shipping conferences, for a short period, relegated Port Adelaide to part of the Port Melbourne hinterland by dropping direct calls and transporting containers by land from Melbourne to Adelaide until economic arguments demonstrated that a direct service to Adelaide was warranted (Bird, 1986).

Hayuth (1981) postulated a five phase model of seaport development resulting from the introduction of containers into the shipping industry and the impact this had on seaports and the associated trade routes, hinterlands and forelands. The model is based on a study of US seaports and leads to the development of the load centre seaports (dominant seaports where cargo concentrates and handling efficiency is realised (Mayer, 1978)). As with the Anyport model, the phases represent the changes made by seaports in response to the changes occurring around them. This response reflects the generation or position on the port ladder management models the seaport occupies.

Phase 1(I)- Preconditions for change. Seaports are of a size and spatial distribution that resulted from pre-container trade with reasonably well-defined but not static hinterlands. The seaports have external pressure on them to meet the existing demands of break bulk cargo handling and adapting to technological changes, particularly the introduction of containers, and so are ready to change.

Phase 2 (II) - Initial container port development. Undertaken by a few seaports initially due to the commercial risks involved. The development of container seaports favoured large seaports for several reasons, such as exposure to outside ideas, pressure on cargo handling capacity, economies of scale and access to capital. Some small seaports also develop container capacity due to favourable harbour or location factors not necessarily attributed to size.

Phase 3 (III) - Diffusion, consolidation and port concentration. As container transport evolves from an experimental stage, more seaports are exposed to and adopt the technology and management approach to handle the trade. Early adopters tend to concentrate trade and form dominant seaports; smaller seaports become feeders to these. This concentration expands the boundaries of the dominant seaport hinterlands and brings distant seaports into competition with each other.

Phase 4 (IV) - The Load Center. The changes that adoption of containers as a primary transport technique places on all participants in the transport chain concentrates trade in larger seaports, *"load centers"*, by concentrating container traffic on selected routes. This concentration causes smaller seaports to compete for the remainder of the trade, including feeder traffic to the larger load centres.

This change in seaport structure leads to a change in hinterland connections in which "trunk lines" are established from the load centres to major trade sources providing for deeper hinterland penetration and the emergence of inland distribution centres at significant transport intersections.

Phase 5 (V) - The Challenge of the periphery. As load centres face expansion constraints, diseconomies of scale emerge, replacing the economies of scale present up to this point. The diseconomy may arise due to lack of room to expand, congestion in transport routes and operation of large container operating areas. This circumstance allows smaller seaports to bid for traffic in what may be an overcapacity situation following the dispersion of container technology throughout the seaport system. This situation further changes hinterland connections, and the traditional hinterland boundaries become fluid.

These phases are depicted in Figure 5-6.

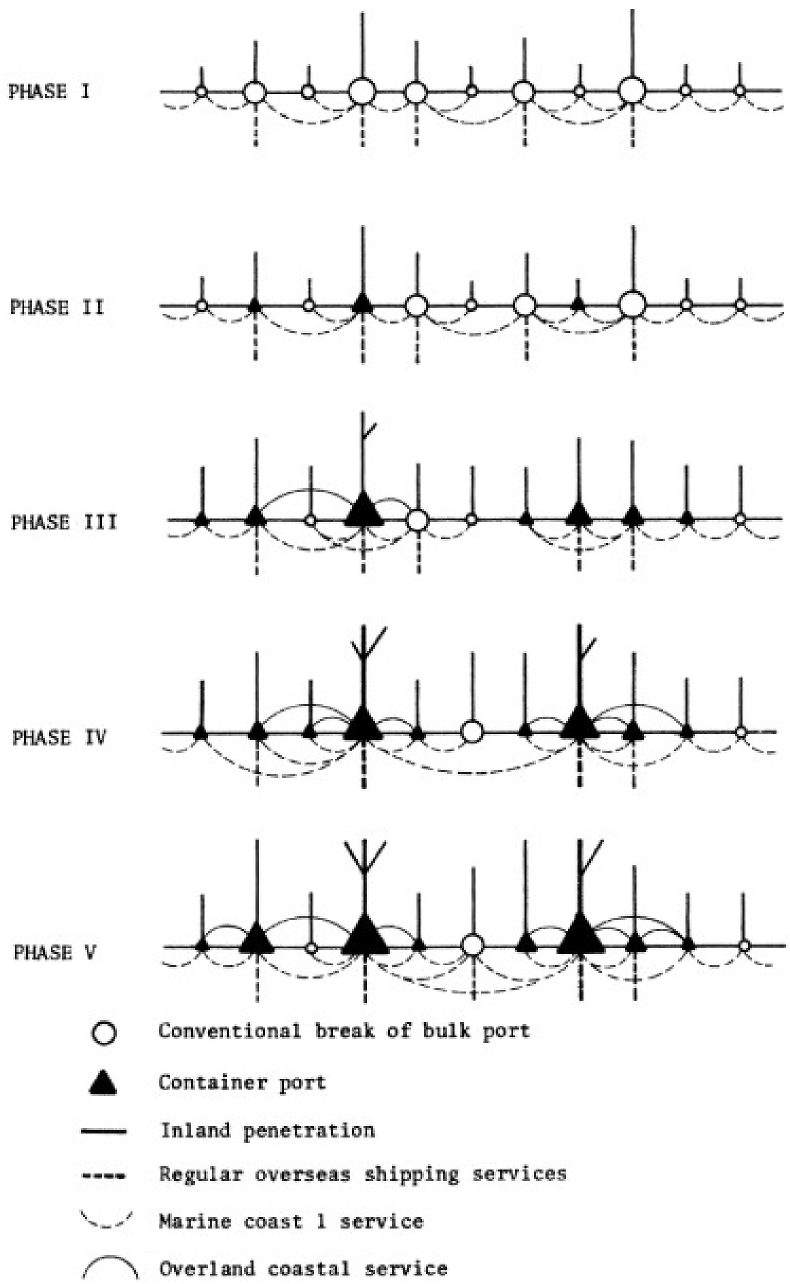


Figure 5-6 - Phases of US container port development.

Source: Hayuth (1981, p.162).

Wiradanti, Pettit, Potter, and Abouarghoub (2018), argue that concentration and deconcentration occur in a cycle. Factors such as those described in Phases 3 and 4 above led to concentration and the rise of new production/consumption regions, congestion, diseconomies of scale (discussed below) and government policy allowing peripheral ports to increase their centrality resulting in a redistribution of shipping patterns or a greater overall shipping task through trade growth. The factors favouring concentration and deconcentration are presented in Figure 5-7.

1970 to 1990	1990 to 2008	Post 2008
Concentration Factors		
Development of load centres, intermodal facilities and conolidation		
Port city dominanace	Port city and existing hub dominanace	Hub port cities, large hub reputation and market power
Stable port hierarchy	Economies of scale and stable traffic concentration	Stable hierarchy of positions
Regional integration and hinterland pentration		Regional and cross border integration, commercial diversification, foreland expansion and hinterland overlap
	Technological inovation	
	Concentration of investment and export led policy	Government support, regulation and politcal stability
		Increasing container transshipment and varying levels of productivity/efficiency
Deconcentration factors		
Hinterland/foreland changes and traffic specialisation		Hinterland/foreland changes, emerging regions, direct connections and traffic specialisation
Congestion, space constraints and diseconomies of scale	Congestion, and diseconomies of scale	
	New port development, modal shift, transnational operators strategies	Increasing container transshipment, secondary port growth, transnational operator strategies and
	Port selection and shipping line concentration	Port selection, flexibility and accessibility
	Port competition and urban growth	Port competition and changing port hierarchy
	Government (national and regional) development plans	Government plans and policy, port devolution

Figure 5-7 - Concentration and deconcentration factors.

Source: Adapted from Wiradanti et al. (2018, p.381).

Hayuth (1988), through a statistical study of seaports in the USA between 1970 and 1985, demonstrated that, based on the number of containers handled, seaports became decentralised rather than centralised during the period. In considering what caused this unexpected situation, contrary to the expected concentration of cargoes in fewer, larger, more efficient ports (load centres) (Hayuth, 1981; Mayer, 1978). Hayuth observes that containerisation is relatively new, only introduced during the 1950s and 1960s. With the newly formed supply chains, large ports founded on traditional general cargo handling lost container trade to other peripheral seaports. Reasons postulated for this reflect current thinking on the role efficient hinterland transport links, particularly rail transport in the case of the USA, legislative environment, government and social priorities and physical ability for a seaport to expand played a role as a new supply chain system came into being. The influence of liner services and overall supply chain costs forced seaports to consider influences outside the seaport boundary. This influence asserted that the concept of the load centre occurred at the carrier level, not the seaport level, reducing a seaport's ability to capture the market based on the seaport location alone. Whilst Hayuth observed the decentralisation and postulated reasons for it, the study could not predict if the trend would continue in a way that was contrary to the current state of thinking.

A similar USA study spanning the period 1970 to 1988 applying statistics to overall seaport general cargo throughput, of which containerised cargo is a subset, by Kuby and Reid (1992) concluded that seaports had centralised at this more expansive level. Depending on the assumptions used in the statistical analysis, the results of both studies at a container trade level are consistent. Kuby and Reid (1992) attribute the seaport concentration to three cross-reinforcing factors. Firstly, the containerisation of cargo. The high capital investment required needs the economies of scale and utilisation achieved in large container ports to provide a cost advantage over smaller ports. More significant seaports have larger landside operating areas for container handling services compared to smaller ports. Secondly, the increasing use of IT promotes global supply chains providing the ability to track goods from door to door and facilitating the regulatory and intermodal stages involved. Thirdly the increasing size of container ships (and inland transport systems, double stack rail in the USA). Large vessels provide maritime capital and operating cost savings per TEU. The increased vessel size limits seaports visited due to draft and crane size limitations within the seaport itself. Shipping lines minimise seaport stops to maintain high vessel utilisation resulting in vessels visiting limited “hub” seaports. Improved landside transport economics means the historical approach of maximising the sea leg of transport (to reduce landside costs) to save money is no longer valid, so fewer seaports can serve larger hinterlands.

Slack (1990), in a study of changes occurring in North American intermodal rail terminals resulting from the transport of containers inland, identified the emergence of load centres due to the capital investment required at intermodal terminals to handle the containers. The model proposed is like the Taaffe transport network in which the first phase sees railways with general intermodal cargo terminals spread across the entire rail network. The intermodal activity is considered part of the general freight task. Phase 2 occurs when the specialised equipment required for container handling results in a specialised service, causing some “rationalisation” of the rail network and intermodal terminals (concentration). Phase 3 is the development of load centres in an intermodal network emerging from the old rail system. The freight task splits into rail and road tasks for first and last mile activity. Slack proposes an additional stage to the

Taaffe model, which maintains that terminals off the *main streets* are all kept in the rail system; these are redundant and close. These closures are evidenced in the Kuby and Reid (1992) study in which some liner ports become redundant nodes and closed.

In the regionalisation concept, Notteboom and Rodrigue (2005) expand the Bird Anyport, Taaffe and Hayuth models to account for links between a seaport and its hinterland. The additional concepts of offshore hubs and regionalisation are introduced, depicted in Figure 5-8.

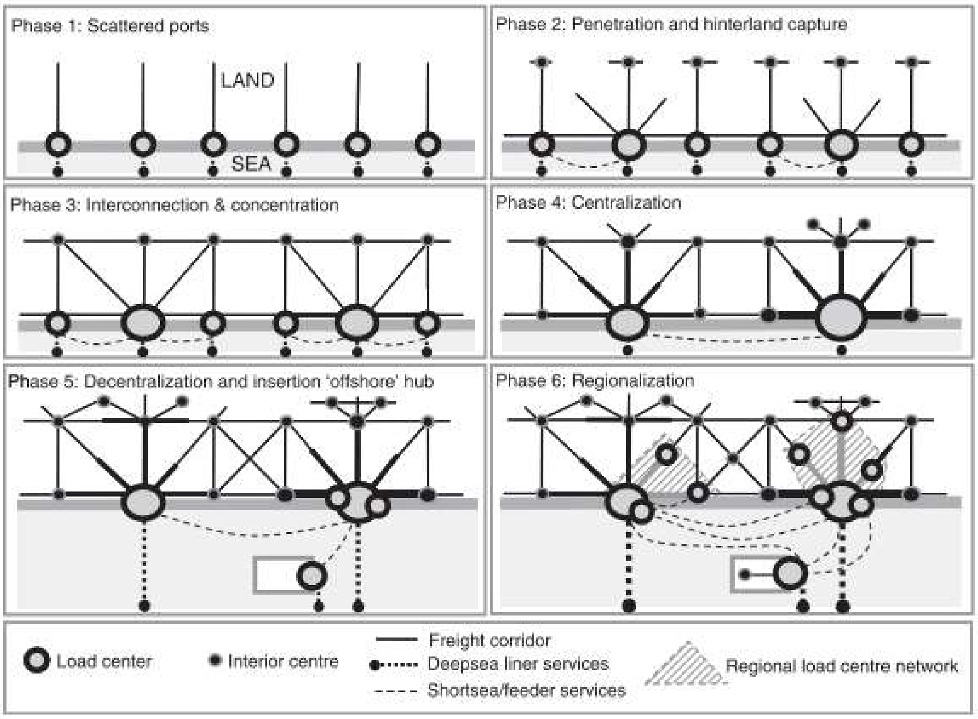


Figure 5-8 - Evolution of idealised transport network according to Taaffe to include regionalisation.

Source: Notteboom & Rodrigue (2005, p.300)

The regionalisation approach explains the relationship with offshore hub terminals present in the hub and spoke networks. Offshore hubs are not directly relevant to the inland links and associated dry port concepts and are not discussed further.

Regionalisation recognises the role of inland terminals acting as active transport nodes in seaport load centre development and seaports expanding their focus to a broader spatial perspective. The seaport hinterland expands through the development of closer relationships with, or joint development of, inland terminals in this hinterland. This relationship forms the “regional load centre network” depicted as Phase 6 in Figure 5-8 above. Regionalisation occurs as seaports necessarily adapt to the requirements of global supply chains and overcome local transport space and congestion constraints by shifting them landward. Notteboom and Rodrigue (2004) describe the regionalisation phase as reducing inland distribution costs and improving logistics integration and supply chain efficiency.

Notteboom and Rodrigue (2005) support the concept through the following observations. Integration of logistics has resulted in single entities controlling many previously separated logistics functions. This rationalisation through mergers and acquisitions gives rise to large logistics operators spanning maritime and landside operations and the concentration of land-based operators. IT advances facilitate effective track and control processes operational integration. Liner companies have recognised the increasing component of land-based and intermodal costs as they have reduced maritime operating costs and the competitive advantage efficient landside container logistics can provide. This integration has seen external market forces impose changes on seaports and their view on their role in the supply chain, representing a shift in the seaport's functional role. The changing role compels seaport operators to look outside the traditional seaport boundary to remain competitive. Notteboom and Rodrigue (2004) depict the changing functional roles in the supply chain in Figure 5-9, with economies of scale achieved through larger hub seaports able to accommodate larger vessels and functional integration of landside distribution.

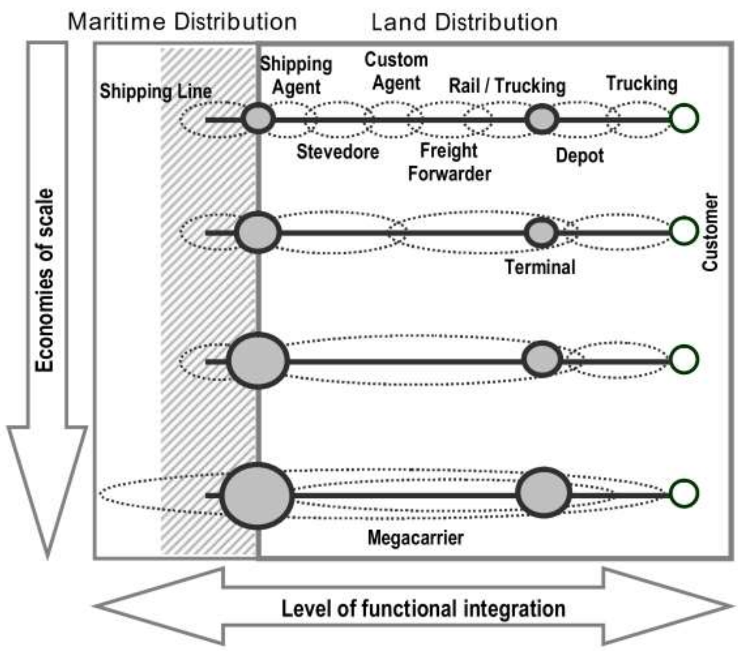


Figure 5-9 - Changing functional roles in the supply chain.

Source: Notteboom & Rodrigue (2004, p.6).

In a discussion of the role of foreland regionalisation (the functional regionalisation of overseas trade sources), Rodrigue and Notteboom (2010b) attribute the development of dry ports to the growing disparity in costs between the foreland and hinterland transport legs and the ability of dry ports to reduce these hinterland costs as larger vessels enter container supply chains. The economies of scale available to carriers for ocean transport are not available to hinterlands above a trigger level as the larger loads must be consolidated/unconsolidated in the hinterland, causing congestion above the trigger level and resultant increase in costs. In a study of Spanish Ports, Cabelle Valls et al. (2020) note the positive correlation between seaport size and selection for use. Introducing dry ports and resultant hinterland regionalisation relieves hinterland congestion and allows cost reductions, Figure 5-10.

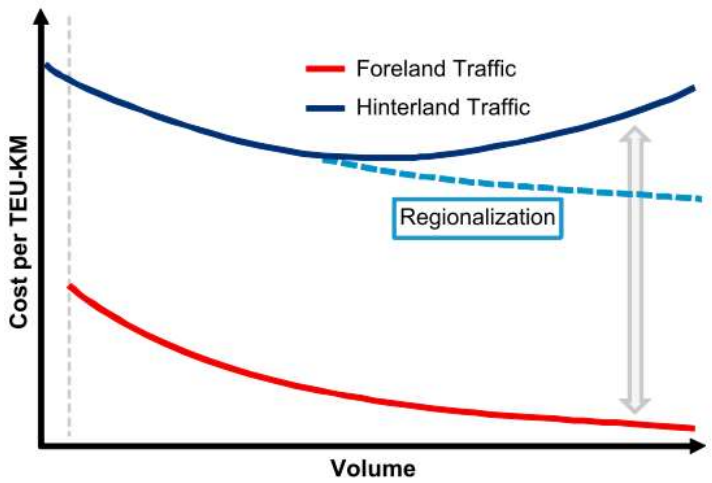


Figure 5-10 - Regionalisation allows further economies of scale in hinterlands.

Source: Rodrigue & Notteboom (2010b, p.26).

The concept of *"transport corridors"* developing discontinuous gateway seaport hinterlands along these networks supported by intermodalism (van Klink & van den Berg, 1998) is adopted in the regionalisation concept of a "direct" hinterland surrounding the seaport with disconnected "distant" hinterlands (in what would traditionally have related to another seaport). Regionalisation is supported through efficient land-based (intermodal) transport enabling the seaport to offer a cost or service advantage over other seaports. The concept is depicted in Figure 5-11. The hinterland of a seaport, whilst conceptually easy to define, is, at a practical level, complex as it will vary between commodity types (Acciaro, Bardi, Cusano, Ferrari, & Tei, 2017). The changing control of the transport routes employed in supply chains, through globalisation and footloose shipping lines, means hinterlands are subject to rapid change, making the traditional port terminology of having captive or dominant hinterlands obsolete (Bichou & Gray, 2005).

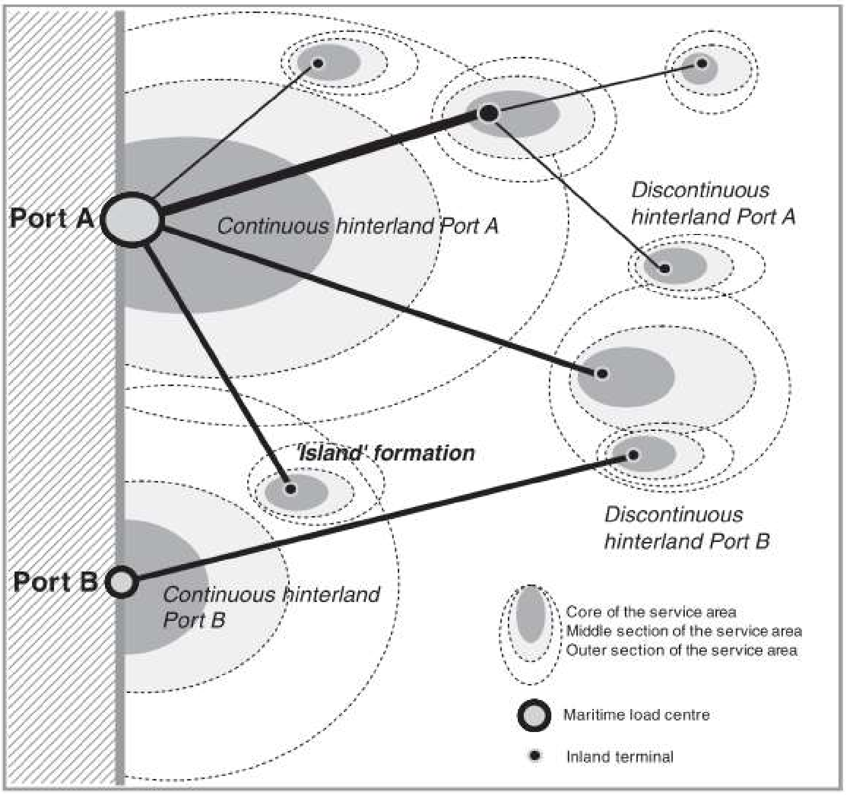


Figure 5-11 - Corridor based island hinterlands.

Source: Notteboom & Rodrigue (2005, p.303).

The emergence of dry ports along transport corridors results from increasing pressure to improve seaport and land transport efficiency as collection and distribution networks form, enabling an increased system throughput. This change to historical hinterland distribution, based on road transport which is sufficient for early seaport connection to the hinterland (Notteboom & Rodrigue, 2009), results in pressure for a modal change from road to rail (and barge), reducing congestion at the seaport, (Notteboom & Rodrigue, 2004).

In considering the regionalisation phase of seaport development, Notteboom and Rodrigue (2004) offer reasons why the previously discussed centralisation and decentralisation of seaports occurs. Smaller seaports connect to the networks created by the newly developed dry ports and so access extensive hinterlands supporting the decentralisation of seaport container movement. Conversely, the economies of scale enabled through the dry ports' presence promotes the dominance of load centre seaports and the associated centralisation. In a study of British seaports, Hoare (1986) supports the break between seaports and a closely tied hinterland for sources of export goods, demonstrating that the introduction of containers has centralised exports with large container seaports drawing trade from more distant inland regions at the expense of *"local"* seaports. This move is supported by a concentration of shipping line ownership, seeking economies of scale in operations, and improved landside transport links. The study does not link the centralisation with inland port development and regionalisation concepts of later years but recognises landside transport efficiencies as enabling traditional hinterland links to be broken. Garnwa et al. (2009) support the British experience. They note the effect of introducing containerised shipping makes the seaports in the south-east of the UK more attractive to shipping lines due to the proximity to Europe and the Australia trade circuit. This attractiveness promoted the shipper's *"one United Kingdom port of call"* strategy centred on Tilbury to minimise vessel time in port, causing the break of the geographic proximity of cargo sources to a nearby port. Garnwa et al. (2009) attribute the development of dry ports to the separation of cargo sources from a nearby seaport, and the intermodal possibilities opened by container use. This separation enables cargo from northern Britain to use inland transport and dry ports to load and discharge containers. The inland container depots become *"ports without water"* once customs allowed customs clearance at these sites to reduce the cost of additional container handling at seaports to do these checks.

The dry ports can fulfil various value-adding functions to the supply chain and may develop into *"regional load centre networks"* and *"logistics zones"* required to support the regionalisation phase of the seaport development model. The development of transport corridors promotes the polarization of logistics activities at the seaport and dry port and along the axis between them, creating *"logistics poles"* (the equivalent concept in logistics to that of a regional load centre in cargo flow). This polarization attracts further logistics activity to the area, which through economies of scale and associated synergies, attracts other organisations. Other external factors in operating site selection such as land, labour availability and cost and the prevailing legislative regime influence this growth. The seaport acts as a central node to the logistics poles in this phase. However, the seaports also rely on the dry ports to remain competitive. The process is depicted in Figure 5-12.

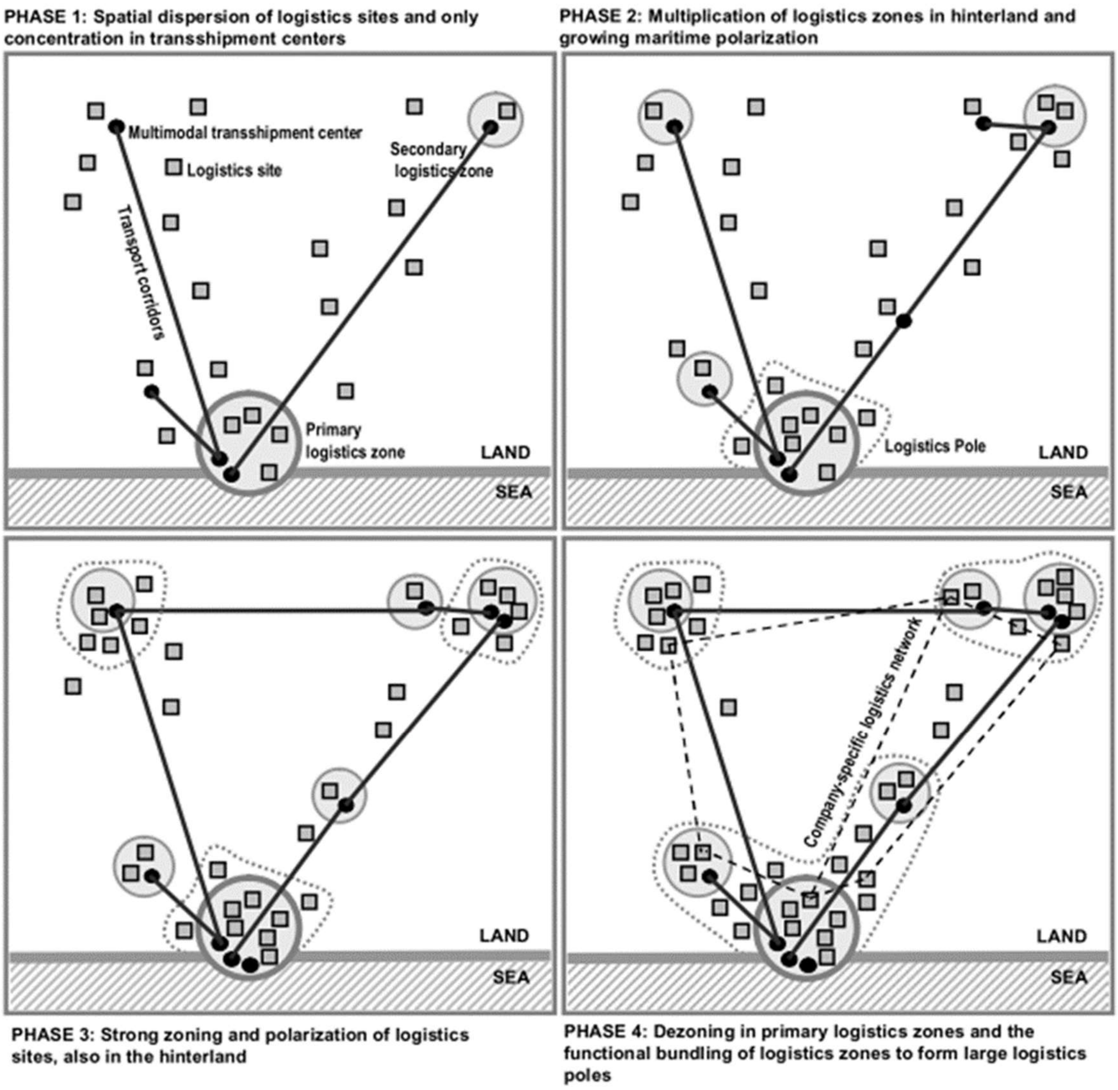


Figure 5-12 - Spatial development of logistics nodes.

Source: Notteboom & Rodrigue (2004, p.12).

5.1.4 SEAPORT LIFE CYCLE MODEL

Cullinane and Wilmsmeier (2011a) and Wilmsmeier, Bergqvist, and Cullinane (2011) examine the development of a seaport under a "*marketing model port life cycle*" depicted in Figure 5-13. A dry port has a role in extending seaport life in this model. Cullinane and Wilmsmeier (2011a) consider the derived transport demand to be the reason seaports grow, and the physical constraints encountered by a seaport in satisfying this demand drive the development of dry ports in the right circumstances. These physical constraints are reached at the mature phase of the development of a seaport and, if not addressed, result in the seaport's decline in the supply chain reflected by a reduction in trade volume.

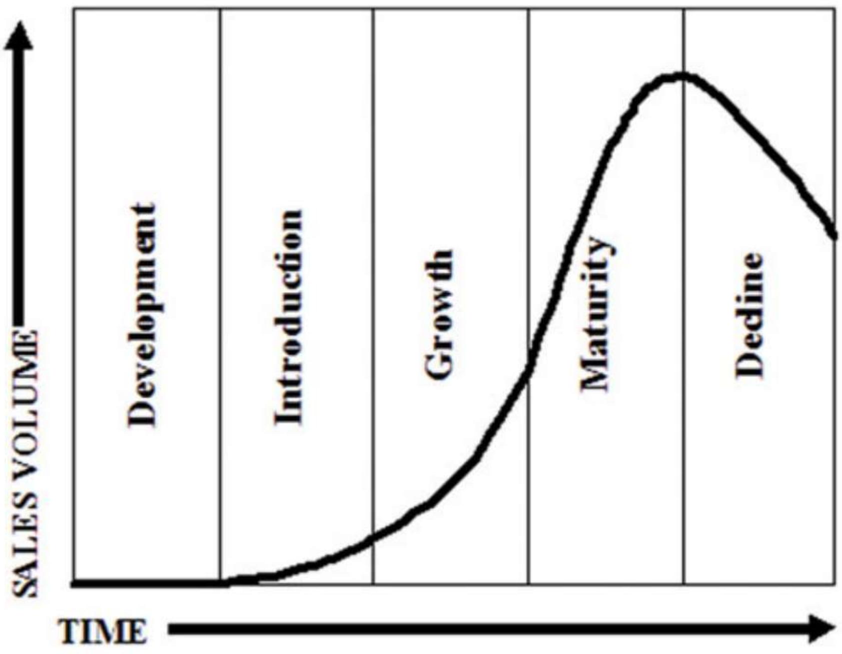


Figure 5-13 - Product lifecycle.

Source: Cullinane and Wilmsmeier (2011a, p.365).

A seaport responds to growth requirements in two ways, with and without a structural change. Structural change relates to the seaport consuming increasing amounts of land to achieve increased capacity and non-structural change is implementing a technological change or accessing more land by reclamation or similar. When seaport growth is no longer achievable by either of these means, that is the cost of accessing further land is prohibitively high and technological improvement is not possible, then the seaport has reached the limit of its growth in that location.

The lifecycle stages are as follows:

Development and introduction - During this stage, the seaport commences operations with a limited hinterland and non-standardised basic services (for the study of contemporary European, American and Australian seaports, this phase has long passed and is not of such strategic interest as the mature and decline phases (Monios & Bergqvist, 2016)).

Growth - During this stage, economies of scale are realised through the introduction of infrastructure and process innovation and standardisation, creating additional growth as the process feeds on itself, driven by increasing transport demand in the area. Infrastructure and storage require an increasing land area. Hinterland reach broadens through infrastructure development.

Maturity. - During this stage, seaport growth slows, whilst the transport demand continues because of completing standardisation and infrastructure improvements within the physical constraints of the seaport. This situation allows competition from other seaports for the enlarged hinterland served by the mature seaport.

Decline - During this stage, seaport activity constraints arise as a lack of further land or process innovation is available to remain competitive in the hinterland. Other seaports encroach, market share drops, and eventually, actual seaport throughput declines may follow.

As with other seaport development models, a seaport may be at different lifecycle phases in terms of its spatial form with different areas of activity (Monios & Bergqvist, 2016).

The lifecycle stages are not of fixed duration, and internal or external factors can alter the time a seaport occupies a stage or even reset the seaport's position in the lifecycle. Eventually, as seaport growth continues, a lack of physical space at the seaport and congestion moving goods in and out of the seaport impact ongoing growth. If not addressed, this results in a diversion of cargo to other seaports. To achieve ongoing growth, "*Standortspaltung*" or location splitting must occur (Schätzl, 1996), provided sufficient and efficient transport links exist between the locations. If it is possible to secure appropriate land and transport links, a dry port can be a suitable solution to this Standortspaltung. In practice, this is ultimately an economic decision, so a dry port may be attractive economically even before reaching the seaport capacity constraint. Cullinane and Wilmsmeier (2011a) support this need and the view that the promotion of intermodal transport is critical to maintaining the growth or maturity stages of a port life cycle. The ability of seaports to "restructure" through such activities as channel deepening, berth modifications and employing new technology such as larger cranes and container handling equipment and location splitting is considered a significant addition to the marketing product life cycle (Wilmsmeier & Monios, 2020). Standortspaltung is an important consideration and evidence of how a dry port can extend the life of a seaport. The life cycle stages relationship between seaports and dry ports is a complex interaction discussed in Section 5.1.8 of this chapter.

R. H. Charlier (2013) describes a "port life cycle" more generally, drawing on a broad range of concepts and historical examples to support a similar rise and eventual demise of seaports, concluding that the lifespan of seaports is not indefinite. The paper describes the importance of recognising and managing the seaport's life cycle position and understanding the physical, political, technological position (both landside and marine) and asset management approach (engineering lifespan) in which it exists. The causes of moving from one phase to another are not necessarily a result of space or efficiency limits but can arise from political decisions, changes in trade routes and social pressure. Applying these concepts to the life cycle model introduces ageing, obsolescence and restructuring phases to the lifecycle.

5.1.5 SEAPORT OPERATIONAL SCALE MODEL

Rodrigue (2006) discusses drivers of transport demand, demonstrating a relationship between geographic and functional integration in which seaports must operate. The globalisation of supply chains results in an increasing operational scale of actors seeking to gain market advantage and grow market size through improved distribution processes and the associated geographical integration of activities. Functional integration occurs as the transport sector links these global processes at a local scale, consistent with the earlier theme of Notteboom and Rodrigue (2004).

The expansion of operational scale in freight distribution is characterised by four distinct phases, depicted in Figure 5-14, in the geographic (local to global) and functional (initial to integrated) integration:

Phase A – The development of an isolated freight service to serve a specific isolated market.

Phase B - As the potential of the service develops, the market increases and previously separate distribution systems merge to form a more extensive (regional) market.

Phase C - The introduction of standardised processes and modes to the distribution network allows intermodal distribution over a large supply chain.

Phase D - The distribution system and market demands form an interdependent system at a global level.

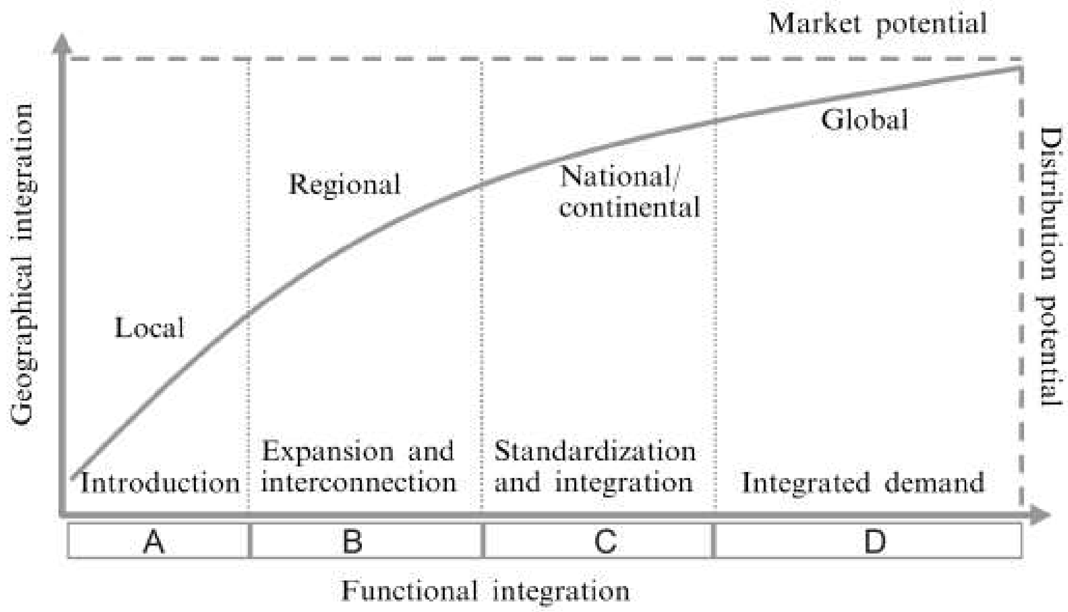


Figure 5-14 - Expansion of the freight distribution operational scale.

Source: Rodrigue (2006, p.1453).

These changes to operational scale relate to the changes in transport systems as reflected in early seaport models (Taaffe and Bird) but expand from these to encompass changes brought about by globalisation. The phases also relate to the phases of container transport system development, Figure 5-15, which drive the growth and consolidation of seaports and enable the tracking of container movements into hinterlands (Krośnicka, 2018).

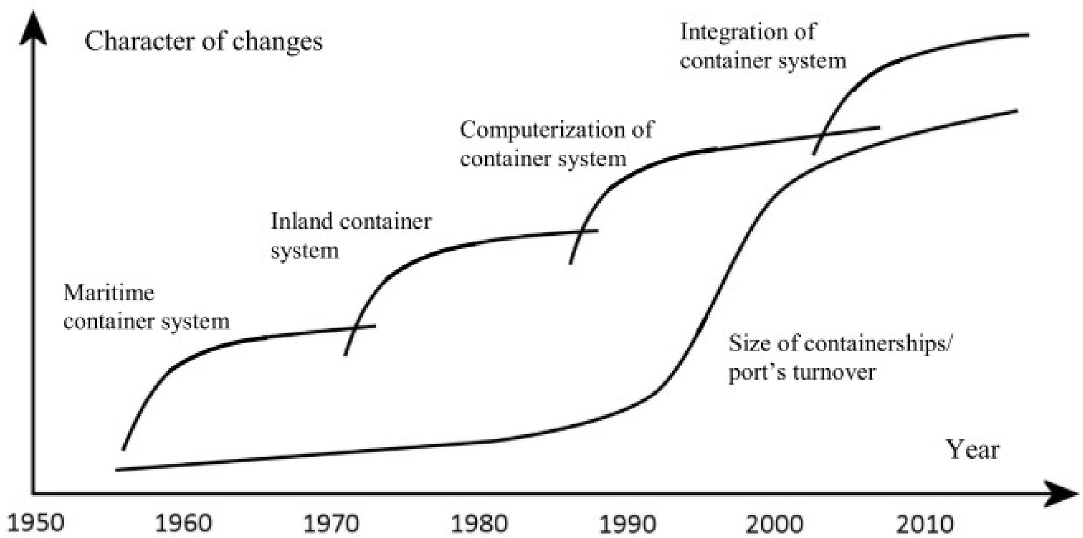


Figure 5-15 - Stages of container system growth and development.

Source: Krośnicka (2018, p.2).

The size of container ships has continued to grow between 2010 and 2022 creating closer integration of container systems as seaports move into the customer centric stage of management.

5.1.6 DRY PORT LIFE CYCLE MODEL

The life cycle model can be applied to dry ports (Bentaleb, Fri, Mabrouki, & Semma, 2016; Harrison, 2008; Leitner & Harrison, 2001; Monios & Bergqvist, 2016; Rodrigue et al., 2010), with five phases described by Leitner and Harrison (2001) and Bentaleb et al. (2016) generalised as follows:

Preparation/development - Sites are evaluated, support is garnered for the development and the question, *"Is the facility required?"* is answered.

Establishment/introduction - Transport modes are planned and established with anchor tenants secured. The reach and service provision of the facility is limited.

Expansion/growth - Actors are attracted to the facility, and further investment takes place; the facility gains from economies of scale. Services are added, and more space is consumed.

Stabilisation/maturity - Facilities expand within space constraints, but new arrivals slow down, and competition from other facilities with available space for expanded services occurs.

Reduction/decline - Actors leave for better options elsewhere and changing external conditions require operations to change.

Bentaleb et al. (2016) expand on the model by considering the seaport and dry port as a dyad interacting to create the dry port in the supply chain. This interaction introduces the directional development concept to the dry port model discussion, elaborated on later in this chapter. The dry port life cycle model incorporating directional development is presented in Figure 5-16.

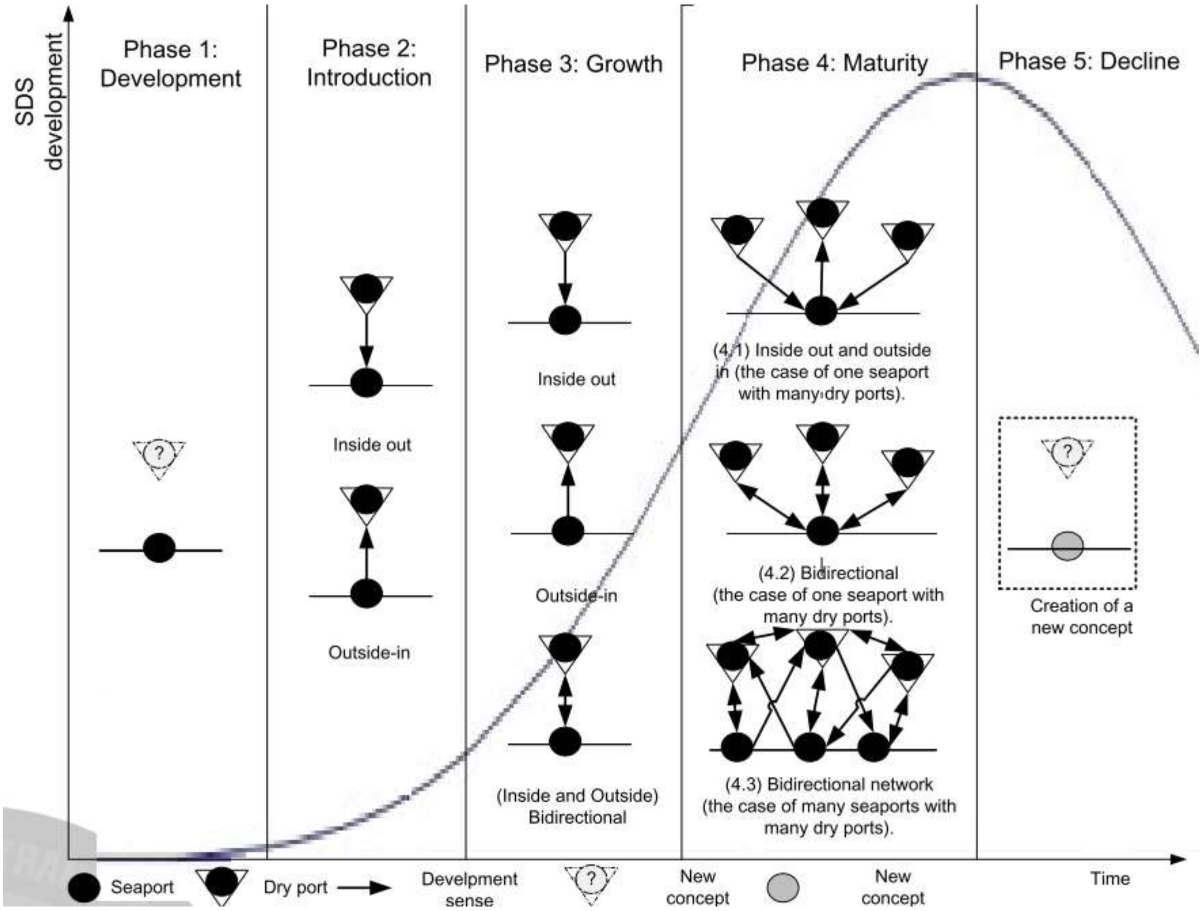


Figure 5-16 - The dry port life cycle model.

Source: Bentaleb et al. (2016, p.121).

Monios and Bergqvist (2016) use the stages of the facility development and operation, rather than a throughput level, to determine a life cycle model. The model incorporates “similar” stages to the above model except for an important concept of entering an extension strategy phase rather than finishing with a reduction/decline period. Upgrades and modifications to infrastructure and services avoid facility decline. This extension phase is explored by Bergqvist and Monios (2021) using a longitudinal case study of the port of Gothenburg and Falköping terminal, whereby a change in ownership and business model was successfully employed to expand and grow the terminal in a way not considered possible under the original public actor supported approach. The authors align the dry port development over time with the life cycle model and the important drivers to the success of the Inside-Out directional development.

As with seaports, various actors are involved in the development and operation of dry ports and influence the lifecycle stage of the dry port. External forces such as competition from other dry ports or changes to seaport circumstances allowing port-centric logistics to expand, Chapter 3: Attributes, Definition and Classification of a Dry Port, can significantly alter the lifecycle stage. Market forces act to eliminate excess capacity and the involvement of many actors, including public authorities, potentially makes the closure of an inland port contentious, (Rodrigue et al., 2010).

Andersson and Roso (2016) explore the role of value-adding services in attracting customers to a dry port and is relevant to the growth phase of the life cycle model. Importantly, a "stop at a transport node" must add value for the customer, so value-adding services over and above the modal change are required. The progression of services moves from those that comprise the basic transport functions of loading/unloading and storage to relatively low-value additions such as maintenance, warehousing, administration/customs and security. Higher value services include postponement activities (local labelling, power supplies, manuals and packaging) and delivery sequencing. The approach aligns with the UNESCAP functional evolution of dry ports presented by Beresford et al. (2012), depicted in Figure 5-17. Further discussion on attributes is presented in Chapter 3: Attributes, Definition and Classification of a Dry Port.

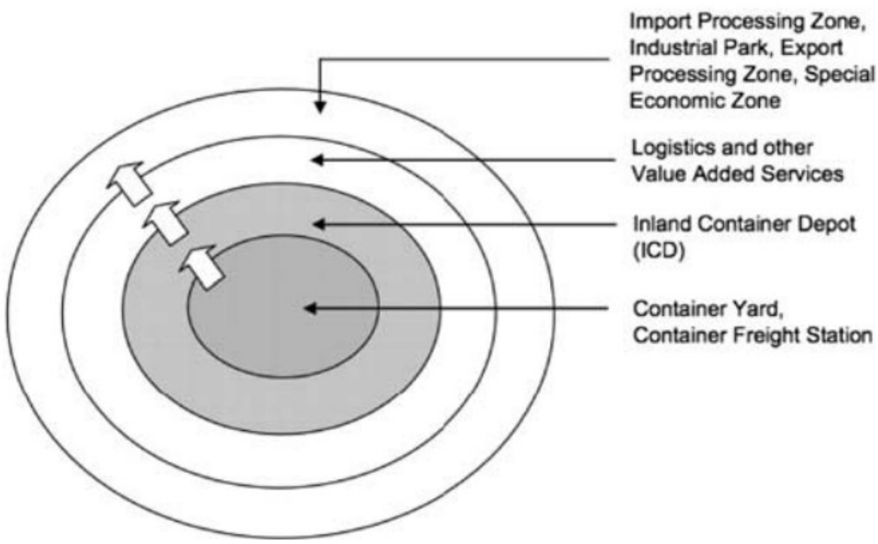


Figure 5-17 - UNESCAP functional evolution of dry ports.

Source: Beresford et al. (2012, p.275).

5.1.7 DRY PORT SEAPORT LIFE CYCLE RELATIONSHIP

The life cycles of seaports and dry ports are not necessarily aligned. They can function under different governance structures, government planning regimes and capacity constraints at different stages of their respective life cycles, bringing both synergies and conflicts between the entities. The importance of the relationship to establish efficient hinterland connection is evidenced in closer ownership, though not as closely integrated as the marine transport area, and the entities' operating approaches (Wilmsmeier & Monios, 2020). The important criteria to integrate operational activities are discussed in Chapter 6: Development Criteria for Dry Ports.

The alignment of the lifecycle phases between seaports and dry ports (intermodal terminals) is depicted in Table 5-1. Seaports in the mature or later stages can use a dry port development to enter the restructuring phase and prolong their operational life. Similarly, a dry port can undertake an extension strategy to prolong operations.

Table 5-1- Alignment of life cycle phases of seaports and intermodal terminals.

Source: Monios & Bergqvist (2016, p.29).

Port	Intermodal Terminal
	Planning, funding & development
	Finding an operator
Growth	Operations and governance
Maturity	
Ageing	Extension strategy
Obsolescence	
Restructuring	

This mutual cycling in a well-functioning *"port-hinterland"* life cycle system can prolong a seaport life restricted by infrastructure or land availability limits within the seaport (Wilmsmeier & Monios, 2020). The concept is depicted in Figure 5-18, with the seaport life extended through conceptual location splitting activities allowing for the introduction of other extension strategies (Wilmsmeier & Monios, 2020).

