The Dry Port Concept

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ABSTRACT

Environmental problems have received increasing attention during the last decade and with them also the role that logistics systems can play in reducing the environmental impact; however, logistics concepts in the role of decreasing environmental impacts have not been extensively researched until recently. One of these concepts is a concept of dry port, which is the focus of this thesis. The purpose of this thesis is to define the dry port concept and to develop the same through identification of its impacts as well as factors that influence the implementation of the concept.

The dry port concept is based on a seaport directly connected by rail to inland intermodal terminals, where shippers can leave and/or collect their goods in intermodal loading units as if directly at the seaport. With dry port implementation CO₂ emissions should decrease, queues and long waiting times at seaport terminals should be avoided, and the risk of road accidents should reduce. Besides the general benefits to the ecological environment and the quality of life by shifting flows from road to rail, the dry port concept increases the seaports’ throughput without physical port expansion. It also brings a competitive advantage to a seaport since it improves the seaport’s access to areas outside its traditional hinterland. This is closely related to regional development that results from the establishment of new businesses in the area once the necessary logistics infrastructure is in place, by means of dry ports.

Although the concept of a dry port should bring numerous benefits to the actors of the transport system, there are still many impediments to the implementation of the same; land use, infrastructure and institutional impediments are identified as the most common. Therefore, a dry port must fit into the transport system where regulations are designed to optimize the use as well as the development of existing infrastructure and its belonging modes of transport.

Key words: intermodal transport, seaport inland access, intermodal terminal, dry port, environment.
LIST OF APPENDED PAPERS

The thesis is based on the work contained in the following papers:

**Paper I**


**Paper II**


**Paper III**


**Paper IV**


**Paper V**


**Paper VI**

To my family and my beloved Bacio
PREFACE

Dry, what? Dry port? Is it a wine? That used to be the reaction to the subject of my research. Many of you probably think of port wine when you hear or read about dry port and funny enough it was the result of my very short hit list when I googled “dry port” some seven years ago. Now, there are thousands of hits on the exact subject of dry port related to intermodal transport. Over the years the interest for dry ports has greatly increased. Why? Well, you should read my thesis for the answer.

However, the working title (in my head) of the thesis was “The Importance of Being a Dry Port”, and the same has been inspired by “The importance of being Earnest: a trivial comedy for serious people” by Oscar Wilde. You are probably wondering what Oscar Wilde has to do with dry ports. Well, believe me, he does. When I started this “Dry Port” project I met a number of people from industry supporting the idea of dry port, but when I asked if they knew what characterized the dry port concept the answer was either “No” or wrong. However, they had heard about it, and they knew that it had to do with seaports and their inland terminals. And, in this world in which we are living, where we are hungry for something new or innovative, the dry port concept was welcomed. It was so welcomed that many have used the notion whenever they found it suitable or not. Instead of an inland terminal for a seaport, why not call it a dry port? It sounds much better, more advanced. The fact that the inland terminal is not more advanced than a simple transhipment platform is of no importance; it is important to call it a dry port. At that point in time I remembered Oscar Wilde’s drama about two Earnests (dry ports in my case), one real and one fake. Everything was fine until they both were at the same place at the same time when things started to go wrong. That’s when I came in the scene with my research to make it clear, or at least I was hoping I would make it clear; although, even today, I doubt I have succeeded completely. Well, I had, to some extent theoretically; otherwise you wouldn’t be reading this doctoral thesis. However, about persuading practitioners, I succeeded just partially. Their dictum was, is and will be, “money makes the world go around”; therefore, call it whatever you want as long as it brings money. Maybe they are right?! Or not!

Although the extent of my success might be unsure, one thing is for sure and that is my gratitude to all the people who in one way or another contributed to this thesis. Let’s start…
Kent Lumsden, what to say but THANK YOU! YOU ARE MY HERO! Thank you for allowing this research to be led by my own curiosity, my own ideas and all the questions that popped up along the bumpy research-road. Thank you for being my mentor and not only a supervisor.

Dan Andersson, thank you for the help with the covering paper; thank you for all your “I don’t understand what you mean by this? Are you sure?” and look-alike questions; and thank you for being here.

Johan Woxenius, dry port was your “baby”; thank you for letting me raise it!

My colleagues at the department as well as colleagues from the outside: Thank you for sharing the bad and the good of this world of ours. Thanks for fika, lunches, dinners, gossips, movies, laughs, cries, travels …

John Black and Paul Beavis, thank you for all the help down under; my favourite paper would not be possible without your generous help! Paul, thanks for arranging all the interviews and visits, thanks for reviewing the paper and thanks for being a pal! John, above all thank you for sharing your wisdom with me. Hope we’ll meet again!

Kaj Ringsberg, thanks for your kindness and guidance through all these years!

All the journals’ reviewers…well, to be honest I hated most of you upon reading the reviews; however, after rewriting the papers considering your comments the hate gradually turned into appreciation. Your comments resulted in my papers being so much better and being published! Thank you!

Hopefully we’ll all cross paths again, someday, somewhere; as Dan said, although the thesis is finished the journey has just begun!

Göteborg, September 2009

Violeta Roso
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1 INTRODUCTION

“What gets us into trouble is not what we don’t know; it’s what we know for sure that just ain’t so.” Mark Twain

…and that’s how I got into “trouble” with the following definition: “Dry Port is an inland terminal which is directly linked to a maritime port” (Economic Commission for Europe, 2001). What does it say? Not much or too much? Depends how one takes it. The EC’s definition of a dry port is concise in words but too broad in meaning, and one can assume that each and every inland terminal that has any kind of link to a seaport may be called a dry port. And, it just ain’t so! Therefore, I sought to define this concept; however, it was just the beginning…

1.1 Background

Since it appeared on a large scale in the 1960’s, the container shipping industry has improved its performance at an impressive pace. It is the backbone of global trade estimated to account for 13% of seaborne trade in volume and 49% of the value (Cullinane and Khanna, 2000). The maritime part of the intermodal transport chains has employed ever larger ships to cope with increasing transport demand and for facilitating lower unit costs as discussed by Cullinane and Khanna (2000). With latest vessels on order reaching 14,000 TEU (World Cargo News, 2006) to fully utilize the economies of scale, progress in ports and hinterland operations must match (McCalla, 2007; Parola and Sciomachen, 2005).

Despite heavy investments in container terminal capacity, larger ships and larger flows of containers severely strain seaport operations (see Mourão et al., 2002; McCalla, 2007). Port capacity can be increased by physically expanding existing ones (McCalla, 1999), but is at considerable costs and endeavours (Pellegram, 2001). Other options include adding conventional equipment or improving the productivity by new forms of technology as analysed by Ballis et al. (1997), work organisation as suggested by Paixão and Marlow (2003) or by information systems such as those described by Henesey (2006). Also, the transport services to the ports’ hinterland, defined by van Klink and van den Berg (1998) as the “the interior region served by the port”, are strained by the increasing flows. Parola and
Sciomachen (2005) modelled and simulated the potential growth of container flows and their findings show that the modal imbalance results in increased road traffic congestion, since a growth in the sea flow implies an almost proportional increase in the road flow. Besides the introduction of double-stack trains in the US in 1984 (DeBoer, 1992), productivity in the land part of the transport chains has generally not followed the progress at sea. According to the European Union Road Federation (2008), in the period from 1996-2006, European hinterland transport market share for road increased, while for rail it decreased; see Figure 1. Furthermore, with a 76% market share, road transport dominates the inland freight transport market in EEA member countries (European Union Road Federation, 2008). The modal share of rail and road diverged due to the removal of trade barriers and the liberalisation of markets, which resulted in increased utilization of road transport.