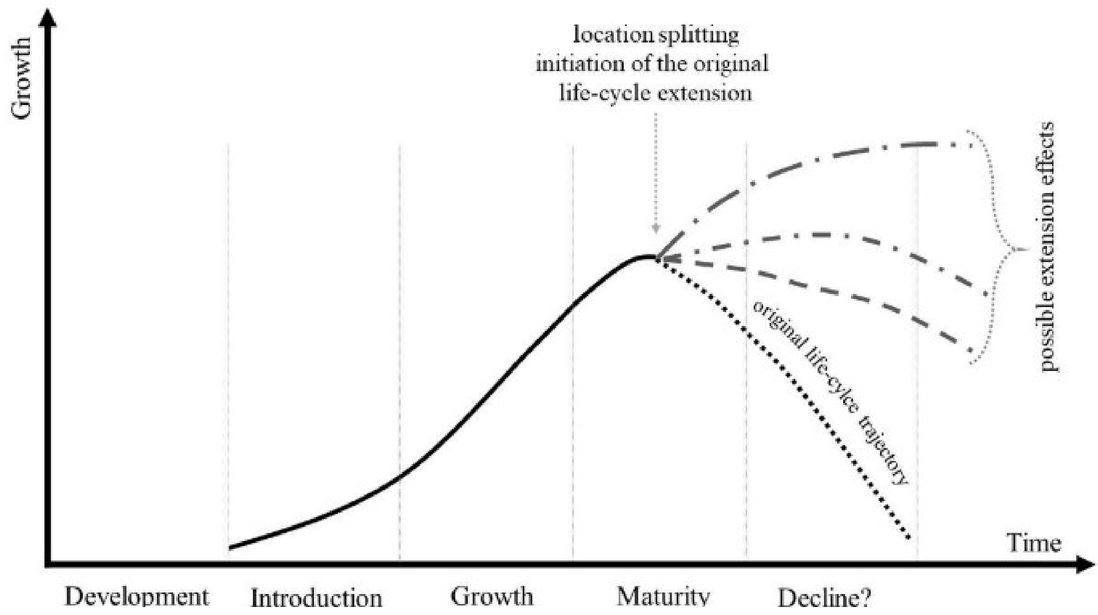


Figure 5-18 - Seaport life cycle extension through location splitting.

Source: Wilmsmeier & Monios (2020, p.13).

A dry port's ability to extend the seaport's life is explored by Jeevan, Yeng, and Othman (2021), using Malaysian seaports as a case study. The authors support the seaport life cycle model as a sound planning tool using an understanding of the lifecycle stage of the seaport as a basis for developmental decision making. As the studied seaports move through their respective life cycles, co-ordinated development of related dry ports (and transport links) in their life cycle is required to support the seaport by providing improved transport efficiencies and overcoming seaport space constraints.

5.1.8 DIRECTIONAL DEVELOPMENT OF DRY PORTS

Wilmsmeier, Monios, et al. (2011) explore the inland development of transport infrastructure and intermodal corridors in developed countries to build upon the main street concept of Taaffe et al. (1963), (premised on the development being driven from the seaward side inland during a time of public seaport ownership). The direction of development of these main streets and associated dry ports as supply chain nodes is explored. The process of landside Inside-Out development is often undertaken by rail and logistics companies seeking to concentrate goods into a particular corridor by seeking a co-operative relationship with a specific seaport and is driven by the policy of public organisations. Outside–In, where development comes from a seaport (port authority) recognising a vulnerability of a carrier undermining the seaport's power by developing relationships directly with dry ports and undermining the seaport's influence in its hinterland. The direction of the development concept is depicted in Figure 5-19.

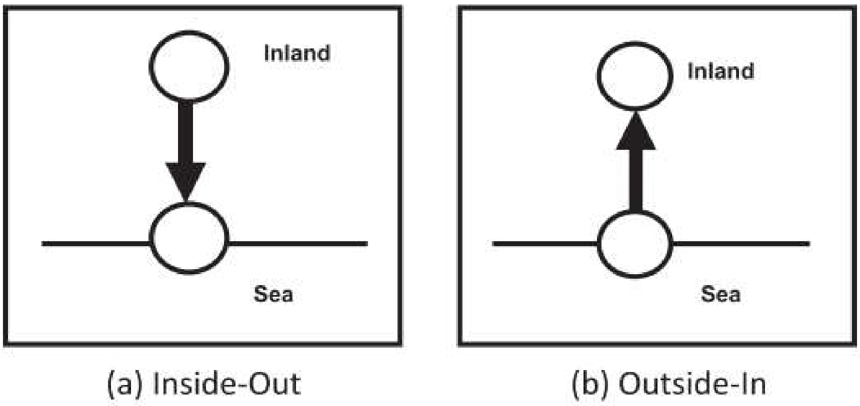


Figure 5-19 - Directional development of dry ports.

Source: Wilmsmeier, Monios, et al. (2011, p.1381).

Not all dry port developments have a directional context. Some develop from existing small inland terminals that grow over time to dry port status and become integrated with a seaport with no overall directional impetus. The research seeks, through case studies, to investigate the role government plays in the development process as a supply chain actor. The role of government development approaches in Sweden, Scotland, and the USA are contrasted.

In Sweden, local municipalities build and own dry ports to achieve modal transfer from road to rail and promote economic activity in the municipality. Such a development would be an Inside-Out model (Monios & Wilmsmeier, 2012a; Wilmsmeier, Monios, et al., 2011). The seaport case study presented is that of Gothenburg (Port of Goteburg), in which inland operators (not municipalities) develop related dry ports. The research indicates that Gothenburg develops closer collaboration with the dry ports to protect its hinterland. An issue of significance in the municipal development approach is the potential for municipalities to develop dry ports in overlapping freight consolidation areas resulting in an inability for the dry port to reach a minimum scale to remain economically viable. As there is no higher level (national) co-ordination, consensus planning is at a regional level with varying degrees of success. This oversupply is a conflict between seaports attempting strategic development of dry ports confounded by regional development strategies (Monios & Wilmsmeier, 2013).

The situation in Scotland is one of Inside – Out development where a publicly owned railway company develops dry ports with little interest shown by Scottish seaports, which surrender their hinterlands to those in southeast England with links to the Scottish dry ports (Coatbridge near Glasgow). Garnwa et al. (2009) identify shipping lines (P&O consortium) as developing a *"through transport system"* by establishing dry ports adjacent to existing railway lines to link ports at Tilbury and Southampton by train. Companies involved with warehousing and property development seeking to establish industrial centres developed dry ports but suffered difficulty attracting business as they were not adjacent to existing freight lines. This situation changed in the 1990s following the privatisation of seaports during the 1980s in the UK when many of the existing dry ports were taken over and rebranded under P&O. The UK government does not build the infrastructure but seeks to influence developments by researching to establish local and regional planning papers and develop favourable planning regimes to attract development. The private sector seaports are not risk takers, and no Scottish seaport-linked dry ports are likely to be developed. Whilst direct funding is not possible by the government, there are complicated funding mechanisms for supporting a modal shift away from road transport, this is applied to existing road transport and does not support development that attracts new movements. As a result, the situation in Scotland will promote the closer integration of existing facilities over the development of new ones.

A largely neutral public sector characterises the USA regarding inland corridor development in a country where most goods transported by rail are domestically sourced and distributed. This gives rise to a series of terminals linking inland areas. Changes in legislation assisted the modal shift from road to rail for imports and exports and enhanced seaport linkages with inland freight corridors. The 1980 *Staggers Act,* deregulating aspects of railway operations, made rail transport more competitive with road and, combined with the *Shipping Act* of 1984, allowed shippers to distribute goods inland on a single bill of lading, and promoted west to east coast land bridges. APL (American shipping company) in the mid-1980s developed a transcontinental double-stack intermodal land bridge in competition with the Panama Canal sea transit. This deregulation has seen inland penetration achieved by rail owners along the west coast dealing directly with shippers and treating the gateway ports as simply sources of cargo with only operational rather than strategic interactions. Government has no broad need to fund inland developments. An example of public funding (through applying the public authority, Virginia Port Authority, funds as an operating cost) is the Virginia Port Authority's development of the rail-linked Virginia Inland Port.

Monios and Wilmsmeier (2012a) present examples of Inside – Out dry port development, the Heartland Corridor, where an inland centred Public Private Partnership (PPP) developed high-quality access to a seaport to overcome its position on the periphery. The Alameda Corridor is an example of an Outside-In transport infrastructure development where San Pedro Bay ports (Long Beach and Los Angeles), along with the cities of Los Angeles and Long Beach, built and purchased rail infrastructure to develop a short-haul rail operation linking to various inland terminals (ACTA, 2021a).

Whilst not universally accepted Wilmsmeier, Monios, et al. (2011) reasonably conclude that the direction of development of inland corridors is dependent on a public policy regime that promotes varying investment behaviour and is a warranted addition to Taaffe's' model. Less clear and so presented as a discussion are the "reasons" for the directional development. Outside-In development is less common as the seaport, distinct from all other supply chain actors, has had less need to advance its interests inland, and other actors have taken on the task. Monios (2011) notes that Spanish dry ports are an Outside-In development as they have been primarily seaport driven, with the seaport retaining part ownership to protect their interests but not control the facility. The author notes that service integration is not high as rail companies rather than the terminal operators interact with shippers and plan the container flows. Counter to this is the more common Inside-Out development undertaken by public authorities to promote regional development and modal shift.

Beresford et al. (2012), in their study of dry port development in China, present further examples of Inside – Out development as a general theme whereby central and local governments provide the impetus for development, including zoning and funding, and the seaports co-operate with the dry port development to assist its success. Zheng et al. (2020) describe this approach as a government-driven mode, typically a city-based inland port supported by the Chinese government's recent Belt and Road and Free Trade Zone.

Bask, Roso, Andersson, and Hämäläinen (2014) build on this model by introducing changes to directional development that occur over time, arguing that Wilmsmeier, Monios, et al. (2011) are considering the start-up phase (preparation and establishment phase of the life cycle model) when allocating the direction. By expanding this to the growth phase, a bidirectional development can occur where public authorities, inland and seaport-based actors co-operate to develop the dry port and the services it can offer as part of the overall supply chain. Figure 5-20 shows the changing directional relationship over time.

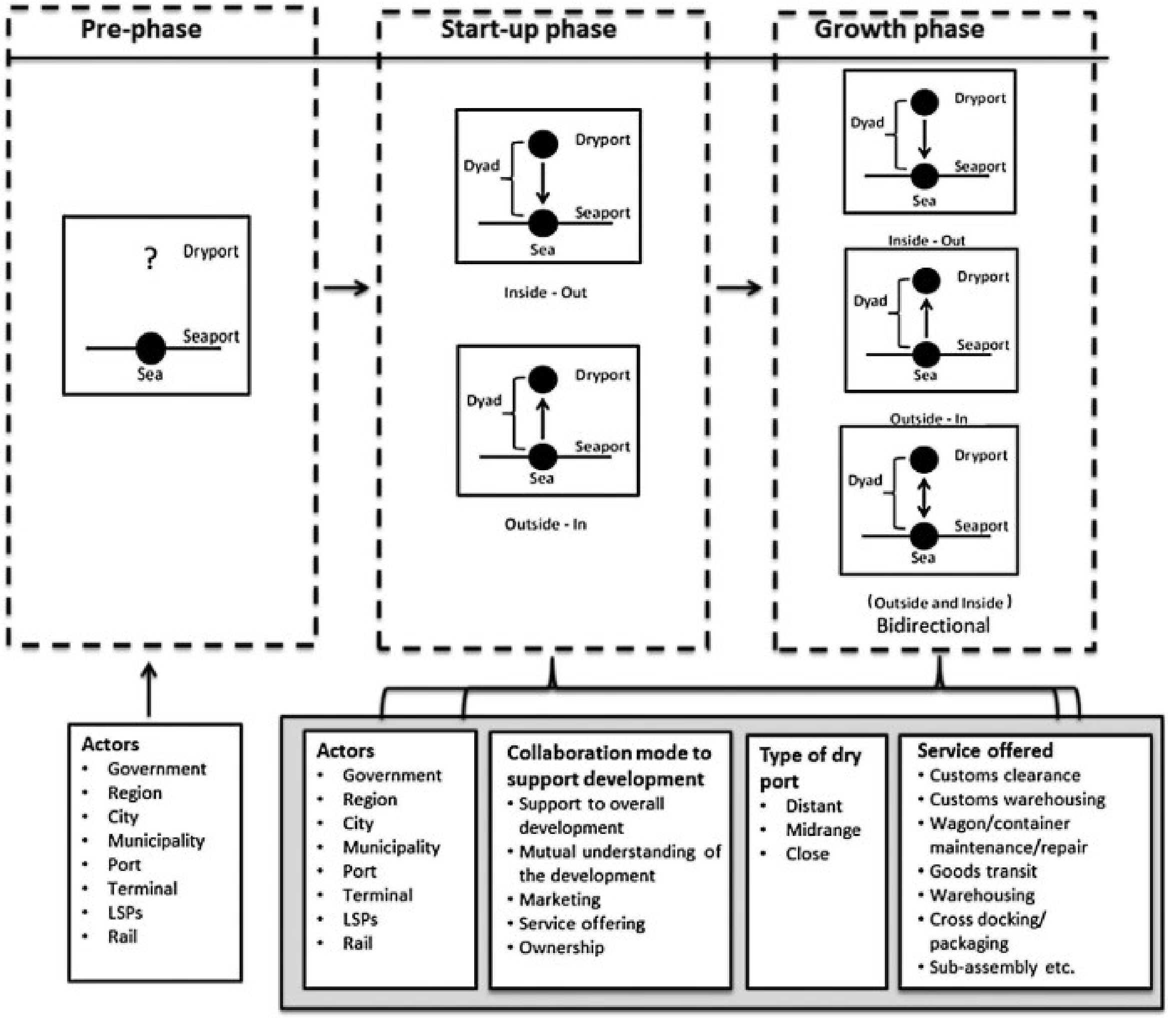


Figure 5-20 - Differing directional developments over time.

Source: Bask et al. (2014, p.93).

The directional development model is explored by Wiegmans, Witte, and Roso (2019), who consider the directional development to vary depending on the infrastructure, spatial, governance and economic dimensions associated with the dry port location. The development can be Inside-Out, Outside-In or Bi-directional depending on the specific conditions existing within the supply chain. The authors identify that dry ports need to assume a greater strategic position as they can have adverse seaport issues that prompt the inland development exported to their location, and seaport ownership may not promote the best development focus for the inland region. To overcome this, the dry port owner can develop strategic objectives, including alliances with other dry ports or seaports outside the original dyad, the mature phase of the dry port life cycle model. These actions strengthen the dry port position relative to the seaports to which it is linked. The literature does not widely explore the role of the dry port as a leader in the supply chain, with research focusing on the role as a part of the overall system (Witte, Wiegmans, & Ng, 2019). This dry port position contrasts with Monios and Wilmsmeier (2012a), who conclude that seaports have little *"institutional capacity"* to undertake development outside the port gate. The development of close dry ports is a practical exception to this rule due to their proximity to the seaport and the role of overflow storage capacity. Thus, it becomes a situation of Inside – Out developments taking precedence with seaports trying to influence the outcomes.

The literature discusses the potential preference for directional development resulting from institutional and infrastructure differences between developed and developing economies. In their literature review, Nguyen and Notteboom (2018) found no statistical preference for the direction of development between the two types of economies.

5.1.9 THE PORT-CITY RELATIONSHIP

A fundamental question concerning dry ports is whether or not to expand the capacity and life of a seaport in its current location. Either grow through the previously discussed methods of land expansion, the introduction of new technology and the development of a dry port to ease congestion and provide increased throughput capacity. Or alternatively, move to a new area and develop a new seaport where congestion is not a problem and efficient transport links service the hinterland. The exploration of the port-city relationship provides insight into decisions on this choice.

Whilst many transport geography research papers seek to examine the "success" of port cities through population growth and investment; the research papers are relevant to the exploration of dry port development as the breakdown of the relationship between the port and city provides drivers for dry port development.

Roberts, Williams, and Preston (2021) observe, along with the benefits of economic growth and the potential of tourism and maritime culture and identity, there are negative aspects of the port-city such as congestion and environmental degradation. The negative aspects are exasperated by the growth in the population of coastal cities, which brings additional traffic and environmental pressures to the port-city in its own right. Understanding the state of the port-city relationship provides insight into the readiness or otherwise of the supply chain in which the seaport is a node to develop a dry port. The observation that *"economic benefits [of seaports] often spill over to other regions, whereas negative impacts are localised in the port-city"* (Merk, 2013 p.7) is one reason for dry port development.

The location of coastal cities and their development have long been linked spatially and functionally to seaports. With changes in technology, the introduction of containers and intermodalism in global supply chains, and the negative impacts seaports have on surrounding urban areas as they grow, this historically strong link weakens (Ducruet & Lee, 2006; Hayuth, 1982; Merk, 2013; Zhao, Xu, Wall, & Stavropoulos, 2017). The port-centric approach of retaining traditional seaport roles supports the port-city relationship. It maintains the economic benefits of the seaport located in the city and is assisted by city planning to preserve the historic distribution corridors to support the distribution of goods from the seaport rather than developing a dry port (Monios et al., 2018).

Early studies, based on European and American developments, consider the retreat of the seaport from the heart of the city as cargo moved from general cargo to containers, and the storage associated with growing seaports could no longer be secured close to original seaport locations, and the seaports migrated away. Subsequently, urban activities moved to occupy the vacated area (Hoyle, 1989). In the Australian context, Hoyle cites Brisbane Port as an example where the seaport retreated from earlier riverside wharves and now occupies existing and reclaimed land at the Brisbane River mouth remote from the city centre. The move away from the city seaward and the factors causing this are depicted in Figure 5-21. In recent studies, Zhao et al. (2017) reach a similar conclusion to Hoyle. Figure 5-22, depicts the sequence of events in Hoyle's model.

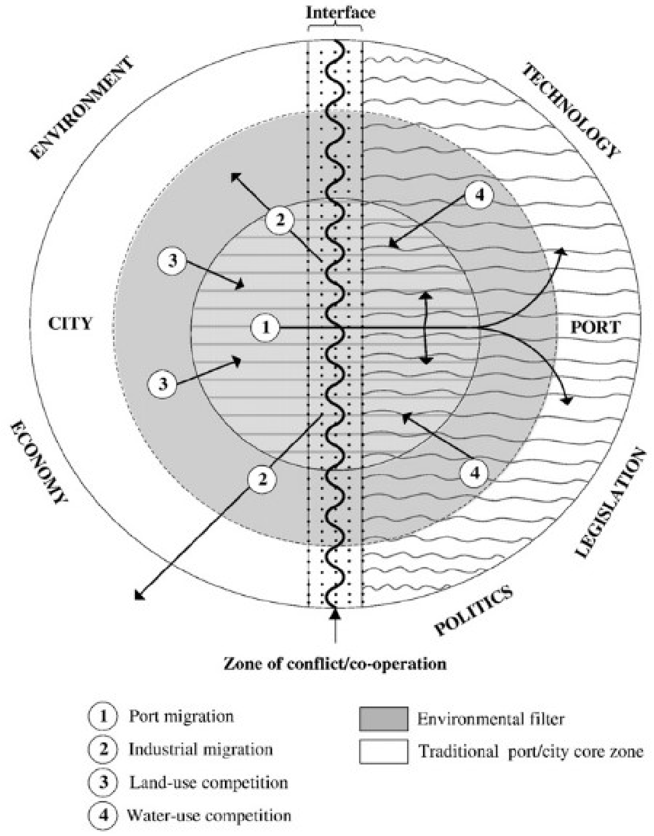


Figure 5-21 - Port-city interface model, characteristics and trends.

Source: Hoyle (1989, p.432).

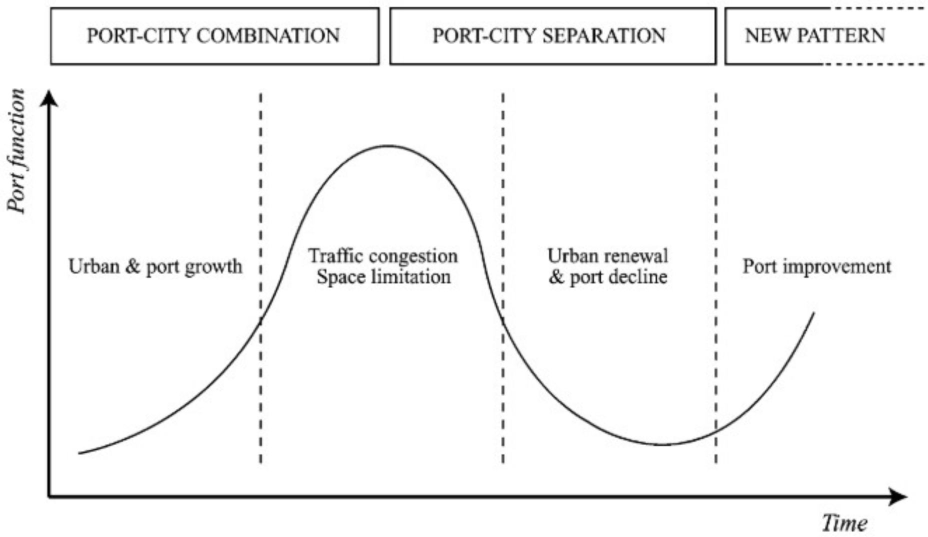


Figure 5-22 - Port-city spatial and functional evolution.

Source:Ducruet & Lee (2006, p.113).

Ducruet and Lee (2006) conclude that regional factors and local plans largely drive port-city development. This conclusion is not necessarily surprising as these factors influence dry port development, which has many similar considerations in their development.

In a review of port-city policy effectiveness, Merk and Dang (2013) find that best-practice transport policy effectively supports high seaport throughput. These best-practice policies focus on improving hinterland access, modal shift and providing dedicated freight corridors. Environmental policies measured by CO2 emissions and PM2.5 levels have mixed success as seaport activity is likely not the only source of this pollution.

Lee, Song, and Ducruet (2008) studied the port-city development from an Asian port perspective and compared these to the model developed by Hoyle, Figure 5-23. They add a sixth stage to Hoyle's model, the importance of environmental factors when the introduction of intermodal transport results in the port-city developing akin to a non-port-city when the spatial relationship breaks down. A difference between Asian and Western port cities exists. The Western regeneration of disused city dock areas is not present in the Asian context resulting in distributed locations with a trade role unlinked in their operation.

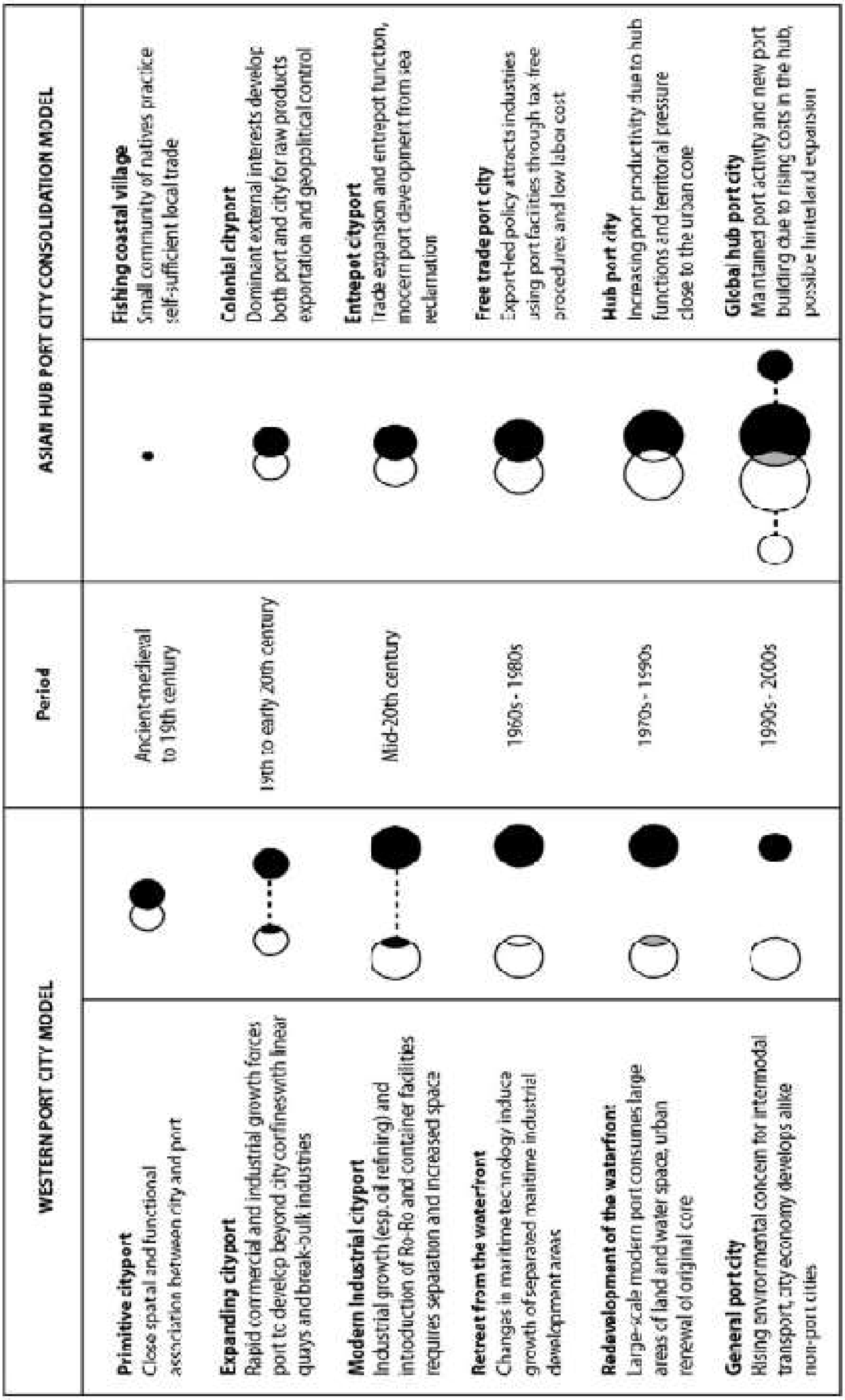


Figure 5-23 - European and Asian port-city development models.

Source: Lee et al. (2008, p.380).

5.1.10 DEVELOPMENT MODEL SUMMARY AND CONCLUSION

The seaport development models are all similar in reflecting changes in the role of seaports over time, moving from key positions in a transport system to nodes in global supply chains competing for custom. The introduction of standardised containers is a fundamental change to the transport system.

Management models such as the UNCTAD port generations provide an understanding of how seaports must respond to the changing role of seaports in the supply chain.

Spatial and functional models describe the changes to the supply chains and in particular the competition for hinterland and seaport concentration and deconcentration pressures.

Lifecycle models describe the stage a seaport is in its life and provides insight as to how eventual decline can be avoided. This can be a lengthening of the phase or a repositioning in the lifecycle. Methodologies to prolong or reset the seaport's position in the life cycle can be through a restructuring phase including location splitting, by the introduction of a dry port, which acts to prolong the growth and mature phase of a seaport lifecycle.

Dry ports are also modelled on the basis of a lifecycle, similar to seaports dry ports can take action to reposition the entity in the lifecycle.

Seaports and dry ports can function under different governance structures, government planning regimes and capacity constraints at different stages of their respective life cycles, bringing both synergies and conflicts between the entities. However mutual cycling in a well-functioning *"port-hinterland"* life cycle system can prolong a seaport life restricted by infrastructure or land availability limits within the seaport. Seaports in the mature or later stages can use a dry port development to enter the restructuring phase and prolong their operational life. Similarly, a dry port can undertake an extension strategy to prolong operations.

As seaports move through their respective life cycles, co-ordinated development of related dry ports (and transport links) in their life cycle is required to support the seaport by providing improved transport efficiencies and overcoming seaport space constraints.

The dry port directional development model describes the process of landside Inside-Out development, often undertaken by rail and logistics companies seeking to concentrate goods into a particular corridor by seeking a co-operative relationship with a specific seaport and is driven by the policy of public organisations. Whilst Outside–In development comes from a seaport (port authority) recognising a vulnerability of a carrier undermining the seaport's power by developing relationships directly with dry ports and undermining the seaport's influence in its hinterland. Not all dry port developments have a directional context. Some develop from existing small inland terminals that grow over time to dry port status and become integrated with a seaport with no overall directional impetus. The directional development will vary depending on the infrastructure, spatial, governance and economic dimensions associated with the dry port location.

The models are important to the development of the dry port development framework as they provide an understanding of the reasons why a seaport dry port dyad is required, the benefits that accrue to both entities through the development and the management approach needed to make it successful.

Seaport and dry port development models and attributes are summarised in Table 5-2.

Table 5-2 - Seaport and dry port development models and attributes

	Model type	**Attributes**	**Geographic development**
Seaport models			
UNCTAD generations (1994, 1999) and subsequent G5 and G6	Management	1st generation seaports, focus on the interface between land and sea. This isolated the seaport from the rest of the transport activity, and the surrounding community and treats port users and functions independently of each other. 2nd generation seaports emerge through recognition of the seaport having a role in a broader area of the supply chain, expanding to transport, industrial and commercial services. 3rd generation seaports, introduction of container transport. Seaports promote trade as they became a node in a global supply chain without captive hinterlands. This involved offering value-adding services. 4th generation seaports, are associated with container terminals, and private sector involvement in infrastructure development, with port authority management focusing on policy, planning and port promotion. 5th generation seaport, provide service featuring service quality, technology, with efficient IT and communications systems, sustainable development including green credentials and high port-city co-ordination, clustering in areas of maritime cluster management and seaport cluster management and be a hub with global linkages and high quality inland connections. 6th generation seaport, (future) fully automated terminal operations and hinterland connections to handle a 50,000 TEU vessel.	Based on worldwide trade.
WORKPORT (2000) **(EU WORKPORT Project co-ordinated by Dr A. Naniopoulos)**	Management	A continuous evolution model with the following components: Ownership, increasing private sector involvement, particularly in superstructure and cargo operations, Cargo form, substitution of unitised cargo for break bulk cargo, introduction of containers, Cargo handling processes, increasing automation and mechanisation in quay and stacking operations, Cargo support processes and information provision, proliferation of methods through increasing use of IT and increasing complexity of communications network, Working culture, decreasing workforce numbers as cargo operations become more capital intensive, Port function/port development processes, increasing diversity of port related activities, Health and safety aspects of the working environment, introduction of formal health and safety policies and decreasing accident and absenteeism rates, and Environment increasing environmental awareness and introduction of environmental management systems.	Based on European seaports.

Bird Anyport (1980) and the subsequent regionalisation concept of Notteboom and Rodrigue	Spatial	A fundamental port model that can be adapted to reflect the different spatial settings in which seaport concentration occurs. Reflecting changes within the seaport as it adapts to changing cargo handling and vessel advances moving away from the original townsite seaport location to provide specialised deep-water berths and cargo handling infrastructure such as container handling. Notteboom and Rodrigue build upon the model with a fourth development stage, *"regionalisation"* in which the distribution of cargo inland becomes the most significant factor for a seaport to remain competitive. Transport corridors and logistics poles are promoted along with a mode shift away from road transport, addressing issues of local traffic congestion around and limited land availability in growing seaports.	Based on British seaports.
Taffee transport network (1963)	Spatial	Based on six phases of expanding transport networks in developing economies with a focus on landside links. The first phase, scattered ports, is small, long established unconnected ports distributed along a coastline where restricted and poorly connected hinterlands exist. The second phase, port concentration begins as *"lines of penetration"* into the hinterland develop. Development of feeder routes allows some seaports to grow their hinterland at the expense of others. The third phase arises as the feeder routes grow and develop internal transport nodes, attracting cargo and creating greater seaport concentration as the larger seaports *"pirate"* cargo from smaller seaports. The fourth phase, larger feeder networks form and link up through lateral interconnection. The fifth phase the increasing interconnection until all seaports and inland nodes are linked. The sixth phase a higher-level concentration with priority linkages, such as national highways and trunk train lines forming *"main streets*".	Based on seaports in Ghana and Nigeria.
Hayuth container handling (1981)	Functional	A five phase model following the introduction of containers and the impact on seaports and associated trade routes, hinterlands and forelands and leads to the development of the load centre seaport. Phase 1, Preconditions for change. Seaports are of a size and spatial distribution that resulted from pre-container trade with reasonably well-defined but not static hinterlands. They are adapting to technological changes, particularly the introduction of containers, and are ready to change. Phase 2, Initial container port development. Undertaken by a few seaports due to the commercial risks involved. The development of container seaports favoured large seaports, some small seaports develop container capacity due to harbour or location factors not necessarily attributed to size. Phase 3, Diffusion, consolidation and port concentration. As container transport evolves more seaports are exposed to and adopt the technology and management approach to handle the trade. Early adopters tend to concentrate trade and form dominant seaports; smaller seaports become feeders to these. This concentration expands the boundaries of the dominant seaport hinterlands and brings distant seaports into competition with each other.	Based on U.S. seaports.

		Phase 4, The Load Center. The changes that the adoption of containers as a primary transport technique, places on all participants in the transport chain concentrates trade in larger seaports, *"load centers",* causing smaller seaports to compete for the remainder of the trade, including feeder traffic to load centres. This leads to a change in hinterland connections in which "*trunk lines*" are established from the load centres to major trade sources providing deeper hinterland penetration and the emergence of inland distribution centres. Phase 5, The Challenge of the periphery. As load centres face expansion constraints, diseconomies of scale emerge through lack of room to expand, congestion in transport routes and operation of large container operating areas. This allows smaller seaports to bid for traffic and further changes hinterland connections, and the traditional hinterland boundaries become fluid.	
Life cycle (2011) (Wilmsmeier, Bergqvist, and Cullinane)	Life cycle	The development of a seaport considered in a "*marketing model port life cycle*" of four stages. Development and introduction - the seaport commences operations with a limited hinterland and non-standardised basic services. Growth - economies of scale are realised through the introduction of infrastructure and process innovation and standardisation, creating additional growth as the process feeds on itself, driven by increasing transport demand in the area. Infrastructure and storage require an increasing land area. Hinterland reach broadens through infrastructure development. Maturity. - seaport growth slows, whilst the transport demand continues because of completing standardisation and infrastructure improvements within the physical constraints of the seaport. This allows competition from other seaports for the enlarged hinterland served by the mature seaport. Decline - seaport activity constraints arise as a lack of further land or process innovation is available to remain competitive in the hinterland. Other seaports encroach, market share drops, and eventually, actual seaport throughput declines may follow. The lifecycle stages are not of fixed duration, and internal or external factors can alter the time a seaport occupies a stage or even reset the seaport's position in the lifecycle.	
Operational scale (2006) (Rodrigue)	Spatial/functional	Considers the relationship between geographic and functional integration in which seaports operate. The globalisation of supply chains increases the operational scale of actors seeking to gain market advantage and size through improved distribution processes and the associated geographical integration of activities. Functional integration occurs as the transport sector links these global processes at a local scale. The expansion of operational scale in freight distribution is characterised by four distinct phases. Phase one – The development of an isolated freight service to serve a specific isolated market. Phase two - As the potential of the service develops, the market increases and previously separate distribution systems merge to form a more extensive (regional) market. Phase three - The introduction of standardised processes and modes to the distribution network allows intermodal distribution over a large supply chain.	

		Phase four - The distribution system and market demands form an interdependent system at a global level.	
Dry port models			
Life cycle (2001) (Leitner and Harrison)	Life cycle	The development of a dry port is considered in five stages. Preparation/development - Sites are evaluated, support is garnered for the development and the question, *"Is the facility required?"* is answered. Establishment/introduction - Transport modes are planned and established with anchor tenants secured. The reach and service provision of the facility is limited. Expansion/growth - Actors are attracted to the facility, and further investment takes place; the facility gains from economies of scale. Services are added, and more space is consumed. Stabilisation/maturity - Facilities expand within space constraints, but new arrivals slow down, and competition from other facilities with available space for expanded services occurs. Reduction/decline - Actors leave for better options elsewhere and changing external conditions require operations to change.	
Directional development **(2011) (Wilmsmeier, Monios, and Lambert).** **(2014) (Bask, Roso, Andersson, and Hämäläinen)**	Spatial	Builds upon the main street concept of Taaffe et al. (1963), (premised on the development being driven from the seaward side inland during a time of public seaport ownership). Explores the direction of development of main streets and associated dry ports. Inside-Out development is often undertaken by rail and logistics companies seeking to concentrate goods into a particular corridor by seeking a co-operative relationship with a specific seaport and is driven by the policy of public organisations. Outside–In, where development comes from a seaport (port authority) recognising a vulnerability of a carrier undermining the seaport's power by developing relationships directly with dry ports and undermining the seaport's influence in its hinterland. The model is expanded by introducing changes to directional development that occur over time, arguing the original model is considering the start-up phase when allocating the direction. By expanding this to the growth phase, a bidirectional development can occur where public authorities, inland and seaport-based actors co-operate to develop the dry port and the services it can offer as part of the overall supply chain.	Based on European and USA dry ports.

5.2 FREMANTLE PORTS

Fremantle ports can be considered a fourth and emerging fifth generation seaport with the presence of privately operated container terminals and associated private sector infrastructure development with port authority management focusing on policy, planning and port promotion and, through the state government ownership, responding to community needs.

The isolation from other Australian capital city container ports establishes the Inner Harbour as a load centre following the Hayuth model. However, as operational constraints grow, the periphery is becoming important as a decision on the location of the next container seaport nears. Deconcentration of container seaports could occur on the West Australian coastline.

Fremantle Ports faces the port-city relationship conundrum of trying to expand the landside and transport routes or move away from the original city location to a less congested area allowing the development of uncongested transport links. This relationship and the change it brings to the Inner Harbour are discussed in Chapter 2: Case Study- Fremantle Ports.

5.2.1 FREMANTLE PORTS HISTORY AND RELATIONSHIP TO DEVELOPMENT MODELS

Following taking possession of the Swan River area for the British crown in 1829 and the appointment of a Harbour Master under a British Act of Parliament, the Port of Fremantle is officially established (Urquhart, Morley, & Moulds, 1989). Various proposals for developing a seaport commenced in 1839 (National Archives of Australia, 2019). C.Y. O’Connor designed the Port of Fremantle, and construction work commenced in 1892 following the approval of a Parliamentary Committee earlier in the year (Urquhart et al., 1989). The seaport is constructed in the mouth of the Swan River with North and South moles built from rock quarried from Rocky Bay and Boya. The seaport location is some 12 miles from Perth, which was not accessible due to a rock bar (Tull, 1989). The seaport construction occurred when ships were converting from wooden sailing vessels to iron steamships, and the harbour required dredging to accommodate the increasing size of vessels and their associated draft. The Port of Fremantle officially opened on 4th May 1897, Figure 5-24. Bulk loading facilities are established in Kwinana in 1955 to support the heavy industry zone, which expanded during the 1960s and 1970s (FPA, 2019d). The Fremantle Harbour Trust, created in

1903, was later changed to the Fremantle Ports Authority and has always been a government controlled entity (National Archives of Australia, 2019).

Figure 5-24 - Official opening of Fremantle Port in May 1897.

Source: Barker (2019, website accessed 13/4/2020).

Following colonisation, seaports were dispersed around the Australian coastline. Early West Australian seaports had irregular shipping services and were established with convict settlers to deter French settlement (Albany 1827), as whaling stations (Esperance) or as free colonies, the Swan River Colony (Perth 1829), where the Swan River entrance was a seaport, but it was so shallow that cargo had to be lightered (Rimmer, 1967; Tull, 1989). This period reflects Stage 1 of the Taffee and Rimmer development models, with Perth being a "*Setting*" in the Anyport model and the UNCAD first generation of seaports.

Albany is established two years before the Swan River Colony. It was the seat of political power and developed on the back of whaling and sealing with little inland agricultural development. Albany became a bunkering port for steamers bound for the east coast and was a gateway for gold prospectors heading to the Kalgoorlie goldfields. As Perth established itself as the seat of government, a rail line was built between Albany and Perth in 1885 (opened in 1889 (Tull, 1989)), and the Port of Fremantle opened in 1897 as trade and passengers through Albany Port declined (WAM, 2019). Rail was present in Fremantle from the opening of the port, Figure 5-25. Other rail lines emanated from Perth, including the Great Southern Railway, Eastern Railway, Northern Railway and Midland Railway, which merged into a single system, the Western Australian Government Railways (RHWA, 2019). Albany was relegated to a second-order port as Fremantle grew through immigration and trade and the commencement of mail steamers into Fremantle in 1890 (National Archives of Australia, 2019). In August 1900, the Post Master General in London nominated Fremantle over Albany as the port for mail steamers (Urquhart et al., 1989). This situation reflects Stage 2 of the Taffee and Rimmer models, in which some ports expand at the expense of others, and hinterland connections grow.

Figure 5-25 - Rail was present from the start of the Fremantle Port, 1894.

Source: Barker (2019, website accessed 13/4/2020).

Before servicing the *Kooringa,* the first purpose-built container ship in the world, Figure 5-26, Fremantle Ports was handling 3-ton seatainers as part of an Australian coastal trade at the North Fremantle sea-freight terminal. The rail and transit shed facilities at the time are depicted in Figure 5-27. The port is the first seaport in Australia to receive overseas containers, the *Encounter Bay* berthing on 28th March 1969, Figure 5-28. A dedicated 12 Berth Container Terminal, which included a locally constructed portainer crane, facilitated the arrival of purpose-built container ships (FPA, 2019a).

Figure 5-26 - The Kooringa at Fremantle Inner Harbour, 1964.

Source: FPA website accessed 31/7/19, FPA (2019b).

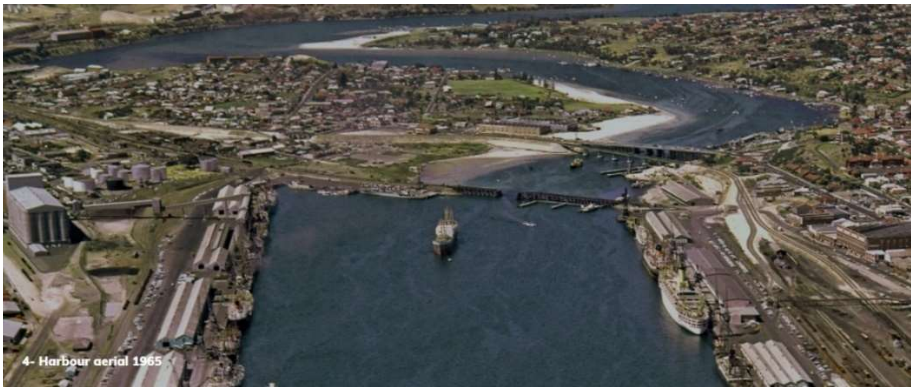


Figure 5-27 - General view of port storage and rail infrastructure, 1965.

Source: FPA website accessed 31/7/19, FPA (2019b).

Figure 5-28 - Encounter Bay arriving at Fremantle, 1969.

Source: FPA website accessed 31/7/19, FPA (2019b).

An era of port expansions followed this and the introduction of technology to improve container handling ability and efficiency to meet the increasing volumes of containers moving through the seaport and larger container carrying vessels. Number 12 Berth is lengthened from the original design to include number 11 Berth. In 1980, work commenced on the reconstruction of Berths 4 and 5 for use in containerised cargo. In 1982 a second portainer crane is installed on number 11 Berth. The container yards, upgraded Berths 4 and 5, and another portainer crane opened in 1983. In 1988 the "Seafreight 2000" project was announced under which the Inner Harbour would be dredged to 13m from the existing 11m to allow entry of larger containerships of up to 12.5m draft to berth and is completed the following year. The resulting dredge spoil was used to reclaim land at Rous Head for port-related activities. In the same year, number 9 Berth was reconstructed to give a continuous berth face of 1180m from Berth 4 to 9.

A national rail land bridge standard gauge rail service was introduced linking Kwinana and Fremantle Inner Harbour (Leighton rail yards) by standard gauge to the Trans-Australian railway at Kalgoorlie and in doing so, the Kewdale dry port via the Swan River rail bridge, Robb Jetty and Cockburn Junction. The Kewdale Freight Terminal and associated marshalling yards could not take the expected longer standard gauge trains at the time, so the Forrestfield site was adopted in a north-south direction in alignment with the existing rail (EAWAD, 2011). This general layout remains to the present day. During this time, an associated upgrade to Berths 8 and 9, including storage and container working facilities and an upgrade of the original portainer crane for use on Berths 4 to 9 commenced. Further capacity building commenced in 1996 when Berth 3 is redeveloped to provide further berth length, and nearby grain silos are slated for demolition for additional container areas with bulk grain exports relocating to the Outer Harbour. Technological advancement in the form of DUKC is introduced to maximise vessel drafts in 1997. In 2002 planning started for a North Quay rail loop to enable greater use of rail over road transport for the Inner Harbour. Work commences in 2005 and is finished in 2006. This year the first post Panamax portainer crane is installed in the port. A berth strengthening and channel and harbour dredging program is commenced in 2009 to handle larger container vessels. The Inner Harbour and entrance channel are deepened to 14.7m and the outer deep water channel to 16.5m lifting the maximum vessel draft to 14m. The dredge spoil is used to enlarge the Rous

Head area further. A second post Panamax portainer crane is installed, followed by a third in 2010.

During 2012 and 2013, the Rous Head area is further developed to provide truck marshalling areas, truck fuelling and parking facilities and container storage. Support services are located in the area with quarantine and short-term warehousing facilities introduced. Technology is deployed into the port services to improve supply chain dynamics, with a Congestion Management System and truck marshalling area linked with better communications and data collection. The fourth and fifth portainer cranes arrive at the port. The terminal line in the North Quay Rail Terminal is extended to 690m to allow improved access from the container terminals and improve train turnaround times in 2014. The sixth and seventh portainer cranes arrive in 2015 and 2018, respectively (FPA, 2019b).

The growth in container trade during this period is depicted in Figure 5-29.

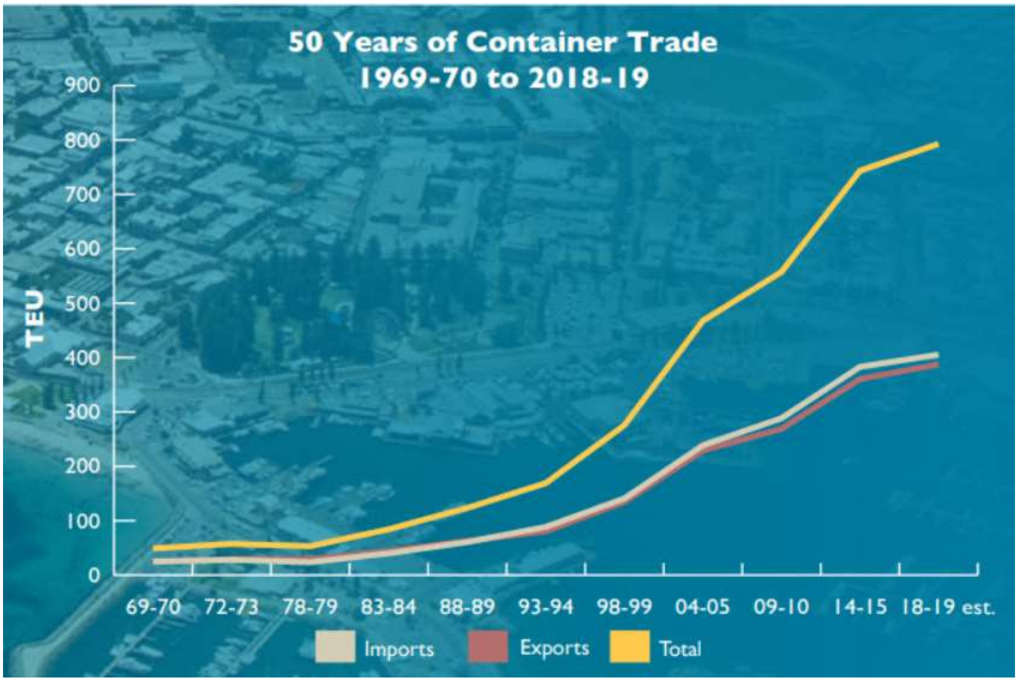


Figure 5-29 - Growth in Fremantle Ports container movements.

Source: FPA website accessed 31/7/19, FPA (2019b).

From the late 1990s, community pressure on the Fremantle Ports operations has grown, as evidenced in various studies commissioned by the Fremantle Ports and media and community group reports on the impacts of the port operations along with efforts to move freight from road to rail. In 2000 Fremantle Ports commissioned an Inner Harbour Buffer Definition Study to evaluate noise, risk, light and odour impacts and define appropriate land use surrounding the Inner Harbour to ensure port operations were not *"unduly restricted"* or subject to controls that *"reduce efficiency and/or competitiveness"* (FPA, 2002). Reporting in 2000 and commissioned by a government steering committee in 1997, the Fremantle Waterfront Master Plan describes the planning process to *"redevelop the western end of Victoria Quay"*, which is underutilised as the port activities are focussing on the North Quay and eastern end of Victoria Quay following the introduction of container shipping (Cox et al., 2000). The 2000 Inner Harbour Port Development Plan explicitly recognises the relationship between the port and the community *"careful planning is required if the needs of an operating port are to be reconciled with broader environmental and social goals of the community"* (FPA, 2000 p.2). Redevelopment plans are advanced in a staged manner (MacTiernan & Scaffioti, 2019). The introduction of rail to North Quay in 2002 and the development of the North Quay Rail Terminal extension in 2014 are integral to the plan to move more freight to rail to *"reduce the growth of port-related truck traffic"* (FPA, 2014c). The City of Fremantle transport study identifies freight from the Inner Harbour as a significant contributor to road congestion in the city and, whilst supporting ongoing Inner Harbour operations, promotes moving freight to rail and environmentally sensitive upgrading of road networks (Fremantle, 2015).

During this time, the Kwinana heavy industrial area is promoted by the WA state government, and in the 1950s, the Kwinana Bulk terminal is constructed (DoT et al., 2016b), with further development in the 1960s and 1970s. In 2011 the Bulk Terminal and associated storage and loading facilities undergo a major revitalisation to handle iron ore export (Banks, 2012).

This time frame sees the Fremantle Port move through the second and third generation and into the fourth generation UNCTAD seaport. With the Inner Harbour no longer handling any solid bulk cargo, having developed the Outer Harbour and moving these products to that location. The Fremantle Ports management recognises the importance of looking beyond the seaport boundary with involvement in land use planning, access preservation and community engagement and accommodation, with the Fremantle Port developing the attributes of a fifth generation seaport.

The development of the Inner Harbour from general cargo to specialised container handling facilities in association with dredging works to provide deeper drafts and movement of bulk cargo to the Outer Harbour are consistent with the Bird Anyport model stages of setting, expansion and specialisation; Tull (1985) supports this interpretation.

In respect of the life cycle model, the port moved through the growth phase when infrastructure improvements, additional land, dredging and rail links were established and is well into the mature stage as recent container growth has slowed along with rail movement proportions stabilising for the Inner Harbour. It is unlikely that further dredging and land reclamation will take place as additional dredging in the river to satisfy increasing vessel draft requirements may not be technically viable, and environmental and community constraints place pressure on the Inner Harbour and its transport links. Once throughputs grow to exhaust the current spare capacity, the Inner Harbour will enter the decline phase as new Outer Harbour (or other) facilities take over.

The port-city relationship has progressed following Hoyle's model. Urban and seaport growth occurred from the early years, and the introduction of container services result in congestion surrounding the seaport becoming increasingly significant. This prompts activity to reduce increases in congestion as the seaport continues to increase throughputs through the growing use of rail and the Forrestfield/Kewdale dry port. The areas vacated by the seaport associated with earlier cargo handling are reclaimed for accommodation, commercial activities, heritage preservation and public spaces as part of the *"port-city separation"* phase.

5.2.2 INNER HARBOUR

The Inner Harbour is a fourth and emerging fifth generation seaport following the UNCTAD and subsequent generation models, with private operators controlling two container terminals and a third private entity operating the NQRT. Fremantle Ports is engaged with the Fremantle community and seeks to co-ordinate development and the needs of the Inner Harbour operations with expectations of the surrounding community evidenced through the participation in industry working groups and community liaison and numerous studies and planning documents developed in the last 20 years.

The remoteness from the other container seaports serving Australia leaves the Inner Harbour at a relatively early spatial and functional model stage. Specialisation has occurred with the progressive dredging, land reclamation and infrastructure upgrades that allow servicing of vessels of up to 90,000GT and LOA of 300m and a beam of

42m with drafts to 13.5m and above (subject to DUKC consideration) at the Inner Harbour (FPA, 2018b). The isolation of the seaport has meant that hinterland penetration has occurred, but there is little inter-port connection.

The Inner Harbour is at the mature stage of the lifecycle model, having improved the seaport's physical and management systems. No further land is available to expand operations, and dredging has reached a practical maximum depth in the Swan River. Trade growth continues, but ultimately landside access will constrain it.

The development of the Forrestfield/Kewdale dry port facility resulted from rail works not directly connected to seaport requirements and was not directional in its initial development. This lack of direction is consistent with Bask et al. (2014), who state that dry ports can develop from existing rail marshalling yards and Harrison (2008), who proposes site selection based on assessing areas currently operating as an industrial area or logistics centre. This concept is discussed in Chapter 7: Dry Port Site Selection. The development of NQRT was through public ownership processes to provide efficiency in the link to the privately upgraded and operated dry ports in a bi-directional arrangement. The Kenwick, privately developed terminal, is an Outside-In development with ARC Infrastructure developing the facility.

The Forrestfield/Kewdale dry ports are at the stabilisation/mature phase of their lifecycle, with facilities expanded to their physical constraints and experiencing competition from another development, Kenwick, with space and capacity available.

The Kewdale facility could improve operability by reconfiguring the terminal, particularly the mainline rail access that requires shunting to enter the facility.

5.2.3 OUTER HARBOUR

As a future development, the Outer Harbour is not classified within the presented seaport model stages. Instead, it is analogous to the preparation/development stage of the dry port models. The seaport models provide insight as to why it is under consideration. The port-city relationship pressures evidenced at the Inner Harbour result in the need for a more remote facility. In relationship to the centralisation/decentralisation factors, the Outer Harbour development would be a decentralising step, despite being controlled by the same port authority. Greater decentralisation through developing a regional seaport such as Bunbury establishing a container trade could delay the Outer Harbour development. A significant factor against the peripheral competition comes from the Westport study conclusion that Bunbury is excluded from the final shortlist of transport solutions (Westport, 2019e), as the state government ultimately controls seaport development in the state.

In Chapter 4: Common Reasons for Dry Port Development, the conclusion is reached that an Outer Harbour development should include a quayside rail terminal to link to existing dry ports by extending rail links to the new location as an outside-in development.

Chapter 6: Development Criteria for Dry Ports

6.1 LITERATURE REVIEW

In developing a dry port, the literature presents several common factors that influence the functions and attributes the development will have and the likelihood of the facility's success. Examining these factors explains their importance and role in dry port development. In a literature review, the findings of Rodrigues et al. (2020) support the concept of each supply chain experiencing a unique set of circumstances requiring consideration of the development criteria in the context of the individual setting.

6.1.1 TRANSPORT LINKS AND MODE

Transport links between a seaport and a dry port are a primary development requirement without which a dry port cannot develop (Roso, 2008). UNCTAD (1991) describes an attribute of a dry port as being located inland with direct transport links to the seaport. These transport links include road, rail and barge, with various levels of efficiency, cost, flexibility and community and environmental impact. Rodrigue and Notteboom (2012) describe rail as a primary enabler of many dry ports worldwide.

Discussion on transport links must include consideration of transport mode and intermodal transport, with non-bulk rail (container) transport necessarily involving a road component for pick up or delivery of full or consolidated container loads. The intermodal transport approach combines the flexibility of road transport with the line haul efficiency of rail transport (Roso, 2008). Practically, unimodal and intermodal transport approaches compete (Bontekoning, Macharis, & Trip, 2004). Factors influencing and attributes of the transport approach can be drawn from general freight situations and those involving a seaport and dry port in the logistics chain; this is discussed in Chapter 8: Freight Transport Modal Choice Survey.

Community and environmental impacts are externalised or *"societal costs"* of transport and, depending on how they are attributed, influence the direct cost of a particular transport mode to the transport owner (Bergqvist, Macharis, Meers, & Woxenius, 2015) and the choice between that mode and others by shippers and consignees. The internalisation of external costs to *"user pays"* is an objective of the European Council and through the greening of supply chains. Greater involvement in planning and development approval of communities raises it as a consideration of business operators.

The ability of transport links to handle short-term volume surges arising from larger vessels and seasonal variations, such as the Christmas period, is essential and is discussed for each mode in this section.

Transport links and modes must be considered in the context of the distance between the seaport and dry port, be it close, mid-range or distant. The differing economics, in particular, direct costs, of transport modes vary with distance and generally favour road for shorter and rail for longer transport distances. Considering external costs and applying user pay approaches can alter this balance.

Road transport

Road transport is the most common land-side form of containerised freight transport. It is the most flexible in scheduling port gate to end use location delivery and vice versa and is capable of handling short-term capacity surges with extended operating hours or diversion of trucks from other activities.

In contrast to rail, road transport is a greater cause of congestion, noise and pollution in areas surrounding a seaport. Road construction to expand the road network's capacity into seaports impacts the local community through land acquisition processes and disruption during construction.

A primary method for seaport operators to alleviate the congestion caused by trucks is to introduce a vehicle booking slot system at the seaport. The booking system reduces truck queueing at the seaport and can be used to spread the container pickup and delivery times across the entire day and into weekends. The booking system impacts one of road transport's significant advantages over rail transport by reducing the flexible scheduling for container movements.

Whilst dry ports may result in road transport losing some market share, the transport mode benefits from the reduced congestion (Nguyen et al., 2021) and the gains in participating in a greater overall freight volume resulting from seaport growth.

Rail transport

Rail is a desirable transport mode that can reduce road congestion and community noise impacts around seaports and lower unit CO_2 emissions (Roso &

Lumsden, 2009). Due to rail capacity and economies of scale, it can handle the increasing number of containers arriving on each vessel as vessel size increases and cater for movement surges associated with seasonal goods. Rail is often in direct competition with road freight and has historically lost market share. In the EU, between 1995 and 2013, intermodal road/rail transport increased by 60% (tkm basis); however, the modal split ratio for road transport increased by 4.6%, and rail decreased by 3.3% over the same period (for barge transport the ratio was unchanged). This result demonstrates that road transport is gaining share under an increasing total transport task (tkm basis) (Elbert & Seikowsky, 2017). The USA's situation is similar with intermodal rail growth of 4.6% per annum between 1990 and 2000 compared to road transport growth of 6.9% per annum (Resor, Blaze, & Morlok, 2004).

In the Australian context, rail transport targets exist for seaport container movements, New South Wales (Port Botany), target 40%, Victoria (Port of Melbourne), target 30% (Lubulwa et al., 2011), and Fremantle, target 30%, (DOTARS, 2006b). In the case of NSW in 2016, containers were 17.5% by rail against a target of 28% by 2020 (TNSW, 2018), falling to 16.6% from January to June 2020 (BITRE, 2019, 2021b), and Victoria, the actual value of 4.9% in 2010 (Lubulwa et al., 2011), climbing to 6.1% in January to June 2020 (BITRE, 2021b) falling far short of the targets. Brisbane's rail transport share was 2.1% and Adelaide's 20.9% for January to June 2020 (BITRE, 2021b). Fremantle Ports' rail share is 18.4% for 2021 (FPA, 2021a).

There are six suburban short-haul rail operations for container movement in Australia. Yennora, Minto, and Enfield dry ports linked to Port Botany, Direk/Penfield linked to Port Adelaide Outer Harbour and Forrestfield/Kewdale, and Kwinana linked to Fremantle Ports Inner Harbour. In Victoria, the Port Rail Transformation Project has commenced and will provide rail links from the Port of Melbourne to urban terminals (BITRE, 2021a). The Kenwick facility in Western Australia is under development.

Rail container transport involving a seaport will be part of an intermodal transport operation with a road leg to deliver import or pick up export containers which, depending on the particular supply chain, may make this a more costly transport option than solely road (unimodal) transport. Due to the necessary consolidation of cargo to fill a train, delivery/transit time may be longer and not as flexible in timing as road transport; the highly reliable service scheduling of rail may offset this disadvantage. Schedule frequency is an important consideration in selecting rail over road transport, and aside from shuttle services on dedicated lines, which do not compete with passenger trains that have priority (a form of rail congestion), it is unlikely to match road transport (Elbert & Seikowsky, 2017).

The advent of containerised goods makes intermodal road/rail transport more competitive as the intermodal changes required for the use of rail have improved the efficiency of this task (BITRE, 2016). The importance of rail and reducing rail transport costs by utilising quayside rail terminals for container handling is recognised in the European inland port sector (EFIP, 2019b) and is the method used at Fremantle Ports Inner Harbour through development of the NQRT.

Barge

Whilst commonly used in the European transport system (Bergqvist & Woxenius, 2011), China (Notteboom, 2007) and to a lesser extent in the USA (Konings, van der Horst, Hutson, & Kruse, 2010), barges are not used in any Australian seaport context for linking a dry port to a seaport and are not explored in this thesis.

Intermodal transport

In the same way that dry port definitions vary, so does the definition of intermodal transport (Agamez-Arias & Moyano-Fuentes, 2017). As research into intermodal transport has grown since the 1990s, its definition has broadened from specific tasks to a more generalised theme (Bontekoning et al., 2004). To provide a broad range of consideration of intermodal transport, a modified version of the 1997 EU definition of intermodal transport is used for this thesis *"intermodal freight transport is the movement of goods in a single freight unit through two or more successive modes of transport, with no handling of the freight during transportation* [except to the extent that the handling of the freight adds value to the supply chain]*"* (Agamez-Arias & Moyano-Fuentes, 2017 p.788). This definition is consistent with the inclusion of intermodal terminals fitting within the definition of a dry port whilst acknowledging that a dry port can offer a wider range of services than a simple modal change.

The introduction of the 20ft container, (stemming from a concept developed by Malcolm Mclean in America (Behdani et al., 2020)) and its offshoots have advanced the economics of intermodal transport by allowing the use of standardised equipment throughout a logistics chain. ISO standard containers include 10ft, 20ft, 40ft (all with varying access doors), half-height, refrigerated, tanktainers, car carrier and flat rack types (Smita, 2019).

In an early exploration of the emerging field of intermodal transport research, Bontekoning et al. (2004) identify the following characteristics of a rail-based intermodal transport system.

- The splitting of transport tasks between long-haul and short-haul components. Trucks perform the short-haul section, collecting or distributing the goods and rail haulage the long-haul of large freight volumes to reduce cost. The intermodal aspect is more than just using two transport modes requiring schedule co-ordination.
- Schedules that are *"synchronised and seamless"* resulting in the actual cargo not being stored or handled during the transport task.
- Standardised transport units that allow standardised transport and handling equipment to be employed.
- Transhipment involving splitting the short and long-haul components of the task in a synchronised fashion.
- Management of multiple supply chain actors is to achieve a co-ordinated approach over distinct aspects of the transport task conducted by different organisations.

This captures the important aspects required in the intermodal transport task but does not reflect the changes that dry ports add to the supply chain. Short-haul rail can be an economically viable component of an intermodal transport operation, so line haul is a more appropriate term for the rail component. The value-adding operations at a dry port can also result in cargo being stored, handled or even modified at the dry port before ongoing transport.

Depending on the train configuration, determined by local conditions which vary across the world (longer trains being possible in the relatively flat topography of Australia, Russia and the United States when compared to Europe) (Carboni & Dalla Chiara, 2018), intermodal transport eliminates differing numbers of truck movements in and out of a seaport. In the USA, at the Port of Los Angeles, a 30 car double stack train removes approximately 400 truck trips (PoLA, 2019). In Europe, a train replaces

25 trucks (Roso & Lumsden, 2009), and at Port Botany, Australia, a train replaces at least 54 trucks (TNSW, 2018).

Role of distance and differing economics of transport modes

The differing characteristics of road and rail transport result in the modes having different cost factors over the transport task from the container loading/unloading point to/from the source or destination of containerised goods.

As discussed in Chapter 8: Freight Transport Modal Choice Survey, there is a range of factors that influence the selection of transport mode by shippers. Based on survey results in the literature, the most important determinant of mode selection is transport cost. This primary transport mode selection factor supports the need for discussing the break-even distance between road, rail and intermodal transport costs.

Research on the break-even distance between rail and road on a direct cost basis has not provided a single break-even distance, as each transport case must be specifically analysed. The lack of a single definition of the distance between a source and delivery point in a transport task contributes to the inability to generalise on break-even distance. The distance can be:

- Straight line distance.
- Trucked route distance, door to door.
- Rail linehaul distance between the intermodal terminals.
- Total intermodal distance, including pre and post-rail haulage.
- The distance between the economic activity locations.

The costs included in the break-even distance analysis influence the break-even distance. Simple direct costs can expand to include other logistical costs, such as returning empty containers, storing containers awaiting transport, and holding inventory. Costs are not static; changing fuel prices, congestion, and freight volumes change cost structures. This results in significant variation in break-even distance based on the European examples reported, Figure 6-1 (Meers, Vermeiren, & Macharis, 2014). This variation is not inconsistent with an Australian NSW study on dry port size and distance to the seaport relationship with the ability to cover operating costs and provide a financial return, Figure 6-2. The geometry of the positions of the seaport, dry port (terminal and customer), and customer distance from the dry port all influence rail freight competitiveness, Figure 6-3.

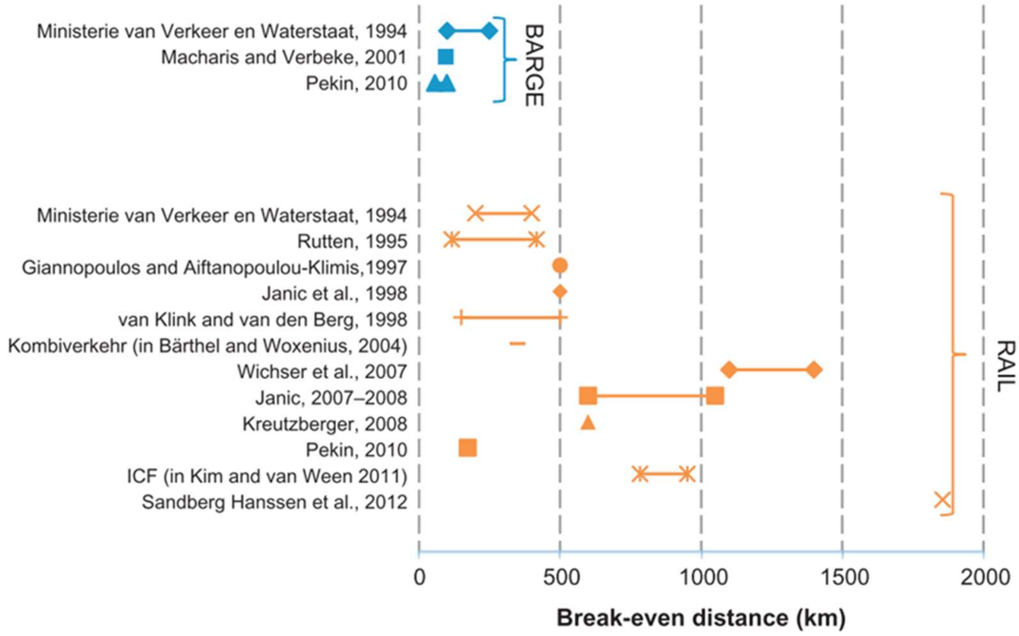


Figure 6-1 - Break-even distances for intermodal transport compared to road.

Source: Meers et al. (2014, p.227).

Terminal Size	Overall container volumes pa			Distance to port (one-way)			
	Loaded TEU's (export)	Empty TEU's (inbound)	Total TEU's	300 kms	500 kms	650 kms	800 kms
Small	<2,500	<2,500	5,000	☒	☒	☒	☒
Medium	2,500 to 10,000	2,500 to 10,000	5,000 to 20,000	☒	☒	☒	☐
Large	10,000 to 20,000	10,000 to 20,000	20,000 to 40,000	☒	☑	☑	☑
Super	>20,000	>20,000	>40,000	☐	☑	☑	☑

☒ Not sustainable ☐ Marginal ☑ Sustainable

Figure 6-2 - Commercial viability relationship with size and distance from the seaport.

Source: Sd+D (2004, p. 10).

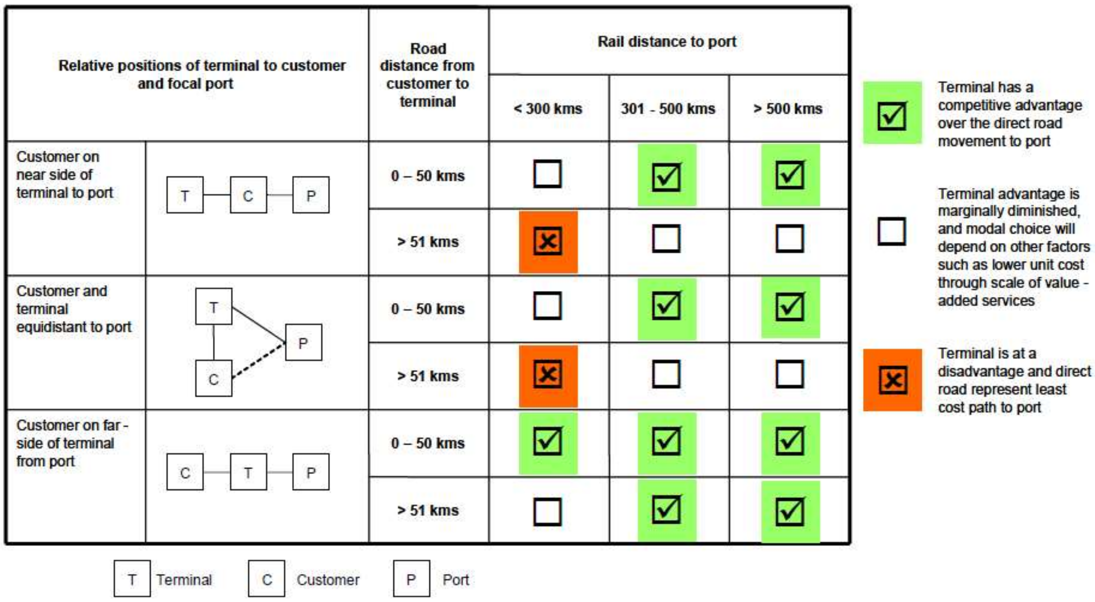


Figure 6-3 - Geometric relationship and distances affect rail competitiveness.

Source: Sd+D (2004, p.21).

Rules of thumb are applied to the break-even distance. Typically, 500km in Europe (recently, a focus in Europe has been around a 300km haulage distance as a break between short and long haul (Meers, Macharis, Vermeiren, & van Lier, 2017)). Five hundred miles in the USA (Kim & Van Wee, 2011). Freight forwarders use these distances and often see trucking as the base case for transport and intermodal road/rail as a riskier approach about which they are not fully informed (Elbert & Seikowsky, 2017). The break-even distance is important if a dry port in a metropolitan area surrounding a seaport is to be successful in promoting a modal shift from road to rail transport.

The direct costs associated with intermodal train transport occur in up to five separate areas (drayage associated with seaport yard movements removed in the situation of a quayside rail terminal):

- Drayage from the pickup point to the rail terminal.
- Handling at the rail terminal.
- Rail line haul.
- Handling at the rail terminal.
- Drayage from the rail terminal to the delivery point.

This list contrasts with road transport which has three components:

- Handling at the quayside terminal.
- Road line haul.
- Handling at the delivery point.

Relying solely on the lower rail line haul cost, compared to road transport, to cover the additional traditionally high terminal handling costs resulted in the rule of thumb for break-even distances in the transport industry. With increasing vessel size, congestion around seaports and environmental imperatives, each component of the intermodal cost structure has been researched. New practices and technologies reduce intermodal costs and lower break-even distances to make "short-haul" rail competitive with road transport. The requirement to pass through dry ports in an intermodal system makes dry port design and operation a key factor in intermodal transport competitiveness (Carboni & Dalla Chiara, 2018).

The situation at the Port of Naples in 2012 demonstrated the importance of external factors on modal costs, congestion and resulting container dwell time charges favour transport by rail to a close dry port over Italy's dominant road transport approach (Monios & Wilmsmeier, 2012a). Conversely, at Port Botany, misalignment of stevedore operations and poor accessibility to the rail network add additional costs and delays to movement in the intermodal system (Ernst & Young, 2014).

At a macro level, modelling the drayage cost pre and post-line haul activity shows that reduced drayage distances improve intermodal rail economics (Kim & Van Wee, 2011). In the case of a seaport, an *"on dock"* quayside rail terminal eliminates a drayage task. Wang et al. (2020) consider the differing economics of the dry port having quayside rail compared to offsite rail access, which introduces a second road transport component between the rail terminal and dry port. The drayage leg is not uncommon in developing economies where transport costs are low relative to land values adjacent to rail terminals. Over and above a rail to terminal movement, the location of the dry port influences the pre or post-linehaul drayage (depending on whether it is an export or import activity). The terminal locations have other restrictions on their location, particularly in an urban setting when a short-haul rail approach is being considered, discussed further in Chapter 7: Dry Port Site Selection. In the European context (for all land-based freight movement), trans-shipment and pre and post-haulage costs account for 20% and 25 to 40% of the intermodal transport cost, respectively. Using long heavy vehicles (LHV) in the pre or post-haulage drayage role lowers these costs (both internal and external), reducing the break-even distance. LHVs are outside the standard road legal dimensions for length or weight. Depending on route flexibility, the use of such vehicles can displace some rail freight back to road transport (Bergqvist, 2014).

Using double-stacked containers on rail is common and a contributor to economies of scale for rail and reduces costs (Resor et al., 2004; Rodrigue & Notteboom, 2012; Slack, 1990). Double-stacking is not always a benefit in the case of short-haul rail, where service frequency can be more important than the potential cost saving achieved by high train loading taking longer to consolidate.

Reis (2014) identifies the various factors that influence modal choice decisions between road and rail transport in a study of sub-400km transport in Europe, concluding that distance is not explicitly identified in the literature (aside from a few isolated cases) as a factor in modal choice decision making. The lack of this identification of distance may result from several factors, the difficulty in providing a single definition of distance, the role of pre and post-line haul distance in determining economics and the relationship to the transport distance of many of the costs associated with transport. Zgonc, Tekavčič, and Jakšič (2019) identify factors associated with distance, rather than the distance itself, as an important consideration in modelling modal choices. It is arguable that distance is considered in each specific case for choice and cannot be considered in isolation as it has no independent relevance to the economic considerations.

6.1.2 INTERNAL AND EXTERNAL TRANSPORT COSTS

Europe is considering how road freight operations which externalise costs to a larger extent than intermodal transport options, barge and rail, can be internalised, making the *"user pay"* and *"polluter pay"* enhancing intermodal transport approaches through the development and application of policy and market mechanisms (EU, 2012). Europe's seaport and dry port organisations support this approach (EFIP, 2019b).

Two externalised costs are considered:

- *Infrastructure costs - defined as "the direct expenses plus the financing costs. Annual infrastructure costs in 2016 are thus equal to the sum of the annual depreciation and financing costs. The transport infrastructure costs include investments in new infrastructure, renewal costs of existing infrastructure, expenditures on the maintenance of infrastructure, and operational expenditures enabling the use of transport infrastructure", (EU, 2019 p.9).*
- *External costs – defined as "the following externalities were taken into account: accidents, air pollution, climate change, noise, congestion, well-to-tank emissions, and habitat damage", (EU, 2019 p.11).*

Demir, Huang, Scholts, & Van Woensel (2015) summarise the negative external costs of freight transport studied in the literature, presented in Figure 6-4. The authors nominate other areas of external cost that are not studied but warrant research: energy production, vehicle manufacture, the maintenance and end of life disposal of transport equipment and the infrastructure construction associated with the transport mode.

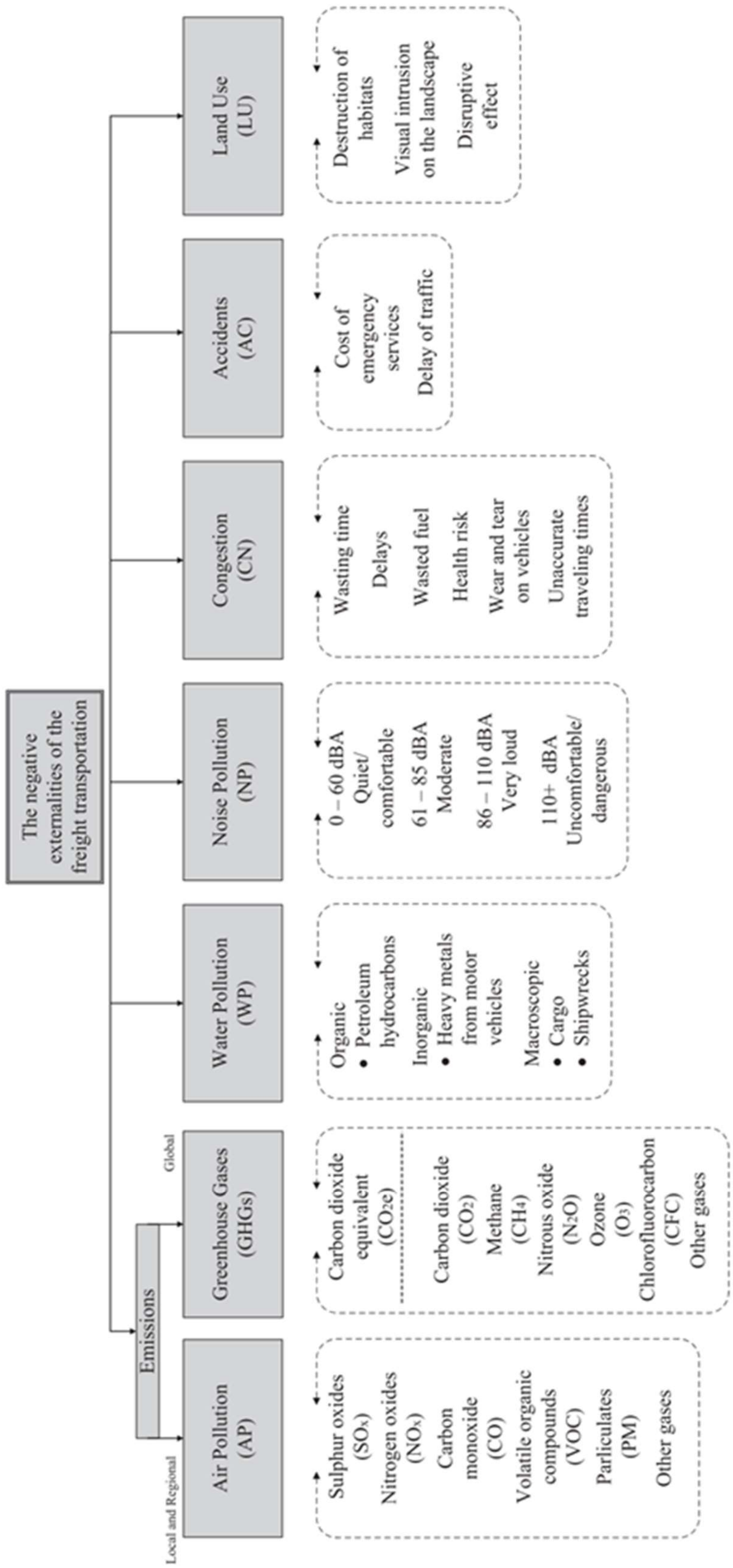


Figure 6-4 - Negative external costs of freight transport.

Source: Demir et al. (2015, p.97).

Infrastructure costs in the European Union, 2016, were 0.023€/t/km for heavy goods vehicles and 0.030€/t/km and 0.032€/t/km for electric and diesel freight trains, respectively. External costs were 0.042€/t/km for heavy goods vehicles and 0.011€/t/km and 0.018€/t/km for electric and diesel freight trains, respectively. The breakdown of external costs over all transport ranks the external costs as accidents at 29%, congestion (only calculated for road vehicles) at 27% and the balance grouped as environmental costs. Of the environmental costs, air pollution and climate change contribute 14%, noise 7% and habitat damage 4% of the total. For rail, the highest environmental cost was noise. In the EU28, no freight transport mode fully covers the external costs through levied taxes and charges (EU, 2019).

In a report on NSW intermodal terminals, an externalised cost differential between road and rail is estimated at $25 to $50 per TEU (Sd+D, 2004). This value is consistent with the current WA state government subsidy for container transport from the Inner Harbour to the Forrestfield/Kewdale dry port.

As external costs are specific to a given transport system, exact values and rankings cannot be generalised to all situations (Bergqvist et al., 2015; Janic, 2007). The data provides insight into the relative external impacts of different freight transport modes.

The user pays system is an example of the conflicting aims of the different actors in a supply chain. Whilst progressive road freight organisations are looking to green their operations, many small transport operators competing on price are not, putting them at odds with community expectations.

In considering *"Green Port Dues"*, differential charging by seaports depending on hinterland transport mode Bergqvist and Egels-Zandén (2012) identify that private actors have little incentive and are more likely to oppose the promotion of such an approach (as it leads to higher internal costs) leaving the role to public actors such as state port authorities to introduce. Once introduced, the "*Corporate Social Responsibility"* imperative will silence some critics. The fee structure must ensure the increased costs to business create the desired environmental benefits and do not simply shift the supply chain elsewhere.

6.1.3 INFORMATION TECHNOLOGY

The area of IT in sea ports and dry ports has been important for a long time, with the introduction of the *"port infostructure"* function playing a significant role in third generation ports (UNCTAD, 1994 p.15). Implementation of digital systems requires standardisation of processes and sharing of information, which is absent from many relationships between supply chain actors requiring a change in relationships from transactional to integrative (Song, 2021). Effective IT systems are required to enable a transfer of seaport functions to dry ports (Bergqvist & Woxenius, 2011), an important development criterion. Efficient IT and container tracking are necessary for the effective functioning of intermodal transport (Acciaro & McKinnon, 2013) enabling proper supervision, control and planning of the network (Agamez-Arias & Moyano-Fuentes, 2017). This management includes controlling and informing different participants on schedules, arrival notification, arrival times, inventory levels and changing demand (Clott & Hartman, 2016). The number and differing objectives of the supply chain actors inhibit information sharing and may result in differing IT platforms used in the transport chain, causing inefficiencies (Elbert & Seikowsky, 2017). The highly fragmented maritime transport supply chain complicates the introduction of digital systems., The Maersk Line cites the example of a container transported from Kenya to the Netherlands requiring 200 pieces of paper and involving 30 different parties (Song, 2021). In a literature review, Rozic et al. (2016) identify a fundamental need to have technology in place at a dry port to receive and position containers to provide the savings in transhipment activity and a high standard of service required to achieve cost savings for customers. A 2019 European Federation of Inland Ports strategy paper acknowledges the importance of IT in European dry ports as being at the start of the “smart inland port” process, which is a requirement for the successful future of dry ports (EFIP, 2019a).

Information technology is essential for the operation and control of vehicle booking systems (VBS) which are becoming widely used in seaports to relieve truck congestion. The VBS co-ordinates truck arrival times for container pick up and drop off and is used in conjunction with extended gate hours (Gracia, González-Ramírez, & Mar-Ortiz, 2017; Kotowska & Kubowicz, 2019). In reviewing research on truck appointment systems, Huynh, Smith, and Harder (2016) argue that whilst the studies conclude a well implemented VBS can benefit supply chain participants, the research is deficient as it does not consider the actual booking features of specific systems. In practice, whilst VBS may offer reduced congestion at the seaport, it impacts other supply chain actors as usually the VBS is viewed from the seaports’ perspective. Using a VBS increases road transport overheads due to the additional administrative burden and potentially larger truck fleet required to meet booking schedules. Costs also increase if the truck fleet operation cannot be optimised. In addition to meeting booked slots, a schedule has to satisfy pick-up and drop-off times imposed by shippers and consignees. A lack of transparency in booking systems can favour one operator over another.

VBS reduces external costs of the transport mode and acts against a modal shift from road to rail transport.

6.1.4 LOCATION

Geographical location is important in dry port development. It brings regional attributes such as infrastructure ownership approach, transport characteristics and modes (Hayuth, 1994), efficiency, government policy and regulation, historical influences and commercial objectives of the actors (Notteboom & Rodrigue, 2009; Rodrigue & Notteboom, 2010a), access to a source or destination of freight due to a sufficiently large population (Rodrigue & Notteboom, 2012), user behaviours and speed of development (Ng & Cetin, 2012) into consideration. These regional attributes, *"regionalism"*, lead to divergence from the homogeneous consideration of the transport modes and networks and associated terminals independent of the geography driven by supply chain analysis. Varese, Marigo, and Lombardi (2020) reinforce this concept in a literature review.

The study of transport geography concludes that the relationship between infrastructure, locations and their interactions along with the region's physical and socioeconomic attributes will determine the systems of circulation of goods. The concept of formal and functional regions supports this conclusion. Formal regions are physically bound geographic areas displaying homogenous characteristics. Functional regions are where relations based on functionally integrated systems define the area. The formal regions have historically been stable over time, whereas functional regions are subject to continual change. Early approaches to inland logistics meant that the two were often in harmony, but recent trends have broken this alignment. These trends are globalisation, where global supply chains have crossed the formal regions, economic integration, where multilateral agreements attempt to harmonise regulatory and jurisdictional regimes (e.g., the European Union), and intermodal transportation bringing a higher level of integration between systems of circulation, moving toward the supply chain controlling the spatial and organisational behaviour (Rodrigue &

Notteboom, 2010a). These trends allow *"a regionalism of freight distribution [to] be constructed as a set of functional regions in which gateways, corridors, hinterlands, regulation, governance, value chains and labour are of particular relevance in their definition"* (Rodrigue & Notteboom, 2010a p.498) to be considered and supports the fragmentation of and competition for hinterlands. An important distinction is between European and North American compared to Asian and Pacific freight flows, the focus of the former is imports compared to an export focus of the latter bringing differences to container logistics (Notteboom & Rodrigue, 2009; Rodrigue & Notteboom, 2010c). The difference in the developing (excluding Africa) versus developed economies, which broadly aligns with these regions, results in the local factors of consolidating cargoes from many small suppliers and lack of co-ordinated transport systems resulting in local conditions dominating global supply chain requirements such as in India (Ng & Cetin, 2012).

There are conflicting arguments in the literature on the role of developing versus developed, generally European/USA versus Asian, economies in the direction of dry port development. Through a statistical analysis of the literature, Notteboom and Nguyen (2019) conclude that the direction of dry port development is not related to this, Chapter 5: Development Models for Seaports and Dry Ports.

Location is critical in the European context as it determines whether international borders are crossed in the land-side transport component of the supply chain. Whilst the customs union removes the need for customs checks, the varying social customs, languages and commercial skill level of the actors in different countries will influence the supply chain efficiency and extent of the seaport hinterland (Guerrero, 2019).

6.1.5 ROLE OF SUPPLY CHAIN ACTORS

Dry port development, management and operations result in the involvement of different actors, each of which seeks to advance its own goals. The increased integration of seaport and hinterland supply chains leads to a change in the relationship and function of supply chain actors (Nguyen et al., 2021). As a result, dry ports come into being with a wide variety of ownership and governance structures. The actors involved in developing a specific dry port will directly influence the function it serves (Rodrigue et al., 2010), and if these actors change over time, the dry port function can also change, as evidenced by the Falköping terminal (Bergqvist & Monios, 2021). The effectiveness of hinterland logistics and the supply chain created is dependent on the behaviour of these actors and how they collectively organise and collaborate (Bergqvist & Egels-Zandén, 2012) in a *"hinterland access regime"* (P. de Langen & Chouly, 2004). Van Der Horst and De Langen (2008) describe why coordinating the actors is difficult to achieve. The reasons include unequal distribution of costs and benefits, reluctance or inability to invest (particularly for small actors), acting in their own strategic interests, resisting changes that assist competitors, absence of a dominant actor that can influence the supply chain and risk averse behaviour with a short term view of benefits accrued. From a survey of Singaporean container shipping firms, Yuen and Thai (2017) identify similar barriers, a lack of trust and commitment to the process, resistance to change from existing practices, differing organisational objectives, a lack of resources and measurement failure (the inability to correctly attribute costs across actors preventing an equitable distribution of benefits). A lack of co-ordination directly impacts the efficiency of the networks and does not always satisfy the shippers and consignees it serves (Clott & Hartman, 2016). Baccelli and Morino (2020) and Roso and Lumsden (2009) note that conflicting interests of the supply chain actors need to be recognised and overcome, whilst Holguín-Veras, Kalahasthi, Campbell, González-Calderón, and Wang (2021) observe this is not a transparent interaction and varies over time. Lonza and Marolda (2016) identify the differing requirements and expectations of actors in the supply chain. The differences range from transport providers wanting visibility of freight volumes, planners and service providers wanting the best use of infrastructure and importers/exporters wanting predictable transit times and undamaged goods.

Frémont and Franc (2010) classify the actors into three groups, *"economic agents"* such as shippers and freight forwarders and handlers who have a direct economic interest, *"public authorities"* such as port authorities and various government levels (local and national) and *"community groups"* representing social outcomes including the environment. The various groups have differing views on cost, traffic flow and environmental areas related to the use or otherwise of intermodal as compared to the road only transport, as presented in Table 6-1.

Table 6-1 - The differing view on the benefits associated with intermodal transport.

Source: Frémont & Franc (2010, p.550).

	Costs	Traffic flow	The environment
Economic agents			
Shippers	Reducing inland transport prices	Need for reliable transport chains	Showing interest in taking into account sustainable development
Shipping lines	Competing with other transport organizers to attract freight from shippers	Offering reliable transport chains	
Forwarders		Offering reliable transport chains	Anticipating a possible inclusion of environmental costs in transport costs
Freight handlers	Same as above if the freight handler is also a transport organizer (as in Hamburg)	Reliability of the operation of maritime terminals	
Public authorities			
Port management	Interport competition	Interport competition	Promoting a sustainable development
National, regional and municipal governments	Economic development and jobs	Regional planning	
Public opinion			
	Same as above	Low tolerance for environmental externalities NIMBY syndrome	

A primary influence in using a dry port is accepting a modal shift from road to intermodal transport (rail or barge). The differing priority of decision making factors shows the varying objectives of supply chain actors. Table 6-2, derived from a European supply chain study, shows the differing priority in factors.

Table 6-2 - Decision making factors for the switch from road to intermodal transport.

Source: adapted from Elbert & Seikowsky (2017).

Actor	**Freight forwarder**	**Terminal Operator**	**Railway operator**	**Shipper**	**Intermodal Operator**
Fuel price	√				
Quality (on time delivery)		√	√	√	√
Flexibility	x				x
Pre/post haul distance			√		√
Lack of infrastructure standardisation	x	x	x		x
Specialised equipment	x				
Fiscal incentives	√	√	√	√	√
Environmental constraints /legislation	√			√	

Regarding modal choice, a lack of information and the resulting uncertainty about intermodal transport performance results in decision makers in freight forwarding potentially favour remaining with road transport over using an intermodal approach. If shippers outsource transport to freight forwarders, the freight forwarder decides the transport mode. The freight forwarder's arrangements with organisations such as shipping lines influence the transport mode selection (Elbert & Seikowsky, 2017). According to a stated preference survey, Meers et al. (2017) observe that actual users of a specific transport mode report its performance as higher than non-users. This difference contributes to reluctance to change transport modes.

The different attitudes of actors in the supply chain are reflected in the preferences of various actors in Sweden and Belgium regarding what aspects should be targeted to make seaports more "sustainable", Figure 6-5.

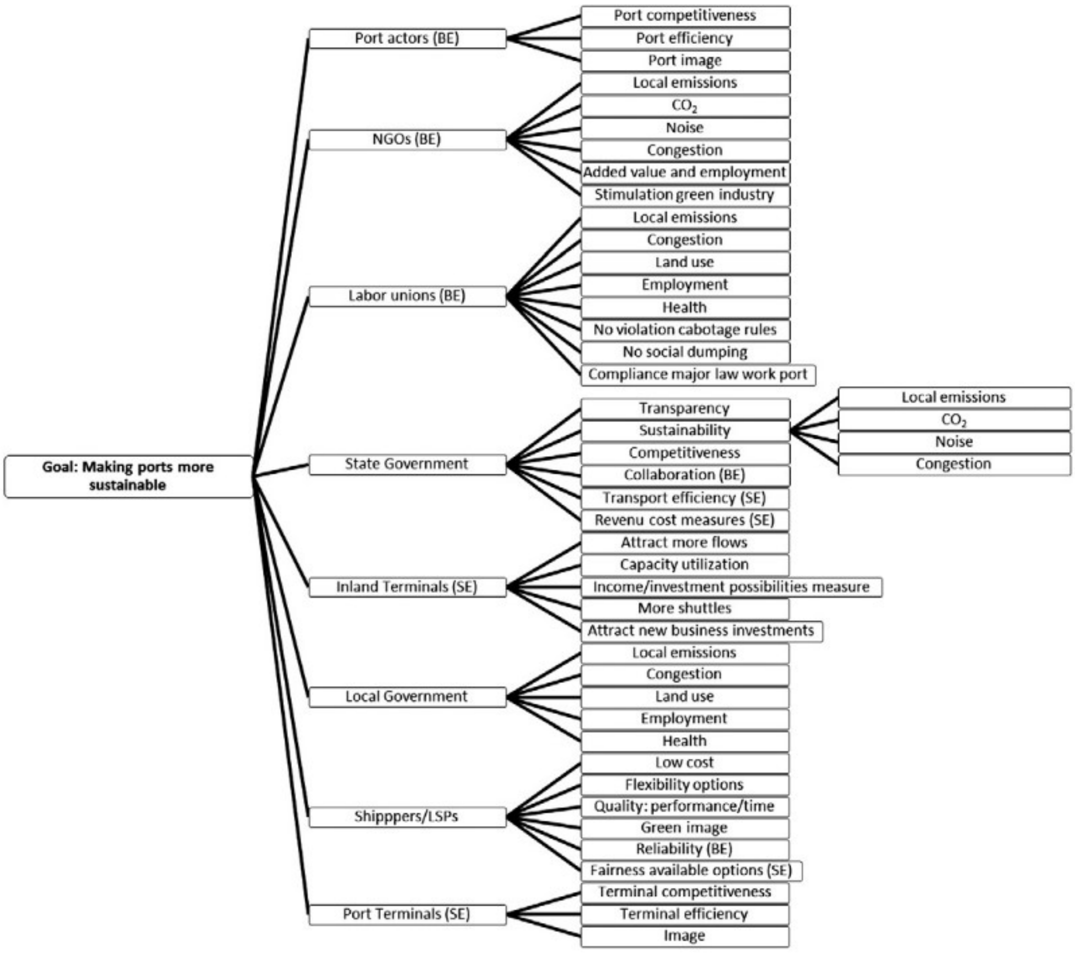


Figure 6-5 - Priorities of actors for making seaports sustainable.

Source: Bergqvist et al. (2015, p.83).

It is essential to recognise that the success of a dry port relies on actors who select the transport mode supporting an intermodal approach for the transport of goods.

The ultimate choice of transport mode is a mix of numerous factors in the supply chain with the interaction of the various actors, transport economics (pricing) and reliability, service frequency, commercial affiliations, transport distance, consignment size and established practices all having an influence (Meers et al., 2017). In a literature review of English and Swedish language documents, including grey sources, Flodén, Bärthel, and Sorkina (2017) identify the common factors of cost, transport time and reliability and service quality as important. Cost is identified as the primary selection factor and can include the cost associated with changing equipment and practices to move from one mode to another. The often-reported environmental advantages of rail transport are not ranked highly by transport mode selectors in their decision making and sit well behind the factor of cost. The results of the literature review are summarised in Figure 6-6, which shows the relationship between the decision making factors with cost as the primary benchmark, related choice qualifiers that must be satisfied and the factors that apply in particular circumstances. Secondary factors are service frequency, goods damage, and environmental impacts. However, information technology (track and trace capability) ranks as a low requirement. The important aspects have remained relatively stable over the 26 years (1990 to 2016) that the reviewed literature covered. This topic is further explored in Chapter 8: Freight Transport Modal Choice Survey.

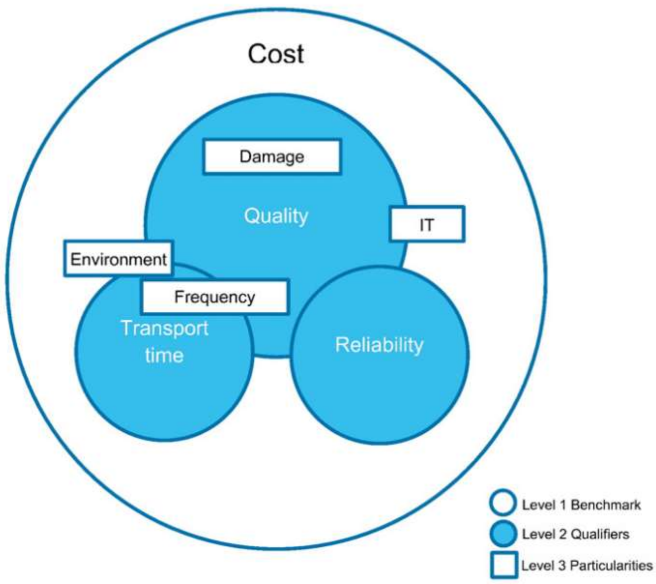


Figure 6-6 - Relationship between decision making factors.

Source: Flodén et al. (2017, p.40).

Seaport and dry port owners

Both seaport and dry port owners seek to maximise the supply chain throughput (Talley & Ng, 2017) and increase the hinterland serviced (Nguyen et al., 2021). These objectives lead to higher equipment utilisation rates, decreasing unit costs for handling providing economies of scale. However, it can result in longer terminal dwell times which can be contrary to customer objectives resulting in negative perceptions of the facility and possible throughput reductions. Counter to this is increasing market power as terminal throughput increases market share and provides power over suppliers to lower input costs and provide customers price reductions on bundled services (Protic et al., 2020). Growing competition between seaports to increase and protect hinterlands incentivises them to take on a co-ordination role in the supply chain to improve efficiencies, costs and capacity. The fourth generation in seaport development models reflects this role of the seaport as a co-ordinator.

Private investment in rail serviced dry ports is generally in a brownfield rather than greenfield location due to the capital expense of developing the rail network connection and the risk of stranding assets in the competitive market of road versus rail freight (DoIRD, 2017a; Liedtke et al., 2012; Sd+D, 2004). This topic is further discussed in Chapter 7: Dry Port Site Selection.

Seaports can promote a modal shift from road to rail by implementing modal quotas or port pricing. The application of a modal split clause included in a contract between DP World and the Port of Rotterdam is an example of this (Bergqvist et al., 2015). As previously discussed, this is not a favoured approach across supply chain actors.

Public sector actors

Public sector actors influence dry port development through zoning (land availability), utility and infrastructure provision and taxation regimes. Government approved seaport budgets can offer incentives for a modal switch from road to rail (Monios, 2011) or provide funding for the development of intermodal terminals to reduce investment barriers (Liedtke et al., 2012). The promotion of economic development and the expectation of reduced emissions and congestion (Rodrigue et al., 2010), with public sector actors promoting *"public good"* and *"social output"* (Baccelli & Morino, 2020), justify the public sector approach. Relaxation of labour regulations and a supportive customs agency improved supply chain performance in the UK (Garnwa et al., 2009).