![Figure 1 Inland transport modal split [% tkm] in EU 1996-2006 (European Union Road Federation, 2008)](image)

A change in the geographic orientation of trade (from east to west) has also contributed to the shift because the new markets are not suitably connected by rail links and offer much more flexible road transport connections (European Environmental Agency, 2003). Comparing rail and road transport trends (see Figure 2) again are in favour of road despite existing environmental problems, showing the emergence for new solutions through new policies or new transport concepts. There is a hope for deceleration of this negative trend for the rail sector due to the latest efforts of European Parliament towards the internalisation of external costs of heavy goods vehicles (CER, 2009). This is a first and very important step towards lifting the current ban on applying environmental charges to trucks. In their study about the social cost of intermodal freight transport, Ricci and Black (2005) discuss that the intermodal transport is a major potential contributor to solving the environmental problems and that full internalisation of external costs would greatly benefit intermodal transport.
Environmental problems have received increasing attention during the last decade and with them also the role that logistics systems can play in reducing the environmental impact (Aronson and Brodin, 2006). However, logistics concepts in the role of decreasing environmental impacts have not been extensively researched until recently (Aronson and Brodin, 2006). One of the concepts with the role of decreasing environmental impacts is a concept of dry port that is the focus of this thesis. The concept was neglected for many years and was recently reborn due to increased interest in environmental issues related to growing containerized maritime transport. As container transport volume continues to grow, seaport inland access becomes a critical factor for the seaports’ competitive advantage. Therefore, progress only in the maritime part of the transport chain and in seaport terminals, without improvements in seaport inland access, is not sufficient for the entire transportation chain to function. This thesis emphasises the importance of functional seaport inland access that might be obtained by intermodal solutions, in particular by means of advanced intermodal terminals or dry ports; the importance is not only for the seaports but for other actors of the transport system and the society as well.

Intermodal terminals have been extensively studied by many researchers. Tsamboulas and Dimitropulos (1999) as well as Höltgen (1995) discuss the term “freight nodal terminal” that, although similar in concept, varies in its definition among countries: “Gueterverkehrszentren” in Germany, “plateformes multimodales logistiques” in France, “freight villages” in the UK or “interporti” in Italy. They all provide transhipment from one mode to another, as well as auxiliary services such as warehouses, customs, maintenance workshops, and insurance offices. Depending on the role and the offered services, the transport industry operates different kinds of intermodal terminals under different names. Slack (1999) suggests the implementation of satellite facilities/terminals for container storage in order to relive congestion at seaport terminals. Furthermore, Höltgen (1995), in his review of different intermodal terminals in Europe, aims to

![Figure 2 Freight transport modal split projection (European Environmental Agency, 2003)]
find a unique definition for the same and suggests the classification of intermodal terminals; furthermore, the author discusses the role freight nodal terminals have in regional development. In his work on intermodal terminals, Woxenius (1997) discusses whether or not the terminals are barriers for intermodality. Considerable research has been conducted on how to improve the efficiency of rail–road terminals (Konings, 1996; Ballis and Golias, 2002; Kozan, 2006) and how to find the optimal location for inland intermodal terminals (Rutten, 1998; Macharis and Verbeke, 1999; Arnold et al., 2004; Pekin and Macharis, 2007). However, few studies have investigated sustainability resulting from the use of these intermodal terminals as a tool for solving environmental problems, and even less have considered their impact on regional development.

The first mention of dry port, in the context of intermodal transport in scientific journals dates back to 1986 (Hanappe, 1986) and in transport related trade journals in 1980 (Munford, 1980); it took almost 20 years to revive the interest for the subject among researchers (Tsilingris and Laguardia, 2007; Leveque and Roso, 2002), as well as among policy makers eager to find solutions to various environmental issues caused by growing containerized transport (European Commission 1998, 2000/a, 2001).

1.2 Purpose and research questions

The summary of the literature review shows the lack of research regarding the role logistics concepts have in reducing the environmental impact and in particular the lack of research on the dry port concept and its impacts on the transport system; therefore, this thesis has the intention to contribute to the knowledge of the dry port concept.

The purpose of this thesis is to define the dry port concept and to develop the same through identification of its impacts as well as factors that influence the implementation of the concept.

The existing definition on dry port by Economic Commission for Europe (2001) is vague and the intention is to define the concept more accurately with the services offered as well as to define different types of dry ports. Furthermore, the research applied contributes to the purpose by identification of impacts the dry ports make on the transport system, from the perspectives of different actors of the transport system as well as through the factors that influence the implementation of the dry port in the system.

The formulation of a research problem depends on the researcher’s knowledge and frame of reference; with a weak and ambiguous frame of reference it can be hard to formulate the research problem more precisely than the subject (Hellevik, 1987). The ambiguous frame of reference, or lack of the same regarding the specific subject of dry ports was an issue at the beginning of the research process. Therefore the question that arose at the very begging of the research process is related to the definition of dry port. In order to further develop the concept and
identify its impacts it was necessary to define it; therefore the starting or primary research question is:

**PRQ**: What key principles characterize the dry port concept?

The core idea behind this primary research question is to define the concept and its applications, i.e., what types of dry ports are applied. Once the same is done the next task is to elaborate on the impacts the dry port makes, from the perspectives of different actors of the transport system.

**RQ1**: What impacts does the dry port concept generate for actors of the transport system?

Research question one is actually a summary of a number of issues regarding different impacts in a form of different benefits or influences, such as about the potential advantages or disadvantages that a dry port brings for different actors of the transport system in general. Moreover, it is about specific impacts the concept makes, such as to what extent a well implemented dry port concept can increase the use of rail and therefore lower the amount of road traffic in seaports and consequently lower the local environmental impact. Once the dry port is implemented into the seaport’s transport system it affects physical and administrative flows at the seaport and by that the system as a whole; the intention is to identify in what way.

All previously mentioned issues are regarding the concept and its impacts, in particular about the benefits the dry ports generate for different actors of the transport system (Figure 3). The results of the research show that a great majority of these impacts may be interpreted as potential benefits for the actors of the transport system; however, despite that, still there are many impediments to the implementation of the concept. Therefore, research question two is related to the factors that influence the implementation of the dry port into the transport system (see Figure 3); however, with the assumption that the initial factors or prerequisites, such as the demand, substantial volumes, interested operators, and existing basic infrastructure are already fulfilled.