The government also influences modal choice by seeking to internalise external transport costs (EU, 2019). In the German context, this is achieved by taxing transport modes in proportion to the negative impacts it causes or through payment of subsidies (investment grants) or granting of concessions that lower external costs (vehicle tax and weight limit concessions for drayage vehicles) and achieves a social payback, through supporting the development of intermodal infrastructure or increasing its (cost) competitiveness (Liedtke et al., 2012).

Liedtke et al. (2012) observe the high number of intermodal terminals developed and their subsequent replacement due to insufficient capacity or competitiveness and, through modelling, demonstrate over investment can be caused in established markets but are an effective mechanism in developing economies. This is discussed in Chapter 5: Development Models for Seaports and Dry Ports, where the Swedish experience supports this observation.

In a study of large seaports and associated hinterland systems de Langen and Chouly (2004) identify the importance of port authorities and public actors in providing an *"organising capacity"* to support the hinterland access regime. These entities can also contractually impose service obligations on service providers to ensure facilities and services that might not contribute to maximisation profits are provided (Lubulwa et al., 2011).

Monios and Wilmsmeier (2012a) identify the influence of other actors in the supply chain. Private operators seek returns through economies of scale and co-location of facilities. Garcia-Alonso, Monios, and Vallejo-Pinto (2019) show this in the Spanish context, concluding that distance to a seaport is the primary influence on seaport choice and provision of rail services (in what are relatively short haulage distances) is not. The choice of seaport used is a private operator choice whilst the provision of a rail facility is a public body decision.

Hintjens (2018) describes the role that port authorities have in bundling cargo streams to promote modal shift, lowering both internal and external costs through facilitation and internalising some of the costs to themselves as a path to reducing the external costs to the community and building overall trade flows.

Garnwa et al. (2009) compare the development of dry ports in the UK and Nigeria, providing insight into the roles and conflicts of the various supply chain actors. The public sector's role in dry port development in the UK was clear when customs instituted guidelines for “Inland Container Depot” development. The guidelines nominated that these dry ports must:

- Be located near major road transport and preferably have access to rail transport.
- Be available for use by all.
- Be established by consortia rather than individual organisations.
- Provide co-operation rather than competition between transport modes.

Customs importantly legislated for conducting customs clearance at the dry port. Privatisation of seaports in the UK promoted competition for freight and hinterlands, driving efficiency and price reduction in the supply chain.

Contrasted with Nigeria, where ports were initially run by the public sector and required customs clearance at the seaport coupled with poor rail and road infrastructure, dry ports have struggled to develop.

Public sector views are essential in the Australian context as three main container seaports, Melbourne, Sydney, and Fremantle, operate under a government port authority managed landlord model (Lubulwa et al., 2011).

Shippers (exporters) and consignees (importers)

Shippers and consignees will act to minimise the supply chain costs. These costs include not only the direct transport cost but costs associated with holding inventory, insurance and depreciation (Talley & Ng, 2017), and service level, which includes on-time delivery, transit period and timely information provision (Agamez-Arias & Moyano-Fuentes, 2017; Protic et al., 2020).

Cost minimisation is shown in the results of a stated preference study reported by Meers et al. (2017), in which short-haul (<300km) container transport cost is a 75% determinant of modal choice with reliability at 8%, duration at 4% and frequency at 3%.

The determinants of modal choice, including in the context of importers and exporters of containers, through the Fremantle Ports Inner Harbour are further investigated in Chapter 8: Freight Transport Modal Choice Survey, through a survey conducted on Inner Harbour container importers and exporters.

Transport operators - road and rail actors

Roso (2008) identifies the tension between road and rail transport providers and a powerful road transport lobby committed to retaining the road freight task as an impediment to developing the Minto intermodal terminal in Sydney. Road transport for freight into and out of Australian seaports is dominant over rail transport and highly competitive. However, the model of many small trucking organisations competing with a few dominant actors is inefficient and leads to higher freight costs (Lubulwa et al., 2011).

Road transport reflects the least complex hinterland transport chain (Van Der Horst & De Langen, 2008). Whilst road transport typically involves many small organisations, it is "relatively" easy to co-ordinate compared to intermodal systems as rail requires additional co-ordination due to the increased number of actor types (Acciaro & McKinnon, 2013).

Community actors and the environment

The growing awareness of environmental concerns associated with transport, both freight and private vehicles, by individuals, government and corporations is leading to greater consideration of the impacts freight transport is having on the environment and community in a general *"greening"* of supply chains. The community and environment are linked as the external transport costs impact the community directly or indirectly and generally adversely impact the environment.

Residents in proximity to seaports are essential actors in the supply chain, as government regulations in response to community pressure can impose additional freight costs. These costs can be in the form of restricted operating hours, vehicle size and noise restrictions primarily impacting road transport (Lubulwa et al., 2011). The growing activism of residents results from the concentration of (externalised) costs through containerisation but the dispersion of the benefits (Lonza & Marolda, 2016).

Overall environmental and community outcomes improve by a modal shift away from road transport to dry ports (EFIP, 2019b). However, the modal shift causes the balance of the burden of impacts to shift, from communities surrounding the seaport to those near the dry port. Dry port developers must address this as dry port development may be resisted by local residents due to the congestion and associated air quality and noise impacts, they bring (Flämig & Hesse, 2011; Roso, 2008). Behrends (2017) postulates that this movement of impacts can be addressed by local government adopting *"rail-adapted"* land use planning to separate rail and dry port locations, including main distribution roads, away from residential and commercial areas.

Modelling by Henttu et al. (2011) demonstrates that cost savings and CO_2 emissions reduction result from utilising a dry port and rail network compared to road-based approaches. Emission reduction in part results from reduced truck terminal queuing by introducing a dry port into the supply chain (Roso, 2007).

6.1.6 DRY PORT DEVELOPMENT TRIGGER POINTS

The trigger point for the development of a dry port can be considered in terms of the seaport lifecycle, Chapter 5: Development Models for Seaports and Dry Ports. The "extension strategy" that Monios and Bergqvist (2016) apply to the intermodal terminal lifecycle, based on the "restructuring phase" of Charlier (1992), can equally apply to a seaport where the development of a dry port is an approach implemented to reposition the seaport in the lifecycle and extend the maturity phase. Alternatively, as discussed in Section 5.1.4 Seaport Life Cycle Model, economic analysis can be the trigger to introduce a dry port into the supply chain without reaching other capacity constraints. This economic approach considers the dry port under an Outside-In development approach in the early part of the life cycle, whereby a port authority or terminal operator seeks to develop a new facility or enter into an arrangement with an existing dry port (Wilmsmeier & Monios, 2020).

In the analysis of decision making by Lovric et al. (2020), several of the factors explored in this thesis are included in a model to determine whether or not a dry port is a viable solution to the issues facing the seaport. The variability of each case and the inability to determine exact trigger points are recognised as specific modelling for the seaport dry port combination that requires evaluation (simulation) for the unique conditions. The use of multi-criteria analysis using the AHP method is applied to the decision making, consistent with the Westport study approach (Westport, 2020a).

The Westport study recognises the challenge of predicting when a trigger point is reached, as it relies on modelling future trade levels and associated logistics tasks and the impacts on hinterland links. Whilst the study looks at triggers for a new seaport development, many of these are the same as for the development of a dry port, and the decision can be between improving hinterland connectivity or moving to a new seaport location. *"Predicting the timings of when any of the six drivers [for development of* *the Outer Harbour] will reach their trigger points is problematic, as they are highly dynamic and influenced by variables outside of Westport's and the Government's control"* (Westport, 2020c p.39).

Various aspects need consideration to determine if there is a need for a dry port which then becomes a question of the viability of an intermodal rail freight solution against direct road transport. In the Australian context, DoIRD (2017a) identify several criteria or potential trigger points that, if reached, promote the development of an intermodal terminal:

- Minimum volumes to support a rail task.
- Satisfaction of the supply chain service requirements for frequency, transit time and reliability.
- The existence of necessary rail infrastructure.

Service satisfaction is discussed in previous sections of this chapter, and the rail infrastructure requirement in Chapter 7: Dry Port Site Selection.

Dry port container throughput

The consideration of container throughput needs to be approached from two directions. That of sufficient throughput to make a dry port economically viable and seaport throughput levels that impose high enough external costs on the community triggering an intermodal solution to lessen the impact, discussed in Chapter 4: Common Reasons for Dry Port Development.

Dry port design capacity and actual throughputs vary over a vast range. Actual and design throughputs vary between 2,000 and 3,600,000 TEU per annum (Jeevan, Chen, & Lee, 2015; Nguyen & Notteboom, 2018; Rodrigue, 2012; Roso & Lumsden, 2010; Roso, Woxenius, & Olandersson, 2006; Sd+D, 2004; Zeng et al., 2013)

Nguyen and Notteboom (2018), in a study of literature covering 107 dry ports around the world, determine an average annual throughput of approximately 172,000 TEU, with approximately half the studied dry ports having a throughput of under 70,000 TEU, skewing the results to many smaller facilities. The authors also establish dry port throughput as a fraction of the associated seaport(s) as 5% on average, again skewed to the low side with 50% having 1.7% or less of the traffic and 90% having less than 16.4% of the throughput. These proportions reflect the low share of rail (and other non-road) transport associated with seaports worldwide. Australia has a higher than average rail share of 10 to 11% (BITRE, 2019).

For a regional supply chain in Australia in 2004, a minimum throughput of 10,000 loaded TEU per annum is required for an intermodal terminal to cover cash operating costs, with a minimum operating level of 15,000 TEU per annum needed to be sustainable (Sd+D, 2004).

Minimum throughput levels are required to make dry ports financially viable. Related to this are throughput levels of seaports that necessitate the inclusion of a dry port in the supply chain to overcome inefficiencies that can arise as the seaport throughput grows.

The previously discussed prediction of growth rates is vital in understanding when these points will be reached to avoid either early and possible unsuccessful developments or allow loss of hinterlands due to inefficiencies and competition from other seaports.

6.1.7 DRY PORT LAND AREA REQUIREMENTS

Four primary characteristics determine the land area required for an intermodal terminal, the area for the rail operation, the handling of containers to and from rail wagons, warehousing and internal roadways (GHD, 2006).

Consideration of the rail siding length is a fundamental design criterion and, if possible, should facilitate the loading and unloading of complete train consists without breaking them up, which causes inefficiencies in both time and cost. The container yard area will be determined by facility throughput, average container dwell times and the type of loading and unloading equipment used. Container handling equipment will require different operational areas and have differing stacking abilities (ESCAP, 2017).

As throughputs vary widely, the area required for the operation of a dry port varies significantly from 0.8 to 1,600ha (Roso et al., 2006; Saka & Cetin, 2020; Zeng et al., 2013). A Nguyen and Notteboom (2018) review determines the average area of a dry port as 198ha, with 67% under 100ha and 50% under 45ha.

6.2 FREMANTLE PORTS

6.2.1 INNER HARBOUR

Location

The Western Australia location provides a supportive framework for dry port development. A history of government planning for intermodal terminals is discussed in Chapter 7: Dry Port Site Selection and a WA state government target for rail share supported by a freight subsidy to promote modal change.

Transport links

There are two transport modes for the transport of containers to and from the Inner Harbour, road and rail. Rail transport is through the NQRT with links to Kwinana, Forrestfield/Kewdale and Kalgoorlie (FPA, 2014b), and from here to the east coast of Australia and the future Kenwick facility (ARC, 2020). The rail extends to Bunbury in the state's southwest but is not used for container transport to or from the metropolitan area or the Inner Harbour.

Road links are depicted in Figure 6-7, with road freight from the north approaching the Inner Harbour along Port Beach Road and from the south and east being funnelled across the Fremantle traffic bridge and onto Tydeman Road.

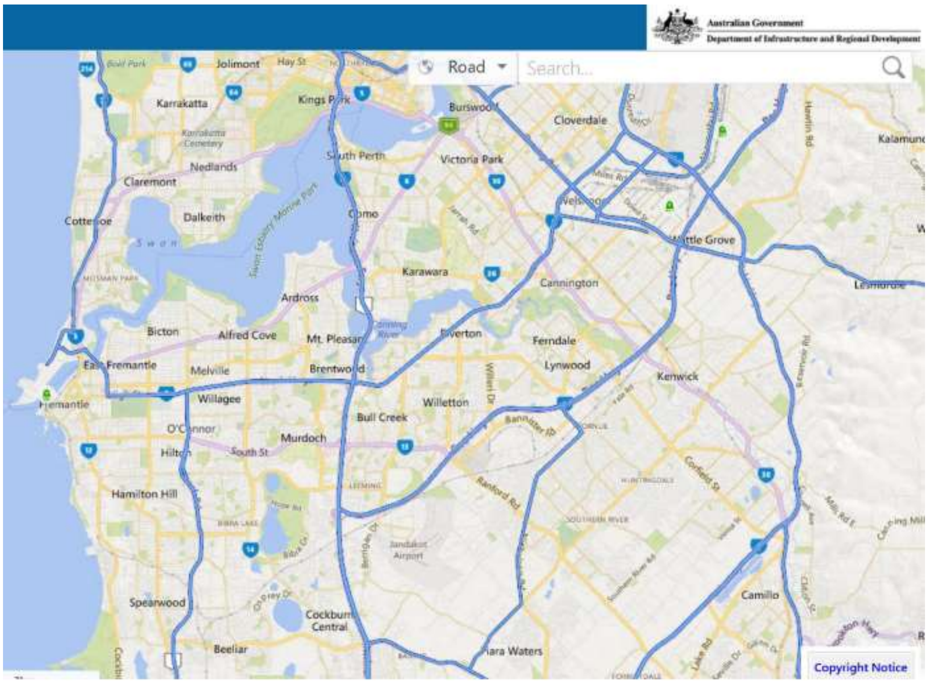


Figure 6-7 - Main road transport links to Fremantle Ports Inner Harbour.

Source: DoIRD website accessed 2/09/2019, DoIRD (2019b).

Road upgrades such as the grade separation of the Welshpool Road and Leach Highway intersection to improve the east-west road connectivity from the Inner Harbour to the Kewdale/Welshpool industrial areas are planned. The planning for the High Street upgrade between Carrington Highway and Stirling Highway will reduce congestion in the Fremantle area and improve road access to the Inner Harbour (McGowan & Saffioti, 2018; MRWA, 2018).

Fremantle Ports promote short-haul rail between the NQRT and Forrestfield/Kewdale and Kwinana to reduce road congestion in the Fremantle area and overall container transport costs, Figure 6-8 and Figure 6-9.

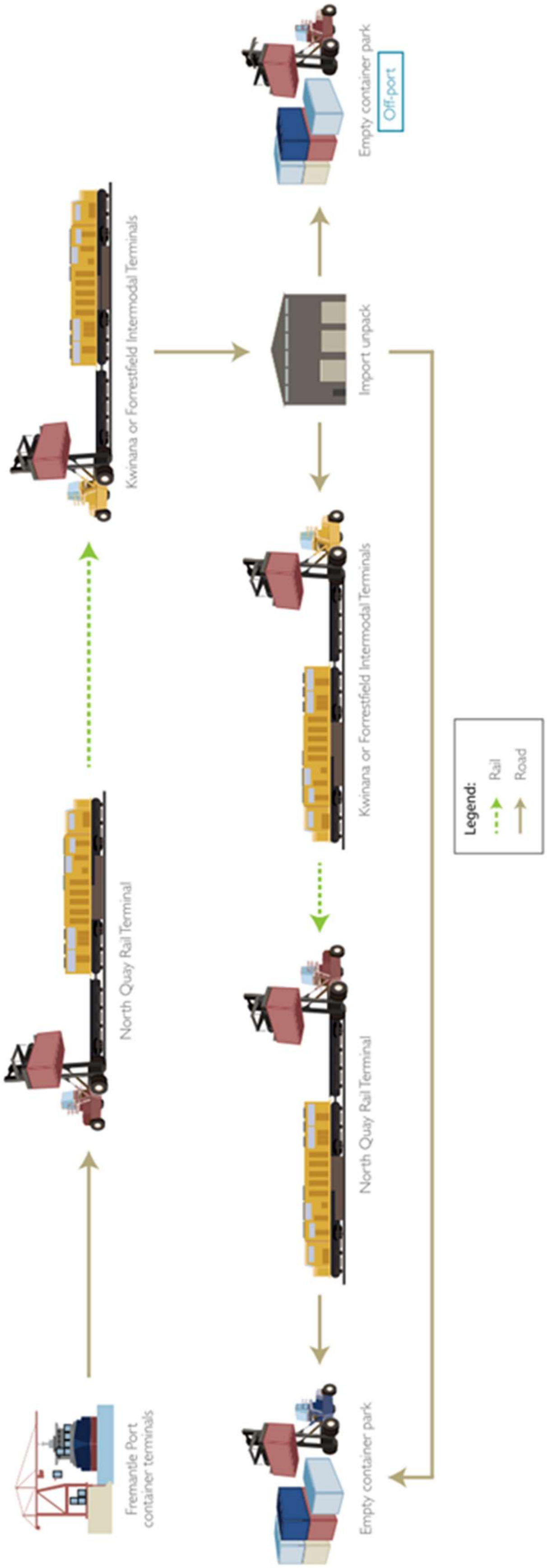


Figure 6-8 - Intermodal movement of containers through the Inner Harbour.

Source: FPA (2014b, p. 12).

Figure 6-9 - Rail link to the Inner Harbour.

Source: FPA (2016b, p.16).

Whilst reduction in road congestion can be rightfully claimed with consistently over 100,000 truck movements eliminated through the use of rail (FPA, 2019c, 2021a), externalised cost reductions rely, at least in part, on the state government subsidy, currently $50 per 20ft TEU equivalent. Despite improvements to the rail infrastructure, such as the development of the NQRT, the efficiency and capacity of the rail are hampered by sharing the line with passenger services on the Fremantle Transperth rail network, with passenger trains having priority over freight services. Rail improvements have advanced with a rail duplication on the Fremantle traffic bridge planned (Scaffioti, 2019; Scaffioti & MacTiernan, 2019); regardless, the route is very indirect (DOTARS, 2006b), and due to the cost and difficulty of finding an alternative route in metropolitan areas will remain that way.

The dry port definition requirement of a rail link of sufficient capacity to transport the required freight volumes is satisfied for the Inner Harbour situation. The rail route (once identified upgrades are complete) has sufficient capacity to satisfy the transport task, 30% of container movements, to the expected capacity of the Inner Harbour.

For the 2020/21 year, approximately 150,000 TEU were transported by rail, reducing truck movements by 103,000; each loaded rail consist removes approximately 60 truck movements (FPA, 2021a).

Actors involved

The Westport Steering Committee planning task force recognises the importance of engagement with the various actors in the Fremantle Port supply chain. The actors consulted during the study include existing Fremantle Ports port users, industry peak bodies, local government councils, members of state parliament, unions, conservation groups and community groups (DOT, 2017a).

The previous Liberal State Government defined its supply chain actor role as follows *"main roles in the development of the metropolitan freight transport network: planning and protecting the network, managing the network, building and maintaining the road network, and facilitating and selectively investing in strategic rail, intermodal terminal and port projects"* (DoT et al., 2016b p.2).

The contrast between state government political party approaches to seaport and dry port development is important. The Westport Study plans for an expansion based on government ownership of the Inner Harbour, whilst the previous Liberal government proposed and prepared for a long-term lease (privatisation) of Fremantle Ports, allowing for private investment in port facilities in the Inner Harbour and potential private development of the Outer Harbour (Barnett & Nahan, 2016; WA Government, 2015). The two approaches of how a future port manager may approach relationships with rail and dry port owners and operators are significantly different. As described in the literature, it is arguable that a private operator has different objectives than a state-owned port authority and will focus on primarily profit maximisation.

The role of regulators was evidenced at the Inner Harbour when the ACCC allowed stevedores to give preferential treatment to trucks engaged in dual runs (carrying a container in and out of the Inner Harbour) for five years ending in 2015, in an attempt to reduce congestion and increase terminal efficiency the benefits of which outweighed any public detriment resulting from the preferential treatment (Lubulwa et al., 2011). Affleck (2016) provides an interesting insight into actor behaviour, noting the impetus for trucks to be moving, empty or otherwise, rather than queue at the Inner Harbour, conflicting with the Fremantle Ports' efforts to maximise loaded truck movements.

Edwards (2018a) provides an industry viewpoint on the Outer Harbour development. Whilst not explicitly focusing on dry port development, common themes contrast with other actors, particularly the government owners of Fremantle Ports, regarding infrastructure improvement urgency and funding.

The FPA attempts to act in a co-ordinating role through stevedoring lease arrangements and the NQRT management contract to improve the alignment of seaport and transport operations. This action is hampered by the lack of a public actor freight track operator, making alignment of the commercial interests in the logistics operators in the Inner Harbour to Forrestfield/Kewdale dry port problematic (Hoffman, Chi, & Biermann, 2019).

Community and Environment

The community view is expressed at least in part through the Fremantle City Council's position on freight transport relating to the Inner Harbour detailed in the city's Integrated Transport Strategy (Fremantle, 2015). Whilst acknowledging the importance of the seaport, it seeks to reflect community views through emphasising a move away from road freight to rail whilst seeking to restrict rail activity and community impact and have funds directed to community benefit.

The range of views held in the community is evidenced by the discussion paper, Forma and MacGill (2018), which describes the history of the Fremantle Ports Inner Harbour growth as one of destroying historical buildings and causing unnecessary community impacts by the pursuit of growth in the container trade through the expansion of the Inner Harbour and development of transport links.

Two approaches are used to lower road congestion and the associated noise and pollution impacts of the Inner Harbour. Firstly, support for a modal shift from road to rail transport through the development of a quay side rail terminal in conjunction with a state government funded subsidy for full containers transported on rail. Secondly, Fremantle Ports' involvement with the Freight and Logistics Council, working to increase truck efficiency and intermodal transport share of the freight task.

Fremantle Ports uses three main approaches to reduce the impact of congestion. Work to decrease the number of unladen trucks entering or leaving the port, increase the carrying capacity of trucks to enable more containers per movement and spread activity outside weekday peak hours (discussed in the IT section below).

The percentage of unladen container truck movements has decreased since the commencement of truck surveys in 2002 to 2019 from approximately 27% to 2014 to approximately 24% since, despite an increase in truck numbers in the peak week day 12hr period from 1,350 to 2,030, (FMC Consulting, 2019).

Reflecting both a decrease in the proportion of unladen trucks and increased carrying capacity of trucks used the overall TEU per truck movement has increased from 1.31 in 2002/3 to 1.50 in 2018/19 (FMC Consulting, 2019), the TEU per truck falls to 1.44 in 2021(FPA, 2021a). From 2002/03 to 2018/19 TEU per loaded truck increased from 1.80 to 1.93 (FMC Consulting, 2019).

In the 2019 truck survey, 85% and 93% of container truck movements on Tydeman Road and Port Beach Road are between 6 a.m. and 6 p.m. on weekdays, with 93% of all movements occurring on weekdays (FMC Consulting, 2019).

The tension between road and rail transport actors is evidenced by the Transport Workers Union's response to additional services on the NQRT to Kewdale rail line, arguing for the use of trucks and improved roads over rail except in long-haul freight tasks (Elton, 2020).

Information Technology

Fremantle Ports use technology to improve truck efficiency. The three systems are, 1-Stop the VBS, ContainerChain for empty container park bookings and the Congestion Management System to manage queuing during peak periods in association with a truck marshalling area to reduce queuing on public roads and preserve the first come, first served, non-booked access regime (FPA, 2019f).

The Inner Harbour 1-Stop VBS mirrors the deficiencies associated with the practical application of VBS with impacts on truck logistics and potential inequality of the VBS identified by transport operators (Hall & Brindal, 2013; Limerick, 2014), and a mismatch between shipper and consignee pick up and drop offs and terminal operating times (FPA, 2014d).

The Intermodal Group operations describe an efficient IT system for booking and tracking containers through the NQRT/Forrestfield system (ILS, 2020) in support of the intermodal operations.

Trigger Points

With existing dry ports in place, a discussion of trigger points is not directly relevant to the Inner Harbour situation. However, the growing role of the intermodal transport task is reflected in the development of the new Kenwick intermodal facility and future planning for other Perth metropolitan area terminals.

Inner Harbour throughput is sufficient to support the operation of the dry port and forecast trade growth and the targeted increased proportion of container movements by rail, providing ongoing throughput support for the Forrestfield/Kewdale facility and future Kenwick terminal.

Operating areas for container storage, movement and other support operations have consumed the near dock container space at the Inner Harbour. Whilst additional area further from the quay front could be secured through relocation of other facilities this is less efficient. Reclamation of additional land or expansion of the seaport quay line and berth area in the Swan River is physically precluded from consideration due to natural and existing infrastructure impediments and cost.

6.2.2 OUTER HARBOUR

Transport links

The source or destination of containers discussed in the context of the Inner Harbour will not change overall because of the Outer Harbour development. The cost of relocating rail infrastructure and established commercial and light industrial areas precludes a significant relocation of activity. As the Inner Harbour will be retained as an operating container port, at least in the medium term (Westport, 2020c), there will develop a focus on different sectors within the current sources or destinations due to the slightly differing transport routes and seaport locations depending on the specific supply chain characteristics and economics of using the two seaport locations.

Both road and rail links will be established between the Outer Harbour and the existing Perth freight routes to the east. Rail will link with the existing Midland-Kwinana line and road links through an extension and upgrade to Anketell Road.

The same overall short-haul intermodal economics will apply to the metropolitan dry ports as exist for the Inner Harbour. However, the quayside facilities can be integrated into the seaport design and optimised in contrast to the NQRT introduced to an existing landside layout. The economics of road transport potentially improve with access to the road freight transport network without requiring travel through residential metropolitan areas and acts as a disincentive for intermodal options.

Actors involved

The general location for an Outer Harbour has the agreement of both major West Australian political parties (Buswell, 2011; WA Labor, 2016; WAPC, 2004), a critical consideration as Fremantle Port is government owned and requires government approval of development plans making the public sector a fundamental actor. The future development and locations of dry ports associated with the Outer Harbour will require support and approval by the government of the day.

The differing ownership approaches of the state government are addressed in the Inner Harbour discussion and as noted, would influence the relationships with rail and dry port owners and operators.

Edwards (2018b) argues that government should only set high level policy objectives for the Outer Harbour and allow businesses to design, deliver and ultimately operate the Outer Harbour and inland transport systems under a landlord model in a PPP model.

Community and the environment

The Outer Harbour is in a heavy industrial area, avoiding the near seaport congestion and community environmental issues (but not higher emission levels associated with road transport) associated with the seaport transport links to the hinterland that can serve as a trigger for dry port development.

Trigger Points

A quayside rail terminal will link the Outer Harbour development with existing dry ports, the trigger point reached at the time of construction when rail transport of freight is considered a viable transport mode from the new seaport to the hinterland.

Chapter 7: Dry Port Site Selection

7.1 LITERATURE REVIEW

7.1.1 INTRODUCTION

"*In practice, locating dry ports within already developed metropolitan space is a tricky balance between evidence-based land-use and transport analysis and the politics at the local, metropolitan, state and national scales*" (Roso et al., 2017 p.69). This observation reflects the complex interaction of all the actors and stakeholders along with the existing infrastructure in a supply chain in siting a dry port.

The development of an Australian metropolitan facility, Moorebank, described by Black, Roso, Marušić, and Brnjac (2018), supports the contention. The federal and NSW state governments identified Moorebank as a suitable dry port location in 2003 to support the growth of Port Botany container trade. The complicated development process involved public and private funding in developing an open access regime facility. The facility planned an ultimate capacity of 1.02M TEU per annum and needed environment approvals at both state and federal levels requiring significant environmental offsets and incurred significant community opposition based on traffic levels, increasing accidents, noise and air emissions in the area resulting in proposals to move the facility to a different location. The facility commenced operations in December 2019 (SIMTA, 2019), demonstrating a metropolitan dry port's long-term planning and development requirements. Monios and Bergqvist (2017) describe this extended development period as part of the dry ports' lifecycle model, requiring three to ten years for planning, funding and development with a further one or two years to find an operator.

Rozic et al. (2016) observe that site selection based on cost optimisation can be determined through mathematical models. In modelling an intermodal transport task to optimise modal shift in terms of cost and carbon emissions, Bouchery and Fransoo (2015) highlight modelling difficulties in determining actual emissions and costs. They further establish that in terms of intermodal terminal location, minimising either cost or carbon emissions results in different solutions to the location and note that the modelling approach helps establish policy and relative impacts on modal choice rather than exact location solutions. In a literature review, Agamez-Arias and Moyano-Fuentes (2017) conclude that modelling to optimise intermodal systems is based on cost minimisation and profit maximisation whilst observing a more recent trend to broaden the optimisation by linking resources and network actors. Mathematical modelling is likely to be only able to optimise one aspect for consideration in a dry port location determination, particularly in an established urban setting.

Location studies increasingly consider non-cost variables; infrastructure support, labour availability, environmental benefits and regulatory factors (Monios et al., 2018), alongside economic (Awad-Núñez, González-Cancelas, & Camarero-Orive, 2014), and social welfare factors (Awad-Núñez, Soler-Flores, González-Cancelas, & Camarero-Orive, 2016). Ng and Cetin (2012) discuss this interaction in consideration of location theory and its application to dry ports and the inherent tensions involved in considering economic and non-economic factors in location studies. The potentially inconsistent approaches of selecting locations close to market bases with those located strategically in the transport network to connect local and international destinations challenge the traditional dominance of transport cost-based analysis.

Evaluating the broad range of valid but sometimes conflicting factors requires multi-criteria decision analysis. One such multi-criteria decision making approach is the Analytical Hierarchy Process which has proved suitable for facility location selection (Yang & Lee, 1997) and *"occupies a special place"* in decision making relating to dry port development (Lovric et al., 2020). Using Bayesian Networks to provide weightings in the multi-criteria analysis is useful (Awad-Núñez et al., 2016). The use of a multi-criteria analysis approach in determining the optimum location of a dry port is supported by its application in the Westport study when considering future seaport options (Westport, 2019c, 2019e) (with seaports and dry ports being similar in that they are both nodes within a supply change and involve a transport mode transfer). The criteria presented in

Figure 7-1 reflect the broad range of factors influencing decisions, many of which are relevant to land-based dry port location assessment discussed in Chapter 2: Case Study – Fremantle Ports.

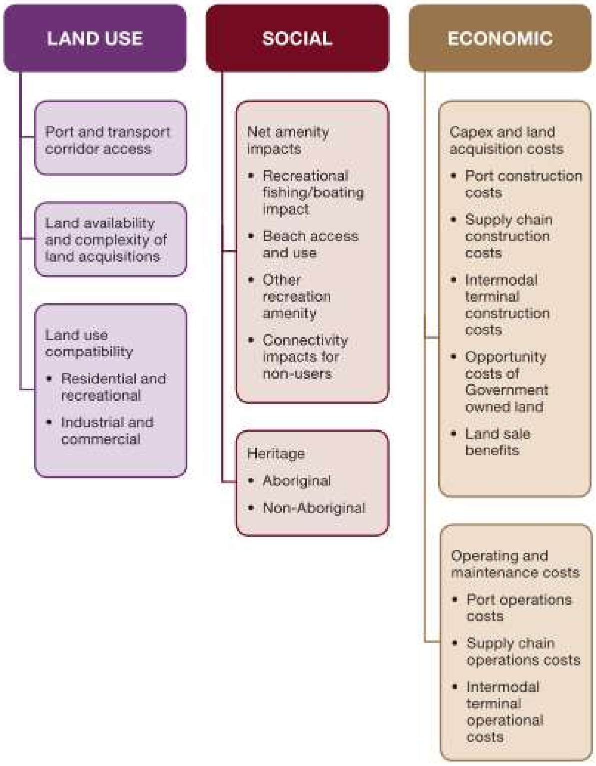


Figure 7-1 - Criteria and sub-criteria used in Westport option decision.

Source: Westport (2019e, p.2).

In a Vietnamese-based case study, Nguyen and Notteboom (2016b) use multi-criteria analysis to include the locational aspects of dry port site selection, such as sophistication of actors, the standard of transport and IT infrastructure, distribution of production and receival sites in addition to capital and operating costs.

Harrison (2008), seeking to classify inland ports for government planning purposes, provides an approach to site selection. It assesses areas currently operating as an industrial area, logistics centre or a site that shows *"logistics potential"* (Harrison, 2008 p5), evaluating them against five "*critical needs*", modal capability, existing demand, advantages of the location, relationship to international trade and presence of a management plan. Bergqvist (2013) supports these factors in examining a dry port development in Arriyadh, Saudi Arabia.

A fundamental factor in considering a dry port location is having enough land area for the facility, discussed in Section 6.1.7: Land Area Requirements. The following factors determine the area requirement, throughput, types and amount of transport equipment used, frequency of operation and co-housed operations such as warehousing, customs clearance, storage (GHD, 2006), and room to store empty containers awaiting repositioning if imports and exports are not balanced (Rodrigue & Notteboom, 2012). An estimate of the land area requirement for a possible terminal in the Kwinana area of Western Australia is presented in Table 7-1.

Table 7-1 - Kwinana terminal direct land area requirement.

Source: GHD (2006, p.86).

Throughput(TEU/yr)	Warehousing	Container storage	Rail Areas	25% (Circulation roads, car parking, misc)	Total Yard Area (ha)
200,000 Facility	10.5	3.5	12.0	6.5	**33**
400,000 Facility	21.0	7.0	18.0	12.9	**59**
600,000 Facility	31.5	10.5	18.0	15.0	**75**
1,200,000 Facility *	42.0	14.0	36.0	23.0	**115**

A dry port's success relies on efficient transport links from the seaport and good connections to the hinterland, a primary factor in considering a dry port location (Yang, 2007). Wiegmans et al., (2014), in a study of Dutch inland ports, show that proximity to main roads is a significant achieving throughput and growth (including bulk freight). This relationship necessitates considering the presence of existing transport infrastructure in site selection (Khaslavskaya & Roso, 2019).

Yang (2007) identifies the transport elements considered in a terminal location model, Figure 7-2. The inclusion of environmental issues in the modelling factors demonstrates the importance of environmental impacts in transporting goods.

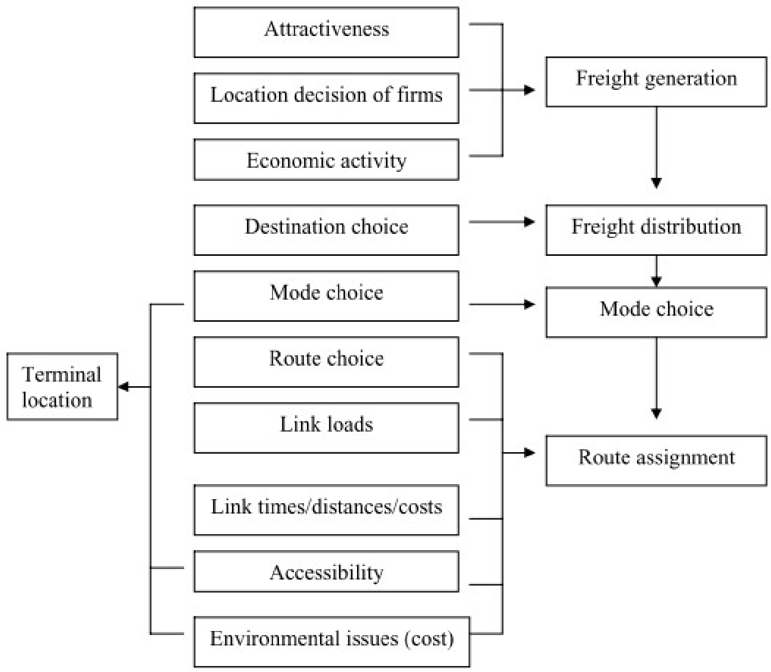


Figure 7-2 - Terminal location model transport factors.

Source Yang (2007, p.36).

Clear and coordinated policy positions between regulators regarding the factors surrounding dry port site selection are essential to avoid conflicts (Hanaoka & Regmi, 2011), with the range of factors presented in Figure 7-3.

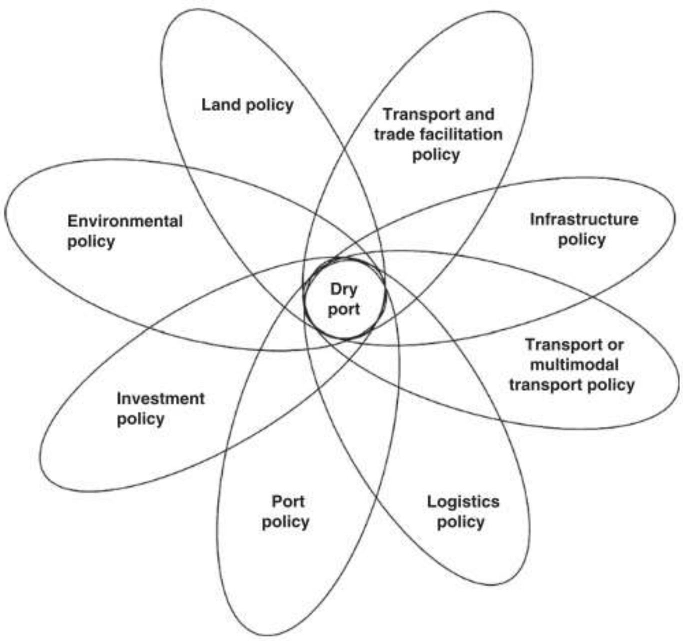


Figure 7-3 - Important policy areas for consideration in siting dry ports.

Source: Hanaoka & Regmi (2011, p.17).

The factors framed within the region's policy settings, or absence of policy, combined with the requirement for adequate space to house the required infrastructure, can be used as part of a candidate site selection process. An Analytical Hierarchy Process approach can rank the candidate sites. Saka and Cetin (2020) adopted this approach for site selection of a dry port in the hinterland of Kocaeli Ports (Turkey), which they conclude can be used for similar processes in different regions around the world. The claimed transferability supports identifying candidate sites with logistics potential and using an AHP approach to rank them.

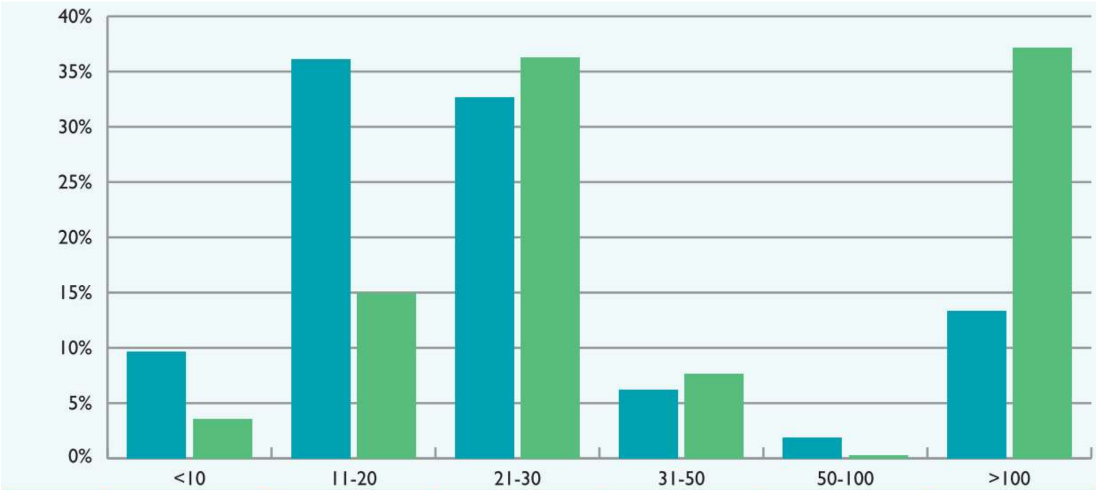
7.1.2 FREIGHT MOVEMENT IN PERTH

Short-haul rail

For the transport distances involved in rail freight from the Inner Harbour or a future Outer Harbour to the majority of goods destinations or sources, the cost structure of short-haul rail becomes an essential consideration as rail must compete with road transport. The short-haul rail requirement is typical of import and export supply chains throughout Australian ports (DoIRD, 2017a). It arises due to the high degree of urbanisation of the Australian population and the destination of containers being close to the import seaport in the capital cities (Ng et al., 2013). An estimated 75% of international trade is confined to metropolitan areas (ESCAP, 2015), resulting in very short train haulage distances of 20 to 30km to service the metropolitan dry ports in Australia (DOTARS, 2006b).

Whilst no specific distance has been established in the literature as a boundary between short-haul and long-haul rail, due to the need to consider the specific economics of each case, a general cut-off distance of 500km (Europe) provides a working basis for the distinction (Kim & Van Wee, 2011). A detailed examination of the differing cost structures and components between road and rail, and the resulting modal selection outcomes, including variation in break-even distance and factors that influence this, are discussed in detail in Chapter 6: Development Criteria for Dry Ports.

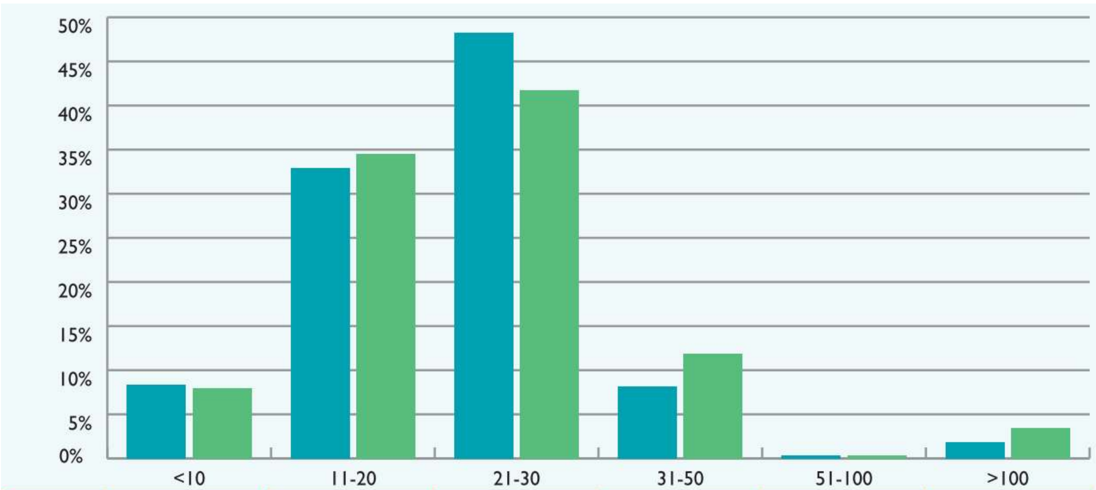
The 2017 FPA container study gives radial distances from the Inner Harbour to the destination or source of containers that pass through the Inner Harbour, Figure 7-4 and Figure 7-5. There is a contrast between the two, with very few import containers (3.5%) distributed to distances greater than 50km from the Inner Harbour compared to sources for export (37.5%). This disparity reflects the export of mining and agricultural products sourced outside the metropolitan area in contrast to imports. Imports are primarily for metropolitan sale or assembly and secondary treatment of imports, materials or goods (Hoffman, McLeod, Curtis, Braun, & Biermann, 2017). As imports dominate the container movements through the Inner Harbour, radial distances of less than 50km are the primary consideration for distance considerations in transport modal selection and lay well within the short-haul rail regime.



	<10	11-20	21-30	31-50	50-100	>100
2011	9.7%	36.1%	32.7%	6.2%	1.9%	13.4%
2017	3.6%	15.0%	36.3%	7.7%	0.3%	37.2%

Figure 7-4 - Radial distance from Inner Harbour to pack location.

Source: FPA (2017b, p.9).



	<10	11-20	21-30	31-50	51-100	>100
2011	8.4%	32.9%	48.3%	8.2%	0.3%	1.8%
2017	8.0%	34.5%	41.7%	11.9%	0.3%	3.5%

Figure 7-5 - Radial distance from Inner Harbour to unpack location.

Source: FPA (2017b, p.6).

Supply chain characteristics in Perth

An important consideration for the location, connectivity and size of dry ports in the Perth region is the source of the trans-shipped containers. Fremantle is a destination rather than transfer focused port (Toh, Oakden, Nagel, Sengpiehl, & Shi, 2008). Interstate and international trade, with minor intrastate activity, generate container movements. Currently, the two primary container sources are approximately in balance. Interstate containers are sourced from Melbourne and Sydney, with approximately half the incoming volume returned as export from Western Australia to the east coast. Rail-based interstate containers are handled through a Perth dry port even though they do not move through the Inner Harbour in the supply chain. The situation for these containers is a quasi-distant dry port. They are imported into an Australian east coast seaport and use the national rail land bridge to transport them to Western Australia (they may not come directly from the seaport but rather via a distribution centre/warehouse that could be part of a complex associated with an intermodal terminal). By contributing to terminal throughput, these containers support the development and operation of the terminals, which can also be close dry ports to the Fremantle Ports Inner Harbour. The containers' source and destination do not influence the physical handling required in the intermodal terminal. It is predicted that international (import/export) trade through the Inner Harbour will grow faster than interstate trade. When combined with a growing rail share, the Inner Harbour international container movements become increasingly significant in intermodal terms (DoT et al., 2016a). DoIRD (2017a) present different ratios of the interstate to international volumes, with only 20% being Inner Harbour sourced but agrees on the growth of international trade exceeding interstate trade and becoming of greater importance. In addition to the increasing modal share, the change results from population growth in Perth, enabling inventory to be sourced directly from Asia rather than distributed from east coast warehouses (WAPOTF, 2017). This change is an example of how a threat to an established hinterland (that of the east coast seaports) occurs by changing locational conditions.

Hoffman et al. (2017), in a review of road freight activity in metropolitan Perth, identified that Perth has relatively few supply chain types compared to other major cities. Three are important when considering dry ports related to container movements to and from Fremantle Ports terminals, Table 7-2.

Table 7-2 - Perth metropolitan supply chain types.

Source: Adapted from Hoffman et al. (2017, p.12).

Stream	Description	Origins	Destinations	Annual tonnage	Truck type
Imported goods	Goods from overseas and interstate into DCs and smaller storage units for distribution to stores and households. Includes small volumes to the east coast. Includes groceries, consumer goods, furnishings, industrial equipment etc	Port of Fremantle container berths; Rail terminals	DCs – Forrestfield, Hazelmere Distributors – all areas Stores – all areas Households – all areas Railyards – to the east coast	Fremantle 3.5M Railyards 1.5M	Semi-trailers with containers (sea freight and domestic);
Rural Exports	Grains, livestock, timber, mineral sands	Wheatbelt, Great Southern, South-west, Pilbara	Grain – CBH Forrestfield & Inner Harbour packers; Livestock – Wellard, Hazelmere & Inner Harbour; Timber – forests to Inner Harbour Wool – farm to Bibra Lake stores & Inner Harbour Mineral sands – mines to warehouses Henderson & Inner Harbour	Grain 0.2M Livestock 0.1M Timber 0.07M Wool 0.1M Minsands 0.65M	Grain – bulk tippers to CBH and packers, then semitrailers and B-Doubles with containers to port; Livestock carriers; Timber – specialist log carriers Wool – vans to stores, then container trucks Mineral sands – B-doubles with specialist containers
Mining inputs Project Cargo	Equipment, chemicals, grinding media	Fremantle, Railyards via transport depots	Goldfields, Pilbara	Pilbara 0.35M Goldfields 0.10M	Container carriers then B-Doubles and road trains

The freight movements show that much of the containerised freight passes through either the Inner Harbour or the Forrestfield/Kewdale rail terminals acting as dry ports. This route reflects the concentration of industry in the Forrestfield/Kewdale area, which is an importer of materials for the dominant industrial activity of assembly and secondary treatment of imports, materials or goods (Hoffman et al., 2017). The band of existing and future industry in the Perth outer metropolitan area, including the Forrestfield/Kewdale area, is depicted in Figure 7-6.

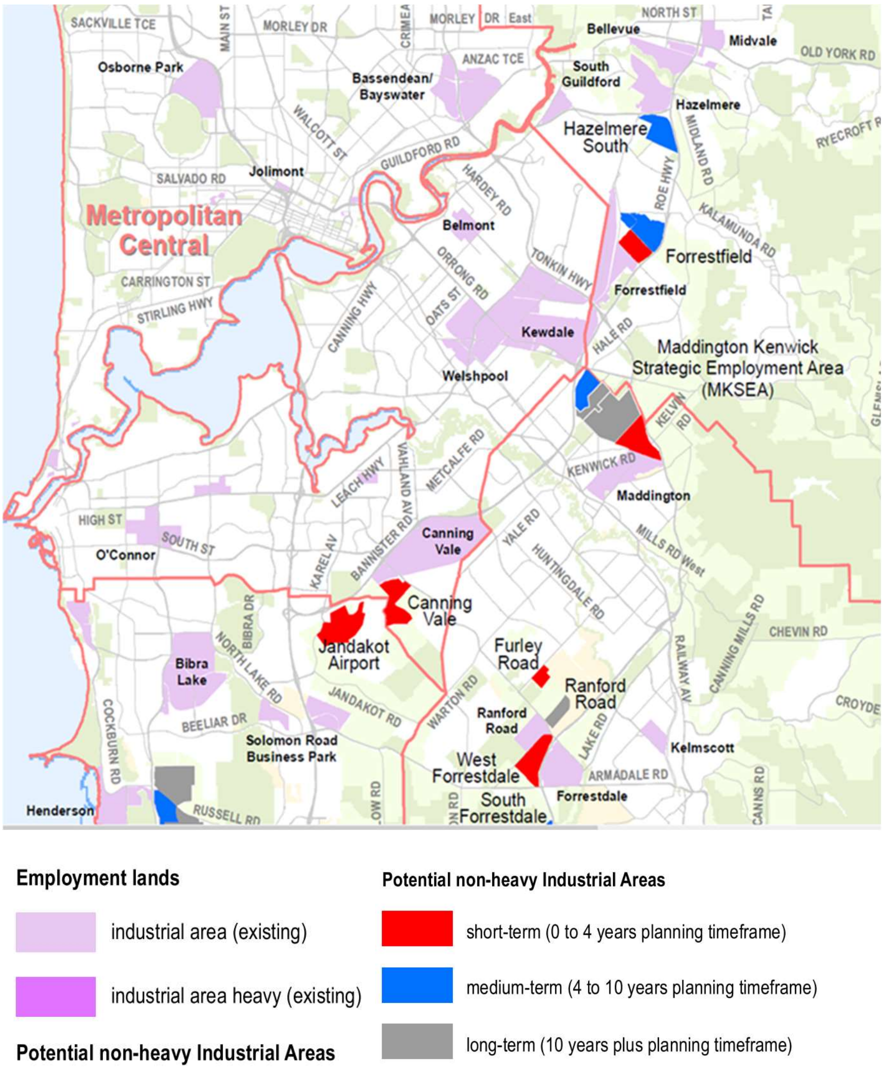


Figure 7-6 - Existing and future non-heavy industry in the central Perth area identified in 2012.

Source: WAPC (2012, separate map).

Fremantle Port Authority has conducted four container movement studies (FPA, 2004, 2012a, 2017b; FPA & WAPOT, 2011). For potential dry port candidate sites, the information gathered concerning container origins, destinations and intermediate stops is of interest for the reasons presented in the 2004 report, Table 7-3, and relates to potential dry port locations. Other factors can be employed to improve road transport. These are not directly related to considering a dry port location except to the extent that the direct, efficient, high-capacity link to the seaport or the overall efficiency and capacity of the road links could be improved. This link is essential for the Inner Harbour as it is transport links rather than the actual terminal capacity that ultimately limits Inner Harbour capacity.

Table 7-3 - Data use from the 2004 FPA survey.

Source: FPA (2004, p.7).

Data Required	Why is it needed?	How will it be used?
1. Ultimate origins and destinations of containers to and from the port.	▪ no recent data exists ▪ previous data did not capture much regional trade ▪ to provide a definitive understanding of the destination of imports and the source of exports	To assist with planning for : ▪ landuse ▪ freight network ▪ location of inland freight terminals
2. Intermediate origins and destinations	▪ to understand the whole of the transport chain between port and consignee / consignor ▪ to identify the extent of multi leg journeys ▪ to understand why containers are being moved between locations ▪ to identify where a mismatch of working hours has generated additional container handling	To assist in: ▪ developing policies and programs geared towards optimising transport efficiency ▪ considering appropriate locations for empty container parks.
3. Determine movement of empty containers	▪ limited existing understanding of how the transport chain for empty containers operates ▪ understand how, where and when empty containers are sourced and stored	Planning for: ▪ inland freight terminals ▪ empty container parks
4. Identify transport mode	▪ to verify modal split in transport task	▪ to plan for increasing attractiveness for rail ▪ to monitor progress towards achieving rail usage targets

The FPA 2017 container movement study report provides valuable comparison data on sources and destinations across the three studies. Sources of container packs for exports are described in Table 7-4 and depicted in Figure 7-7.

Table 7-4 - Pack locations from container movement studies.

Source: FPA (2017b, p.6).

Location	2004	2011	2017
Bayswater/Morley/Malaga	2%	2%	3%
Inner Harbour	2%	9%	3%
Kewdale/Forrestfield/Welshpool	16%	25%	30%
Canning Vale/Jandakot	*	5%	3%
Kwinana/Rockingham/Naval Base/Henderson	5%	26%	12%
O'Connor/Spearwood/Bibra Lake	18%	8%	5%
Outer Perth**	9%	7%	2%
Perth Central	5%	2%	3%
Country	43%	16%	39%

* Note: 2004 totals included in Kewdale.

** Note: Some areas that may previously have been considered Outer Perth, such as Hazelmere, Midvale, etc. are now in the Kewdale/Forrestfield locus.

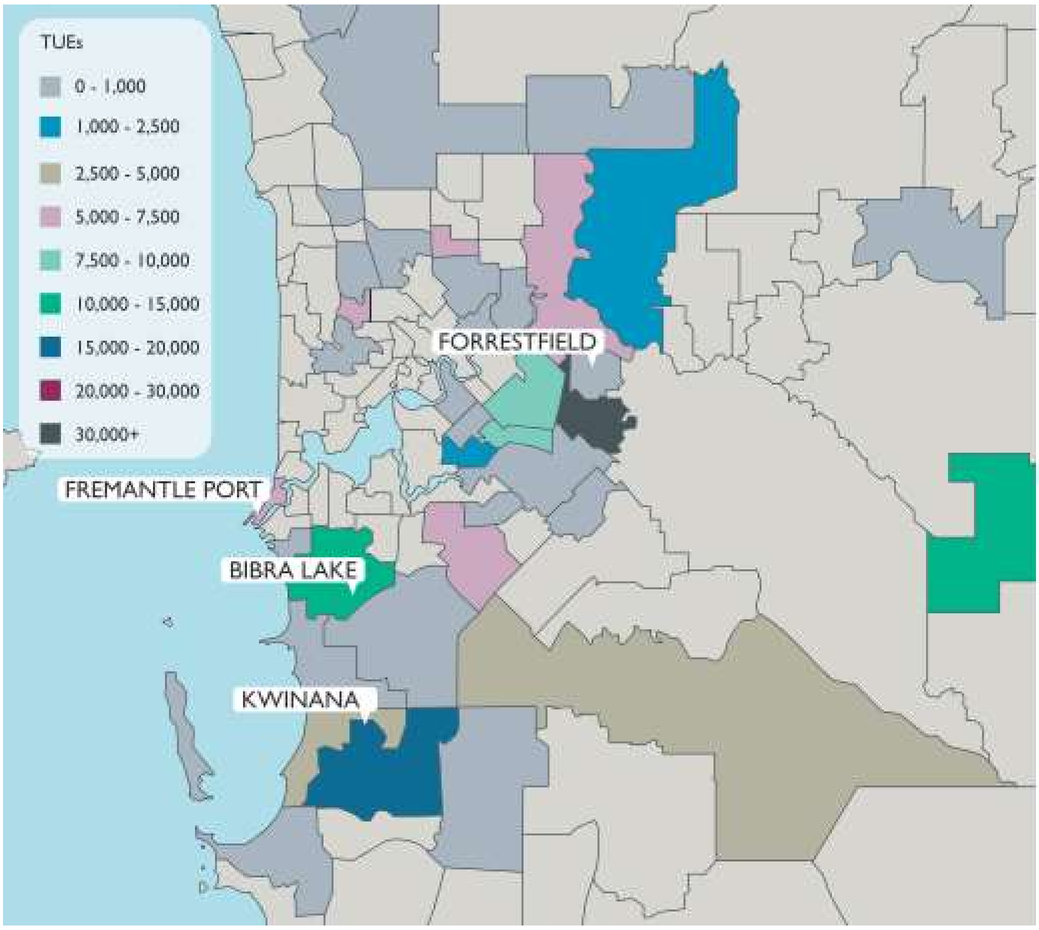


Figure 7-7 - Map of container source packs in the Perth region.

Source: FPA (2017b, p.8).

The location and distribution of unpacks of containers from imports are described in Table 7-5 and depicted in Figure 7-8.

Table 7-5 - Unpack locations and distribution from container movement studies.

Source: FPA (2017b, p.6).

Location	2004	2011	2017
Bayswater/Morley/Malaga	6%	8%	9%
Inner Harbour	3%	6%	7%
Kewdale/Forrestfield/Welshpool	39%	35%	41%
Canning Vale/Jandakot	*	10%	19%
Kwinana/Rockingham/Naval Base/Henderson	2%	3%	4%
O'Connor/Spearwood/Bibra Lake	14%	16%	10%
Outer Perth**	5%	10%	2%
Perth Central	11%	10%	5%
Country	20%	2%	3%

* Note: 2004 totals included in Kewdale.

** Note: Some areas that may previously have been considered Outer Perth, such as Hazelmere, Midvale, etc. are now in the Kewdale/Forrestfield locus area, while others, such as Wangara and Balcatta are now considered in the Malaga locus area.

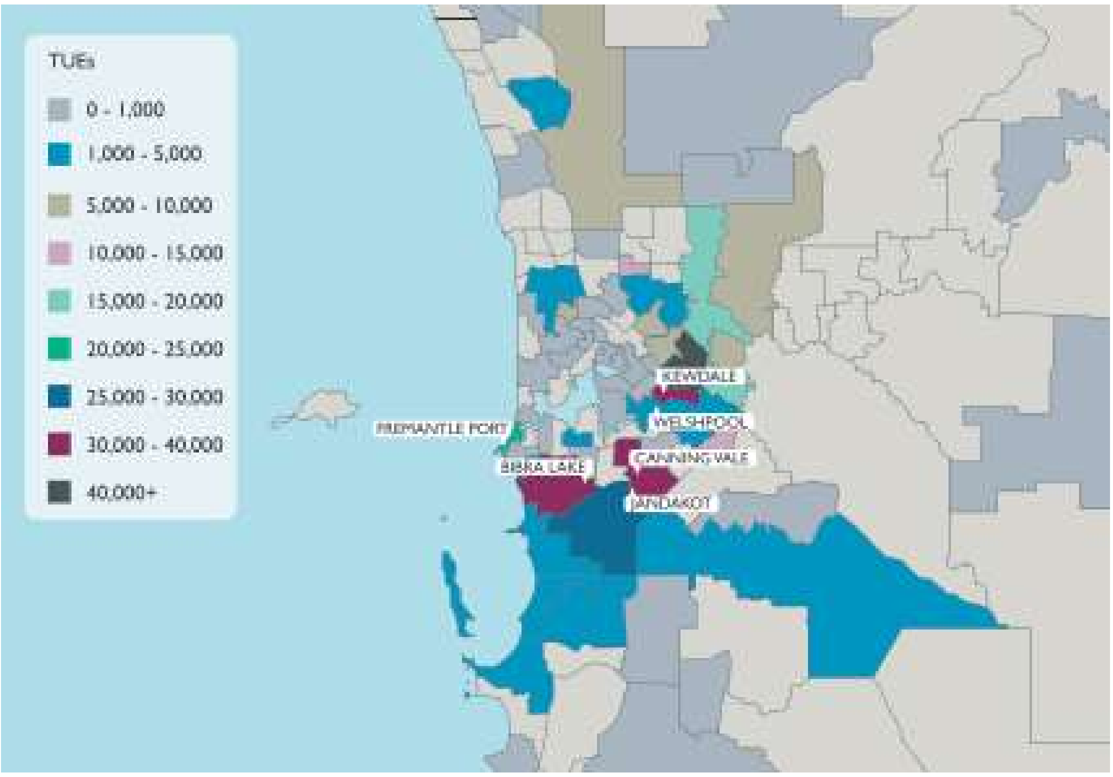


Figure 7-8 - Container unpack locations and container numbers in the Perth region.

Source: FPA (2017b, p.6).

The correlation between unpack locations identified in the container studies closely matches the industrial areas identified by the WAPC (2012) and Hoffman et al. (2017) with 60% of unpacks occurring in Kewdale, Forrestfield, Welshpool, Canning Vale and Jandakot.

For terminals in the metropolitan area, the location needs rail access in place due to the difficulty and expense of developing new rail through metropolitan areas.

7.1.3 EXISTING AND POTENTIAL CANDIDATE SITES IN PERTH AND SOUTHWEST WA

Over the last 20 years, there have been many WA state government studies and responses by stakeholders covering industrial site location, transport corridors and new seaport locations that enable the identification of dry port candidate sites in the Perth area. The government planning documents primarily consider the current and possible future terminals as intermodal terminals from a rail freight perspective, rather than including the seaport activity resulting in a dry port. For this thesis, as all sites in Perth and southwest Western Australia ultimately connect to the Inner Harbour, they are included in the definition of a dry port.

The factors described in the literature that influence site selection relates to intermodal site availability, as evidenced in the following excerpts from several WA state government agencies planning documents. *"intermodal rail terminals can be developed on any suitable site with a network connection. While finding a suitable greenfield site can be challenging in congested cities, locations tend to be available on the outer industrial edges of the cities where land is more available and less expensive. Complementary facilities (e.g. warehouses and distribution centres – DCs) can also be co-located in the precinct which can reduce the total end to end cost of general freight transported on rail services through reduced container PUD (pick-up and delivery) costs, thereby driving terminal throughput"* (DoIRD, 2017a p.12), within the Perth region, *"Intermodal terminals need to be considered in the context of specific supply chains, port locations and road and rail networks."*, (DoT et al., 2016a p.44) and *"not all centres will be suitable locations for intermodal terminals. It is important that terminals are located near the business markets they will serve and are linked to high-capacity, high-productivity road and rail routes. The number of locations suitable for intermodal terminals will therefore continue to be limited and the Government will take a proactive approach to reserve these valuable lands to* *service the future freight task"* (DoT et al., 2016a p.42), *"the economies of scale essential for the commercial viability of the transport and logistics sector require Government to form integrated industrial land use and transport planning frameworks that allow for the development of a relatively small number of large intermodal terminals rather than a large number of small terminals distributed across the metropolitan area"*, (DoT et al., 2016a p.44) and *"a key issue for the Government is the location of additional intermodal capacity in Perth – whether development priorities should continue to be focused in the metropolitan central area or elsewhere. While the Kewdale and Forrestfield precincts have the advantage of existing infrastructure, there are strategic reasons for development priorities to also focus, longer term, on a select number of new large intermodal terminals away from this dominant precinct. This should be towards both the metropolitan south-west and north-east areas where strong freight growth and major greenfield infrastructure development is expected."* (DoT et al., 2016a p.44).

The primary freight handling and freight distribution centres in the Perth metropolitan area are Fremantle (Inner Harbour), Kwinana (heavy industrial area, Outer Harbour and area for new container handling port), Kewdale (intermodal terminal and dry port), Forrestfield (intermodal terminal and dry port) and Perth Airport (DoT et al., 2016a; DPI, 2002; Hoffman et al., 2017).

The characteristics and capacity of intermodal terminals, based on 2015 data, currently in operation in the Perth metropolitan area are presented in Table 7-6.

Table 7-6 - Intermodal terminal capacity.

Source: Adapted from DoIRD (2017a, p.28 and 64).

Terminal	**Kewdale**	**Forrestfield**	**Forrestfield**	**Forrestfield**	**North Quay**
Terminal Owner	PN	SCT	AZ	ILS/ICS	Port of Fremantle
Terminal Operator	PN	SCT	AZ	ILS/ICS	ILS/ICS
Rail Operator	PN	SCT	AZ	ILS/ICS	ILS/ICS/PN
Short-term capacity TEU (no major upgrade)	500,000+	200,000+	200,000+	100,000+	200,000+
Services per week	21+	5+	5	14+	14+
DC's and w/house	Yes	Yes	No	No	No
Multiple access	No	No	No	No	Yes
Trade type	Both	Domestic	Domestic	Import/Export	Import/Export

Forrestfield/Kewdale precinct

The Forrestfield/Kewdale area is a location of national importance, Figure 7-9, Figure 7-10, Figure 7-11 and Figure 7-12, as a focal area for intermodal services due to its connectivity with Fremantle Inner Harbour, major roads, rail and the Perth international airport (FLCWA, 2004; GHD, 2006; Shire of Kalamunda, 2016; WAPC, 2006). The facility handles international, interstate and intrastate freight.

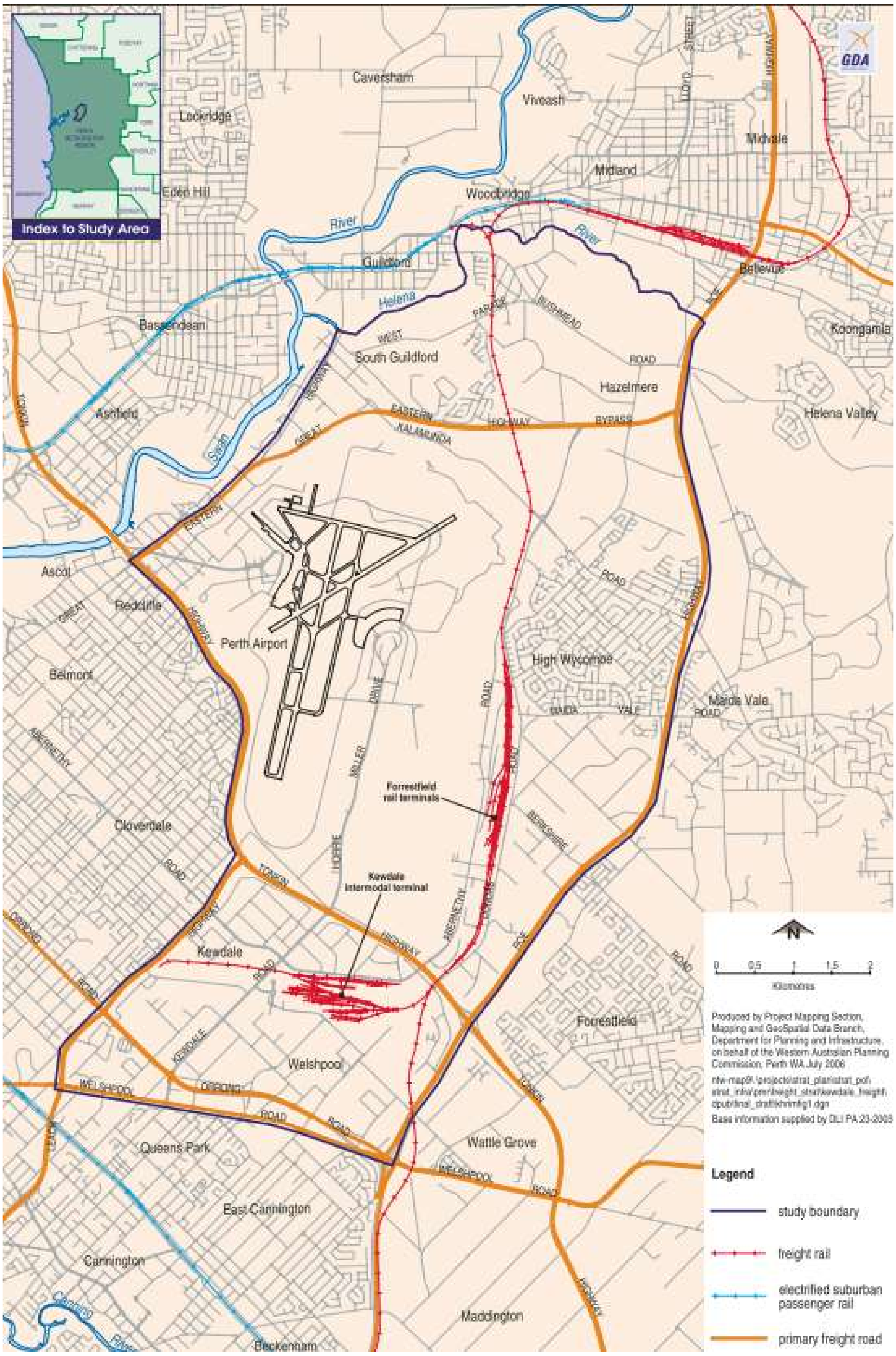


Figure 7-9 - Significant freight centres and transport links.

Source: WAPC (2006, p.4).

Figure 7-10 - Forrestfield/Kewdale hub.

Source: FLCWA (2004, p.2).

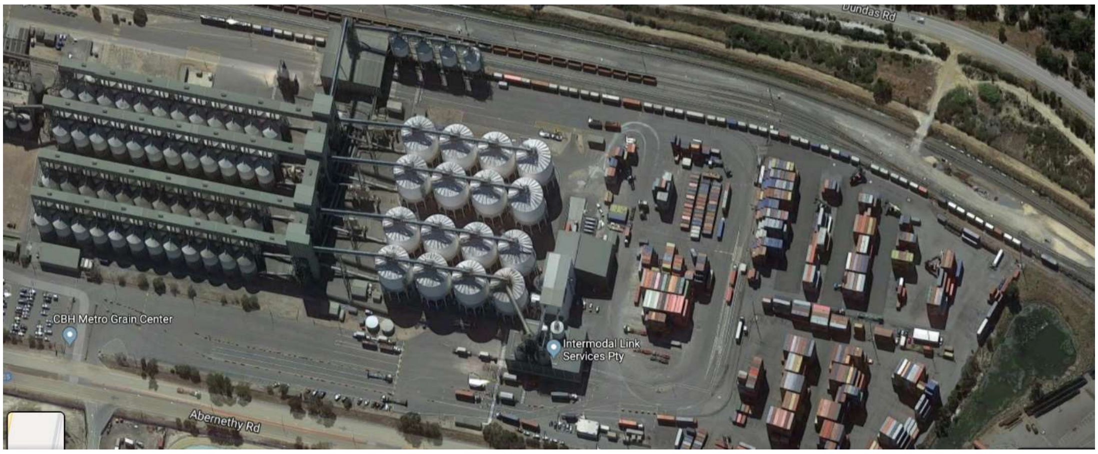


Figure 7-11 - Forrestfield Intermodal Terminal, IML facility and CBH grain loading facility.

Source: Google Maps (accessed 14/9/2019).

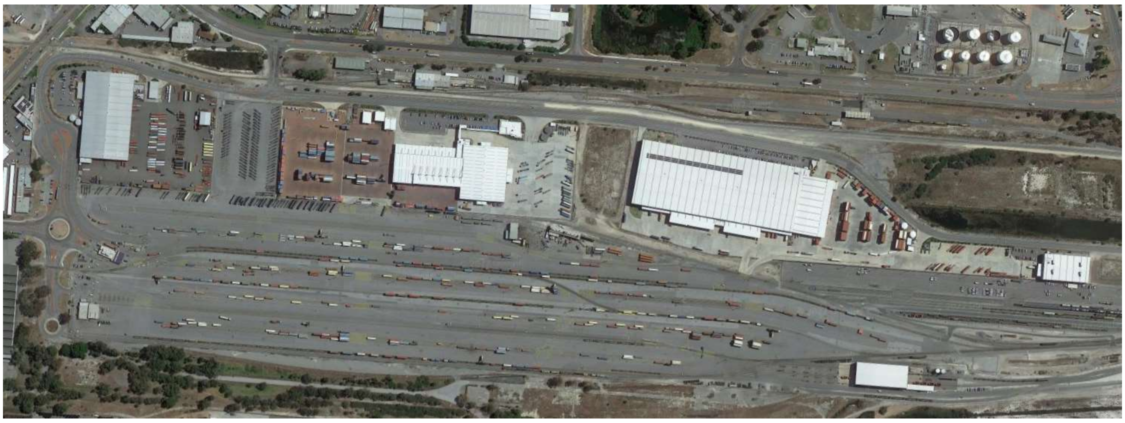


Figure 7-12 - Arial view of Kewdale Intermodal Terminal.

Source: Google Earth (accessed 09/11/2022).

Kenwick facility

A dry port is being developed in Kenwick adjacent to the Roe Highway Logistics Park, Figure 7-13, with an annual capacity of 200,000 TEU, a 2,000 TEU empty container park and 1,000m standing rail siding (ARC, 2020). The Kenwick Intermodal Terminal will have direct rail links to NQRT (ARC, 2019). Rail work is currently underway and is due for completion in late 2021 (PTA, 2020),

Figure 7-14. The Kenwick Intermodal Terminal has road links to major freight roads, Roe Highway and Tonkin Highway (RHLP, 2021). This site, also identified as Kewdale T2, with a potential (conflicting) annual capacity of 300,000 TEU, and in conjunction with the capacity at the existing facility in Kewdale, provides the required long-term needs of the Inner Harbour (DoT et al., 2016a). This capacity equates to a rail transfer of approximately 400,000 TEU per annum, and at 30% of the Inner Harbour container movements equals the 1.2M TEU Inner Harbour limit that is considered the transport constrained working capacity of the Inner Harbour (Chapter 2: Case Study-Fremantle Ports).

This is an example of a location contemplated in the academic literature, a brownfield site with clear logistics potential.

Figure 7-13 - Roe Highway logistics park adjacent to the Kenwick Intermodal Terminal.

Source: RHLP (2021, webpage accessed 24/11/2021).

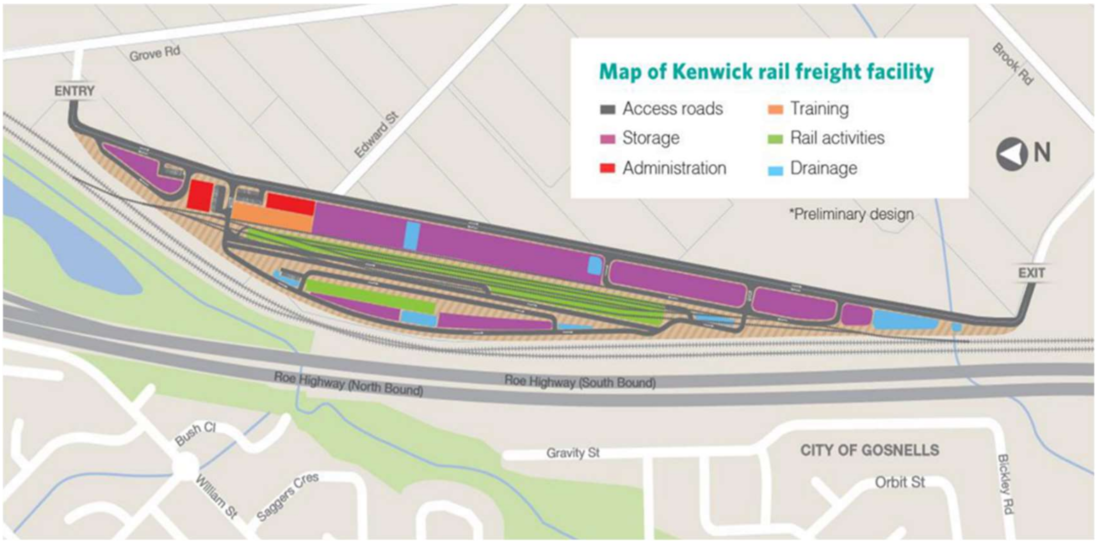


Figure 7-14 - Layout of Kenwick rail facility.

Source: PTA (2020, webpage accessed 24/11/2021).

Forrestfield/Kewdale/Kenwick group

An assessment of the Perth metropolitan intermodal terminal network by WAPOTF (2017) recognises that the NQRT capacity to meet the 30% rail modal share needed matching to these dry ports' existing and future capacity. The timing of completion of Kenwick is important to ensure sufficient container traffic exists to support three terminals as there is a risk of over-investment creating excess capacity. The growth in rail modal share and overall container freight through the Inner Harbour are the determining factors. The combined capacity of the three sites ranges from 325,000 to 525,000 TEU per annum. This capacity compares with the average 2018/19 to 2020/21 year value of 155,000 TEU transported by rail to and from the Inner Harbour (FPA, 2019c, 2020, 2021a), which, allowing for interstate trade of an equivalent number, is still under the lower capacity estimate for the facilities.

Kwinana facility

In its most basic form, a dry port exists in the Kwinana rail yards located approximately 3km south of the proposed Outer Harbour adjacent to Anketell Road. A reach stacker performs the container transfer, moving containers from trucks to a hardstand area and then onto rail wagons, Figure 7-15. The study into the Rowley Road Outer Harbour location did not consider upgrading this location to a more functional dry port.

Figure 7-15 - Kwinana rail yards.

Source: Google maps (accessed 27/01/22)

The potential dry port site selection and development process for a future Outer Harbour in the Kwinana Rowley Road area demonstrates the complexity of developing a dry port in a developed area and the competing values and goals of actors. Whilst the study will be revisited with the Westport nominated Outer Harbour location adjacent to Anketell Road (Rowley Road being north of this location), an examination of the work undertaken in identifying a site and planning a dry port is warranted.

Kwinana offers potential for a candidate site as areas of suitable size with proximity to rail (Midland – Kwinana rail line), road networks planned or existing (Rowley and Russel Roads), cargo catchment and distribution are in the area. The location is consistent with the land use planning policy (GHD, 2006, 2007; WAPC, 2009a). To develop an integrated intermodal terminal and logistics centre with the capacity to handle the large number of empty containers created by Western Australia's trade imbalance (significantly more imports than exports) for the Outer Harbour, an area of approximately 170Ha (capable of handling over 1.2M TEU per annum) would be required (DoT et al., 2016a). A site identified in the Latitude 32 Industry Zone between

Russell and Rowley Roads has both an area available for development and access to previously considered potential Outer Harbour development sites, Figure 7-16.

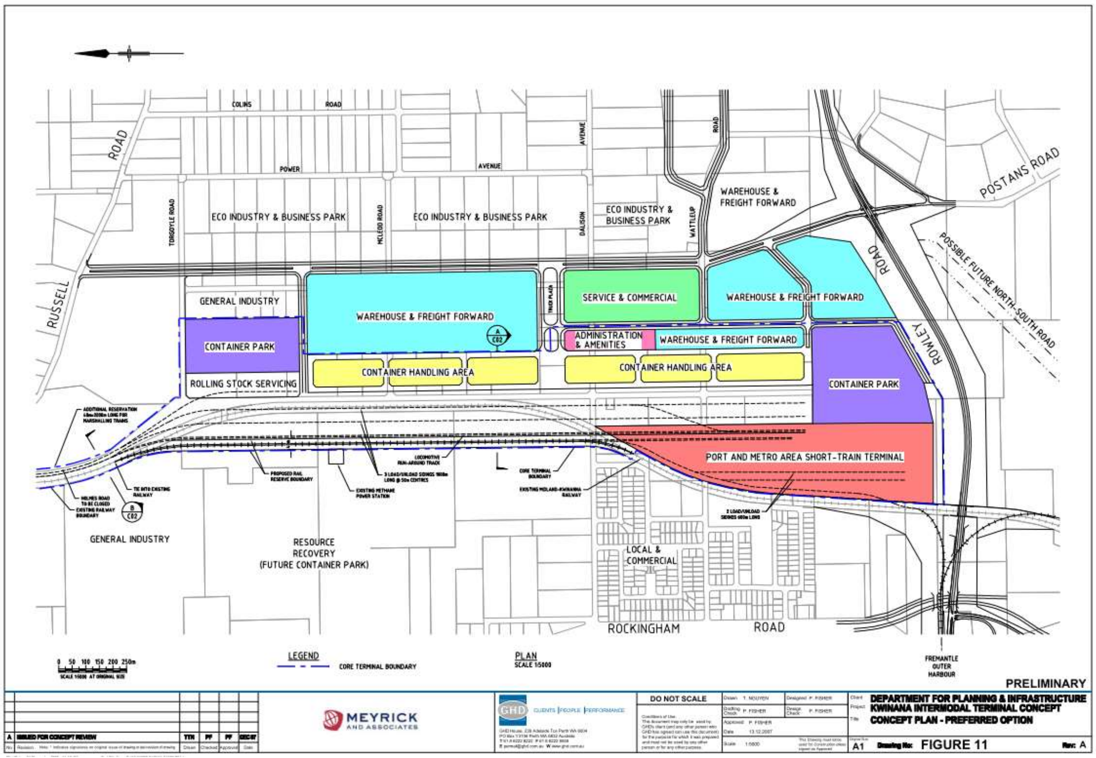


Figure 7-16 - Candidate site in Kwinana (Latitude 32) with connections to possible Outer Harbour location.

Source: GHD (2007, p.44).

This site indicated as the “government nominated” area in Figure 7-17 is an outcome of a study of intermodal terminal candidate sites. The GHD (2006) report was commissioned to recommend the location of additional intermodal capacity in Perth, particularly whether an expansion in the Forrestfield/Kewdale area or opening up a new terminal away from this site is justified. The reason for establishing a second terminal location is to reduce the risk to the intermodal network through distributed terminals and lessen the impact on local communities in the Kewdale area. Kwinana is a location with attributes necessary for an intermodal terminal. The planned role of the terminal was servicing interstate and growing intrastate demand for intermodal facilities with an additional international intermodal location required for a future Outer Harbour.

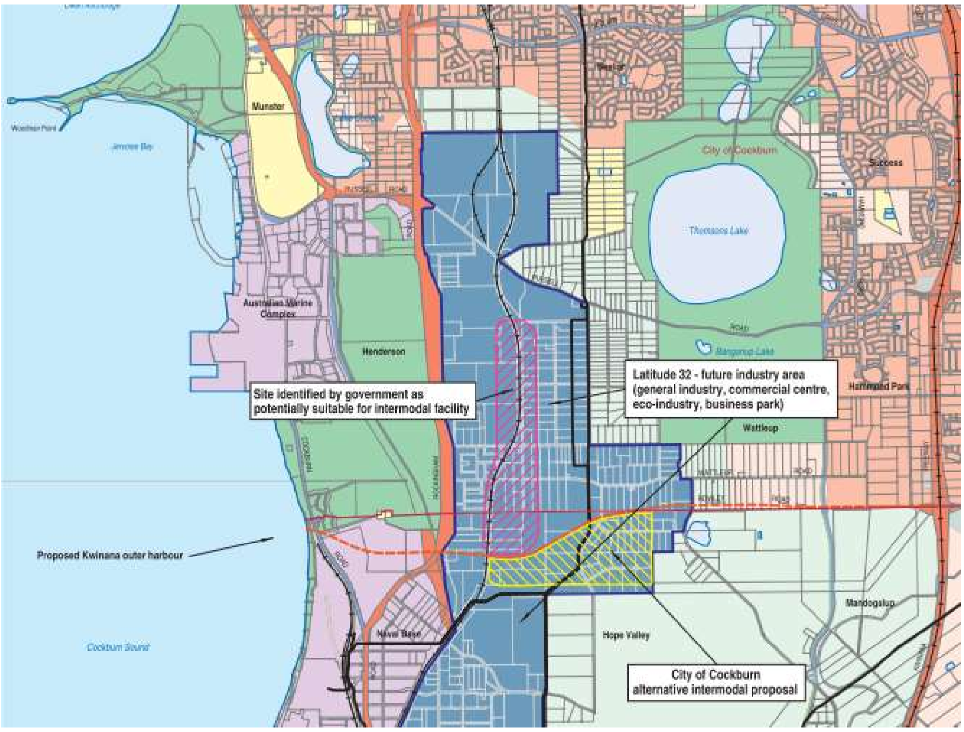


Figure 7-17 - Candidate site in Cockburn.

Source: WAPC (2009b, p.1).

The state government Freight Network Master Plan (DPI, 2002), recommended commencing planning for the expansion of or additional intermodal facilities in these locations, recognising the importance of the intermodal terminals at both Forrestfield/Kewdale and Kwinana. The Kenwick dry port development satisfies one aspect of the master plan.

A site selection study (GHD, 2007) concluded that a location between Russel and Rowley Roads in the Latitude 32 area was the preferred terminal site with suitable topography, room and appropriate land use zoning. This location was challenged by the City of Cockburn and other interested parties (local mining companies, transport industry representatives, local government, industry representatives and community members) and culminated in a second report comparing the two sites. Cockburn provides a candidate site just south of the Kwinana location, Figure 7-17, offering similar connections (GHD, 2009). The second report (GHD, 2009) concluded that the originally preferred site was superior. This conclusion led to the inclusion of planning for the location in Land Use Master Plans and the Structure Plan for Latitude 32 (WAPC, 2010).

The commissioning of the Westport study has re-opened the Latitude 32 Structure Plan for update (Landcorp, 2019).

Through the Indian Ocean Gateway concept, the City of Kwinana proposes an intermodal terminal developed on reclaimed land (created from dredge spoil) immediately adjacent to the new Outer Harbour. This approach would form a land-backed seaport with a seaport-based terminal linked to existing transport corridors through road and rail extensions to the coast. The location of the seaport rail terminal removes the need for the short transport leg and double handling associated with the nominated government preferred inland location (Kwinana, 2015). This approach develops a quayside rail terminal distinct from a close dry port.

The viability of a Kwinana terminal in the Latitude 32 area, unless at least 20% rail share is achieved at the Inner Harbour, is questioned, and at this throughput level, the facility will support only modal change. A multi-function dry port development relies on the Outer Harbour development to be viable on throughput terms (WAPOTF, 2017). The question would remain on the ability of such a location to compete with a quayside terminal and port-centric logistics. Government thinking on this is unclear, recognising that the exiting dry ports can link to an Outer Harbour quayside rail terminal, but undecided on how the Latitude 32 Industry Zone should link to the seaport (DoT et al., 2016a). A quayside rail terminal is currently the first-ranked development approach by Westport (2019e).

Bullsbrook location

Bullsbrook is a candidate site for an intermodal terminal in the structure plan under the *Perth and Peel @ 3.5 million* framework (WAPC, 2019), Figure 7-18. The function of the intermodal terminal is to serve Perth areas to the northeast and northwest. In recognition of the need for sustaining freight volumes, the interaction of this location with other industrial areas, Pinar, Neerabup and North Ellenbrook is investigated as sources and destinations for containers (DoT et al., 2016a). The development is progressing with the state government considering a market lead proposal (Pearce, 2020). This progress is consistent with the medium-term industrial development identified by WAPC (2012) depicted in Figure 7-19.

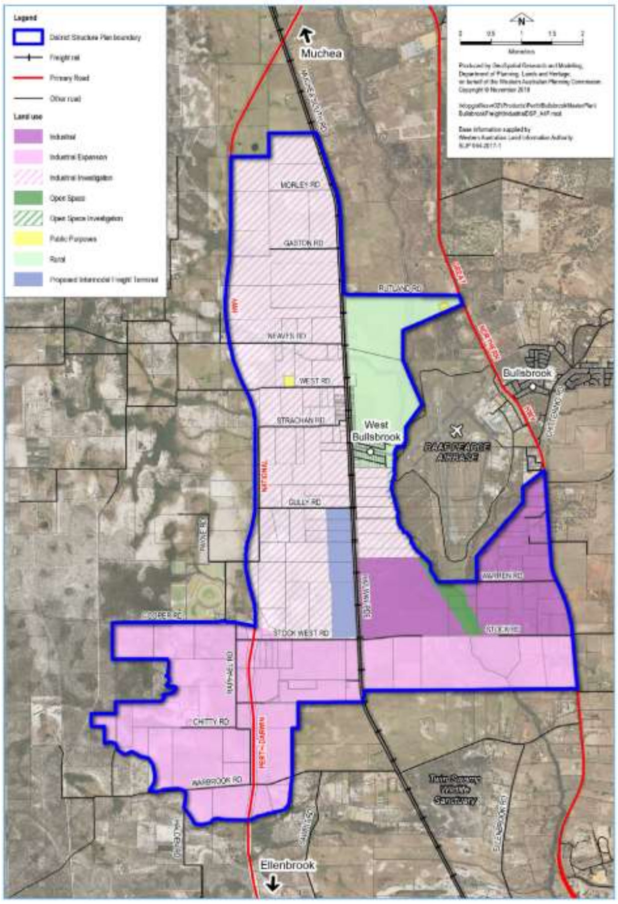


Figure 7-18 - Bullsbrook candidate terminal site.

Source: WAPC (2019, p.1)

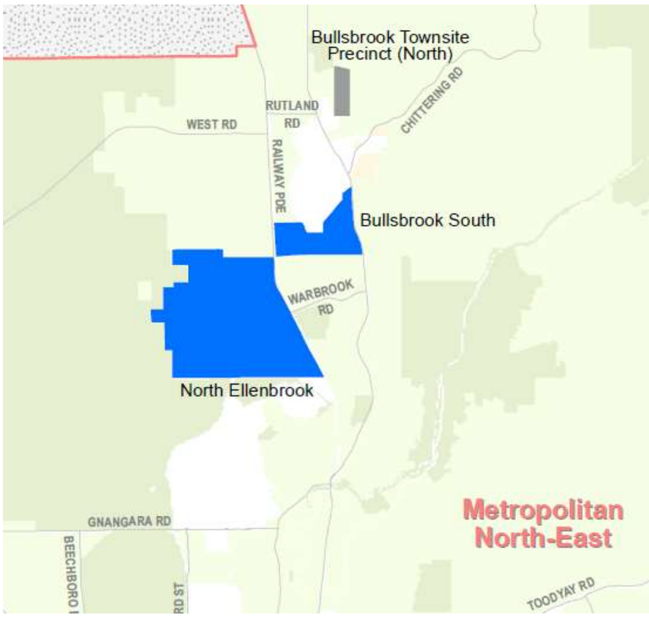


Figure 7-19 - Medium term industrial development areas, 4 to 10 years from 2012.

Source: WAPC (2012, separate map).

Mundijong location

Investigations indicate this is not a likely candidate site for an intermodal facility with a direct rail link to the Inner or Outer Harbour as it shares a catchment with a Cockburn facility.

This location is an example of where overcapacity can occur if an overarching consideration of demand is not present in planning developments.

Nowergup/Pinjar location

This area sits outside locations with some form of rail access and intermodal terminal planning for Perth. It lies within the metropolitan northwest; WAPC (2012) identify this as a future industrial area, Figure 7-20 and

Figure 7-21. Due to difficulty in developing new rail through the metropolitan area and the cost associated with building a line from Bullsbrook west into Pinjar, the area is unlikely to have an intermodal facility built, instead relying on direct road transport or possibly rail to Bullsbrook and a road leg to the area.

This location is an example of the need to site dry ports near existing infrastructure due to the high cost of development, particularly rail.

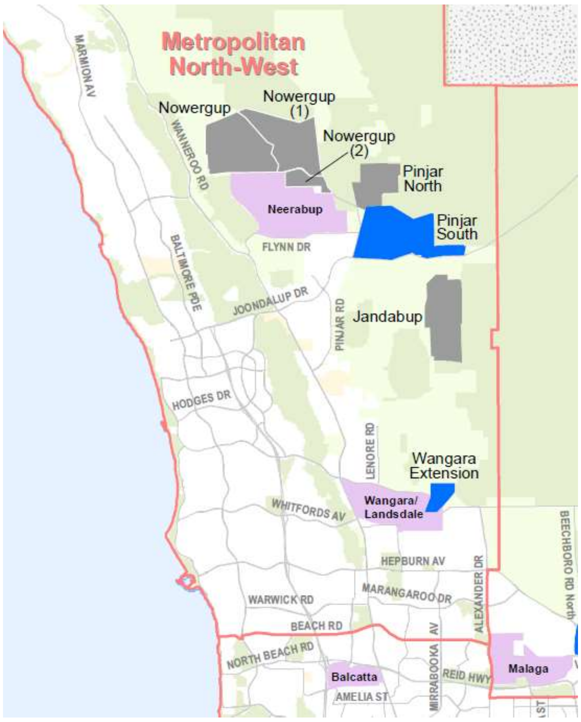


Figure 7-20 - The metropolitan northwest has not been identified as an area to be serviced by rail in 2012.

Source: WAPC (2012, separate map).

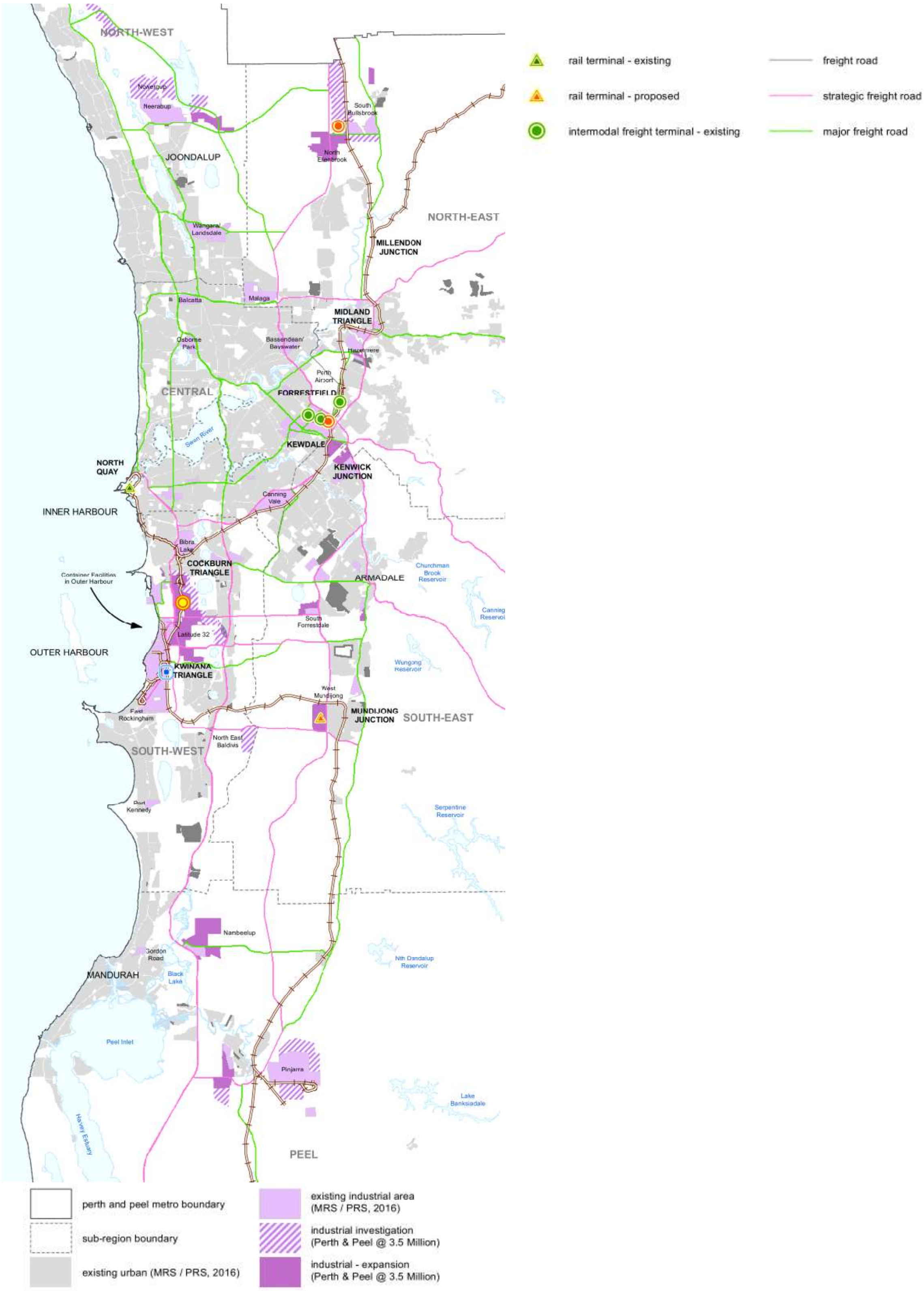


Figure 7-21 - Current and future freight infrastructure and locations.

Source: DoT et al. (2016a, p.55)

7.1.4 POTENTIAL DRY PORT CANDIDATE SITES OUTSIDE THE PERTH METROPOLITAN AREA

Outside the metropolitan area but of importance to Western Australian container import and export facilities is Bunbury in the southwest of the state, which as a region is primarily a source of export containers. Two potential dry port locations exist in this region, the Picton rail siding and Kemerton Industrial Park, along with an intermodal terminal in the Port of Bunbury.

Picton rail siding

A rail siding at Picton in southwest Western Australia is an idle dry port, previously used for mineral sands export in containers. A forklift or reach stacker transfers containers from trucks to rail wagons at the siding. The siding is not in use, with all containers transported to Perth by road as ownership of mineral sands mines changed.

The siding still exists and has ready access to major roads to Bunbury, other southwest towns and Perth, Figure 7-22.

Figure 7-22 - Picton rail siding.

Source: Google maps (Accessed 11.11.2019)

Kemerton industrial park

The Kemerton Industrial Park has no connection to the mainline rail between Perth and Bunbury. The design of the industrial park includes planning for a rail spur. To date, there has not been sufficient demand for container or bulk movement of materials in or out of the industrial park to warrant the development of a rail spur. The combination of the construction of the Albemarle lithium hydroxide plant and the potential for a reopening of the Greenbushes to Bunbury rail line with an associated rail spur at Kemerton (Smith, 2019) could result in a dry port in the industrial park. The lithium plant will produce significant container numbers with a planned start-up capacity of 60,000 to 75,000t per annum, climbing to 100,000t per annum over time (Albemarle, 2019b). The product export is through the Fremantle Ports Inner Harbour (Albemarle, 2019a). All export products from the industrial park tenants are transported to Fremantle Ports Inner Harbour by road.

Planning for a rail spur into the industrial park has been considered for some time (GHD, 2015), Figure 7-23.