**RQ2**: What factors influence implementation of dry ports into seaports’ hinterland?

In other words, this question is dealing with the influence the different actors of the transport system have on the implementation of the dry port, i.e., on the process from the decision to the realization.
1.3 Scope and delimitations

The scope of the thesis is the seaports’ inland access with dry ports, i.e., advanced intermodal terminals, as a part of the intermodal transport chain. Considering intermodal transport as transport of standardized units involving at least two different traffic modes, only transport processes involving containers were analyzed in the studies. The scope as such is quite broad and gives the opportunity for research from different perspectives. However, to sharpen the focus, as well as to keep it within the researcher’s domain, some issues were not included in this research. The thesis does not cover the economical or legal perspective of dry port application, such as cost analysis or different contract forms between the actors/partners or business models, not because the same were not interesting, but mainly because it differs from country to country and from case to case. The thesis deals with environmental issues, i.e. reduction of environmental impacts due to dry port implementation; however, the same has been limited to study of consequences resulting from direct emissions from transport modes without considering up- and downstream environmental effects nor terminal handling activities related emissions.

The reader should also be aware of limitations regarding collection of certain data that were considered to be sensitive issues, such as data concerning the profits or profit related information, which in this case was volume handled on a specific route. Therefore, the same has not been discussed in the respected paper. Other sensitive issues such as the process of dry port implementation itself seemed to be sensitive due to competition. In other words, the well functioning dry ports were reluctant to reveal detailed information regarding either different phases of their implementation process or the development of their operations. The same influenced the research in a way that the initial idea of the study had to take another direction. However, none of the above has influenced the overall purpose of the study.
1.4 Thesis outline

The thesis consists of this covering paper and six appended papers.

1.4.1. The covering paper

The purpose of the covering paper is as it says, to cover or to summarize what is written in the appended papers. In order to do so, first, a review of the current state of knowledge and research in the field is given. Furthermore, the research process with chosen approaches and methods is discussed. Finally, through summary of the appended papers and their interrelationship, the contribution of the work to the field is indicated.

1.4.2. The appended papers

Here, the appended papers are briefly discussed from the point of the reception they received, i.e., by the journals in which they were published. Additionally, authoring and co-authoring on the papers is explained.

Two of the appended papers are co-authored: Paper I by my (at the time) second supervisor Johan Woxenius and my main supervisor Kent Lumsden; and Paper V by Kenth Lumsden; I am the primary author of these papers. I am the single author of the other four papers: Papers II, III, IV and VI.


Paper VI “A review of dry ports – Characteristics, driving forces and impediments” is published in proceedings of NOFOMA 09 conference. The paper has been rewritten and submitted to Maritime Economics & Logistics.
1.5 Terminology

The important terminology that is used in the covering paper as well as in appended papers is presented here. The definitions for the following terms are from “Terminology on combined transport” Economic Commission for Europe (2001), if not marked otherwise.

*Multimodal transport* is a carriage of goods by two or more traffic modes.

*Intermodal transport* is the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more traffic modes without handling the goods themselves in changing modes.

*Combined transport* is intermodal transport where the major part of the European journey is by rail, inland waterways or sea and any initial and/or final legs carried out by road are as short as possible.

*Intermodal terminal* is a place equipped for the transhipment and storage of intermodal loading units.

*Intermodal Transport Unit (ITU)* is a container, a swap body and a semi-trailer suitable for intermodal transport.

*Container* is a generic term for a box to carry freight, strong enough for repeated use, usually stackable and fitted with devices for transfer between modes. Most maritime containers are ISO containers. Two main standards exist in terms of length: 20 and 40 feet (6.10 and 12.20 meters), one and two TEUs (twenty feet equivalent unit), respectively.

*TEU* is a twenty-foot equivalent unit. A standard unit based on an ISO container of 20 feet in length (6.10 m), used as a statistical measure of traffic flows or capacities. One standard 40’ ISO Series 1 container equals 2 TEUs.

*Semi trailer* is a non-powered vehicle for the carriage of goods, intended to be coupled to a motor vehicle in such a way that a substantial part of its weight and of its load is borne by the motor vehicle.

*Swap body* is a freight carrying unit optimised to road vehicle dimensions and fitted with handling devices for transfer between modes, usually road/rail. A swap body is equipped with folding legs on which the unit stands when not on the vehicle.

*Transhipment* is movement of ITUs from one means of transport to another.

*Hinterland*, as defined by van Klink and van den Berg (1998), is the continental area of origin and destination of traffic flows through a seaport, i.e., the interior region served by a seaport. According to McCalla (1999), hinterland includes the areas behind the port to which the port sends imports and from which it draws exports.
2 FRAME OF REFERENCE

The frame of reference gives insight into the current state of knowledge and research in the field, and as such provides an explanation of the problem being studied. In this section, the frame of reference that is used during the whole research process is comprehensively explained.

2.1 Freight transport networks

Freight transport systems are characterised by sequential transfers of goods between points of origin and destination, generally defined as nodes. Activities, such as consolidation, sorting, storage and transhipment between vehicles and traffic modes, are carried out in nodes. A node can be defined as a source, an origin or a transhipment node, depending on the transport assignment. Links represent transport and transfer activities connecting nodes, and together with the nodes the links compose the transportation network; see Figure 4. In the real system, links are served by vehicles and vessels using infrastructure. For the physical unit corresponding to transhipment nodes, the word terminal is used although the traffic mode specific terms airport, seaport and station are more common in colloquial speech.

![Figure 4 The components of the transportation network (Lumsden, 1998).](image)

Transhipment nodes with a central role in a network are, varyingly and often inconsistently, called hub, dock, gateway and turntable in the transport industry. To straighten up the terminology a gateway is here defined as a link between different networks, while Fleming and Hayuth (1994) restrict the meaning to
nodal points transshipping between intercontinental transport flows and continental axes.

In an intermodal gateway (see Figure 5), networks based on different traffic modes are linked, while intramodal gateways link networks using the same traffic mode. Traditional examples of intermodal gateways are seaports, airports and intermodal road-rail terminals. Intramodal gateways include consolidation terminals where trucks operating long-distances and pick-up and delivery routes are coordinated respectively and seaports offer transhipment between trans-ocean container vessels and feeder vessels or barges.

Figure 5 Intermodal and intramodal gateways (Lumsden, 2006).

Intra-European rail services are still commonly operated by use of intramodal gateways compensating for incompatible legislation, electric power supply systems, signaling systems, loading profiles and sometimes also rail gauge between neighboring countries. Figure 5 shows how gateways can be classified as receiving or forwarding nodes in a network since transports do not begin or end in gateways, but only use these as a link to other networks. In other words, gateways connect different types of networks.

2.2 Intermodal transport

In 1956 the McLean Trucking Company in the U.S. started experiments with standardized boxes in the attempt to streamline a distribution system from shipper
The basic idea behind loading units (containers) is the consolidation of smaller consignments, with the same origin and destination, into one loading unit. Soon, it was proved that containerization provided opportunities for efficient transportation, and in the 1960s it spread to Europe. Along with containerization came intermodality and the shipping industry was revolutionized. With containerization, transhipment time is reduced due to simpler and faster handling; consequently, terminal time for the traffic modes is reduced (Lumsden, 1998). Furthermore, damage to goods and packaging costs are reduced since the packaging may be eliminated and with it the disposal of the same. Nevertheless, the concept has certain drawbacks since carriers for loading units and handling equipment have to be adapted to the loading unit. Moreover, there is a problem of empty container repositioning, also called empty container management, which is covered in research by Hultén (1997), Shintani et al. (2005), and Shen and Khoong (1995). However, Choong et al. (2002) are more specific, dealing with empty container management for intermodal transportation networks in an effort to minimize total costs related to moving empty containers.

Prior to containerization the carrier’s responsibility for the goods terminated at the side of the vessel, and all inland movements were controlled by shipper or forwarder, giving them substantial market power. The new requirements imposed by containerization contributed to the decline of some established seaports and to the growth of new ones (Notteboom, 1997). The concept of containerization, together with intermodality, extended seaports’ inland access and redefined seaport competition in a way that seaports have to strive for a position in intermodal corridors (Nottebohm, 1997; van Klink and van den Berg, 1998).

Transport systems have always been designed according to geographical conditions as well as according to the demand for the transportation, which was determined by the goods quantity and service quality. Currently, environmental issues play an important role in the design as well. One way to accomplish those demands is to employ rail through intermodality. There is no generally accepted definition of intermodality. The European Commission (2000/a, p6) defines intermodal transport as the following: “There is a consensus that intermodal transport constitutes a transport process in which the two following conditions are fulfilled:

- Two or more different transport modes are deployed
- The goods remain in one and the same transport unit for the entire journey.”

Van Klink and van den Berg (1998) added one crucial characteristic to the definition above, which is: “The ability of carriers to provide the shipper with one bill of lading.” This means that the stripping and stuffing of containers are not included in the intermodal process; the unit should remain unopened during the process.

Reduced energy consumption, optimization of the usage of the main strength of different modes (European Commission, 2000/a; Rutten, 1995), a reduction of
congestion on road networks, and low environmental impacts (Woxenius, 1998; Kreutzerberger et al., 2003) are considered the advantages of intermodal (road-rail) transport. However, the main disadvantages would be unease of monitoring, reliability, and complexity of the chain (European Commission, 2000/b).

Certain characteristics require the use of intermodal transport, such as accessibility or geography, since direct access or door-to-door service is not always available by one traffic mode. Moreover, there are economies of scale resulting in lower costs per unit with the use of appropriate intermodal transport solutions. Finally, environmental issues influence the choice of traffic mode; for example, whether or not an energy efficient traffic mode will be employed as a trade off to flexibility.

In the late 1950s, intermodality, together with the concept of containerization, started to spread world-wide. However, the final act of the 1980 “United Nations Conference on a convention on International Multimodal Transport of Goods” was of more historical importance. The convention recognized the following points (Höltgen, 1995):

- International multimodal transport as one means of facilitating the orderly expansion of world trade;
- The need to stimulate the development of economic and efficient multimodal services for the requirements of the trade concerned;
- Special principles apply to multimodal transport, including through rates and liability;
- The right of the state to regulate.

The fundamental idea behind intermodal transport is that all economic and operational advantages of each traffic mode should be joined together in one transport chain to improve the efficiency of that transport chain and, thus, the overall efficiency of the transport system (Jensen, 1987).

The viability of intermodal transport on long distances is argued by many academics; for example, by van Klink and van den Berg (1998) and McCalla (1999). Those authors elaborate that seaports can generate scale economies to operate cost effective intermodal transport with high frequency to different destinations beyond their traditional hinterland, i.e., to use rail to enlarge their hinterland and at the same time to stimulate intermodal transport. Rutten (1998) proposes movement of goods transports from road to intermodal rail over distances longer than 100 km when the quality and service of the intermodal transport is comparable or better than the road. Moreover, the intermodal transport cost should be lower than or equal to the road transport cost (ibid, p. 281). According to van Klink and van den Berg (1998), rail services are generally competitive at distances over 500 km. However, the critical distance varies due to the portion of transshipment costs, which varies depending on the combination of traffic modes. Distance is not the only prerequisite for the success of intermodal transport, but also the volume of goods and the frequency of the service provided (Woxenius, 1998).
Despite the advantages stated above there is a relatively low share of rail in the transport of containers from seaports to the hinterland (European Union Road Federation, 2008). Apart from lack of sufficient rail infrastructure or free slots, according to Engström (2007) there are many obstacles that prevent transport buyers from using the railway as a major means of transportation, lack of flexibility (in time and space) and damaged goods being the most significant. Furthermore, the author discusses that shippers sometimes make decisions on not using a specific mode of transport, rail in this case, based on soft variables such as feelings or resistance to change or lack of know-how instead of facts and data. Short transit time and high reliability are significant criteria of successful logistical structure as they reduce the shippers’ need for safety stocks (Coyle et al., 2000).

Woxenius (1998) presented a reference model of intermodal transport where he illustrates actors, activities, and resources as well as factors that influence intermodal transport. The gray area in the model represents the intermodal transport system while items outside the box represent the system’s surroundings consisting of factors that influence the system. The links between actors, activities and resources are not made explicit in the model since the same cannot be determined on a general level; however, those links are horizontal across the figure, i.e., the haulier performs road haulage with a truck.

![Figure 6 A reference model of intermodal transport (Woxenius, 1998)](image)

2.2.1. Hinterland transport

The main problems seaports face today, as a result of growing containerised transport, are lack of space at seaport terminals and growing congestion on the access routes serving their terminals. Parola and Sciomachen (2005) modelled and simulated the potential growth of container flows. Their findings show that the
modal imbalance results in increased road traffic congestion, since a growth in the sea flow implies an almost proportional increase in the road flow. Consequently, seaport efficiency is threatened by increased bottlenecks in the landside transportation system serving the seaports. For some seaports the weakest link in their transportation chain is their back door, where congested roads or inadequate rail connections cause delays and raise transportation costs. With a 76% market share, road transport dominates the inland freight transport market in EEA member countries (European Union Road Federation, 2008). Furthermore, during the period of 1996-2006, European hinterland transport market share for road increased about 5%, while for rail it decreased by 4% (European Union Road Federation, 2008). The strategic decision would be the implementation of rail or improved inland intermodal terminals serving seaports. However, the Transport Research Board (1993) survey identified infrastructure, land use, and environmental and institutional impediments that reduce the efficiency of freight movements on land access routes or limit the options available to correct these impediments. Furthermore, the quality of inland access depends on the behaviour of a large variety of actors, such as terminal operators, freight forwarders, transport operators, and port authorities (de Langen and Chouly, 2004).

van Klink and van den Berg (1998) define hinterland as those places that can be served by the port cheaper than from other ports belong to the port’s hinterland. In practice, however, direct monetary costs do not determine the competitiveness of the port towards a certain inland market only; costs related to risks and time should also be considered. As elaborated by van Klink and van den Berg (1998) and McCalla (1999), seaports can generate scale economies to operate cost effective intermodal transport with high frequency to different destinations beyond their traditional hinterland; i.e., to use rail to enlarge their hinterland and at the same time to stimulate intermodal transport. The individual seaports try to attract as much flow as is economically feasible and the size and shape of a seaport’s hinterland is not statically or legally determined but varies dynamically due to developments in technology, economy, and society.