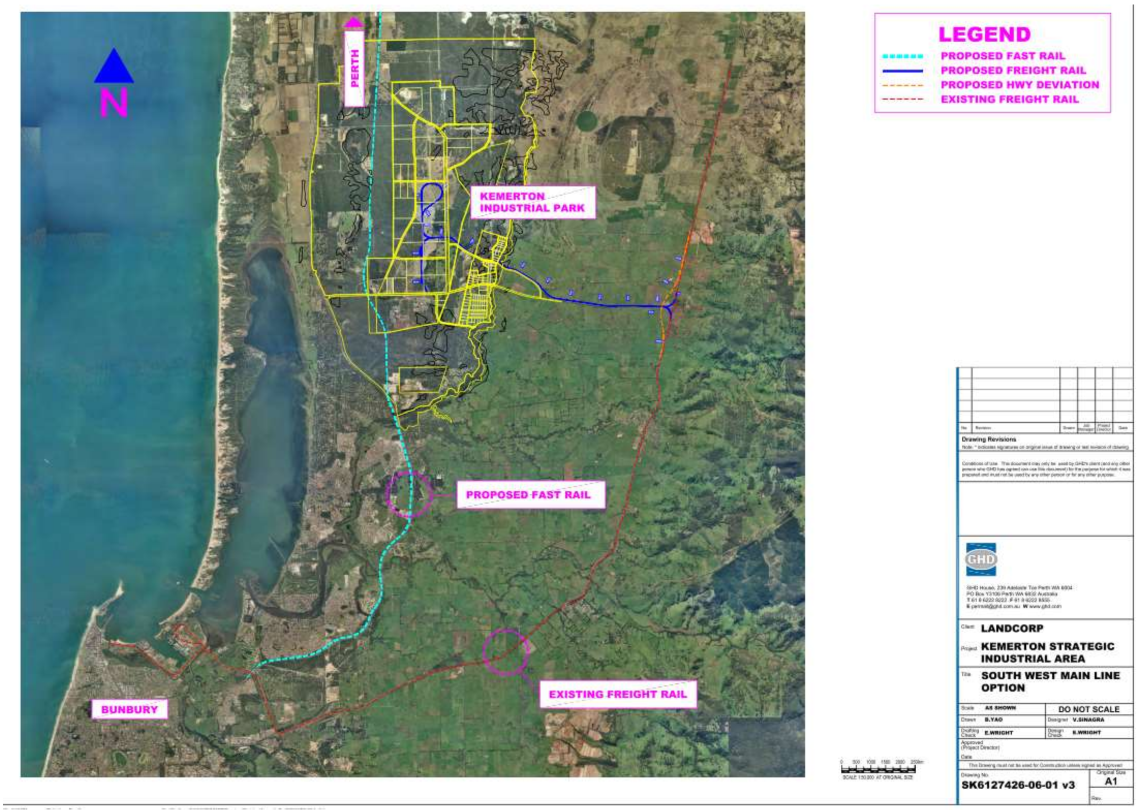


Figure 7-23 - Possible layouts for a rail spur into the Kemerton site.

Source: GHD (2015, p.49).

Port of Bunbury

Recently an intermodal terminal located at the Port of Bunbury has been considered but is subject to further investigation (Westport, 2019a). The facility could serve several purposes, that of being a seaport rail terminal enabling container movement through the Port of Bunbury for transport to and from Perth (a concept rejected by Westport) or a transfer point for containers currently sourced from or destined for the southwest to or from rail wagons for movement to or from the Fremantle Ports Inner Harbour.

7.1.5 FREMANTLE PORTS

As is typical of Australian container seaports, short-haul rail links the Inner Harbour to the Perth dry ports. A similar situation will apply to the Outer Harbour. Import container movements dominate. Manufacturing and assembly inputs are the majority of imports, with minor amounts of mining project cargoes destined for distant locations. This balance of imports results from Perth's narrow range of supply chains. Most import unpacks occur less than 50km from the Inner Harbour along the industrial corridor in Perth, with 60% of unpacks occurring in Kewdale, Forrestfield, Welshpool, Canning Vale and Jandakot. Export sources include the Perth metropolitan area; however, the number of export containers related to agricultural and mining activity outside this area contributes to the greater than 100km radial packing distances.

Rail links the Inner Harbour to the existing (Kewdale, Forrestfield and Kwinana), an under construction (Kenwick) and a northern area location (Bullsbrook) dry port locations in the Perth metropolitan area. Forecast industrial development areas are well catered for by these facilities aside from the Nowergup and Pinjar North sites which are unlikely to be linked to the rail service due to high development costs and competition from direct road transport.

The short-haul rail operation to deliver containers to an unpack location cannot support a prehaul drayage operation to an intermodal rail facility even with high-efficiency vehicles. The closure of the Leighton Railyards and the development of the NQRT to support the rail transport from the Fremantle Ports Inner Harbour illustrates the need to remove a prehaul drayage. The Outer Harbour development could consider port-centric logistics due to the nearby Latitude 32 development area. The Outer Harbour development could plan the availability of land for a warehousing distribution centre role.

This leads to the conclusion that: **the Fremantle Ports Outer Harbour development would be best suited to an on-dock rail service linked to the existing and future metropolitan dry ports rather than the development of a dry port in the Latitude 32 or Kwinana industrial zone.**

The WA state government's consideration for an intermodal terminal in the Kwinana area is associated with interstate rail transport and reducing risk around a small number of intermodal terminals servicing transport needs. The function, restricted to intermodal transfer without containers sourced from the Outer Harbour, may support the development at Kwinana.

Multi-criteria analysis is relevant to the Fremantle Port situation. The general location of the future Outer Harbour container port development followed the examination of various metropolitan and regional port locations without finalising the exact port layout and position (WAPC, 2004). The Westport Study used the approach to select between available options to facilitate handling the state's containers over the next 50 years (Westport, 2019c, 2020c).

7.1.6 SITE SELECTION CONCLUSIONS

The WA state government's long-term planning for intermodal terminals considers not only dry ports but interstate rail freight movements, which depending on the source of these containers, may result in the intermodal terminal being a quasi-distant dry port linked to an east coast seaport.

Consistent with the literature, finding locations for the placement of terminals in the existing Perth metropolitan areas is not straightforward. Several state government sponsored studies have reinforced the concept of utilising areas of existing or high logistics potential for dry port development.

The use of MCA for locating a dry port is demonstrated through the use of the MCA method for establishing the location of a future Outer Harbour and container handling capacity options.

In deciding between possible sites for an intermodal terminal in the Kwinana area, a comparative approach against established required criteria was adopted. This is consistent with an MCA approach.

In practical applications, mathematical modelling is not used as a direct method for deciding between intermodal terminal locations by the WA state government. Mathematical modelling plays a role in transport and congestion modelling and future trade forecasts, which are critical factors in deciding on development timing.

Due to constraints on developing greenfield intermodal terminal locations in a metropolitan area, site selection becomes a process of selecting from several sites based on comparing the available required features or cost and practicality of developing these for the facility.

In the context of the Inner Harbour, the Kewdale, Forrestfield, Kwinana and Kenwick facilities will serve to prolong the life of the Inner Harbour provided there is an increase in the rail share of the transport task. This increase in rail transport is critical as road congestion ultimately limits container numbers through the Inner Harbour container terminals.

For an Outer Harbour seaport development, the restricted supply chain types and the proximity of the seaport to destinations of the dominant import container flows leads to the development of an on-port rail terminal linked to the existing metropolitan dry ports rather than a new close dry port specifically to service the Outer Harbour. This situation results in a traditional waterside development, incorporating quayside rail infrastructure, relying on existing dry port infrastructure rather than a new specific dry port for the Outer Harbour supply chain.

Chapter 8: Freight Transport Modal Choice Survey

8.1 IMPORTANCE OF MODAL CHOICE

As described in Chapter 3: Attributes, Definition and Classifications of a Dry Port, an efficient and direct transport link to the seaport in the supply chain is a fundamental attribute of a dry port system. The dry port transport link explored in this thesis is that of rail, which results in the dry port being part of an intermodal transport system with containers delivered to and from the dry port from the pick-up or drop-off point by road. In the Australian context, this approach competes with a unimodal road-based transport system and, in some instances, with port-centric logistics. At a fundamental level, organisations that decide the mode of transport choose between various transport options because of the availability and attributes of each transport approach. The growth in the use of 3PL and 4PL service providers increasingly moves the selection away from the owner of the goods. Understanding the factors that influence this modal choice decision is important in making a rail-based dry port's service offerings successful.

8.1.1 MODAL CHOICE SURVEYS

Solakivi and Ojala (2017) review survey methodology into carrier selection (either modal choice or between carriers of a particular transport mode) and provide insight into the survey types, questions and analysis methods. The review papers are listed in Table 8-1. As transport service providers move to logistics suppliers in contrast to what were previously freight carriers, the way organisations approach decisions on transport selection alters. This change often results in the service provider rather than the owner of the goods selecting the transport mode. This is a finding in the FPA 2011 exporter survey (Hall, 2011). The review identifies that most surveys are conducted from the shippers' perspective, with that of carriers undertaken at a much lower rate.

Table 8-1 - Papers reviewed for carrier selection survey.

Source: Solakivi & Ojala (2017, p.513).

Journal	Articles
Transportation Journal (11)	Bardi (1973), Stock and LaLonde (1977), McGinnis (1978), Bardi et al. (1989), Abshire and Premeaux (1991), Evers et al. (1993), Crum et al. (1997), Kent et al. (2001), Premeaux (2002), Voss et al. (2008), Williams et al. (2013)
International Journal of Physical Distribution & Logistics Management (4)	Pedersen and Gray (1998), Kent and Parker (1999), Pearson and Semeijn (1999), Gibson et al. (2002)
Industrial Marketing Management (2)	Anderson et al. (1978), Krapfel and Mentzer (1982)
Journal of Business Logistics (2)	Lambert et al. (1993), Menon et al. (1998)
Journal of Business Research (1)	Coulter et al. (1989)
International Journal of Logistics Management (1)	Semeijn (1995)
Transportation Research Part E (1)	Murphy et al. (1997)
Maritime Policy and Management (1)	Wong et al. (2008)

Since 1973 survey-based approaches have been used to establish the determinants of carrier choice. A Likert scale method is the typical way of asking survey respondents to indicate the importance of different selection factors. A wide range of factors has been tested, with authors identifying 87 different determinants, of which the 20 most frequent are presented in Table 8-2. Likert scales are used widely in organisational study surveys, with a predominance of surveys being a five-point scale (Hinkin, 1995). There are varying views on the degree of discrimination offered through longer scales (Lietz, 2010).

Table 8-2 - Twenty most common determinants in modal choice surveys.

Source: Solakivi & Ojala (2017, p.519).

Rank	Determinant
1	Transportation rate/ Freight charges
2	Loss and damage history of the carrier
3	Ease of claim settlement
3	Transit time
5	Reliability of transit time
6	Tracking and tracing possibility
7	Carrier reputation
7	Availability of pickup and delivery service
7	Quality of sales personnel/ cooperation skills
10	Financial stability of the carrier
10	Availability of equipment
10	Pricing flexibility
10	Quality of carrier personnel (including drivers)
14	Ability to handle special requests
15	Frequency of service
15	Geographic coverage of carrier
15	Information provided to shippers by the carrier
18	Accuracy of invoicing
18	Personal relationship with carrier
18	Availability of consolidation services

Meixell and Norbis (2008), in a review of transport mode choice and carrier selection, identify surveys and mathematical models as the two research approaches for determining modal choice. The review supports the view that Likert scales are a standard tool in assessing transport mode and carrier selection. The most common method of results analysis is ranking mean scores for each determinant.

Support for the ranking of determinants is found in individual research papers in their background and literature review sections, where common determinants such as transport cost, reliability, transit time, capability and quality are noted as previous survey questions (Bardi, Bagchi, & Raghunathan, 1989; Coulter, Darden, Coulter, & Brown, 1989; Evers, Harper, & Needham, 1996; Evers & Johnson, 2000; Meixell & Norbis, 2008; Reis, 2014; Voss, Page, Keller, & Ozment, 2006).

In a stated preference analysis Larranaga, Arellana, and Senna (2017) highlight the importance of transport distance and product value in influencing transport mode selection. Kurtuluş and Çetin (2020), expand the determinant list to include other items identified by various authors, such as shipment size, packaging type, cargo fragility and perishability and availability of infrastructure. Bask and Rajahonka (2017) identify the lack of discussion on the subject of intermodal choice before 2003 (consistent with the research field in intermodal transport emerging in the 1990s (Bontekoning et al., 2004)). The lack of consideration of environmental sustainability is being overcome with these as research areas emerging in the literature.

In a review conducted by Tavasszy, van de Kaa, and Liu (2020), the authors identify similar determinants to those discussed above and use a Best-Worst MCDA approach to rank seven attributes, six generally highly ranked determinants in the literature: door to door travel time, transportation cost, on-time reliability, service frequency, flexibility and loss and damage performance and the less commonly explored CO_2 emissions. Overall results rank transport cost, on-time reliability then door to door travel time as the top three determinants in order of importance, reduction of CO_2 emissions being the least important,

8.2 PURPOSE OF THE MODAL CHOICE SURVEY

The Fremantle Ports case study shows that the seaport and the main Perth metropolitan dry port complex (Forrestfield/Kewdale) developed and have attributes consistent with the literature. A survey of Fremantle Ports container exporters and importers to understand why container freight users select either road transport or intermodal transport in moving containers to or from the Inner Harbour will further support the consistency or otherwise of the case study with the literature.

The survey results are compared, as far as is practicable, with the 2011 FPA survey of exporters (FPA & WAPOT, 2011; Hall, 2011), the 2012 importer survey (Hall, Brindal, & Stephens, 2012) and the 2017 FPA container movement study (FPA, 2017b). Consistency with these surveys supports the findings of the thesis survey.

The timeframe over which the FPA surveys and study are conducted allows the technological, physical (congestion) and social changes that have occurred over a decade to be considered. During this time, Fremantle Ports is engaged with the transport industry through membership of the Freight & Logistics Council WA and the WA Port Operations Taskforce and community through the Inner Harbour Community Liaison Group consistent with a fourth or developing fifth generation seaport reaching into the hinterland and community.

The thesis survey structure allows a comparison of reasons between exporters and importers, adding depth to the analysis and case study. This comparison is limited by the low proportion of overall container movements for importers in the survey response.

8.3 DETERMINANTS FOR THESIS QUESTIONNAIRE

The lack of consistency in the language used in the literature for describing the 20 most frequent determinants identified by Solakivi and Ojala (2017) is presented in Table 8-3. The list is supplemented by including determinants identified in later papers with a focus on modal choice, distinct from earlier papers on carrier selection within a mode. Meixell and Norbis (2008) observe that later researchers in the field argue earlier studies were not sufficiently focused, being either too broad in the determinants description or focused on motor carrier factors.

Finally, *"green"* factors are included as *"greening of supply chains"* is becoming a relevant determinant. This was absent in the papers Meixell & Norbis (2008) reviewed and identified as an area for future research. Bask & Rajahonka (2017) observe that environmental considerations are still emerging as a topic in the research literature.

Table 8-3- Determinant descriptions from a range of papers.

Source: Summary by Author.

Survey determinant	(Bardi et al., 1989)	(Coulter et al., 1989)	(Premeaux, Abshire, Mondy, & Rader, 1995)	(Evers et al., 1996)	(Evers & Johnson, 2000)	(Tsamboulas & Kapros, 2000)	(Voss et al., 2006)	(Mancera, Klaas, Weidmann, & Nash, 2017)	(D Meers et al., 2017)
TOP 20 ITEMS									
Transportation rate/freight charges	Door to door transport rates or costs	Cost		Cost Equipment free for loading/ unloading	Competitive rates	Transportation cost	Rate charged		Transport price
Loss and damage history of the carrier	Freight loss and damage	Loss/damage history Carrier reputation	Condition of equipment cleanliness Past performance of the carrier Freight loss experience with the carrier	Amount of loss and damage			Carrier reputation		
Ease of claim settlement	Claims processing	Claims service	Ease of claim settlement (loss or damage) Overcharge claims service	Processing of loss and damage claims			Complaint follow up	Reliable handling of complaints Prompt handling of complaints	
Transit time	Total door to door transit time	Speed of transit time	Total transit time for the shipment	Transit time	Transit time				Transport time
Reliability of transit time	Transit time reliability or consistency	Reliable transit time	Reliability of on-time delivery and pick up Carrier dependability	Reliability of service	Consistent delivery	Reliability	Delivery reliability		Transport reliability
Tracking and tracing possibility	Shipment tracing		Computerised billing and tracing services	Communication	Communication	Availability of information systems	Billing accuracy		
Quality of sales personnel/co-operation skills	Quality of carrier salesmanship	Quality of sales personnel	Carrier representative's knowledge of shipper's needs	After sales service					
Financial stability of the carrier	Financial stability of the carrier	Financial stability of the carrier	Financial stability of the carrier						

Availability of equipment	Equipment availability	Loading and unloading facilities	Carrier transportation equipment designed to facilitate easy and fast loading and unloading	Availability of equipment			Equipment availability		
Pricing flexibility	Willingness of the carrier to negotiate rate changes Willingness of the carrier to negotiate service charges		Carriers' leadership in offering more flexible rates Discount programs offered by carriers						
Quality of carrier personnel (incl drivers)	Quality of operating personnel	Quality of drivers Quality of dispatchers	Carriers' co-operation with shippers' personnel Courtesy of vehicle operators		Quality of customer service		Response Driver quality	Availability of suitable contact person Rapid reaction of a contact person from the service provider	
Ability to handle special requests	Special equipment	Handling capabilities (special items)	Handling expedited shipments Carrier's attitude towards acceptance of small shipments Carriers' ability to handle special requests					Customisation of service providers when solutions offered	
Frequency of service	Frequency of service Scheduling flexibility		Scheduling flexibility	Frequency of service		Adequate frequency of services			Transport frequency
Geographic coverage of carrier		Carriers' coverage	Geographic coverage of carrier						
Information provided to shippers by the carrier			Information provided to shippers by the carrier					Informed about exceptional on-time events Use of a web service portal by the service provider	

Accuracy of invoicing		Billing service	Computerised billing and tracing services						
Personal relationship with the carrier		Familiarity with the carrier	Personal relations with the carrier					Personal contact with sales staff	
Availability of consolidation services		Domestic distribution/consolidation services	Carriers' willingness to participate in freight consolidation practices						
INTERMODAL ITEMS									
Pick up/drop off points				Availability at origin points Availability at drop-off points	Warehouse location				
Shipment size				Suitability for shipment size	Size of order				
Directness of service				Directness of service					
GREEN FACTORS									
Regulatory environment						Policy factors of the region (transport policy)			
Environmental impact									

8.3.1 FREMANTLE PORTS AND SHORT-HAUL RAIL

The Inner Harbour supply chain is characterised by the majority of pick-up and drop-off locations being close to the seaport, (Section 7.1.2 Freight Movement in Perth). This means consideration of the factors surrounding short-haul rail and its economics, Chapter 6: Development Criteria for Dry Ports, Intermodal Transport, are relevant to understanding modal choice survey responses for transport to or from the Inner Harbour.

8.3.2 FPA 2011 EXPORTER SURVEY

Fremantle Ports surveyed exporters in 2011, exploring the following aspects of direct relevance to this thesis; landside transport, off-port hub/inland port and rail transport (FPA & WAPOT, 2011; Hall, 2011). The primarily *"face to face"* qualitative survey of 40 exporters represented 74% of the annual export TEU, of which 10% were using rail to deliver containers to the Inner Harbour.

The survey findings provide insight into questions for the current survey, and some alignment of questions allows a longitudinal comparison between the two.

- The additional cost of transporting containers to the dry port is not offset by savings associated with its use.
  - Discussed in Section 0 Intermodal Transport.
- The flexibility of road transport to alter times, cope with JIT and live loading and later cut off times compared to rail promote road transport.
  - Discussed in Section 0 Road Transport.
- To promote intermodal use the dry port must provide better access and efficient handling.
- The location of the dry port is important if "off route" diverting of trucks creates additional costs.
  - Consistent with the geometric relationship and distances affecting rail competitiveness *(Sd+D, 2004 p.21)*.
- Exporters are unaware of what the intermodal service can provide regarding container weight handling, capacity and how the 'system works".

- Consistent with Bask & Rajahonka (2017), transport mode decision makers have little or no knowledge of modes other than those they use. This lack of knowledge is an important aspect as shipper “perceptions” of modal performance can be aligned to important modal choice factors and so influence modal choice (Evers et al., 1996), and perception influences shipper satisfaction with a service (Evers & Johnson, 2000). Satisfaction at an individual carrier level can also influence a shipper's perception of the satisfaction of modal choice (Evers & Johnson, 2000).

Reasons identified in the 2011 survey for not using rail as expressed by non-rail users are summarised in Figure 8-1.

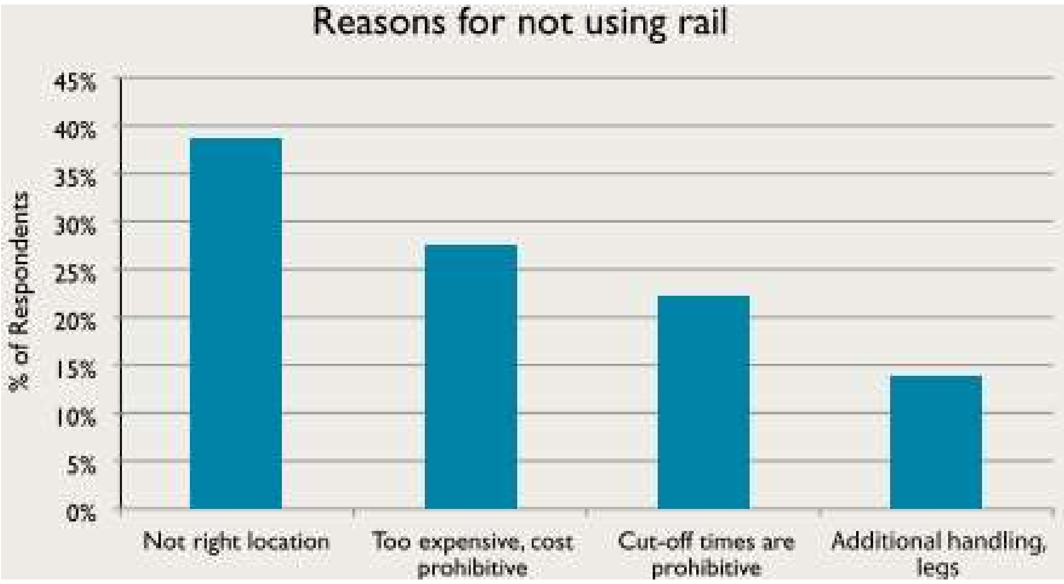


Figure 8-1 - Inner Harbour non-rail users exporter's reasons for not using rail.

Source: FPA & WAPOT (2011, p.6).

An important consideration in interpreting the results, and comparing them to the current thesis survey, is the survey population, that being primarily exporters, and the difference in the distribution of containers between importers who have destinations in the Perth metropolitan area and exporters who are more widely spread. Exporters were surveyed in 2011 because of this difference, as they were *“geographically more suited to use of off port facilities”* (Hall, 2011). The statistics of distance from the Inner Harbour and proportion of the container exports covered by the 2011 survey are depicted in Figure 8-2 and Figure 8-3.

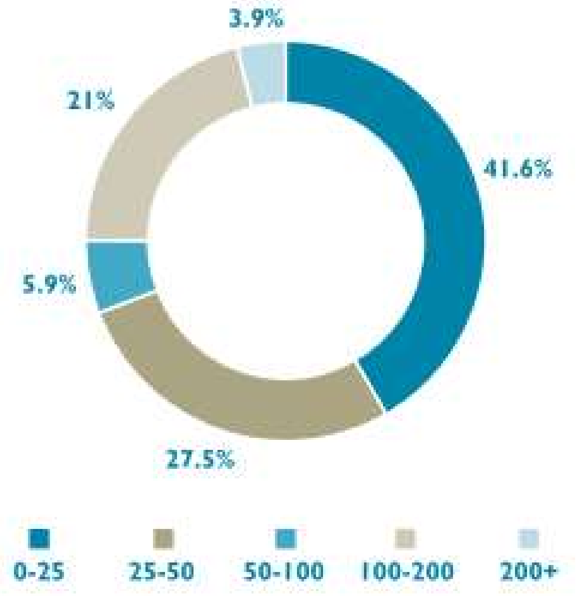


Figure 8-2 - Exporter distance from Inner Harbour.

Source: FPA & WAPOT (2011, p.4).

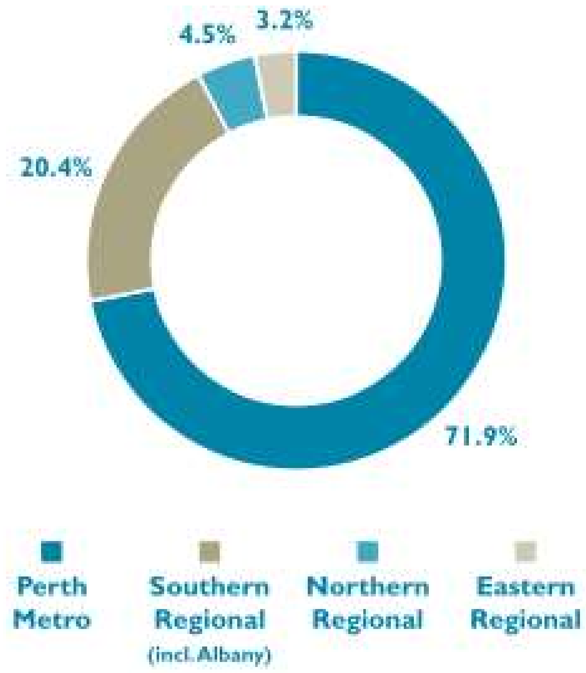


Figure 8-3 - Distribution of exports from each region.

Source: FPA & WAPOT (2011, p.4).

8.3.3 FPA 2012 CONTAINER IMPORTER SURVEY

The 2012 study, conducted over three months, surveyed importers (goods owners) and freight agents involved in the import of containers to understand the use of rail transport and intermodal hubs in the supply chain (Hall et al., 2012). Many small volume importers and a general reliance on agents in the import supply chain were evidenced. Of the respondents, 23% were agents, representing 61% of the cargo in the import supply chain. The survey identified that only 3% of respondents own their transport fleet.

The current survey targets cargo “owners” to understand how these organisations select transport modes. The survey identifies if the organisations default to agents or logistics providers to select transport modes.

As with the earlier FPA survey, findings of the 2012 survey provide insight into questions for the current survey, and some alignment of questions allows a longitudinal comparison between the two:

- Misalignment of operating hours between various operators in the supply chain.
    - Discussed in Section 0 Road Transport.
- The additional cost of transporting containers to the dry port.
    - Discussed in Section 0 Intermodal Transport.
- The requirement for double handling containers if rail is used.
    - Discussed in Section 0 Intermodal Transport.
- Location of the intermodal facility.
    - Discussed in Section 0 Intermodal Transport.

8.3.4 FPA 2017 CONTAINER MOVEMENT STUDY

The study, conducted over four weeks, covered the movement of import and export containers. It sought to understand physical container movements rather than the reasons behind the movement and associated transport mode.

The 2017 study is relevant to the current survey as it provides information on container source and destination locations, as previously reported in Chapter 7: Dry Port Site Selection. These are summarised in Table 8-4 and Table 8-5.

Table 8-4 - Distance to Inner Harbour from container sources and destinations

Source: FPA, (2017b); FPA & WAPOT (2011).

Distance (km)	**Import unpack %**		**Export pack %**		
	2011	**2017**	**2011 (Exporter survey)**	**2011**	**2017**
<10	8.4	8.0	-	9.7	3.6
11-20	32.9	34.5	-	36.1	15.0
21-30	48.3	41.7	-	32.7	36.3
31-50	8.2	11.9	-	6.2	7.7
0-50	**97.9**	**96.2**	**69.1**	**84.7**	**62.5**
50-100	0.3	0.3	5.9	1.9	0.3
>100	1.8	3.5	24.9	13.4	37.2

Table 8-5 - Proportion of containers packed or unpacked in a country location.

Source: FPA (2017b).

Location	**Import unpack %**			**Export pack %**		
	2004	**2011**	**2017**	**2004**	**2011**	**2017**
Country	20	2	3	43	16	39

The study identifies container staging, the intermediate dwell of a container between source and destination in rail and road transport, which occurs in approximately 80% of full container trips. Staging counters the concern identified in 2011 associated with additional container handling. Staging allows for a widening of pick-up and drop-off times at the Inner Harbour, reducing congestion and is reflected in *"after hours"* activity in the North Quay container terminals.

8.3.5 SURVEY POPULATION

The survey population for the case study of Fremantle Ports is organisations that currently import or export containers through the Inner Harbour. It is not unreasonable to assume that some of the current Inner Harbour users would be future users of the Outer Harbor as these seaports will be the only locations within the state through which significant container numbers pass. The container seaports are nearby and likely to be managed under the same port authority.

Consistent with Solakivi & Ojala (2017), the thesis survey, as are the majority of modal choice surveys in the literature, is conducted from the perspective of the shipper (owner of the goods) both as an exporter and importer.

The survey seeks to understand why container freight users select road or intermodal transport in moving containers to or from the seaport. So current as distinct from possible future port users comprise the population, this serves as the sampling frame.

The sample population is the container customer list of Fremantle Ports of port users who import and export containers through the Inner Harbour.

The survey is conducted based on respondents remaining anonymous if they wish. It is explained that consolidated survey results would be made available to Fremantle Ports, and if the respondent allows, their specific results will be provided. This approach is used to increase the response rate.

A total of 194 surveys were issued, 78 to exporters and 126 to importers.

8.3.6 CONTROL OF SAMPLING ERRORS AND BIAS

The sample design was considered and the use of the Fremantle Ports contacts for importers and exporters ensured the sample was representative of the correct population. If some current exporters or importers were not on the contact list sample bias may be present.

The survey included a supporting comment from Fremantle Ports to promote participation levels and reduce sample bias.

Responses were anonymous and multiple contacts with survey participants were made to reduce sample bias.

The use of questions widely used in the literature for modal choice surveys reduced the occurrence of measurement errors.

8.3.7 RESPONSE RATE

A high response rate was expected for the following reasons:

- Fremantle Ports' involvement enhances the credibility of the survey.
- The currency of the survey due to the ongoing Westport study.
- The value respondents perceive in having their views available to Fremantle Ports.

Of the 194 surveys distributed, 43 were completed and returned, with a response rate of 22%. For export surveys, 24 responses or 31% were received, and 19 responses or 15% for importers. Whilst lower than the average survey response rate of 28.7% reported by Solakivi & Ojala (2017), it sits comfortably in the range of 9 to 75% reported.

The exporter survey response represents approximately 44% of the full TEU exports, and the importer survey response only 2% of the full TEU imports as reported by FPA for the 2020/21 financial year (FPA, 2021a).

The response rate from a group expected to be strongly engaged was somewhat less than anticipated. It is postulated that this is attributed to; the COVID-19 lockdown, resulting in people working from home, potentially reducing engagement and hampering communications and survey fatigue of larger organisations (particularly importers) who are engaged with intensive surveying associated with the Westport Study. This could result in some non-response bias as not all organisations are impacted equally by these factors.

8.4 SURVEY QUESTIONS

8.4.1 QUESTIONNAIRE STRUCTURE

Consistent with Munn & Drever (1990), the survey is constructed in straightforward language understandable to the survey respondents with no double negatives and arranged by category. Question length is short and expressed in the active voice without using terms that imply a vagueness (Lietz, 2010). No negatively worded questions are included in the survey (Lietz, 2010; Munn & Drever, 1990).

Modal choice questions are presented on a Likert scale with the following scoring applied to the results for interpretation.

Not important at all	Unimportant	Neutral	Important	Most important
1	2	3	4	5

8.4.2 SURVEY BACKGROUND QUESTIONS

Background questions explored are.

- Whether the organisation imports or exports goods.
- What mode of transport is used?
- Where the destination or source of goods is.
- How far containers are transported (radial distance) to or from the port.
- Is a freight forwarder used for export?
- The number and type of containers involved in the freight task.

There is a specific exploration of the organisation's environmental policy, including greenhouse gas reduction and whether this is considered in transport mode selection.

8.4.3 TRANSPORT MODE SELECTION QUESTIONS

Mode choice determinants are explored in the following question structure.

In selecting the mode of transport used by your organisation how important is the **factor** in the selection?

- Transport cost.
- Transit time (duration of transport task).
- Reliability (consistency) of the transit time.
- Pick-up and drop off times.
- Pick up and drop off locations.
- Frequency of the service.
- Geographic coverage of the service.
- Greenhouse gas emissions of the transport mode.

- Availability of consolidation services.
- Shipment size the carrier can accommodate.
- Ability of the carrier to handle special requests.
- Loss and damage history of the carrier.
- Tracking and tracing possibility of your consignment.
- Financial stability of the carrier.
- Availability of online services.

In a free form response, respondents are asked the top three reasons for the mode choice and why the alternate was not chosen.

8.5 APPROACH TO INTERPRETING THE SURVEY RESULTS

8.5.1 LIKERT SCALE STATISTICAL ANALYSIS

The literature is divided on whether Likert Scales can be treated as ordinal (ranked but not measured) or integer (ordered and measurable) scales and the statistical analysis that can be applied to survey results. As an ordinal scale, statistics such as mean and standard deviation are not strictly applicable to Likert Scale responses, but methods that are not based on distributions such as rank, median or range are (Allen & Seaman, 2007). Others argue that the Likert values, whilst not strictly an integer scale, can be treated as such for statistical analysis in most cases without materially misrepresenting results (Norman, 2010).

Unlike many research surveys, he primary analysis of the survey results is not to decide whether two surveyed groups are different or if some characteristic of a surveyed organisation can be correlated to a mode selection deciding factor. Some differences do appear to be related to import or export activity; however, this may not be the actual reason they differ. The survey is intended to provide a ranking of Fremantle Ports' container customers for comparison to the rankings found in the literature. They cannot be statistically compared as the literature provides a compilation of many surveys with differing questions and no statistical information behind the ranking. The purpose is to rank the order of importance (based on mean scores) that organisations place on different factors. This ranking approach is considered a valid analysis of the Likert Scale responses for the survey. The ranking is compared to the literature to see if the factors are similar. This approach satisfies the purpose of the survey as described in Section 8.2 Purpose of the Modal Choice Survey.

For comparison of selected survey results responses are presented in the form of histograms.

8.5.2 GROUPING OF FREE FORM RESPONSES

Free form responses to the questions on the top three reasons for using or not using a particular transport mode are grouped into like response categories. The percentage of total comments is calculated. The reasons for or against a particular transport choice were often, but not always, repeated by a given respondent. The total number of comments is included in the groupings as these provide emphasis to the mode choice.

The responses are not weighted for container numbers associated with the respondent in calculations.

8.5.3 INCOMPLETE RESPONSES

Incomplete surveys are not discarded. Instead, answers are used where relevant. Where question answers are missing, calculations of mean and frequency are based on the question response number rather than the overall survey returns.

8.6 THESIS SURVEY RESULTS

The mode selection survey results are presented in rank order in Table 8-6. Responses to all determinants (except one) have a mean above three, indicating some importance (above neutral) was attached to every factor. The single exception is cargo consolidation with a mean of under three for importers, a not unexpected result as importers do not consolidate cargo.

Table 8-6 - Rank of importance to mode choice by respondents on mean scores.

Source: Author survey.

Rank	**Determinant**
Rank 1	Transport cost
Rank 2	Reliability (consistency) of the transit time
Rank 3	Transit time (duration of transport task)
Rank 4	Frequency of the service
Rank 5	Pick-up and drop-off times
Rank 6	Pick up and drop off locations
Rank 7	Financial stability of the carrier
Rank 8	Track and traceability of the carrier
Rank 9	Loss and damage history of the carrier
Rank 10	Shipment size that can be handled
Rank 11	Ability to handle special requests
Rank 12	Geographic coverage of the service
Rank 13	Availability of Online service
Rank 14	Level of greenhouse gases emitted by transport task
Rank 15	Availability of consolidation service

The importance of cost was evident, either for or against a particular transport mode, in the free form comments on road/rail use, with cost being the highest frequency response aside from the lack of rail infrastructure as a reason not to choose rail, Table 8-7. Reliability is not expressed as an important consideration in the free form responses. The transport provider is the determinant of modal choice in 8% of the free form responses. In the survey, 71% of export respondents arranged their own transport. Of the 29% of respondents who use a freight forwarder, 14% (1 respondent) directed the transport mode. For importers, 74% use a freight forwarder, and two respondents nominate the freight forwarder as the decision maker in free form comments.

Table 8-7 - Percentage of times free form comments made.

Source: Author survey.

Comment	%			
	Import (excludes Rous Head unpack)	**Export** (Total)	**Export** (Rail Users)	**Export** (Road Users)
No rail available	25	25	-	30
Cost for or against	16	14	33	11
Proximity to port	10	12	-	14
Flexibility	6	10	-	11
Transporter decides	6	10	17	8
Not aware of what rail can offer	6	1	-	1
Transit time	4	2	-	3
Reliability	-	2	-	3
Reduces congestion	-	2	17	-
Rail capacity	-	2	17	-
Other	27	18	17	18

The importance or otherwise of carbon emissions is investigated in the survey, exploring if organisations have an environmental policy that includes carbon reduction. Of the respondents, 60% do not have a policy, 28% do, and 12% do not know, with the latter meaning the policy, if it existed, was ineffective. When asked if the environmental policy is used in transport mode selection, only three respondents from organisations with a policy stated it is a transport mode selection factor and one organisation without a policy.

The response to the modal choice ranked determinants for organisations with or without an environmental policy are similar. Respondents from organisations with a policy rank its importance somewhat higher than those without. Both types of organisations indicate that carbon emissions are not an overwhelming factor in the selection, with the highest number of responses being neutral, supported by the second to last ranking of the factor in the overall listing, Figure 8-4.

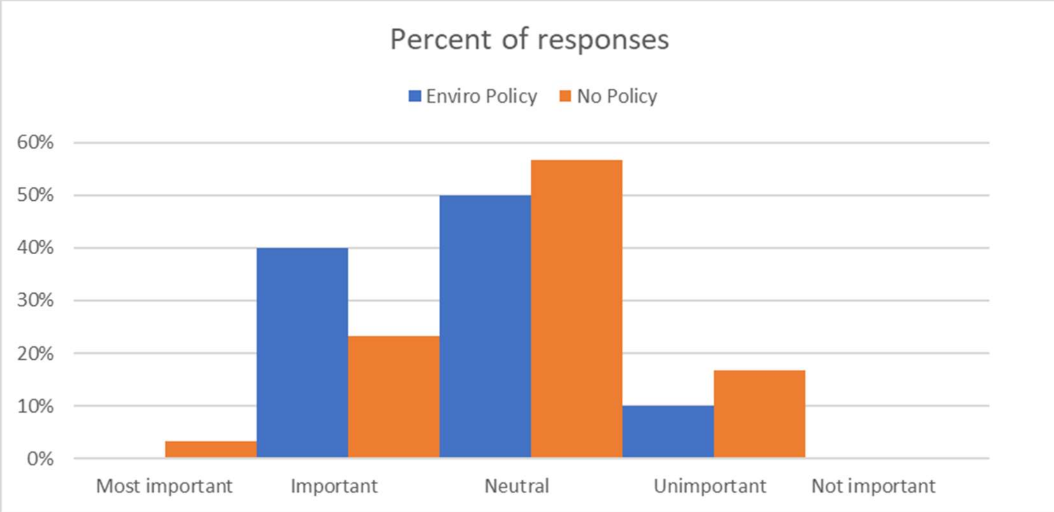


Figure 8-4 - Ranking of carbon emissions in transport mode choice.

Source: Author survey.

The lack of significance of carbon emissions in modal choice is evidenced by Tavasszy et al. (2020) in a modal choice survey across several industries incorporating the views of industry participants and scholars.

8.7 COMPARISON TO LITERATURE RANKING

The mode selection survey results presented in rank order are well aligned with the literature as described in Section 6.1.5 Role of Supply Chain Actors (Flodén et al., 2017) and (Solakivi & Ojala, 2017), where the primary selection determinant of the transport cost was followed by qualifying factors of transport time, reliability and service quality. Reliability was only narrowly behind transport cost in ranking. The lack of importance of environmental emissions was mirrored in the survey, ranking second last in the factors considered.

Cargo consolidation has a low ranking in both lists. The most apparent difference in the two rankings is the relative importance of the loss and damage history of the carrier, ranked second in the literature but in the bottom half of the current survey and not a finding of any of the FPA surveys or study. Differences also occur in service frequency ranking, which is relatively more important to the Inner Harbour users and a lesser extent, track and trace offerings, with this ability being aligned with the lower ranking identified by Flodén et al. (2017). The Inner Harbour transport mode determinants broadly agree with the literature on the determinants of mode choice. The marked difference in the importance of damage and loss history is possibly due to differences cargo types handled through the Inner Harbour compared to the broader literature. The comparison is presented in Table 8-8.

Table 8-8 - Comparison of survey and literature ranking of mode choice determinants.

Source: Solakivi & Ojala (2017) and Author.

2021 Thesis Survey		**Literature Ranking (for determinants surveyed)**	
Rank 1	Transport cost	Rank 1	Transportation rate/ Freight charges
Rank 2	Reliability (consistency) of the transit time	Rank 2	Loss and damage history of the carrier
Rank 3	Transit time (duration of transport task)	Rank 3	Transit time
Rank 4	Frequency of the service	Rank 5	Reliability of the transit time
Rank 5	Pick-up and drop-off times	Rank 6	Track and trace possibility
Rank 6	Pick up and drop off locations	Rank 10	Financial stability of the carrier
Rank 7	Financial stability of the carrier	Rank 14	Ability to handle special requests
Rank 8	Track and trace ability of the carrier	Rank 15	Frequency of the service
Rank 9	Loss and damage history of the carrier	Rank 15	Geographic coverage of the service
Rank 10	Shipment size that can be handled	Rank 18	Availability of consolidation services
Rank 11	Ability to handle special requests		
Rank 12	Geographic coverage of the service		
Rank 13	Availability of Online service		
Rank 14	Level of greenhouse gases emitted by transport task		
Rank 15	Availability of consolidation service		

The low ranking of the environmental consideration of greenhouse gas emissions by respondents is consistent with the topic being an "emerging area" in the literature and in agreement with the observation of Flodén et al. (2017) that the environmental advantages of mode (rail) selection lag well behind the transport cost. The prominence of cost and other "bland" supply chain factors as a determinant is at odds with the argument of Khaslavskaya and Roso (2019) that an outcome-driven approach can result in improved overall supply chain outcomes.

8.8 COMPARISON OF IMPORTERS AND EXPORTERS

Two fundamental differences between exporters and importers are evident. The different distances from the Inner Harbour of the pack and unpack locations and the absence of any import respondent using rail. This may not be a difference due to the import or export criteria and is more likely due to the types of products imported and exported. This is supported by Hoffman et al. (2017), in a review of the Perth supply chains. This review identifies imports as primarily groceries, consumer goods, furnishings and industrial equipment, whilst exports are grains, livestock, timber and mineral sands. It is expected that agricultural and mining items from rural areas will be transported further than consumer goods bound for metropolitan distribution and more consumption by the larger urban population.

Import destinations are closer to the Inner Harbour than export sources by individual respondent numbers and container numbers, Figure 8-5 and Figure 8-6.

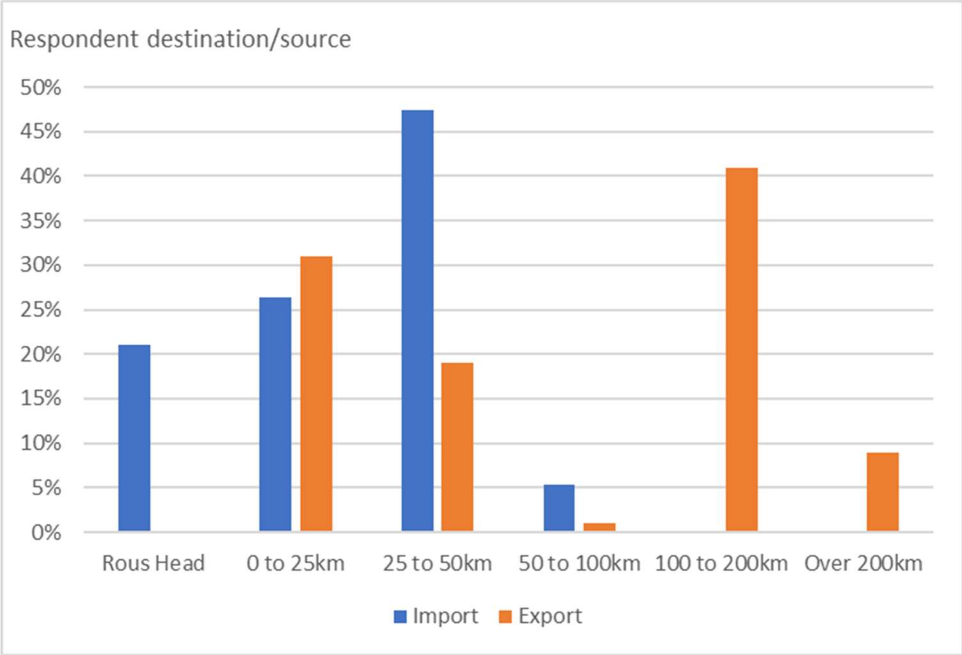


Figure 8-5 - Distance to pack and unpack locations by response number.

Source: Author survey.

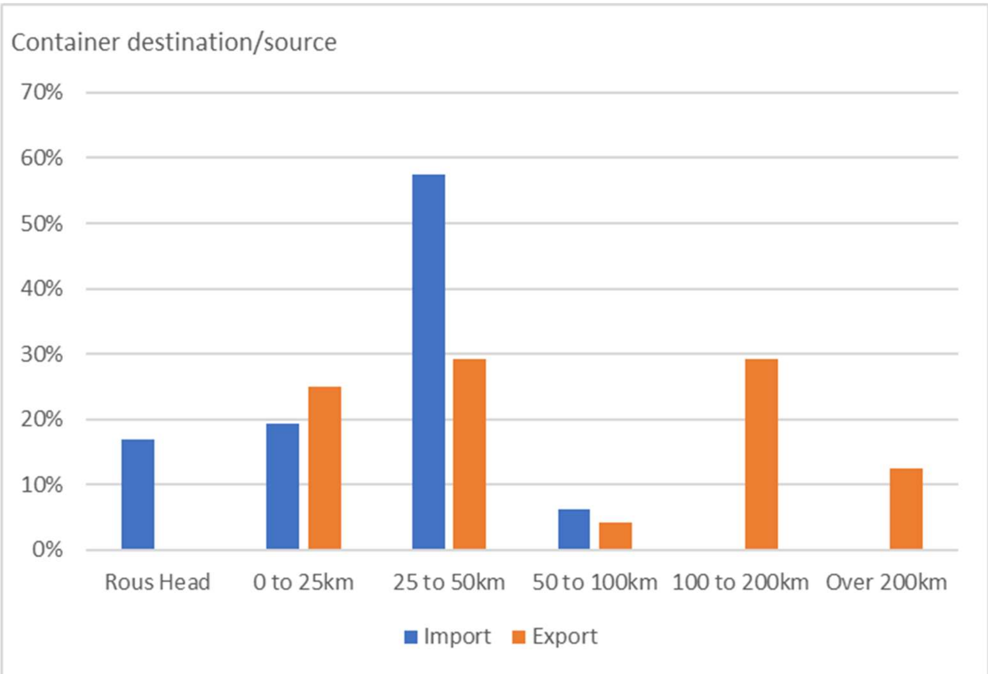


Figure 8-6 - Distance to pack and unpack locations by container number.

Source: Author survey.

Minor differences between importers and exporters are present in the ranking of determinants. The top six include five of the same ranking determinants, the ranking and respective maximum, minimum and mean values are presented in Table 8-9.

Table 8-9 - Top six ranked determinants for import and export mode selection.

Source: Author survey.

	Import	**Export**
Rank 1	Transport cost (max 5, min 3, mean 4.22)	Reliability (consistency) of the transit time (max 5, min 3, mean 4.35)
Rank 2	Reliability (consistency) of the transit time (max 5, min 2, mean 4.06)	Transport cost (max 5, min 3, mean 4.31)
Rank 3	Transit time (duration of transport task) (max 5, min 3, mean 3.94)	Transit time (duration of transport task) (max 5, min 3, mean 4.00)
Rank 4	Financial stability of carrier (max 5, min 2, mean 3.78)	Frequency of the service (max 5, min 3, mean 3.95)
Rank 5	Frequency of the service (max 5, min 2, mean 3.72)	Pick-up and drop-off times (max 5, min 2, mean 3.87)
Rank 6	Pick-up and drop-off times (max 5, min 2, mean 3.61)	Pick-up and drop-off locations (max 5, min 2, mean 3.78)

Rail users, only present as exporters in the survey, ranked reliability (consistency) of the transit time as the most important determinant, whilst road-based exporters ranked cost above this. The importance of transit time reliability for rail could reflect the longer transit times and reduced schedule frequency compared to trucks. Rail users have earlier shut-off times and rely on the rail service to deliver containers on schedule or risk missing a vessel slot. Road-based transport is inherently more flexible and can be adjusted to suit vessel schedule changes and satisfy JIT supply chain delivery.

The growing significance of agricultural products (including meat and perishable goods) in Inner Harbour container trade discussed below could influence exporter rankings. The study by Tavasszy et al. (2020) shows the importance of travel time and on-time reliability for perishable goods and other products compared to transport cost, Figure 8-7.

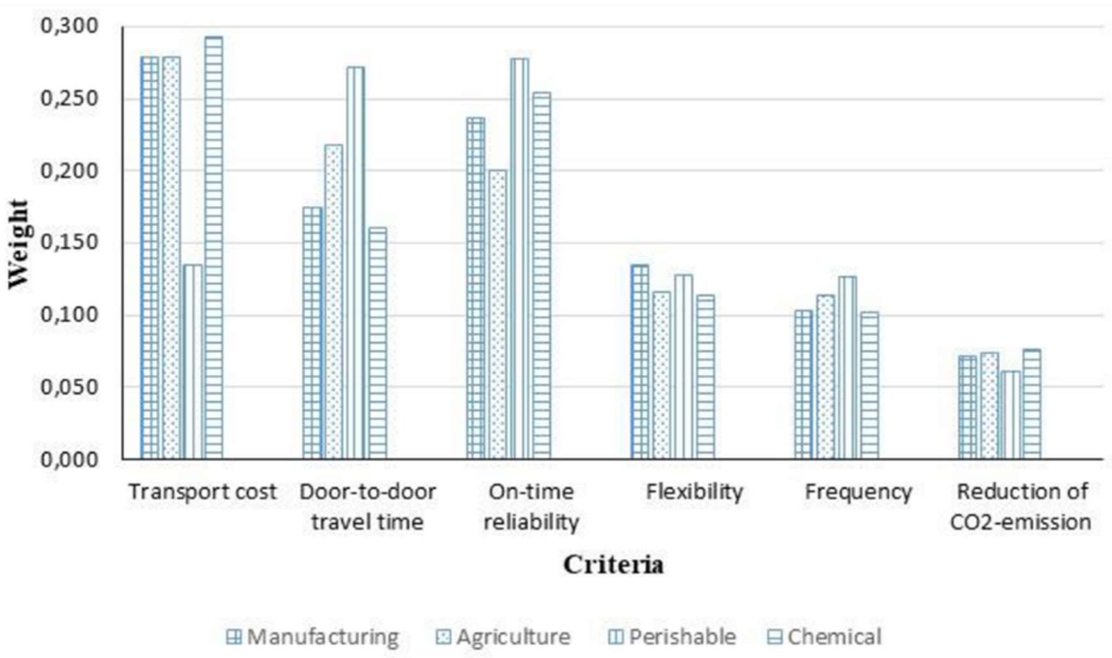


Figure 8-7 - Determinant of mode choice in different industries.