De Langen and Chouly (2004) define captive or primary and contestable or secondary hinterlands; primary hinterland is the area where the port is well established and secondary hinterland, with rivalry among ports all regions where one port has a substantial competitive advantage because of lower generalized transport costs to these regions belong to the captive hinterland of this port. The concept of hinterland changes constantly and it is generally accepted today that serving seaport hinterlands is more competitive than before containerisation and intermodality (McCala, 1999). There is a strong interdependency between a seaport’s foreland and hinterland, which is particularly apparent in intermodal transportation. The notion of seaports’ role and spatial coverage is dealt with, e.g., by Heaver et al., (2001), Notteboom (2002), Notteboom and Winkelmans (2001), Robinson (2002) and van Klink and van den Berg (1998). Seaports are not competing only with seaports in their local area but also with distant seaports attempting to serve the same hinterland. Figure 7 shows Notteboom’s model of the development of a seaport’s hinterland in four phases (Notteboom, 2001). The market areas of the small seaports are limited to their immediate hinterland while
larger seaports extend their hinterland, as shown in phase 1. The second phase shows large seaport penetration into distant hinterland, i.e., capturing the hinterlands of neighbouring smaller seaports. Due to low volumes the small seaports do not run shuttle trains to their distant hinterland; therefore, shipping lines, unable to serve a substantial hinterland, do not call to those small seaports. Inland hub formation in distant hinterlands takes place in phase 3, as well as the emergence of new inland terminals. In the fourth phase hubs in the immediate hinterland are formed, offering small seaports the possibility to use the hinterland network, leading toward a certain degree of decentralization.

Figure 7  A Theoretical model on the development of a seaport-linked rail network (Notteboom, 2001).

Notteboom (2006) and van Klink and van den Berg (1998) state that many seaports, as well as shipping lines, integrate vertically to control hinterland transport. With an increasing level of functional integration, many intermediate steps in the transport chain have been removed (Figure 8). However, the vertical integration must be done cautiously and must respect anti-trust legislation since slot-sharing alliances and conferences are allowed at sea but have been disputed by competition authorities (Slack et al., 2002). Even van Klink and van den Berg (1998) discuss EU regulations on competition since the same frustrate the role of
seaports in intermodal operations and hamper the realization of the EU transport policy’s central goal to make transport more efficient and sustainable.

![Figure 8 Functional Integration of Supply Chains (Notteboom, 2006)](image)

### 2.2.2. Inland intermodal terminals

An intermodal road-rail terminal can simply be described as a place equipped for the transhipment and storage of intermodal loading units (ILUs) between road and rail. There are intermodal terminals in a great variety of shapes and sizes (see, e.g., Woxenius, 1998) and a number of value-added services such as stuffing and stripping, storing and repair of ILUs might be offered. As suggested by Höltgen (1995), intermodal terminals can be classified according to some basic functional criteria like traffic modes, transhipment techniques, network position or geographical location. Nevertheless, the transhipment between traffic modes is the characterising activity.

A specific class of terminals has evolved around the need for connecting inland conurbations with seaports. Depending on the role and the offered services, the transport industry operates these kinds of terminals under different names. From a legal point of view, it is of particular importance if customs services are provided. The UN Economic Commission for Europe (UN ECE, 1998) defines an Inland Clearance Depot as a common-user inland facility, other than a port or an airport, with public authority status, equipped with fixed installation and offering services for handling and temporary storage of any kind of goods (including containers) carried under Custom transit by any applicable mode of inland surface transport, placed under Customs control and with Customs and other agencies competent to clear goods for home use, warehousing, temporary admission, re-export, temporary storage for onward transit and outright export.
India introduced Inland Container Depots (ICDs) in 1983 and Indian Customs (2004) bases its definition of an ICD on the UN ECE definition above, but restricts it to containers. India also uses the term Container Freight Station (CFS), which differs from an ICD since containers are stuffed and stripped there. Hence, an ICD is a consolidation node for containers whereas a CFS aggregates individual consignments into containers. A CFS function might be added to an ICD. ICDs are normally located outside the port towns but there are no site restrictions regarding CFSs.

In Europe there has been a focus on business areas offering a wide range of logistics services. In a survey, Cardebring and Warnecke (1995) define an Intermodal Freight Centre as a concentration of economically independent companies working in freight transport and supplementing services on a designated area where a change of transport ILUs between traffic modes can take place.

Tsamboulas and Dimitropulos (1999) also discuss the term freight nodal terminal that, although similar in concept, varies in definitions among countries: Gueterverkehrszentren in Germany, Plateformes Multimodales Logistiques in France, Freight villages in UK or Interporti in Italy. They all provide transhipment from one mode to another as well as auxiliary services such as warehouses, customs, maintenance workshops, insurance offices, etc.

An Inland Freight Terminal is, according to UN ECE (1998), “any facility, other than a port or an airport, operated on a common-user basis, at which cargo in international trade is received or dispatched”. An Inland Port is located inland, generally far from seaport terminals; they supply regions with an intermodal terminal offering value added services or a merging point for different traffic modes involved in distributing merchandise that comes from ports (Harrison et al., 2002). The term dry port is used synonymously. Finally, according to the European Commission for Europe (2001, p. 59), a dry port is simply “an inland terminal which is directly linked to a maritime port”. However, Beresford and Dubey (1990) use a dry port definition that corresponds to the definition of an Inland Clearance Depot cited above. Since the former definition on dry port is rather broad in its meaning, all above mentioned terminal facilities might use the notion of dry port due to their links to seaports. The Beresford and Dubey definition is very specific regarding ownership and services, and in particular customs clearance, although with no mention of a specific type of connection to a seaport.

All terms related to the inland terminal facilities, mentioned above, together with the definitions and the sources are summarized in Table 1.
Table 1 Terms used in relation to inland terminal facilities

<table>
<thead>
<tr>
<th>Source</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>UN ECE (1998)</td>
<td>Inland Clearance Depot</td>
<td>A common-user inland facility, with public authority status, equipped with fixed installation, and offering services for handling and temporary storage of any kind of goods (including container) carried under customs transit by any applicable mode of inland surface transport, placed under customs control to clear goods for home use, warehousing, temporary admission, re-export, temporary storage for onward transit, and outright export.</td>
</tr>
<tr>
<td>Indian Customs (2004)</td>
<td>Inland Container Depot</td>
<td>A common user facility with public authority status equipped with fixed installations and offering services for handling and temporary storage of import/export laden and empty containers carried under Customs transit by any applicable mode of transport placed under Customs control. All the activities related to clearance of goods for home use, warehousing, temporary admissions, re-export, temporary storage for onward transit and outright export, and transshipment take place from such stations.</td>
</tr>
<tr>
<td>Cardebring &amp; Warnecke (1995)</td>
<td>Intermodal Freight Centre</td>
<td>A concentration of economically independent companies working in freight transport and supplementing services on a designated area where a change of transport units between traffic modes can take place.</td>
</tr>
<tr>
<td>EC for Europe (1998)</td>
<td>Logistic Centre, Freight Village,</td>
<td>Geographical grouping of independent companies and bodies that are dealing with freight transport (for example, freight forwarders, shippers, transport operators, customs) and with accompanying services (for example, storage, maintenance and repair), including at least a terminal.</td>
</tr>
<tr>
<td>UN ECE (1998)</td>
<td>Inland Freight Terminal</td>
<td>Any facility, other than a port or an airport, operated on a common-user basis, at which cargo in international trade is received or dispatched.</td>
</tr>
<tr>
<td>Harrison et al. (2002)</td>
<td>Inland Port</td>
<td>Located inland, generally far from seaport terminals; they supply regions with an intermodal terminal offering value added services or a merging point for different traffic modes involved in distributing merchandise that comes from ports.</td>
</tr>
<tr>
<td>EC for Europe (1998)</td>
<td>Dry Port</td>
<td>An inland terminal which is directly linked to a maritime port.</td>
</tr>
</tbody>
</table>

Inland intermodal terminals, as important nodes in the transport network, have gained substantial attention in transportation literature. Considerable research has been conducted on how to find the optimal location for inland intermodal terminals (Rutten, 1998; Macharis and Verbeke, 1999; Arnold et al., 2004) and how to improve the efficiency of road-rail terminals (Ballis and Golias, 2002; Kozan, 2000). Abacoumkin and Ballis (2004) and Ballis and Golias (2002 and 2004) use modelling and simulation for improvement of road-rail freight transport terminals, and consequently the improvement of intermodal transport chains as a whole. Rutten (1998) has an objective to determine the interrelationships between terminal locations, number of terminals, shuttle train length, and system
performance. Earlier research by Slack (1990) on inland load centres shows the importance of their development for intermodal transportation; in his later research (1999) he emphasizes the inland terminal’s - satellite terminal’s - role in reducing environmental effects. Seaports are among the most space-extensive consumers of land in metropolitan areas and their expansion often generates environmental and land use conflicts; therefore, satellite terminals (inland intermodal terminals in remote areas) are seen as an alternative to seaport expansions (Slack, 1999). Transport terminals are of importance not only for the transportation research field, but they are also at the very centre of critical issues in economic, political, urban, and other geographic subfields (Goetz and Rodrigue, 1999). Bergqvist (2008) discusses regional attractiveness in terms of environmental sustainability, cost-efficiency and transport quality through the establishment of intermodal road-rail terminals, with the focus on regional logistics collaboration.

Modelling of container terminals is of great value in many applications such as planning and evaluation of new facilities, determining the required resources, improving the operational procedures of existing facilities, and evaluating alternative equipment systems (Ballis and Abacoumkin, 1995). Many transportation related models in literature are used for finding optimal location of intermodal terminals such as Macharis and Verbeke (1999), Racunica and Wynter (2004), Arnold et al. (2004). Empty container movements are studied and modelled by Jula et al. (2006) in an attempt to reduce congestion by optimizing the empty container reuse. Abacoumkin and Ballis (2004) and Ballis and Golias (2002 and 2004) use modelling and simulation for improvement of road-rail freight transport terminals, and consequently, the improvement of intermodal transport chains as a whole. Ballis and Abacoumkin (1995) designed the model to evaluate different configurations of the simulated system of seaport container terminals, i.e., to examine the differences between “the observed” operations strategy and the strategy dictated by the operational rules of the seaport in the case. Andersson (2001) developed a PC based tool to support a strategy to co-operate within a supply chain and to enable simulation and optimisation of the total supply chain with the target to reduce costs, lead-time, and capital employed.

Höltgen (1995) discusses the basic problem of differentiation between “conventional” transhipment terminals and the various types of large scale intermodal logistics centres, as well as tries to find a unique definition for the same. The problem is that the concept for intermodal logistics centres varies from country to country, although there is a common background: it should contribute to intermodal transport, promote regional economic activity, and improve land use and local goods distribution. Furthermore, the author discusses that complexity of combined (intermodal) transport terminals due to numerous areas of influence (see Figure 9) can create bottlenecks in the freight flow. Even Woxenius (1997) discusses whether or not the terminals are barriers for intermodality. Despite their important role in transport networks, terminals sometimes impede the development of intermodal transport with additional transhipment costs at road-rail terminals or due to shippers’ lack of freedom in choosing traffic modes once they move their business to intermodal freight centres (ibid, pp.15).
Woxenius et al. (1994) classified five different types of terminals according to their role in intermodal transport networks; see to Figure 10. Terminals for direct connections are of limited capacity and the handling of units is performed at terminals near the shipper and the receiver. Terminals for corridors are designed for fast transhipment of all types of loading units as well as terminals for fixed routes, but on a smaller scale. The main characteristic of the hub and spoke design is that all transports pass through a central terminal, which has a large capacity and offers efficient transhipment. The demand for transhipment capacity on terminals for allocated routes is limited since only a few loading units are handled at each station.

According to Zimmer (1996), an ideal intermodal terminal is not a certain physical configuration of pavement and tracks, but an organisation of services integrated with a physical plant that meets the business needs of a specific marketplace. These physical plants may take many forms, which are influenced by the characteristics of the landscape, their proximity to the seaport or major industrial complex, their location relative to the main rail infrastructure, and their distance from the country’s highway network.
2.3 Environmental effects from transportation

With a 76% market share, road transport dominates the inland freight transport market in EEA member countries; furthermore, the road transport share has grown steadily over the past decade at the expense of rail and inland waterway transport (European Union Road Federation, 2008). Since a growth in the sea flow implies an almost proportional increase in the road flow, with a growing container transport volume, seaport inland access as a part of a transport chain becomes a critical factor not only for functionality of the transport chain as a whole but as a point of action for lowering the environmental impact.

Kreutzberger et al. (2003) have provided an overview of literature dealing with the issue of external effects of both intermodal and unimodal transport and came to the conclusion that intermodal transport has substantially better environmental performances than unimodal road transport if only “energy use” and “CO₂ emission” are taken into consideration, but even more if local emissions (except SOₓ), accidents, congestion, and noise are incorporated in calculations. Furthermore, Ricci and Black (2005) in their study about the social cost of intermodal freight transport discuss that intermodal transport is a major potential contributor to solving the environmental problems. The authors have conducted an extensive study involving different transport corridors, one of which is presented in Figure 11, showing the advantages regarding external costs intermodal transport has compared to all road; they concluded that full internalisation of external costs would benefit intermodal transport, as would various other measures tending to raise its efficiency.

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* Only some of the possible links are shown

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Figure 10 Five different traffic patterns for transport from A to B (Woxenius et al., 1994).
Congestion and environmental concerns have become major policy factors in the EU. The environmental impacts of the transport sector have increased significantly, contributing 45% of total CO₂ emissions, and within the EU the road sector is responsible for almost 90% of emissions compared to other traffic modes (European Environment Agency, 2003). With CO₂ being the main contributor to transport greenhouse gas (GHG) emissions, policies targeting the reduction of CO₂ emissions are imperative.