Source: Tavasszy et al. (2020, p.39).

Whilst the Fremantle Ports' users were not surveyed for industry type the type of goods they export was. Different cargo types, which at a high level are a proxy for the type of industry from which they are sourced, are presented in Figure 8-8 covering the most highly ranked determinants and those presented in Figure 8-7 where available.

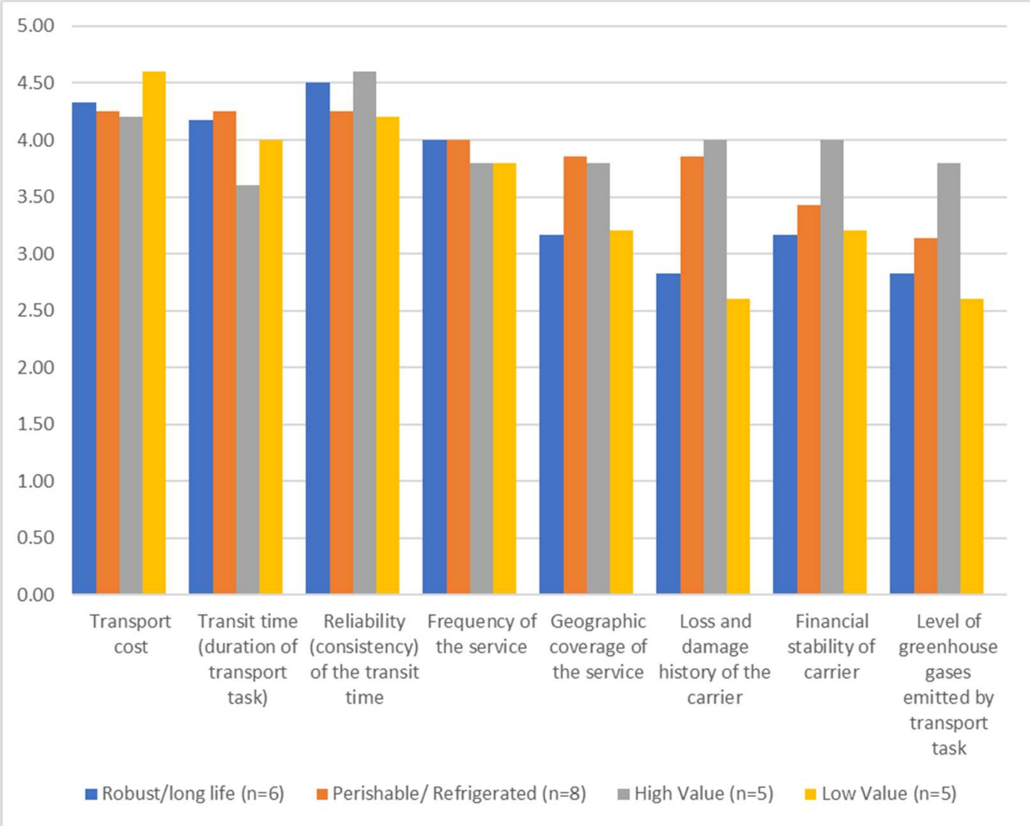


Figure 8-8 - Exporter determinant of mode choice by cargo type.

Source: Author survey

The differences in cargo types do not reflect the variability in transport cost, transit time and reliability of transit time as the literature. The histogram indicates that the high value goods exporters place more value on the financial stability of the carrier and its loss and damage history than the others. Low value goods show greater importance on transport cost and lower importance of loss and damage history and greenhouse gas emissions than other exporters, particularly high value goods. These results are intuitively sensible.

The combined importer/exporter Fremantle user results for varying cargo types are shown Figure 8-9.

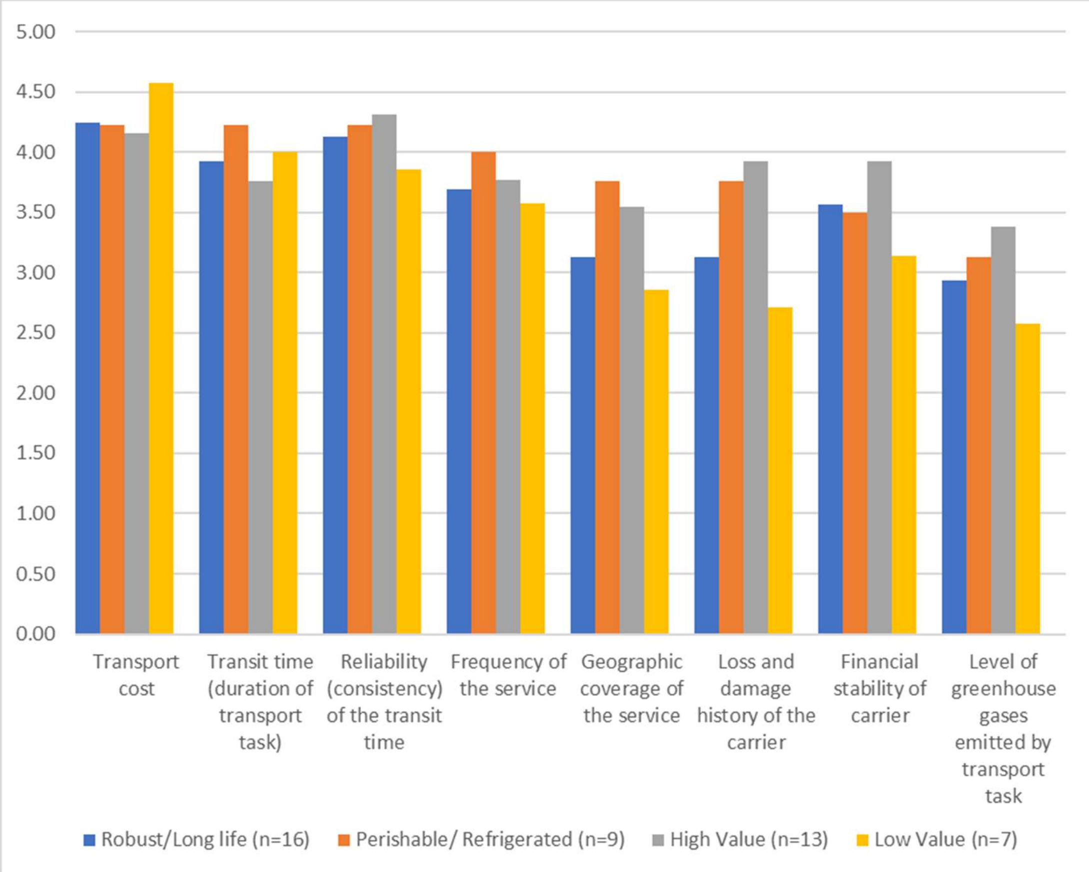


Figure 8-9 - Combined exporter and importer determinant of mode choice by cargo type.

Source: Author survey

As with the exporter values, there is not as much variation between the goods type as evidenced in the Tavasszy et al. (2020) study. Similar trends to the exporter survey are present.

8.9 COMPARISON TO FPA 2011 AND 2012 SURVEYS AND 2017 FPA STUDY

Despite the different survey and study approaches and somewhat differing objectives, comparisons can be made between the thesis survey and previous work by Fremantle Ports. The 2011 FPA survey was conducted face to face and has an infrastructure focus. The 2012 FPA survey included both an online survey and face to face interviews with an operational focus (including aspects of rail and intermodal terminal operations). The 2017 FPA study captures a four-week snapshot of container movements. These compared to a transport mode selection via an online survey for this thesis, the underlying factors are similar enough to usefully draw some comparisons over time.

The 2011 FPA survey targeted exporters, so a comparison between the current survey exporter responses and the earlier survey is drawn. The 2017 FPA study provides information on the source and destination of containers and allows a comparison point for this aspect. The 2012 survey focussed on the transport providers and the logistics chain.

8.9.1 RESPONSE COVERAGE

The difference in the number of (exporter) respondents 32 (40 when freight forwarders and importers are included) for the 2011 survey compared to the current 24 reflects the current survey's smaller portion of export volume (TEU number), 44%, compared to the earlier value of 74%. Annual full export container volumes grew from approximately 125,000 to 223,000 TEU over the period. The proportion of full container exports of the overall full container movement through the Inner Harbour (both import and export) steadily increased over the survey period (up to 2019 with a drop in 2021 associated with COVID-related increased consumer goods imports), Table 8-10.

Table 8-10 - Growth in proportion of full export containers.

Source: FPA (2011, 2021a).

Year	Full Imports (TEU)	Full Exports (TEU)	Full Export %
2011	393,208	168,870	36
2017	343,113	214,859	38
2019	362,350	259,951	42
2021	391,401	223,404	36

The thesis survey results show that 45% of container movements were by rail sourced from 13% of export respondents compared to 10% of containers by the entire 2011 survey group.

The thesis survey response of 19 importers and 2% of import volumes cannot be directly compared to the FPA 2012 survey as agents were not surveyed. The FPA 2012 survey received results from 81 importers representing approximately 18% of import containers for the 2011/12 year. The low response by importers in the thesis survey reflects the difficulty engaging importers observed by FPA.

8.9.2 CONTAINER TRANSPORT DISTANCE AND MODE

Exports

The export group locations based on respondents from the thesis survey are balanced between the Perth metropolitan area and regional areas, with 54% of the current respondents within 50km of the Inner Harbour and 42% greater than 100km distant, Figure 8-10. The 2011 survey does not provide distance data based on respondent numbers.

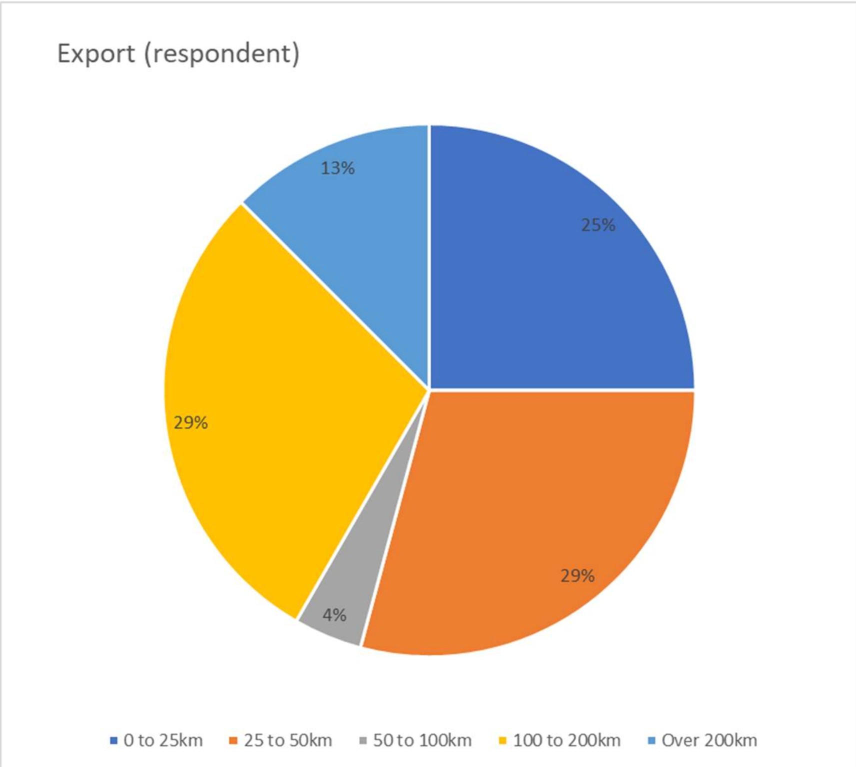


Figure 8-10 - Exporter number distance from Inner Harbour.

Source: Author survey.

Data from previous surveys allow a comparison of the distance from the Inner Harbour from which the containers are sourced based on the number of containers (TEU). The proportion of containers from each source distance range for the thesis survey is depicted in Figure 8-11.

The thesis survey has containers sourced from greater distances than both the 2011 and 2017 FPA work, with 50% of containers sourced from greater than 50km, Figure

8-11, compared to the 2011 surveys 31%, and 2017 studies 38%. This reflects the growth of exports from outside the Perth metropolitan area noted in the 2017 study. Whilst not defining "country" as a source, a similar trend is presented in the 2017 study. Results show 16% of containers and 39% of containers being sourced from the country in the 2011 and 2017 work, respectively.

In interpreting these values, it must be noted that the differing objectives of the work have resulted in different data sources being used, provided by shippers, transport companies and government statistics. It appears that trends are consistent with an increasing number of containers sourced from areas outside the Perth metropolitan area.

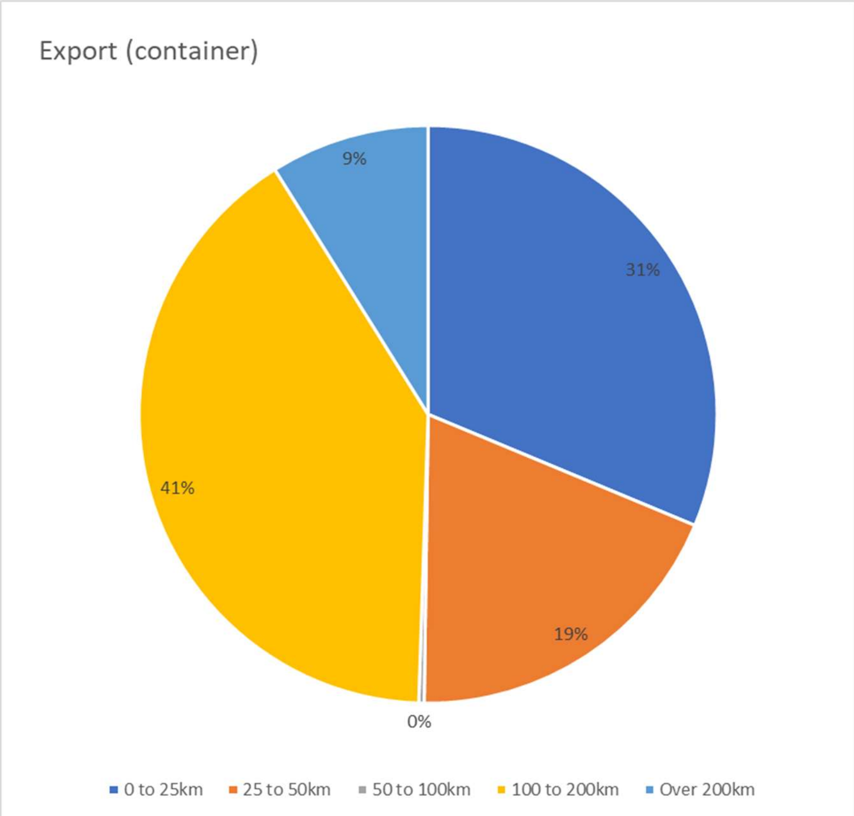


Figure 8-11 - Portion of containers from each distance for Inner Harbour.

Source: Author survey.

The reason for this difference cannot be conclusively identified; however, some general observations on the current data are made. Figure 8-12 shows that approximately 68% of road hauled containers are sourced within 50km of the port, which is similar to the 2011 survey over all sources, at which time rail share was only 10%. In contrast, the rail haul is shifted to longer distances, albeit on a small sample number of three responses. The 2017 study identified 21% of full exports transported by rail, still somewhat below the current survey and 62.5% sourced within 50km.

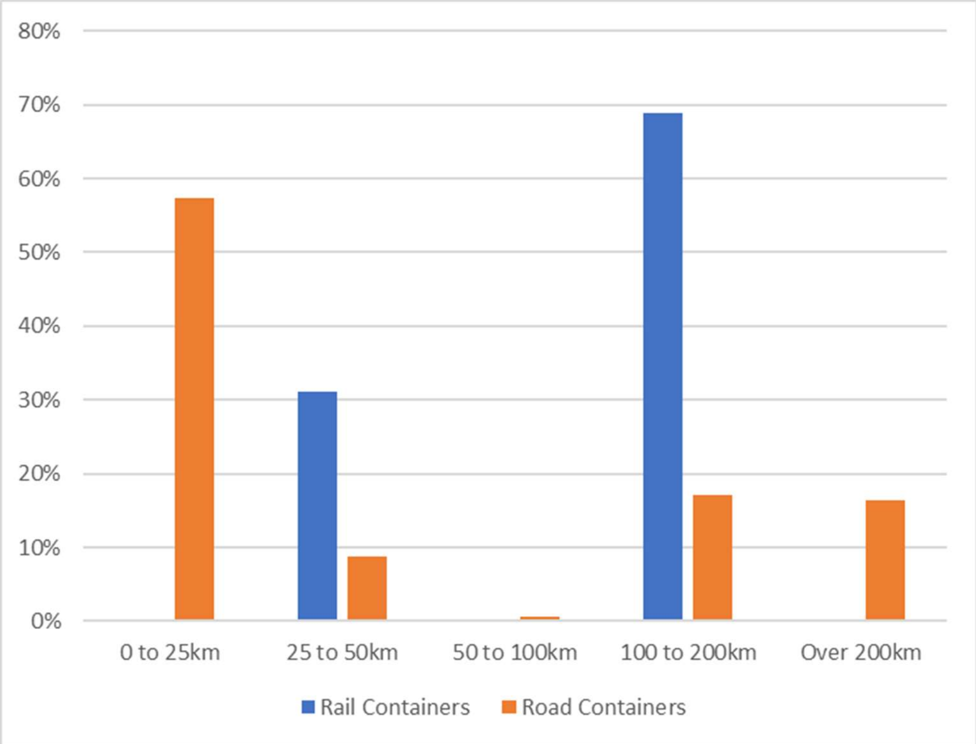


Figure 8-12 - Distribution of travel distance for road and rail hauled export containers.

Source: Author survey.

Changes occurred with transport services offered and changing logistics activity at Rous Head over the 2004 to 2017 period. A Kalgoorlie rail service is introduced after 2011, along with a reduction in container packs at Henderson associated with the completion of oil and gas projects (identified as one of the few significant supply chains in Perth (Hoffman et al., 2017)) and relocation of minerals sands packing activities.

The export of agricultural products (animal feeds and fresh/chilled/frozen meat) grows steadily over the survey/study period and supports the increasing amount of distant container packing locations, Table 8-11. In the thesis survey, the growing amount of regionally sourced meat products is reflected in 99% of reefer containers being sourced from more than 50km from the Inner Harbour.

Table 8-11 - Exports of agricultural products in selected years.

Source: FPA (2011, 2018a, 2021a).

Year	Animal Feed TEU	Fresh/Chilled/Frozen Meat TEU
2010/11	20,993	5,997
2016/17	36,011	7,070
2020/21	42,505	8,752

As with the 2011 exporter survey, the thesis survey shows a difference between sources of 20ft and 40ft export containers. In 2011 93.7% of 20ft and 46.7% of 40ft containers were sourced from the Perth area. Using a 50km proxy for the metropolitan boundary, the thesis survey has 77% of 20ft containers and only 38% of 40ft containers being Perth sourced. This finding is consistent with the increasing amount of animal feed being exported, as hay, in particular, is transported in 40ft containers. Further to this shift in exports is the growing number of 40ft and reefer containers as an overall fraction of exports (as units, not TEU) in 2011. The split between 20ft and 40ft and all reefers was 68.3%, 26.7% and 5.0%, respectively the thesis survey results in the same order are 51%, 41% and 8%.

The regularity of exports (based on respondents) is similar between the thesis and the 2011 exporter surveys. The most significant difference appears to be an increasing number of adhoc exports, Table 8-12.

Table 8-12 - Export regularity by the proportion of respondents.

Source: Hall (2011) and Author.

Export Frequency	2011 Survey (%)	Thesis Survey (%)
Steady	60	54
Steady but seasonal	20	17
Regular but inconsistent	14	12
Adhoc	5	17

The thesis survey indicates that trends identified through the three FPA surveys/study have continued with the growth in agricultural products resulting in exports being sourced further from the Inner Harbour and an increasing proportion of 40ft and reefer containers being used.

Imports

As noted in the FPA 2011 exporter survey and evidenced in the FPA 2012 importer survey, import containers are destined mainly for metropolitan use. The thesis survey finding 90% of respondents, Figure 8-13 and 94% of imported containers are transported under 50km when the Rous Head unpack is included, Figure 8-14. The FPA 2012 importer survey reports 11% by the number of containers unpacked in regional areas (Hall et al., 2012). The FPA 2017 container movement study identifies 97.9% and 96.2% of containers being unpacked within 50km of the port in 2011 and 2017, respectively (FPA, 2017b). The 2017 study notes the influence of Rous Head facility changes on the unpack location. These numbers are reflected in the country unpack locations at 2% and 3%, respectively, for the 2011 and 2017 work.

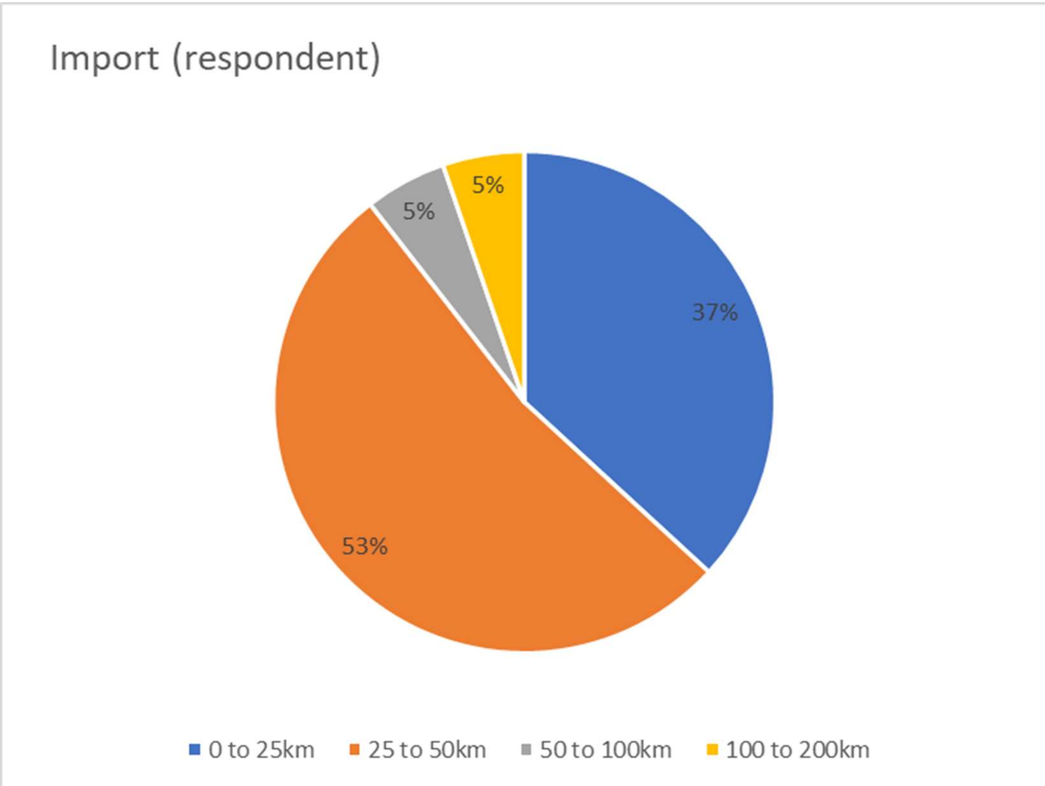


Figure 8-13 - Respondent distance to unpack location.

Source: Author survey.

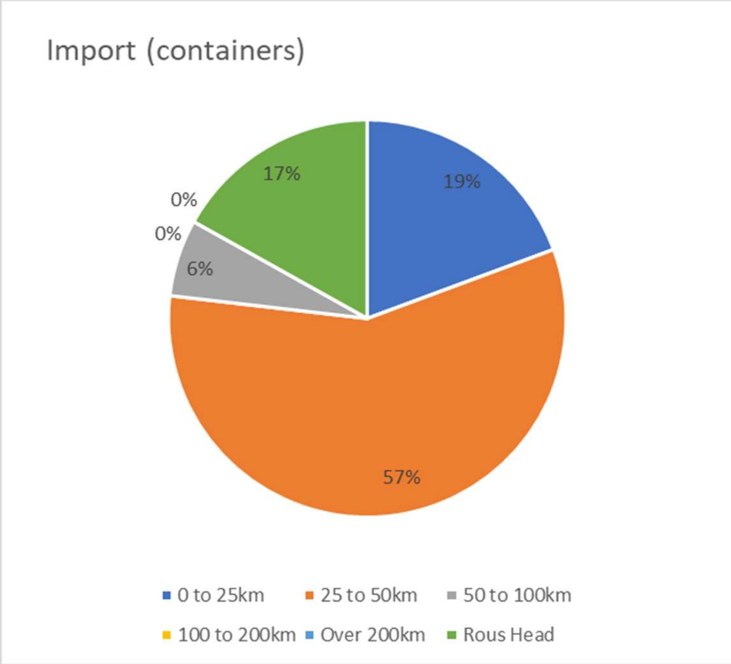


Figure 8-14 - Container transport distance to unpack location.

Source: Author survey.

The Rous Head facility is not discussed in the FPA 2011 survey but is noted as a change in the 2019 Truck Survey, with both packing and unpacking occurring at Rous Head and truck movements associated with this not being identifiable and so not being counted in the Truck Survey. Whilst no exporters responding to the current survey nominated as packing at Rous Head, this is occurring (FMC Consulting, 2019).

The thesis survey is consistent with the FPA surveys and study and shows the dominance of unpacking imports in the metropolitan area.

A further implication of this Rous Head activity is an "artificial" raising of the implied reduction of truck numbers as rail freight fraction increases as this is expressed as a proportion of containers moving through the seaport, not trucks laden with goods being transported to or from the port. The 2019 Truck Survey notes that fewer containers are coming to the Inner Harbour, and container truck numbers have reduced whilst container trade through the Inner Harbour has increased as logistics hubs have developed at Rous Head (FMC Consulting, 2019).

8.9.3 INNER HARBOUR LOGISTICS IMPROVEMENTS

During the period over which the surveys and study are conducted, the following improvements to the road, rail and logistics infrastructure and systems associated with the Fremantle Ports Inner Harbour facilities are identified from FPA Annual Reports, Table 8-13.

Table 8-13 - Landside logistics improvements over the survey period.

Source: FPA (2012b, 2013, 2014a, 2015a, 2016a, 2017a, 2018a, 2019c, 2020, 2021a).

Report	Activities
2012	Additional port land is made available at Rous Head from the previous year's dredging activity. Area being made available for truck marshalling and fuelling, empty container parks, container logistics, storage and short-term warehousing (port-centric logistics), and land to allow longer trains at the NQRT. Improved access between the rail terminal and stevedoring area. Developing a VBS to improve truck scheduling and increase the two-way loading of trucks. Working with DoT, WAF, LTF and WAPOTF to change the industry approach to container movements being dominated by weekday "business hours" times by introducing a booking system and conducting container "bulk movements" outside business hours.
2013	A new truck marshalling area opens, incorporating an electronic call-up system to notify trucks of readiness to enter the terminal for pick up or drop off. Introduction of a booking system for empty container parks.
2014	Off port road improvements to Tydeman and Napier Road intersection. Commencement of work on NQRT rail extension and passing loop at Spearwood to improve rail logistics.
2015	Rous Head developments completed with NQRT train lengths increased and the ability to both import and export directly from rail to the container terminals. Roads in the area are constructed for improved traffic flow and terminal access with a new entry.

	Fremantle Ports promotes the "Port Community System" to improve communications between supply chain participants and reduce paperwork by the introduction of an electronic platform providing rapid and secure data exchange.
2016	Nil.
2017	Truck productivity focus with Rous Head delivering improved truck movements and empty container parks functioning well. IT upgrades introduced with port traffic and congestion conditions provided directly to truck cabins via "Transport Certification Australia's Traveller Information Service" and cloud-based Fremantle Ports Variable Messaging System display boards advising trucks of traffic conditions.
2018	Further improvement to the Truck Control Systems at North Quay.
2019	Improved transport linkage between NQRT and Rous Head empty container parks. Vessel pre-arrival notice to rail service provider introduced. Further improvement is made to the Container Chain container booking system. Reintroduction of the Kalgoorlie rail service.
2020	Off port road upgrades to High Street, a new roundabout and general improvements between Stirling Hwy and Carrington Street. Fremantle Ports establish "Port Eco-System Co-ordination Group" to address COVID-19 logistics issues, particularly empty container storage.
2021	Off-port road upgrades on High Street continued. An additional passenger rail bridge across Swan River is announced, allowing increased freight train slots when completed. Container trade is at a record high with increased imports as community discretionary spending is increased on consumer goods due to COVID-related travel and entertainment restrictions.

8.9.4 RESPONDENT COMMENTS

The general responses in the FPA 2011 and 2012 surveys are similar to the current survey's free form comments and selection factor ranking.

The ranking of responses for not using rail in the FPA 2011 survey is presented previously in Figure 8-1.

The location of off-port facilities in relation to the exporter and the source/destination of containers is identified as important in the FPA and current thesis surveys. If the facility requires containers to be moved "further away" from the port than the source or destination or creates a dead transport leg, it is unlikely to be used. The current survey ranks drop-off/pick-up location as the sixth reason in transport mode selection and 11% of respondent comments are associated with close proximity to the port in support of the modal choice.

Cost is a primary factor in transport considerations across all surveys, *"Underpinning many of the key issues associated with off-port facilities is the concern there will be additional costs"* (FPA & WAPOT, 2011 p.5). Transport cost is the top ranked modal choice determinant and was identified as a reason for mode choice selection in 14% of free form comments in the current survey. The definition of costs that transport users use and incomplete understanding of services offered by an intermodal service, relying on information provided by the (road) transport provider for transport information, is identified as a reason for road use in the exporter survey. This is identified in the current thesis survey, with one exporter noting a lack of understanding of the rail transport system. Similarly, cost concerns associated with additional handling through rail and an intermodal terminal are evident for importers, as is the reliance on agents for transport selection and general import process understanding, which is incomplete for many small-scale importers.

The cut-off times and associated transit duration are reported as impediments to rail use by exporters, particularly in the case of JIT supply chain participants. The transit duration and service frequency ranked three and four in importance in the current thesis survey. A related factor, pick-up and drop-off times is the fifth highest ranked mode choice determinant and an important issue drawn from the FPA 2011 survey where alignment of facility opening hours with the required operating times of importers and exporters is not present.

8.9.5 COMPARISON OF SPECIFIC FINDINGS

The overall FPA 2011 exporter survey and 2012 importer study findings and findings from the thesis survey are mainly consistent.

- FPA 2011 finding - The additional cost of transporting containers to the dry port is not offset by savings associated with its use.
- FPA 2012 finding - The additional cost of transporting containers to the dry port.
    - Thesis finding - The sensitivity to cost is demonstrated by transport cost being the highest ranking determinant. The cost aspect is reflected in free form responses, with cost identified as a reason for modal choice and proximity to the port, making transport to the dry port a higher cost option.
- FPA 2011 finding - The flexibility of road transport to alter times, cope with JIT and live loading and later cut off times when compared to rail promotes road transport.
    - Thesis finding – This is indirectly supported by the second, third and fourth ranking of reliability, transit time and service frequency, all reflecting the desire for flexibility in the transport system. The requirement for flexibility and timeliness to meet cut-off times is noted in free form comments with a lower response rate associated with transit time and reliability.
- FPA 2011 finding - To promote intermodal use, the dry port must provide better access and efficient handling.
- FPA 2012 finding - Misalignment of operating hours between various operators in the supply chain.
- FPA 2012 finding - The requirement for double handling containers if rail is used.
    - Thesis finding – whilst not a direct ranking determinant, related factors such as service frequency, pick up/drop off times and pick up/drop off locations (access related) all rank in the top six determinants whilst geographic coverage is twelfth ranked. Handling efficiency reflected in

loss and damage history, traceability and ability to handle special requests are all in the bottom half of the determinant ranking. The complexity of rail, the extra time to deliver to the seaport, the ability to drop and pick up containers nearby (no empty run) and the requirement for double handling are free form responses related to the topic in the context of not using rail.

- FPA 2011 finding - Location of the dry port is important if "off route" diverting trucks creates additional costs.
- FPA 2012 finding - Location of the intermodal facility.
  - Thesis finding – As discussed previously, transport cost is a high ranking determinant. In free form responses, the diversion aspect is related to proximity to the port and explicitly notes the intermodal facility requires trucks to haul a longer distance than a direct route to the seaport.
- FPA 2011 finding - Exporters are unaware of what the intermodal service can provide regarding container weight handling, capacity and how the 'system works".
  - Thesis finding – free form responses noted a lack of understanding of the rail service and a "perception" that rail is more expensive.

8.9.6 RECOGNITION OF LOGISTICS IMPROVEMENTS

The Rous Head reclamation is a fundamental factor in improving logistics associated with moving containers to and from the port hinterland. The development of extra operating areas removed a constraint on the seaport's growth and, in conjunction with improved systems, allowed seaport throughputs to grow. Whilst these factors can delay the trigger point for the development of a dry port, they facilitate improvements to the rail transport function and increase road capacity allowing the seaport to increase throughput without placing further pressure on the surrounding community.

The ranking of determinants and free form comments provide insight into the effect of Fremantle Ports' improvements to the logistics infrastructure and systems over the period of the FPA study and surveys and the current survey.

The issue of cost is consistently cited as a primary determinant of the transport approach. The activity to reduce congestion (off port road improvements, booking and information systems and enhanced access to terminals) in the face of a growing transport task works to maintain costs. The container freight subsidy assists to grow the rail proportion of the transport task reducing road congestion and associated externalised costs that would otherwise occur.

Lack of understanding of rail transport by non-rail users has been recognised by Fremantle Ports and work with user groups and the various surveys and interviews conducted serve to improve this understanding.

8.10 SURVEY CONCLUSIONS

Consistent with the literature, the cost of the transport task is the highest ranked determinant of transport mode selection. Transit time and certainty about its duration also rank in the top five of both. Cargo consolidation is a low ranking in both lists. The most apparent difference in the two rankings is the relative importance of the loss and damage history of the carrier, ranked second in the literature but in the bottom half of the current survey and not a finding of any of the FPA surveys or study. Differences also occur in service frequency ranking, which is relatively more important to the Inner Harbour users and a lesser extent, track and trace offerings, with this ability being aligned with the lower ranking identified by Flodén et al. (2017). The Inner Harbour transport mode determinants broadly agree with the literature on the determinants of mode choice. The marked difference in the importance of damage and loss history is possibly due to differences in cargo types handled through the Inner Harbour compared to the broader literature.

The low ranking of the environmental consideration of greenhouse gas emissions by respondents is consistent with the topic being an "emerging area" in the literature and in agreement with the observation of Flodén et al. (2017) that the environmental advantages of mode (rail) selection lag well behind the transport cost. The prominence of cost and other "bland" supply chain factors as a determinant is at odds with the argument of Khaslavskaya and Roso (2019) that an outcome-driven approach can result in improved overall supply chain outcomes.

Factors associated with short-haul rail are evident in the ranking of mode selection determinants and act against rail selection. In the determinant ranking, transport cost, service frequency and pick-up and drop-off locations rank highly whilst the environmental consideration is second to last. Free form comments on the reason for or against the modes were split, with distance to the seaport cited by road users as important to their choice. In the case of exporters, rail use was dominated by sources over 100km from the Inner Harbour. Rail users were the only respondents that provided congestion reduction as a free form comment.

The work undertaken by Fremantle Ports to improve hinterland logistics connectivity and the ongoing state government container rail freight subsidy allows the proportion of freight moved by rail to increase during a period of increasing overall freight volumes. The developments are consistent with those presented in the literature to promote modal shift and reduce congestion around seaports. The achievement is significant as it goes against the international trend of rail share decreasing as freight task grows (Elbert & Seikowsky, 2017; Resor et al., 2004). In the Australian context, Fremantle Ports is consistently the top ranked rail transport share container seaport (BITRE, 2021b).

The infrastructure improvements are used in conjunction with Fremantle Ports using its position as a public authority to engage with a broad range of supply chain actors to bring about change consistent with the port being a fourth and emerging fifth generation seaport.

The importance of freight forwarders in the transport mode choice is evidenced in the free form comments on reasons for selecting a mode of transport. Combined with the lack of direction provided by exporters and importers regarding their transport preference for these actors, their role in modal choice is significant.

The thesis survey and FPA surveys and study found similar outcomes relating to the transport of containers. The dominant source and destination of containers remains the Perth metropolitan area with a growing number of containers sourced from the agricultural sector. Factors important to transport mode selection were consistent and highlight issues surrounding cost and schedule frequency and flexibility. The lack of understanding of the intermodal system was also evident.

The survey results are sufficient to satisfy the survey purpose as described in Section 8.2 Purpose of the Modal Choice Survey:

- To understand why container freight users select either road transport or intermodal transport in moving containers to or from the Inner Harbour to support the consistency or otherwise of the case study with the literature.
- Compare the survey results, as far as is practicable, with the 2011 FPA survey of exporters (FPA & WAPOT, 2011; Hall, 2011), the 2012 importer survey (Hall, Brindal, & Stephens, 2012) and the 2017 FPA container movement study (FPA, 2017b). Consistency with these surveys supports the findings of the thesis survey.

The consistency in outcomes between the two sources and the literature supports the applicability of the case study.

Chapter 9: Dry Port Development Framework

9.1 INTRODUCTION

Despite the growing significance of dry ports in container based global supply chains, research in the field of dry ports is still relatively new, and research papers are almost exclusively narrowly focused on a specific dry port issue.

The literature, Fremantle Ports case study and modal choice survey provide the foundation for establishing a dry port development framework. The relationship between these components is described in Figure 9-1. The literature consistently identifies the drivers for and factors important to dry port developments and is demonstrated as valid for the Fremantle Ports case study. This research has drawn together these components from the literature, the case study and modal choice survey into a framework that provides industry practitioners with a guide to reasons why a dry port may be developed and aspects requiring consideration relating to the reason for the development. As discussed in Section 6.1.5 Role of Supply Chain Actors the various actors in the supply chain have varying goals which result in the different ownership, development approaches, functions and management of dry ports. These varying goals are reflected in the different development streams presented in the dry port development framework.

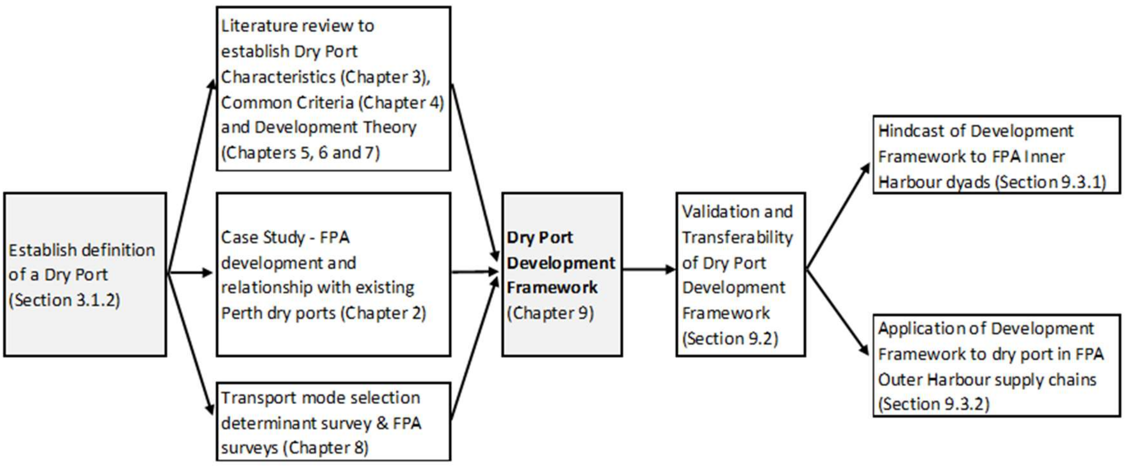


Figure 9-1 - Establishing and validating the dry port development framework.

9.2 DRY PORT DEVELOPMENT FRAMEWORK

A dry port development framework is established through this research to describe components important for developing or including a dry port in a supply chain. This is achieved by drawing together the components that must be considered to assess the suitability of and guide the process of developing or introducing a dry port into a supply chain in a single framework diagram. The literature has not previously presented a framework describing this overall approach.

In the application of development factors, the specific supply chain characteristics must be considered, as this determines the presence or relative importance of the different drivers, development factors and the approach required to bring all the supply chain actors together. The differences in supply chains can result in different responses to the framework as the outcomes of applying the same supply chain strategy to different supply chains can be different (Baccelli & Morino, 2020). The presence of the specific supply chain factors is reflected in the different directional development and development streams presented in the framework. It also results in not all "progress to dry port development components" being present in all developments.

The dry port development framework (based on rail transport) is presented below in Figure 9-2 - Dry port development framework.. The dry port development framework brings together the development driver, trigger factors, mechanism, general considerations and development phase/lifecycle stage of the entity viewed from an Outside-In or Inside-Out perspective, based on the literature and the Inner Harbour component of the Fremantle Ports case study.

The framework implicitly includes supply chain actors, seaport owners (private and public), and government and dry port developers (private and public). The supply chain actors are described by Frémont and Franc (2010) as either economic agents (shippers, freight transporters, shipping lines), public authorities, or community groups and the way the differing objectives of actors interact will influence how the dry port develops. These agendas can be competing, and seaport management can play an essential role in providing an *"organising capacity"* to the differing agendas.

The dry port development framework development driver describes the underlying reason why the development of a dry port is being undertaken and represents the primary factor(s) that will be improved by the inclusion of the dry port into the supply chain. The commonly described suppression of seaport growth due to on or off port logistical constraints, the location splitting "Standortspaltung" to achieve straight economic opportunity or a public actor development to improve regional or externalised transport cost outcomes represent three different Outside-In development streams in the framework. Inside-out developments occur in two streams, either supported by a commercial motive from actors such as land developers or rail transport owners or a public actor development like the Outside-In approach.

The development stage or lifecycle of the seaport or dry port is described and varies depending on the development driver these phases and stages are presented in Chapter 5 Development Models for seaports and dry ports summarised in Table 5-2. The development stage is important as the seaport or dry port must have the management and infrastructure ability to cope with the development. The lifecycle status will raise the importance of the trigger factors and general considerations in progress to dry port development. This will reflect whether the seaport is trying to establish a reset in the lifecycle stage or extend a growth or maturity phase.

Trigger factors in the framework describe the various causes to commence a dry port development which if not addressed will cause a fall in seaport and associated supply chain efficiency. Not every trigger factor needs to be present for a development to proceed.

General considerations are factors that the dry port developer must address in the development process and the advantages that will be gained through the presence of the dry port.

The five fundamental requirements identified by UNCTAD (1991) that must be present or capable of development (including systems to bring them into effect) in all streams are:

- Being located inland with direct transport links to the seaport.
- Catering for import and or export or both.
- Providing intermodal transport.
- Providing secure storage and handling of containers.
- Distributing and/or consolidating cargoes.

The different development streams give rise to different primary and general considerations in the trigger factors. These differences result from differing objectives underlying the development, which have a different focus. Logistics infrastructure resolution will address different issues to that of an investment opportunity or public benefit objective.

The mechanism that brings about the actual "investment" depends on the actors involved and the objective of the development. A dry port development based on a commercial investment opportunity will likely be funded by the developer. An approach to overcoming logistics constraints can be achieved by a direct investment by the seaport or by entering into commercial or operating arrangements with a private entity. In developed economies, direct public sector investment is being replaced by creating a favourable investment climate for private entities.

Once established, subsequent changes to the initial dry port can also be undertaken in a bi-directional manner.

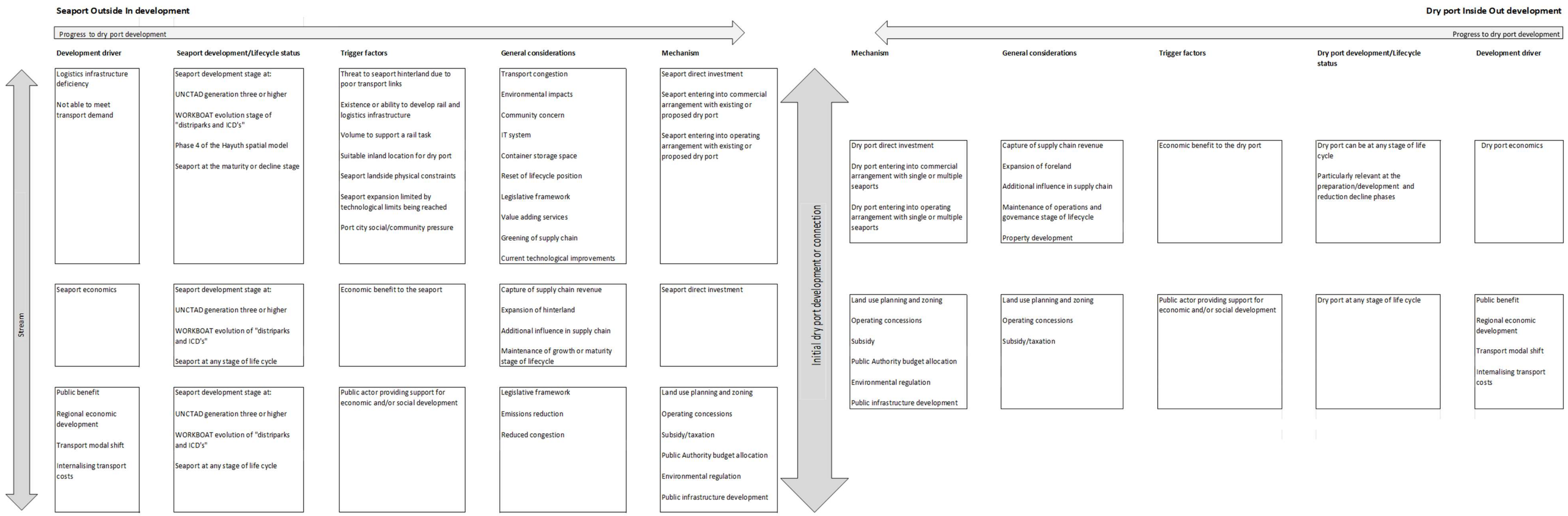


Figure 9-2 - Dry port development framework.

Source: Author.

9.3 DRY PORT DEVELOPMENT FRAMEWORK TRANSFERABILITY AND VALIDATION

9.3.1 TRANSFERABILITY DEFINITION AND SIGNIFICANCE

Transferability of a research paper is the ability of a new reader to apply the results of the original research to a similar situation. Transferability is particularly relevant to case studies as they supply sufficient detail about the research to enable a new researcher to decide if the situation being studied is similar enough to allow transferability of the original work to the new situation (Barnes et al., 2012).

As the thesis is applied research, the transferability of findings is a significant outcome to be of value to industry.

The case study approach shows Fremantle Port to be consistent with the literature in the following areas:

- The Fremantle Port developed following seaport models and passed through the various port generations.
- The Fremantle Port interaction with the City of Fremantle and the surrounding community reflects tensions in port-city relationships.
- The dry ports in the Perth metropolitan area developed following dry port models.
- A survey of importers and exporters and previous FPA surveys show that Fremantle Ports Inner Harbour users have similar rankings of transport mode selection determinants to the literature.

These findings and the research having similar outcomes to the second stage of the broader Westport Study support the transferability of the research findings.

This similarity is significant in two ways. Firstly, the Inner Harbour situation must be transferred to that of the Outer Harbour if the criteria for developing a dry port in the Outer Harbour supply chain are based on the case study findings. Secondly, the dry port development framework described can be used at a practical level in assisting a demonstration of the need for and success of a dry port in other supply chains.

9.3.2 DRY PORT DEVELOPMENT FRAMEWORK VALIDATION

The dry port development framework is validated in two ways.

Firstly, the use of common criteria and development models that are widely described and peer reviewed in the literature are used to form the basis of the dry port development framework.

Secondly, the application and validity to other supply chains can be demonstrated by hindcasting the dry port development framework outcomes against a selection of case studies presented in the literature and other sources. The ability to use six to ten individual case studies that consistently explain the outcome provides for the generalisability of the dry port development framework qualitatively (Ellram, 1996) validating the approach. The dry ports selected for hindcasting the dry port development framework, presented in Table 9-1, are from a range of countries with differing histories, sizes and classifications to demonstrate the validity of the dry port development framework across a range of development scenarios.

The hindcasting of the dry port developments relies on the interpretation of publicly available information. Whilst not always extensive, it is sufficient to demonstrate that the dry port development framework would be valid in considering these developments as the various aspects and components of the dry port development framework were consistently able to address all the case study development items. This demonstrates that the dry port development framework could have been used to show the pathway to dry port development in the situation facing the seaport or dry port in the hindcasting exercise. The success in hindcasting provides confidence in the dry port development framework being used as a practical tool when considering a dry port development in other seaport dry port dyads.