Congestion as a major social and environmental cost of urban transport is targeted by a wide range of policies. Moreover, it involves personal costs such as loss of time, additional vehicle maintenance costs, indirect health effects, and stress. Congested traffic produces more air pollutants, generates greater noise, and consumes more energy than smooth traffic flow (Salomon and Mokhtarian, 1997). Considering these facts and a growing concern for the environment, a focus is emerging on reducing congestion. Parola and Sciomachen (2005) in their study came to the conclusion that the only strategic decision to reduce road freight traffic congestion would be the use of rail.

Among others, Palmer (2005), Albrecht (2001), and Parola and Sciomachen (2005) in their research on environmental effects from transportation have mainly been focused on the effects that occur during the use of the vehicles since that part of the transportation process produces the largest amounts of emissions. However, those effects are just a part of overall negative effects from transportation - external costs.

The paper by Léonardi and Baumgartner (2004) deals with the implementation of different measures for the reduction of environmental effects from transportation such as moving transports from road to rail or ship, driver training, or technical improvements. The conclusion from the study is that CO₂ efficiency increases after the implementation of an IT based scheduling system or a telematic application for data communication, positioning, and navigation (ibid, pp. 463). According to Blinge and Lumsden (1996), technical improvements have mainly been focused on improving motor efficiency, catalytic converters, and fuels.
As Blinge and Lumsden (1996) concluded, to get further towards sustainable mobility the transport sector should be analysed with a broader system approach, where possible improvements of all relevant factors are considered.
3 RESEARCH PROCESS

The choice and the formulation of the research problem usually define strategy and methods to be used to solve the research problem. This chapter discusses the research process and starts with an illustration of the flow of initial ideas. The research process is defined here as the summary of all the sequential steps a researcher engages in in order to follow the path of a specific research approach - conscious scientific reasoning (Kovacs and Spens, 2005).

3.1 Original ideas that inspired the research

The flow of initial ideas during the whole research process is illustrated in Figure 12. The same gives an overview of the relations between the papers since each paper initiated new ideas on what to do next.

Figure 12 Initial ideas that resulted in papers

Upon finishing the first paper, which showed that there are potential environmental benefits resulting from dry port implementation, a new question arose: “How much environmentally better is it with a dry port in the system?” The empirical data from the Port of Göteborg is used as a case to find the answer and
the same, naturally, brought up a new question: “Are there actually any dry ports in Sweden, i.e. intermodal terminals having the previously defined dry port principles?” The results of that study showed the Port of Göteborg’s determination to employ rail for transport of containers to inland destinations through dry ports. Consequently, it was of interest to find out how much the port can gain in the form of time and activity savings, i.e., “Which activities from the seaport can be moved to a dry port?” Furthermore, the literature study performed for the first paper found out that there was an ongoing project about close dry port implementation, which was 7 years delayed at that time. Obviously, it resulted in a new question for research; “What hinders dry port implementation?” Finally, main results from all these studies where gathered and tested through the survey in the last paper.

3.2 Research approach

Research design that is tight and too-structured might blind the researcher to important features in the case, leading to misreading local informants’ perceptions (Miles and Huberman, 1994). Conversely, the loose research design might lead to unsystematic data collection and data overload. This study might be placed in-between these two types of research designs. Previous research on the subject of interest was scarce and consequently, the starting frame of reference had to be rather broad. However, a loose research design and a broad frame of reference at the beginning gradually with each new paper became more structured and narrowed, and as such enabled a very good insight into the problem area.

Two research approaches dominate the academic discussion: the deductive and the inductive approach. Deductive research follows a conscious direction from a general law to a specific case, while inductive research reasons through moving from a specific case to general law (Kirkeby, 1990). According to Kovacs and Spens (2005), there is a dominance of deductive research in logistics and therefore there is a need for more inductive and, in particular, abductive research for theory development. A deductive approach is most suitable for testing existing theories, not creating new ones, which is why its dominance in a relatively new field of research as logistics is surprising (ibid). An abductive approach is different from a mixture of deductive and inductive approaches (Dubois and Gade, 2002). In studies relying on abduction, the original framework is successively modified, partly as a result of unanticipated empirical findings, but also of theoretical insights gained during the process (ibid). According to Kirkeby, (1990) different streams of abductive research coexist in modern science, i.e., there are differences in the approach due to its use in different disciplines. The overall research carried out in this study might be characterized as having an abductive approach (see Figure 13), although it started from a broad literature review of existing research related to the subject of interest. The research design was developed gradually with inputs from empirical findings and new theoretical insights in order to develop the concept and then finally test the results of the research.
This research process started with a broad literature study (Figure 13, step 0) on intermodal transport and its components in general, and as a result of that study some suppositions (Figure 13, step 1) regarding the dry port concept were created and presented in the first paper, which served as a basis for papers that came later. With those results as a basis, new studies were commenced in several steps (Figure 13, step 2), such as modelling and simulation based on the port of Goteborg’s data in order to find out about environmental impacts, a survey about existing dry port applications in Sweden and their impacts, and case studies about the impacts of dry ports on the seaports. Based on those new studies with new empirical evidence, new conclusions and suggestions have gradually been developed (Figure 13, step 1), contributing to further development of the concept. Finally, all conclusions from this research, which were expressed in the first five papers, were tested (Figure 13, step 3) through the survey in the last paper, resulting in final conclusions and suggestions (Figure 13, step 4).

![The abductive research approach in this thesis](image)

*Figure 13 The abductive research approach applied in this thesis (adapted from Kovacs and Spens, 2005).*

In their methodological framework, Arbnor and Bjerke (1997) describe three different approaches: analytical, systems and actors approach. Furthermore, the authors explain that those three different approaches overlap; however, in a way that system approach overlaps with two other approaches that are completely separate. The research in this thesis is basically using a systems approach often also termed holistic. In the system approach the world must be understood in terms of mutually dependent components that create the system as a whole; decomposing reality into parts is meaningless (Arbnor and Bjerke, 1997). This approach is often used in logistics to understand how the different components in the system interact in order to improve the effectiveness and efficiency for the system as a whole, content of each element and how they are put together. This is important since the same are often mutually dependent on each other (Abrahamson, 2003). However, Lindskog’s (2008) literature study of 2007 published articles, reviewing the notion system thinking in the logistics discipline, shows that 93.2% do not mention system thinking or system theory or system.
approach. Therefore, the author concludes that system thinking and its likes are not the core of the logistics discipline in the sense that they are common as explicit notions. If the system is defined as a set of parts coordinated to accomplish a set of goals (Churchman, 1981) then the system here is a seaport transport system consisting of different actors-parts of the system such as seaport terminals and their operators, rail and road operators and inland terminals; however, the same is the subsystem of a whole origin-to-destination transport system, see Figure 19. The goal of the system would be to efficiently transport units from an origin to a destination overseas; efficiently meaning on scheduled time, with no damage to the goods and with the least possible damage to the environment. The attention here is on one node in this transport chain, i.e., an element named “inland terminal interface” (see Figure 19), whose development would influence the system.

Churchman (1981) asserts that the ideal method in systems approach is case study; however, both quantitative methods, primarily simulations, and qualitative methods can be used. Different research methods were applied in this research and the same are explained below.