Table 9-1 - Hindcasting development approach of various dry ports.

Source: (1) Roso et al. (2017), (2) Roso (2008), (3) Black et al. (2018), (4) Auditor General (2017), (5) Roso et al. (2006), (6) Bielenia et al. (2020), (7) PoA (2021), (8) AGORA (2022), (9) Wikipedia (2021), (10) Eurailpress (2017), (11) Monios (2011), (12) Puerto Seco de Madrid (2014) (13) Beresford et al. (2012), (14) Port Technology (2020), (15) Zeng et al. (2013), (16) Cogoport (2020), (17) Business Standard (2022), (18) CONCOR (2022), (19) CONCOR (2020), (20) Lepeska (2022), (21) GPA (2022a), (22) GPA (2022b), (23) SCPA (2021), (24) APB (2022), (25) UoE (2022), (26) G&W (2022), (27) Fender (2006), (28) Spaven (2013), (29) RAIL magazine (2015), (30) Transport Scotland (2017).

	Dry Port Development Framework Factors					
Dyad and Brief Description	**Development Driver**	**Development Direction**	**Mechanism**	**General Considerations**	**Trigger Factors**	**Dry Port Development / Lifecycle Status**
Australia (1), (2), (3), (4)						
Port Botany/Minto – Close dry port. Operated by Macarthur Intermodal Shipping Terminal (JV), 45km from the port. Capacity 45,000TEU pa.	Dry port economics	Inside-Out	Dry port entering into operating arrangement with single seaport	Capture of supply chain revenue	Economic benefit to the dry port	Dry port can be at any stage of life cycle
Port Botany/Enfield – Close dry port. Developed by Sydney Ports, 40km from the port. Approval for 300,00TEU pa.	Logistics Infrastructure deficiency Not able to meet transport demand Transport modal shift	Outside – In	Seaport direct investment (Enfield)	Transport congestion Community concern	Seaport expansion limited by technological limits being reached Port city social/community pressure Threat to seaport hinterland due to poor transport links	UNCTAD generation three or higher
Moorebank – Close dry port. Developed by MIC (GTE). Operated by SIMTA 100% owned by Qube, capacity 1,550,000TEU pa.	Regional economic development Transport modal shift	Outside – In	Public infrastructure development Land use planning and zoning	Reduced congestion	Public actor providing support for economic development	UNCTAD generation three or higher
Europe (5), (6), (7), (8), (9), (10), (11), (12)						
Sweden, Göteborg /Eskilstuna – Mid-range dry port. Owned by the municipality of Miljö. Developed to serve Port of Göteborg 380km from the port. Terminal is 9,000m2	Regional economic development	Inside-Out	Public Authority budget allocation	Not clear	Public actor providing support for economic development	Dry port at any stage of life cycle

	Dry Port Development Framework Factors					
Dyad and Brief Description	**Development Driver**	**Development Direction**	**Mechanism**	**General Considerations**	**Trigger Factors**	**Dry Port Development / Lifecycle Status**
with 800 TEU storage capacity. 2004 throughput 20,000TEU Germany, Port of Antwerp, Port of Hamburg/Leipzig-Wahren Terminal. Mid-range dry port. Built and operated by DUSS_Leipzig-Wahren Ubf, (Deutsche Umschlaggesellschaft Schiene-Straße (German rail-road intermodal company)), 553km from the port, storage for 4,500TEU, throughput 220,000TEU pa	Dry port economics	Inside-Out	Dry port entering into operating arrangement with single seaport	Capture of supply chain revenue	Economic benefit to the dry port	Dry port at any stage of life cycle
Spain, Algeciras Port, Bilbao Port, Barcelona Port and Valencia Port/ Madrid Dry Port. Mid-range dry port. Built by Ministry of Public Works the Community of Madrid and the City of Coslada, together with Ports of Spain and the Land Public Entity (SEPES) operated by Conterail. 19,000m2, throughput 140,000TEU pa.	Seaport economics	Outside – In	Seaport direct investment	Expansion of hinterland Additional influence in supply chain	Economic benefit to the seaport	Seaport at any stage of life cycle
Asia (13), (14), (15), (16), (17), (18), (19)						
China, Tianjin seaport/Shijiazhuang dry port – Mid-range dry port. Operated by CRIntermodal	Regional economic development	Outside – In	Public Authority budget allocation		Public actor providing support for economic development	UNCTAD generation three or higher
China, Multiple seaports/Xi'an – Distant dry port. Operated by CRIntermodal	Regional economic development	Inside-Out	Public Authority budget allocation Land use planning and zoning Operating concessions		Public actor providing support for economic development	Dry port at any stage of life cycle
India, Port Pipavav, Jawaharlal Nehru Port, Mundra Port/Port of Tughlakabad - Mid-range dry port. Built and operated by CONCOR (Container Corporation of India, Government Public Sector Enterprise)	Regional economic development	Inside-Out	Public Authority budget allocation Public infrastructure development	Not Clear	Public actor providing support for economic development	Dry port can be at any stage of life cycle

	Dry Port Development Framework Factors					
Dyad and Brief Description	**Development Driver**	**Development Direction**	**Mechanism**	**General Considerations**	**Trigger Factors**	**Dry Port Development / Lifecycle Status**
USA (20), (21), (22), (23)						
Los Angeles and Long Beach seaports/Dallas (IIPOD) – Close dry port. Union pacific Intermodal Terminal	Dry port economics	Inside-Out	Dry port direct investment	Capture of supply chain revenue Property development	Economic benefit to the dry port	Dry port can be at any stage of life cycle
Savannah seaport/Appalachian Regional (dry) Port – Mid-range dry port ,545km from the port. Developed by State of Georgia, Murray County, Georgia Ports Authority (GPA) and CSX Transportation, Operated by GPA, throughput 50,000 to 65,000TEU pa, 170,00m2 area	Seaport economics Regional economic development	Bi-Directional	Public Authority budget allocation	Capture of supply chain revenue	Public actor providing support for economic development	Dry port can be at any stage of life cycle
Charleston seaport/ Inland Port Greer – Mid-range dry port, 340km to port, Owned and operated by South Carolina Ports Authority (SCPA)	Regional economic development	Outside – In	Public Authority budget allocation	Reduced emissions	Public actor providing support for economic development	UNCTAD generation three or higher
UK (24), (25), (26), (27), (28), (29), (30)						
Southampton, Tilbury, and Felixstowe seaports/Hams Hall Rail Freight Terminal-Mid-range dry port. Purchase by Associated British Ports (APB) – Purchased by APB in 2002, 109,000m2, 120,000TEU pa 3250 TEU storage capacity	Seaport economics	Outside – In	Seaport direct investment	Capture of supply chain revenue Additional influence in supply chain	Economic benefit to the seaport	UNCTAD generation three or higher
Felixstowe, Liverpool, London Thamesport, Southampton and Tilbury Seaports/Coatbridge Freightliner Terminal – Mid-range dry port. Owned by Freightliner (Freightliner was initially government majority shareholder and privatised in 1996 and purchased Coatbridge which was developed in 1968 by government), circa 80,000TEU pa (2015) throughput, 160,000m2, 2520TEU storage	Initially - Transport modal shift, under Dr Beeching 1963 Plan, *"The Reshaping of British Railways"*	Inside – Out	Public infrastructure development	Public Authority budget allocation Public infrastructure development	Public actor providing support for economic development	Dry port at any stage of life cycle
	Subsequently - Dry port economics, under management buy out	Inside-Out	Dry port direct investment	Capture of supply chain revenue	Economic benefit to the dry port	Dry port can be at any stage of life cycle

9.4 APPLICATION OF DRY PORT DEVELOPMENT FRAMEWORK TO FREMANTLE PORTS SUPPLY CHAIN

The dry port development framework can be applied to the Fremantle Ports' existing dry port dyads and the potential Outer Harbour development. The Inner Harbour dyads test the dry port development framework approach, which is then applied to the Outer Harbour.

The Fremantle Ports case study and transport mode selection determinant survey confirm the relevance of common criteria and development models to the Inner Harbour and associated dry ports. The dry port development framework in a hindcasting application is consistent with the Inner Harbour dry port developments. The application of the dry port development framework to the Outer Harbour dyads provides a development pathway to incorporate the existing metropolitan dry ports in the future supply chain.

9.4.1 INNER HARBOUR

The common criteria and reasons for developing a dry port are all present in the Inner Harbour.

- Transport demand, in the form of container trade, with pre-COVID-19 projections for future growth ranging between 2.8% to 5.8% per annum.
- Hinterland connectivity is recognised as a critical factor in the operation and capacity of the Inner Harbour. Setting a rail share target is complimented by the NQRT development to improve hinterland connectivity through more efficient rail and intermodal infrastructure.
- The modal shift reduces road congestion for a given seaport throughput providing an overall capacity increase for the supply chain.

Dry ports often have a directional development, depending on the reason they are introduced. This direction can be Inside-Out, Outside-In, Bi-directional or without specific direction as small intermodal facilities grow and strengthen existing links with a seaport. The dry ports in the Perth metropolitan area have different directional development, due to the long life of Forrestfield/Kewdale direction varied over time.

The application of the dry port development framework is presented in Table 9-2.

Table 9-2 - Application of the dry port development framework to the Inner Harbour.

	Dry Port Development Framework Factors					
Dyad and General Description	**Development Driver**	**Development Direction**	**Sea or Dry Port Development / Lifecycle Status**	**Trigger Factors**	**General Considerations**	**Mechanism**
Inner Harbour						
Forrestfield/Kewdale – multiple factors have applied over time	Logistics infrastructure deficiency Public benefit Transport modal shift	Bi-Directional	Seaport at mature stage of lifecycle Subsidy Public Authority budget allocation	Port city social/community pressure Transport congestion Community concern Reset of lifecycle position	Transport congestion Community concern Reset of lifecycle position Reduced congestion	Seaport has entered into commercial arrangement for NQRT operations Public infrastructure development (rail upgrades)
Kwinana	Public benefit Transport modal shift	Inside-Out	Seaport at mature stage of lifecycle Subsidy	Reduced congestion	Transport congestion Community concern Reset of lifecycle position Reduced congestion	Seaport has commercial arrangement with dry port
Kenwick	Dry port economics	Inside-Out	Dry port can be at any stage of life cycle	Economic benefit to the dry port	Capture of supply chain revenue	Dry port direct investment

9.4.2 OUTER HARBOUR

The future Outer Harbour development and associated supply chain and transport infrastructure are captured in the dry port development framework. It is an Outside-In model with an initial development driver of public benefit, regional economic development and modal shift triggered by a public actor (state government). The general consideration is satisfying emissions reduction and pre-empting congestion through the mechanism of land use planning and zoning, Port Authority budget allocations and public infrastructure development.

Given the proposed location of the Outer Harbour, for the forecastable future, much of the seaport trade will be destined or sourced from the Perth metropolitan area (albeit recognising the increasing volume of export containers sourced from areas outside the city), predominately from the same areas that they currently move from and to in the Inner Harbour supply chain. Like the Inner Harbour, an on-port rail terminal is required to establish a viable short-haul rail operation to the existing and future dry ports distributed around the metropolitan area and intrastate locations.

Dry ports in the Perth metropolitan region are at different lifecycle stages, with Forrestfield/Kewdale being at a mature stage but still with capacity for additional volume and the Kenwick facility commencing in a growth stage. The transport demand to sustain these facilities will be present as this is a trigger for the Outer Harbour in its own right.

As a new location, with newly established road transport links, the Outer Harbour will not suffer local road congestion issues in its early operating years. Other external road transport costs will support rail use, particularly from a public actor's viewpoint. Moving the Outer Harbour location south from adjacent to Rowley Road to Anketell Road is influenced by reduced community impact. Anketell Road is not free of residential areas and this, combined with a general greening of supply chains and potential internalisation of transport costs or ongoing rail subsidy, means intermodal transport has a role in the Outer Harbour supply chains.

Given the existence of dry ports in the Perth region and the role the WA state government has in regional planning, road and rail network development and promotion of rail transport, dry port integration and development in the Outer Harbour supply chain are likely to be initially an Outside-In model but become Bi-Directional over time.

The application of the dry port development framework to the Outer Harbour dyads is presented in Table 9-3.

Table 9-3 - Application of the dry port development framework to the Outer Harbour.

	Dry Port Development Framework Factors					
Dyad and General Description	**Development Driver**	**Development Direction**	**Mechanism**	**General Considerations**	**Trigger Factors**	**Dry Port Development / Lifecycle Status**
Outer Harbour						
Forrestfield/Kewdale/Kenwick	Public benefit Regional economic development Transport modal shift	Outside-In	Land use planning and zoning Public Authority budget allocation Public infrastructure development	Emissions reduction Reduced congestion	Public actor providing support for economic and social benefit	Seaport at UNCAD generation three or higher

Chapter 10: Conclusions

10.1 RESEARCH OBJECTIVES

The overall objectives of this research are to explore and interpret a wide range of topics in the literature applying the published common criteria and development models that favour the development of a dry port to create a dry port development framework and in conjunction with a consideration of the literature review outcomes demonstrate how:

(i) a dry port may benefit the current Fremantle Port Inner Harbour operations with an emphasis on hinterland connectivity, reduction in social impact (road congestion and noise), pollution, operating life and capacity associated with current supply chain links; and

(ii) the Fremantle Port Outer Harbour development, using a dry port in conjunction with waterside infrastructure, may have benefits over a traditional waterside development.

10.2 DRY PORT LITERATURE EXPLORATION AND INTERPRETATION

The following exploration and interpretation of the literature used to construct a dry port development framework for a rail-based dry port satisfy the research objectives introductory statement.

10.2.1 CASE STUDY APPROACH

The single case study approach is an appropriate basis for the research as the Fremantle Ports Inner Harbour seaport and proposals around an Outer Harbour development are unique in terms of the geographic location, specific actors involved and the contemporary nature of the subject matter.

Triangulation was employed in considering the various data sources. When the writer's perspective is considered, there is good agreement between descriptions and conclusions drawn in the thesis and literature, media items, government and interest group studies and reports. The examination of the role of different actors demonstrates the importance of the triangulation approach as the views expressed could be contradictory, and the author's position must be considered when using information put forward.

The development of Fremantle Ports Inner Harbour and motivations for developing the Outer Harbour and the Forrestfield/Kewdale dry port over time established through the case study are in close agreement with development models reported in the literature.

The findings of the FPA surveys and study and the thesis survey on source and destination, type and comments on modal choice are consistent when considering the changes in logistics facilities and the composition of freight over time. The thesis survey questionnaire ranked modal choice factors in a similar order to the literature, with transport cost being the top ranked determinant.

The agreement between the case study characteristics and the literature provides confidence in using conclusions from the research to establish a dry port development framework and answer the research questions

10.2.2 DEFINITION OF A DRY PORT

The evolution of facilities over time combined with the different geographical locations, actors involved in the development of, and functions performed by dry ports combined with historical factors means the taxonomy of dry ports is not well defined in the literature. A broad definition of a dry port is drawn from the literature and adopted for this thesis: "**an inland intermodal hub with direct transport links to a seaport, where some seaport and supply chain functions and facilities are duplicated**". The definition is used to ensure all facilities linked to the Fremantle Ports Inner Harbour and a potential Outer Harbour are considered in addition to not limiting relevant literature from consideration. This definition is consistent with that most widely used in the literature (Khaslavskaya & Roso, 2020).

10.2.3 ATTRIBUTES AND CLASSIFICATION OF A DRY PORT

Dry ports developed with the advent of container based global supply chains as seaports moved from having control over captive hinterlands to competing with other seaports to remain competitive in contested hinterland regions. This results in increased pressure to improve seaport and land transport efficiency as the collection and distribution networks formed, enabling an increased system throughput. Dry ports improve the logistics of containerised cargo by:

- Improved inland transport efficiency.

- Reduced congestion of areas surrounding major container seaports.
- Responding to the move to global supply chains rather than a transport activity from seaport to seaport.

A seaport dry port dyad allows seaports to:

- Remain competitive in contested hinterlands by satisfying the differing priorities of the various actors in the supply chain as maritime factors reduce in relative importance to hinterland drivers in the overall cost and efficiency of the system.
- Improve the cost, responsiveness, security, resilience, environmental performance and innovation of the system as actors move away from a narrow node by node cost analysis to overall system efficiency criteria for supply chain performance.
- Provide sufficient storage space for container flow surges from increasingly large vessels and total container throughputs.
- Reduce surrounding community impacts and externalised costs through a transport modal shift from road to rail as residential areas encroach on transport corridors and migrate to previously industrialised areas as the relationship between seaports and port cities changes over time.
- Improve their position in the seaport lifecycle by resetting their position or maintaining a growth or maturity stage for longer.

Three broad classifications of dry ports exist based on the proximity to the seaport they serve. These are summarised in Table 10-1. Other classifications are presented in the literature based on the function and activity undertaken, transport mode and role in the supply chain but are not as widely used as the distance based classifications. The functional and activity based classifications are essential as they provide insight into the underlying reason for the introduction of the dry port into the supply chain.

Table 10-1 - Summary of dry port classifications.

Author	**Rosso**	**Rodrigue**	**Beresford**
Type 1 • In close proximity to the seaport, possibly on the urban fringe. • Provides container storage and consolidation.	Close	Satellite	Seaport-based
Type 2 • Somewhat remote from the seaport. • It is located near production/consumption base. • Typically, rail/road intermodal.	Mid-range	Load center	City-based
Type 3 • Remote from the seaport, linking the distant hinterland. • Able to take advantage of rail linehaul costs to expand seaport hinterland.	Distant	Transmodal	Boarder

A counter-position to the dry port argument is port-centric logistics. This activity returns some traditional services of seaports, which moved off-port, back to the seaport due to the attributes of the particular supply chain. Sometimes, the port-centric approach is difficult to distinguish from a close dry port.

The following attributes are identified as typical of those present at a dry port:

- The facility must be intermodal.
- There must be strong transport links between the dry port and the seaport.
- The facility provides services that are interchangeable with a seaport, such as customs, storage and value-adding services.

10.2.4 COMMON DRY PORT DEVELOPMENT CRITERIA

The following common criteria for the development of a dry port are identified in the literature:

- The presence of transport links between the seaport and the dry port, including rail, road and barges.
- A cargo that is massified and increasingly able to be transported in ISO standard containers.
- A distance between the seaport and the source/destination of a cargo that can support an intermodal transport operation in the context of the overall supply chain.
- An Information Technology system that can support an intermodal transport network's administrative, tracking and control requirements.

The location of the supply chain is important as it brings regional attributes such as infrastructure ownership approach, transport characteristics, government policy and regulation and historical influences into consideration.

The objectives of the various actors, internal and external, bear on the supply chain and triggering of dry port development. Externalised transport costs (noise, pollution, congestion and accidents) bring community and local government pressure to shift freight transport from road to rail, whilst commercial objectives and long-established operational approaches may see the inertia remain with road transport. Port Authorities have a role in an organising capacity to support an effective hinterland access regime.

Specific trigger point values for developing a dry port in a given supply chain cannot be quantified from the literature. Each supply chain's individual and unique attributes mean that specific trigger values cannot be generalised. The trigger occurs as the supply chain specific factors related to reasons for dry port development, evidenced by an actual or predicted fall in the seaport and supply chain efficiency. This results in the establishment of dry ports at different distances from seaports with differing services supported by throughputs ranging from 2,000 to 3,600,000 TEU per annum with facility areas between 0.8 to 1,600ha. A supply chain economic structure may result in the establishment of a dry port before transport or spatial restrictions are evidenced at a seaport, further clouding the ability to provide generalised values for development triggers.

Dry port site selection is not straightforward, particularly in metropolitan areas, with mathematical modelling proving unable to select specific sites for development unless narrow criteria are applied. A multi-criteria analysis, considering both cost and non-cost variables, is increasingly used in site selection. In metropolitan areas, this approach can be used in conjunction with the identification of sites with logistics potential from historical development (transport infrastructure) to optimise a dry port location.

These factors combine to identify the criteria that form the inputs into the decision making process on the development or otherwise of a dry port in a given supply chain, with each situation requiring a unique analysis.

10.2.5 DRY PORT DEVELOPMENT MODELS

Dry port development models have emerged from seaport models and concepts imported from other research areas.

Understanding the various development models (both dry port and seaport) provides insight into the suitability of a dry port to a given seaport and the likely development approach and justification. This understanding will demonstrate the spatial development of seaports. It must be used in conjunction with understanding how a seaport's functional role must change to provide insight into the role of a dry port in the supply chain. The Taaffe and Bird Anyport type models describe this development from isolated scattered seaports that develop links into the hinterland, eventually interconnecting and giving rise to centralised major and minor seaports that compete for contested hinterlands in a regionalisation environment.

Overarching these factors is the approach of the seaport management to the changes occurring in world trade transport systems. Unless the seaport controlling body reacts to ensure alignment of seaport infrastructure and services to the needs of the actors in the supply chain, the seaport will decline in importance, reflected in reduced cargo volumes. This is described in the UNCTAD four port generation models moving from seaports narrowly focusing on the interface between sea and land to that having private sector involvement with port authorities in management roles focusing on policy, planning and promotion. A fifth generation consumer-centric community seaport is introduced as part of a port ladder of seaport management progression with a sixth generation 50,000TEU vessel handling capability postulated.

There are two ways for a seaport to meet freight growth requirements, with and without a structural change. The first relates to the seaport consuming increasing amounts of land to achieve increased capacity and the second is by implementing a technological change or accessing additional land by reclamation or similar. When seaport growth is no longer achievable by either of these means, i.e., the cost of accessing more land is prohibitive and technological improvement is not possible, then the seaport has reached the limit of its growth in that location.

The emergence of the dry ports along hinterland connecting transport corridors results from increasing pressure to improve efficiency in seaport and land transport as the collection and distribution networks form, enabling an increased system throughput. The dry ports can fulfil various value-adding functions to the supply chain and may develop into “regional load centre networks” and “logistics zones” required to support the regionalisation phase of the seaport development model.

Both seaports and dry ports fit a life cycle model, which describes the phases they pass through from commencement until a decline in operations.

Four phases define the seaport lifecycle:

- Development and introduction - The seaport commences operations with a limited hinterland and non-standardised basic services.
- Growth - Economies of scale are realised as infrastructure improvements are introduced alongside standardisation and process innovation. An increasing land area is required for land-based infrastructure and storage. Hinterland reach is broadened through infrastructure development.
- Maturity. - Growth slows because of completing standardisation and infrastructure improvements within the seaport area's physical constraints, allowing competition from other seaports for the enlarged hinterland.
- Decline - Seaport activity is constrained as no further land or process innovation is available. Other seaports encroach into the hinterland, market share drops and eventually, throughput declines follow.

Five phases define a dry port lifecycle:

- Preparation - sites are evaluated, and support is garnered for the development.
- Establishment - transport modes are planned and established, the reach and service provision of the facility is limited.

- Expansion - actors are attracted to the facility, and further investment takes place.
- Stabilisation - facilities are expanded, but new arrivals slow down.
- Reduction - actors leave for better options elsewhere, and changing external conditions require operations to change.

The life cycles of seaports and dry ports are not necessarily aligned. They can function under different governance structures, government planning regimes and capacity constraints at different stages of their respective life cycles, bringing both synergies and conflicts between the entities. Seaports in the mature or later stages can prolong or reset the seaport position in the life cycle through a restructuring phase which can include location splitting, Standortspaltung, through the introduction of a dry port, which acts to prolong the growth and mature phase of a seaport lifecycle. Similarly, a dry port can undertake an extension strategy to prolong operations.

Dry ports often have a directional development depending on why they are introduced into the supply chain. The direction can be Inside-Out, Outside-In, Bi-directional or without specific direction as small intermodal facilities grow and strengthen existing links with a seaport. The direction will vary depending on the infrastructure, spatial, governance, and economic dimensions in which the dry port is located. This can change over time if the supply chain structure alters.

Inside-Out - development is often undertaken by rail and logistics companies seeking to concentrate goods into a particular corridor by seeking a co-operative relationship with a specific seaport and is often driven by the policy of public organisations.

Outside–In - development often comes from a seaport (port authority) in recognition of vulnerability to a carrier which may undermine the seaport's power by developing relationships directly with dry ports diminishing the seaport's influence in the hinterland.

10.2.6 REASONS FOR DRY PORT DEVELOPMENT

Seaports develop in response to transport demand. The concept of integrated transport demand reflects the attributes of the changes to supply chains from globalisation based on container freight movements. These global supply chains broke the historical monopolistic position of seaports and relegate them to a supply chain node. Dry ports develop where their presence leads to improvement of the transport network, which is generally accompanied by maintaining or improving the ongoing competitiveness of the seaport in that supply chain and the overall supply chain itself.

The competitiveness of a seaport in a supply chain is increasingly important following the introduction of containers and improved landside transport corridors. Introducing a dry port can improve the position of a seaport in a supply chain. The concept of a port hinterland has changed over time. Seaports can have many hinterlands, and whilst primary hinterlands can be an area over which the seaport has firm control, because of efficient and expensive to replicate direct links, the secondary hinterlands are open to threat from other seaports and reflect regionalisation of hinterlands.

10.2.7 DRY PORT SITE SELECTION

Site selection can be based on cost optimisation, determined through mathematical models. Mathematical modelling optimises one or two definable aspects for consideration in a dry port location determination, for example, transport cost, distance, CO_2 emissions. In a conventional urban setting, modelling approaches help establish policy and relative impacts on modal choice rather than exact location solutions.

Location studies increasingly consider non-cost variables. Evaluating the broad range of valid but sometimes conflicting factors requires multi-criteria decision analysis. The use of a multi-criteria analysis approach in determining the optimum location of a dry port is supported by its application in the Westport study when considering future seaport options (with seaports and dry ports being similar in that they are both nodes within a supply change and involve a transport mode transfer). In the urban context, an approach is site selection based on assessing areas currently operating as an industrial area, logistics centre or site that shows *"logistics potential"*. This includes the existence of efficient transport links from the seaport and good connections to the hinterland requiring consideration of the presence of existing transport infrastructure in site selection.

These factors framed within the region's policy setting, or absence of policy, in combination with the requirement for adequate space to house the required infrastructure, can be used to determine a candidate site selection process which can have an AHP approach to rank the candidate sites.

10.2.8 TRANSPORT MODAL CHOICE

Fundamentally organisations choose between various transport options to move freight between the seaport and its hinterland. Transport must be intermodal for a dry port to form part of the supply chain. The determinants of this modal choice have been explored in the literature since the 1960s. Since 1973, surveying is the predominant research method. Before 2003, carrier choice using a given transport mode dominated surveys. Subsequently, surveying intermodal choice gained greater prominence. The literature reveals six highly ranked determinants in making the modal choice, transport cost, travel time, on-time reliability, service frequency, flexibility and loss/damage performance. The types of cargo transported influence the ranking. The ranking order differs for bulk low-value goods compared to perishable or high-value goods and JIT supply chain participants.

Recently, environmental performance, specifically greenhouse gas emissions, is explored but does not generally rank as an essential determinant in transport mode selection.

The importance of cost in mode selection is reflected in the fundamental components of a dry port, an efficient high capacity link between the seaport and dry port and cargo massification to provide economies of scale.

A survey of Fremantle Ports container exporters and importers to understand why container freight users select either road transport or intermodal transport in moving containers to or from the Inner Harbour is undertaken to support the consistency or otherwise of the case study with the literature.

The survey results are compared, as far as is practicable, with the 2011 FPA survey of exporters, the 2012 importer survey and the 2017 FPA container movement study. Consistency with these surveys supports the findings of the thesis survey.

The primary analysis method was a comparison of the survey rankings based on mean values against the literature ranking. The ranking of determinants based on response means is the predominant analysis method in the literature. For comparison of selected survey results responses are presented in the form of histograms and pie charts. Consideration of the low container numbers covered by importer responses must be exercised particularly as no rail based transport importers responded to the survey.

Consistent with the literature, the cost of the transport task is the highest ranked determinant of transport mode selection. Transit time and certainty about its duration also rank in the top five of both. Cargo consolidation is a low ranking in both lists. The most apparent difference in the two rankings is the relative importance of the loss and damage history of the carrier, ranked second in the literature but in the bottom half of the current survey and not a finding of any of the FPA surveys or study. Differences also occur in service frequency ranking, which is relatively more important to the Inner Harbour users and to a lesser extent, track and trace offerings. The marked difference in the importance of damage and loss history is possibly due to differences in cargo types handled through the Inner Harbour compared to the broader literature. The low ranking of the environmental consideration of greenhouse gas emissions by respondents is consistent with the topic being an "emerging area" in the literature and in agreement with the observation of Flodén et al. (2017) that the environmental advantages of mode (rail) selection lag well behind the transport cost.

The thesis survey and FPA surveys and study found similar outcomes relating to the transport of containers. The dominant source and destination of containers remains the Perth metropolitan area with a growing number of containers sourced from the agricultural sector. Factors important to transport mode selection were consistent and highlight issues surrounding cost and schedule frequency and flexibility. The lack of understanding of the intermodal system was also evident.

10.3 DRY PORT DEVELOPMENT FRAMEWORK

A dry port development framework is developed, drawing together the common criteria and development models in the literature into a single tool for demonstrating the approach and requirements of developing a dry port in a specific supply chain. This represents a contribution to research in the field over the current literature, which considers the factors and models in isolation. The dry port development framework adds to the body of knowledge when the West Australian state government is actively considering the future of Fremantle Ports. The dry port development framework draws together information from a wide range of resources, not previously combined in an exploration of the Fremantle Port case study. This has practical implications for the considerations to the future of Fremantle Ports allowing all actors involved, the state government, FPA, private terminal operators and other stakeholders to understand the various development streams available and consideration of the factors involved in a development under each of these streams. The dry port development framework can assist the FPA and state government in providing an *"organising capacity"* in supporting the hinterland access regime, improving overall decision making.

The literature identifies common criteria and development models favouring a dry port development. These are not present in all developments, and the application of development factors must consider the specific supply chain characteristics. This consideration determines the presence or relative importance of the different drivers and factors and the approach required to bring all the supply chain actors together.

The Fremantle Ports case study and transport mode selection determinant survey confirm the relevance to the seaport of common criteria and development models in the literature and demonstrate the use of the dry port development framework by answering the research questions.

The dry port development framework describes the development driver (the underlying reason why the development of a dry port is being undertaken and represents the factor that will improve by the inclusion of the dry port into the supply chain) and trigger points viewed from an Outside-in or Inside-out perspective. It includes the supply chain actors; seaport owner (private and public), government, and dry port developer (private and public). Trigger factors in the framework list the various reasons for dry port development which if not addressed will result in a fall in seaport and associated supply chain efficiency. Not every trigger factor needs to be present for a development to proceed. General considerations are factors that the dry port developer must address in the development process and the advantages gained through the presence of the dry port. The mechanism that brings about the actual investment depends on the actors involved and the objective of the development.

Once established, subsequent changes to the initial dry port can be undertaken in a bi-directional manner.

The dry port development framework is validated in two ways.

Firstly, the use of common criteria and development models that are widely described and peer reviewed in the literature are used to form the basis of the dry port development framework.

Secondly, the application and validity to other supply chains can be demonstrated by hindcasting the dry port development framework outcomes against a selection of case studies presented in the literature and other sources.

Transferability is an essential outcome of this applied research. Case studies on dry ports in the literature are compared to the various aspects of the dry port development framework, which consistently addresses all the development items. This provides confidence in the dry port development framework being used as a practical tool when considering a dry port development in other seaport dry port dyads.

10.4 FREMANTLE PORTS AUTHORITY RESEARCH OBJECTIVES

10.4.1 FREMANTLE PORTS INNER HARBOUR

The common criteria and reasons for the development of dry ports established from the research are all present in the case of the Inner Harbour and led to predictable outcomes following the introduction of a dry port into the supply chain.

Transport demand, in the form of container trade, through the Inner Harbour has grown steadily over the last 50 years, with the last five years to 2021 averaging 2.4%. Pre-COVID-19 projections for future growth ranged from 2.8% to 5.8%.

Hinterland connectivity is recognised as a critical factor in the operation and capacity of the Inner Harbour by the WA state government and the FPA. The state government's long-term planning and development approach in developing dry ports in the Perth metropolitan area and setting rail share targets are complimented by the NQRT development to improve hinterland connectivity by providing more efficient rail and intermodal infrastructure. The modal shift reduces road congestion for a seaport throughput providing an overall capacity increase for the supply chain.

As evidenced through transport studies, road traffic associated with Inner Harbour activities has grown as a percentage of total traffic on Tydeman Road (the link to Forrestfield/Kewdale area) from 5 to 10% over the 18 years of study but remained at a relatively stable proportion of overall traffic counts on Port Beach Road over the same period. During this time container trade has increased by 253%. The suppressed growth of road transport is, in conjunction with improved road transport practices, a result of an increasing share of container movements being carried by rail, from 2% in 2003-04 to 18.4% in 2020-21 (FPA, 2021a).

Rail transport has lower external costs in the form of reduced air pollution, congestion, noise and road accidents experienced by local communities than an equivalent movement of containers by road. The current annualised rail share of container transport, 18.4% (approximately 150,000 TEU), displaces approximately 100,000 road movements based on the 2020-21 Inner Harbour container trade (FPA, 2021a). Rail transport does not eliminate all external costs, and rail activity is voluntarily curtailed between 10 p.m. and 5 a.m. due to community noise concerns.

Road congestion, rather than terminal constraints, limits the capacity of the Inner Harbour, estimated as capable of handling 2.1M TEU through the seaport. The congestion limit of approximately 1.4M TEU is expected in the mid-2030s. The Kewdale, Forrestfield, Kwinana and Kenwick dry port facilities will prolong the Inner Harbour's life provided rail share of the transport task increases. At the WA state government target of a 30% rail share, which requires rail infrastructure upgrades (the dedicated rail bridge being in the planning stage for construction), some 420,000 container movements will take place by rail. This equates to a road transport task of approximately 1M TEU annually or approximately 212,000 TEU above 2018-19 levels. At a 2.8% growth rate, the Inner Harbour transport constrained throughput would be reached in 2030, all else being equal. On this growth assumption, the rail and associated dry port(s) provide some five years of additional capacity to the Inner Harbour before it faces reaching a maturity/decline phase of the life cycle through a threat from a potentially more efficient, deeper draft Outer Harbour or the Port of Bunbury competition from the periphery.

From the exploration of the literature and description of the Fremantle Port Inner Harbour operations, road and rail capacity and the externalised road transport costs and forecast container trade growth presented, research objective (i) is addressed as it can be concluded:

The dry port (Forrestfield/Kewdale and Kwinana Intermodal Terminals) benefits the Fremantle Port Inner Harbour operations as it extends the life of the Inner Harbour as road transport would become prohibitively congested as a result of the externalised costs associated with the transport mode, earlier and at a lower container throughput if all freight moved to and from the Inner Harbour by road.

10.4.2 FREMANTLE PORTS OUTER HARBOUR

The proposed Kwinana location of the Outer Harbour, developed as an outcome of Stage 2 of the Westport project, is adjacent to a heavy industry area of Perth. Existing freight transport links, rail and road, must be extended westward to service the Outer Harbour seaport. The extensions do not pass through significant residential communities. The location provides the opportunity to use dredge spoil and land immediately inland of the seaport for storage and other container supply chain related activity.

The Outer Harbour will be in the growth stage of the seaport lifecycle and will not have the constraints of the mature lifecycle stage pressuring the seaport to develop a dry port. Connection to the rail system is still a consideration in meeting general supply chain greening initiatives to reduce environmental impacts. Rail access will defend the hinterland from the Port of Bunbury, which could develop a local container based hinterland with mining product export and processing reagent imports to service the southwest of Western Australia. This defence could be countered with an efficient rail service from the Bunbury area to the Outer Harbour seaport.

A rail line extension to a quayside terminal provides a connection to the existing and future Perth metropolitan dry ports, which will remain important hubs for freight distribution and accumulation in Perth. The restricted supply chain types in Perth and the proximity of the Outer Harbour to destinations of the dominant import container flows leads to the conclusion that the development of an on-port rail terminal linked to the existing and developing metropolitan dry ports is preferred over the development of a new close dry port specifically to service the Outer Harbour.

The strong correlation between the development of the Inner Harbour and associated hinterland transport links to seaport and dry port development models, port city relationships, and determinants of transport modal choice with the literature provides confidence in the transferability of concepts to the Outer Harbour.

In considering the dry port development framework, the dry port development would be an Outside-In model. The development driver a public benefit, regional economic development and modal shift triggered by a public actor (state government) with the general consideration of satisfying emissions reduction and pre-empting congestion.

The mechanism is land use planning and zoning, Port Authority budget allocations and public infrastructure development.

From the exploration of the literature and consideration of seaport and dry port development models and the existing freight routes and dry port developments in the Perth metropolitan region, research objective (ii) is addressed as it can be concluded:

The establishment of a traditional waterside development, incorporating quay side rail infrastructure, relying on existing dry port infrastructure rather than the development of a new specific dry port for the Fremantle Ports Outer Harbour supply chain, provides the benefits of a dry port to a traditional waterside development serviced solely by road.

10.5 RESEARCH QUESTIONS

In fulfilling the research objective, the three research questions are answered, with each question addressed below.

10.5.1 RESEARCH QUESTION (i)

How can common criteria identified from the literature be combined to demonstrate the suitability of a dry port in a specific supply chain?

Whilst each supply chain is unique in terms of location, actors involved, transport infrastructure, historical development and legislative environment, the common criteria identified can demonstrate the suitability of a dry port in a given supply chain. The common criteria are identified through case studies in the literature on dry ports worldwide. The criteria vary in importance (aside from a mandatory, efficient transport link requirement), and the presence or absence of the various factors influence the success or otherwise of dry port development.

Seaport and dry port development models presented in the literature are important in describing and demonstrating the readiness and need for a supply chain to incorporate a dry port into the system successfully. Development models provide insight into the supply chain's spatial, managerial and lifecycle characteristics. If shown to apply to a given seaport and existing or potential dry port, they provide insight into the actions required to promote or prolong the successful operation of the supply chain in which they exist.

The common criteria for development and dry port development models researched are used to create a dry port development framework. The framework allows consideration of the issues the seaport or dry port face to demonstrate if a dry port development is suitable for a specific supply chain using the common criteria, dry port development models and lifecycle position of the seaport described in the literature. Consistent with the literature, the timing of such a development cannot be predicted as this relies on trade forecasts, which are subject to external factors, to determine when container trade levels and associated impacts on hinterland connectivity reach a trigger level. The dry port development framework describes trigger factors, development drivers and general considerations in dry port development and the mechanism for establishing a dry port from both an Inside-out and Outside-in approach.

The two aspects combine in the dry port development framework to demonstrate the need for and ability to foster a dry port development with the actors involved and provide a framework of elements required in the specific supply chain to make the dry port development successful.

The dry port development framework is validated in two ways.

Firstly, the use of common criteria and development models that are widely described and peer reviewed in the literature are used to form the basis of the dry port development framework.

Secondly, the application and validity to other supply chains can be demonstrated by hindcasting the dry port development framework outcomes against a selection of case studies presented in the literature and other sources.

A development framework describing this overall approach has not been previously presented in the literature and represents an original contribution to knowledge in the area of dry ports.

From research and interpretation of the common criteria, reasons for dry port development and seaport and dry port development models in the literature, a dry port development framework has been created. On this basis, it is concluded that:

Common criteria identified in the literature can be combined to establish a dry port development framework that can demonstrate a dry port's suitability in a specific supply chain.

10.5.2 RESEARCH QUESTION (ii)

How do the characteristics of the current Fremantle Ports operations align with these criteria and models to indicate the role a dry port could play in these operations?

Fremantle Ports Inner Harbour growth and development are closely aligned with seaport development models in the literature. As a WA state government trading enterprise, the freight network and land use planning activities of the state and the FPA have reflected the responses of seaports and their owners in the literature in recognising the changing relationship between the port-city of Fremantle and the Inner Harbour seaports' growth of trade through the introduction of containerised goods and development of globalised supply chains resulting in increased seaport throughputs.

Fremantle Ports entered the international container based supply chains in 1969, with the seaport still in the growth phase. This saw the seaport enter the third generation UNCAD management stage and the second phase of the Hayuth post container spatial development model.

The growth of container trade through the Inner Harbour, growing congestion on road transport routes around the seaport hinterland links, and urban encroachment into traditional seaport operating areas and transport corridors have seen Fremantle Ports respond to the situation as predicted by the literature. The response promotes intermodal transport and associated dry ports to improve hinterland connectivity. Finally, relocation, either in part or in full for containers, of the seaport to a new Outer Harbour development is becoming increasingly near.

As container trade has grown steadily for over 50 years, the Inner Harbour has entered its mature phase of the seaport lifecycle model with few technical and infrastructure improvements available to continue growing beyond 10 to 15 years. Further land expansion is economically exhausted. During this time, Fremantle Ports moved through the fourth and emerging as a fifth generation of the UNCAD model, focusing on customer retention and addressing community stakeholder concerns. This period corresponds to the Load Centre phase of the Hayuth spatial model, with an entry to the fifth phase of a challenge at the periphery becoming evident with the Outer Harbour planning or Port of Bunbury container trade based on a South West hinterland. During this growth, the importance of intermodal transport is recognised. Through the Bi-

Directional development of Forrestfield/Kewdale, the Inside-Out Kwinana operation and the Outside-In development of Kenwick, dry ports have been established or are establishing themselves in the supply chain. The location splitting, Standortspaltung, these developments provide facilitates seaport growth whilst maintaining road transport impacts within acceptable bounds. With the growth of intermodal container transport, the Forrestfield/Kewdale terminals functionally evolved through the UNESCAP stages of commencing as a rail marshalling yard following the closure of the Perth rail yards in the 1960s, starting as a container yard and evolving to a nationally significant facility for handling containers from overseas and interstate with growing logistics and commercial zones in the area. The dry port seaport lifecycle relationship is evidenced through this time with the Inner Harbour passing through the growth into the maturity phase in concert with the dry port's operations and governance and extension strategy prolonging the life of the Inner Harbour. Once the seaport capacity is exhausted, through road congestion (hinterland connectivity), the Inner Harbour will eventually move into the decline (obsolescence) phase of the lifecycle with the transfer of container facilities, in part or full, to a new Outer Harbour.

The Inner Harbour closely followed the port-city relationship described in the literature with the current trade level and City of Fremantle population increase, putting pressure on the seaport activities and hinterland transport links. The various studies undertaken and plans implemented by the Fremantle Ports' management engaging with local government, community and WA state government transport agencies to combat urban encroachment into the Inner Harbour seaport operating areas and key transport links reflect this pressure. This is accompanied by action to promote a modal shift to rail to improve hinterland connections and reduce community impacts of container movements to and from the Inner Harbour.

This leads to the conclusion identified in the Inner Harbour research objective that the existence of dry ports in the Inner Harbour supply chain extends the life of the Inner Harbour by delaying road congestion around the seaport from reaching prohibitive levels.

The shift from road to rail-based transport is a fundamental aspect of a dry port in a supply chain. An online survey of Inner Harbour exporters and importers explores the decision-making determinants of transport mode choice of exporters and importers (or their agents). Survey responses and findings of FPA container transport surveys are consistent with the ranking of modal choice determinants in the literature, finding that transport cost, reliability and transit time are primary criteria. This supports the ability to generalise literature findings to the Fremantle Ports situation.

Characteristics of the FPA efforts and the relationship with the dry port are demonstrated by alignment with the dry port development framework established through the thesis research. The characteristics create a development driver resulting from a logistics infrastructure deficiency with a public actor overlay. Actions are triggered by seaport landside physical constraints and technological limits being approached, causing increasing social and community pressure by the operations combined with the presence of (upgradeable) rail infrastructure and support of the state government. The general considerations for the actions are related to transport congestion, the associated community and environmental aspects, and the need to maintain the lifecycle position in a mature phase. This is achieved through FPA budget allocations, upgrading rail infrastructure in the seaport and government upgrading road and rail facilities inside and outside the port gate through public infrastructure development. The state government also pays a direct subsidy for using rail transport.

From consideration of the case study and criteria and development models for a dry port in the literature, it is concluded that:

The current Fremantle Ports operations align with the criteria and models, and they demonstrate the important role the existing and developing metropolitan dry ports play in the Fremantle Ports' operations.

10.5.3 RESEARCH QUESTION (iii)

Can a dry port development be a viable inclusion in the supply chain created through development of the Fremantle Ports Outer Harbour?

The future Outer Harbour development and associated supply chain and transport infrastructure are captured in the dry port development framework. It would be an Outside-In model with an initial development driver of public benefit, regional economic development and modal shift triggered by a public actor (state government) with the general consideration of satisfying emissions reduction and pre-empting congestion through the mechanism of land use planning and zoning, Port Authority allocations and public infrastructure development.

Given the proposed location of the Outer Harbour, for the forecastable future, much of the seaport trade will be destined or sourced from the Perth metropolitan area (albeit recognising increasing export numbers of containers sourced from areas outside the city). Due to the difficulty in moving the consumption and production areas from their current locations in a developed metropolitan area, containers will predominately be to and from the same areas as the Inner Harbour supply chain. Perth regional urban planning has laid out future industrial development zones and identified related transport and intermodal terminals. These are all linked to the existing or planned road and rail network and represent transport infrastructure used at the Outer Harbour. Like the Inner Harbour, an on-port rail terminal will establish a viable short-haul rail operation to the existing and future dry ports distributed around the metropolitan area and intrastate locations. The economics of moving containers even a short distance from the quay side to an off-port loading facility is not sustainable in the short-haul rail environment in Perth. Once loaded onto a truck at the seaport, economics will dictate the total transport trip is undertaken by road.

The development pathway and staging of an Outer Harbour development are not finalised. Seaport and dry port development models and criteria for dry port development support the development of an intermodal distribution and sourcing of containerised freight for the Outer Harbour.

Dry ports in the Perth metropolitan region are at different lifecycle stages, with Forrestfield/Kewdale at a mature stage but still with capacity for additional volume and the Kenwick facility commencing in a growth stage. The transport demand to sustain these facilities is present as Inner Harbour growth continues. The growing transport demand associated with Perth and state population growth is the congestion trigger for the Outer Harbour.

As a new location with newly established road transport links, the Outer Harbour will not suffer road congestion issues in its early years of operation. Other external road transport costs will support rail use, particularly from a public actor viewpoint, evidenced in the location selected by the Westport study. The transport selection mode survey ranks greenhouse gas emissions as a low consideration, consistent with it being an emerging area in the literature (this ranking may change in importance by the time the Outer Harbour is constructed). The impact on residential areas influences the location of the seaport. Moving south from Rowley Road to adjacent Anketell Road is influenced by reduced community impact. Anketell Road is not free of residential areas. When combined with a general greening of supply chains and potential internalisation of transport costs or ongoing rail subsidy, intermodal transport has a role in the Outer Harbour supply chains.

Consistent with the literature, transport cost is the highest ranking factor in transport mode choice for Inner Harbour users, many of whom will use the Outer Harbour. Reduced congestion associated with the Outer Harbour location will decrease truck operating costs making it more competitive with rail. The state government rail subsidy will continue to be essential in making the direct cost of rail transport competitive at the Outer Harbour. The Port Authority acting in an organising capacity can use its position to influence the other important determinants such as service reliability, service frequency and pick-up and drop-off times through licencing and leasing arrangements to promote the use of the rail service. The state government, in promoting the development of dry ports in the metropolitan areas and upgrading rail lines, further supports rail use by reducing rail transit time and increasing the number of pick-up and drop-off locations.

Given the existence of dry ports in the Perth region and the role the WA state government has in regional planning, road and rail network development and promotion of rail transport dry port integration and development in the Outer Harbour supply chain are likely to be initially an Outside-In model but become Bi-Directional over time.

From consideration of the prerequisites for the successful development of and development models for a dry port in the literature a future Outer Harbour container port development, it is concluded that:

A dry port would be a viable inclusion in the supply chains the Outer Harbour creates through linking with existing Perth metropolitan dry ports rather than developing a specific Outer Harbour close dry port.

10.6 LIMITATION OF RESEARCH

The research focused on developed economies, as Fremantle Ports is in Australia and followed the British development models. There is divergence in the literature regarding development approaches and criteria, particularly with Asian and developing economy countries with a container export-dominated trade compared to the West Australian import-dominated container trade. The divergence is around the importance of the supply chain actors' various common criteria and motivations rather than a total absence of agreement.

No research into river transport and the influence this has on the development of dry ports is undertaken. This is particularly important in the European context.

The individual set of circumstances that surround each supply chain results in the inability of a specific set of criteria and their values to define when a dry port development should commence.

The unfolding COVID-19 pandemic was not investigated regarding how supply chains in the future may change.

10.7 FUTURE RESEARCH

The contemporary nature of the considerations for expansion of West Australian container handling and distribution capacity under the Westport study poses the question of hinterland competition from the Southern Ports Authority, Port of Bunbury. Bunbury port can be expanded to handle containers in preference to developing the Fremantle Ports Outer Harbour for that purpose.

Whilst dismissed by the Westport task force under a multi-criteria analysis; an academic study of the factors would be of research interest.

The threat of the periphery posed by the Port of Bunbury to the Outer Harbour is worthy of research. The Kemerton Industrial Park is slowly attracting heavy industry to the location and, in combination with mining activity in the South West of Western Australia, may develop a container hinterland that encourages competition with the Outer Harbour.

Surveying the modal choice determinants of other Fremantle Ports supply chain actors, carriers (logistics service providers) and agents would provide further insight into how the transport decision to use road or rail is made for imports and exports through the Inner Harbour.

Exploration of the role of multi-criteria analysis in the weighting of factors in the dry port development framework would provide a further dimension to its use in dry port development.

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