3.3 Methods and choices

Yin (2003) asserts that there is a widespread misconception that various research strategies should be arranged in hierarchical order, i.e., a case study approach is used in explorative studies, a survey approach in descriptive studies, and an experimental approach in explanatory studies. As suggested by Yin (2003), all research approaches can be used for all three types of studies; it is also possible to combine research strategies in one study as has been done in this research.

The majority of logistics research is primarily populated with quantitative research according to American researchers Mentzer and Kahn (1995); however, Näslund (2002) argues that it is necessary to use both quantitative and qualitative methodologies to develop logistics research. Vafidis (2007), in his study on Finish and Swedish doctoral theses, shows that the majority of them use multiple methods, in particular when the thesis is a collection of journal or conference papers. The word qualitative implies the qualities of entities or processes that are not measured in terms of quantity or amount. Qualitative research is defined as the studied use and collection of a variety of empirical materials – case study; personal experience; introspection; life story; interview; artefacts; cultural texts and production; observational, historical, and visual texts – that describe routine and problematic moments and meanings in individual life. In contrast, quantitative studies emphasize the measurement and the analysis of causal relationships between variables. These views are supported in the work of Denzin and Lincoln (2000). However, both types of research are more than data collection techniques; those are also research approaches to interpretation of collected data. Yin (2003) argues labelling qualitative research as “soft” while quantitative is considered to be “hard”, data driven and truly scientific; the author claims that these are the attributes of good or bad research, not attributes of a quantitative or qualitative
research approach. Furthermore, according to Yin (2003), research questions focusing on “how and why” are suitable for case studies, while those focusing on “who, what, where, how many, and how much” are suitable for surveys. However, the author states that case study research can be both quantitative and qualitative. Furthermore, Eisenhardt (1989) states that case studies can be used to accomplish various aims: to provide description, test theory or generate theory. However, there is a one common thought, that case study is a research strategy which focuses on understanding the dynamics present within single settings (ibid).

The research applied here was mainly qualitative, with the exception of research applied in Paper II that was quantitative and tried to measure the outcome of modelling and simulation and answer “how much” in order to test a previously posed hypothesis. The qualitative approach was expressed through case studies as well as through surveys, with the surveys being of a qualitative nature due to small number of participants and not statistical surveys. Furthermore, Fink (2002) states that a qualitative survey provides information of a descriptive nature, while a statistical survey provides information answering questions such as “How many?”. Marriot (1990) defines an analytic survey as a survey where the primary purpose of the design is the comparison between sectors or subgroups of the population sampled. The research strategy intended for this study was not a typical statistical survey on a large sample of a certain population, in which the data is analyzed through the systematic use of statistical methodology (Marriot, 1990); rather, the aim was a qualitative survey with respect to the number of participants and the questions asked, which are the combination of the two types of questions. Although a case study can be used for different research purposes such as exploration, theory building, theory testing and theory extensions/refinement (Voss et al., 2002), in this research the case studies were used only for theory building and refinement. According to some authors the main strength of case research is that it is not constrained by rigid limits of questionnaires and models (Voss et al., 2002) and therefore can have a very high impact and lead to creative insights and development of theory. On the other hand, some authors, e.g., Stuart et al., (2002) claim the necessity of having case study protocol which, among other issues, contains questions to be posed. Case studies conducted here were a combination of these two proposals; the questionnaires were formed but the research was not constrained by that since the interviews were semi-structured and allowed for the introduction of new issues and the possibility for the interviewer to follow up on topics more fully. The research purposes and questions with respective research strategies are summarized in Table 2.
Table 2 Matching the research purpose with the methodology (adapted from Stuart et al., 2002)

<table>
<thead>
<tr>
<th>Research purpose</th>
<th>Research question</th>
<th>Research structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description: explore territory</td>
<td>PRQ: What key principles may be identified in relation to the dry port concept?</td>
<td>Conceptually based (Literature study)</td>
</tr>
<tr>
<td>Theory development, Hypothesis testing</td>
<td>RQ1: What impacts does the dry port concept generate for actors of the transport system?</td>
<td>Modelling and simulation Case studies Survey (qualitative)</td>
</tr>
<tr>
<td></td>
<td>RQ2: What factors influence implementation of dry ports into seaports’ hinterland?</td>
<td>Case studies</td>
</tr>
<tr>
<td>Theory validation</td>
<td>(Are the findings robust?)</td>
<td>Survey (qualitative)</td>
</tr>
</tbody>
</table>

The data collection method performed through the work on all appended papers, as well as on the covering paper, was a literature review on intermodal transportation, seaport inland access, and inland intermodal terminals. An additional literature review on transportation related modelling and simulation as well as on environmental effects from transportation was done while writing Paper II. The primary purpose of literature studies is to generate understanding of the research field, to provide an insight of what research has already been done related to the problem being studied, and to identify areas of interest for further investigation. The literature here is scientific journals, conference proceedings, dissertations, theses, EU projects, as well as business-oriented publications. The latter were of particular importance at the very beginning of the research; they served as a source of practical information for initial exploration on the dry port subject. Published materials such as information published on the Internet or annual reports and archival records were helpful, especially to fill some empirical gaps.

Paper I distinguishes from other appended papers because it is conceptual - its findings are grounded mainly in literature. The paper attempts to define the key principles behind the dry port concept, and in order to accomplish that purpose a literature survey (i.e., examination of the situation) has been conducted as a pre-study in order to better understand the problem. The data collection technique, such as interview, that is usually related to case study research has been applied as well in order to get a better overview of the practical side of the research phenomenon.

Modelling and simulation is applied in Paper II. The idea was to evaluate to what extent implementation of a dry port into the system can lower the amount of road traffic in seaports and consequently lower the local environmental impact and for this purpose modelling and simulation was considered to be the appropriate method.
method. According to Beer (1985), “A model is neither true nor false; it is more or less useful.” This quotation is very suitable here since the model from this paper was “more or less useful”; i.e., the results of the simulation of the model enabled evaluation of the dry port concept and demonstration of its potential benefits. However, the model was “neither true nor false” since certain assumptions, regarding item attributes and objects in the model, have been made in order to simplify the modelling. The empirical data that enabled modelling were collected through archival records from the Port of Göteborg and through an interview with the seaport rail manager; the same were used to define processes in the model.

Comparative case studies have been chosen both for Paper IV and V. Mainly face-to-face, open-end interviews with people directly involved in terminal management was the data collection method performed for this study, apart from a literature review. These interviews were of crucial importance for the understanding of the cases; however, data collection also included secondary sources such as internal reports and archival records which, according to Stuart et al. (2002) should strengthen the reliability. Two case studies were done primarily to draw conclusions from their comparison and to analytically generalize; not to statistically generalise what wouldn’t be appropriate based only on two cases (Yin, 2003). The data for Paper IV came from two case studies on close intermodal terminals for Port Botany in Sydney. One case study is on an existing intermodal terminal, and the other is on a planned intermodal terminal. Port Botany and its close intermodal terminals have been chosen due to their distinctiveness, which is that there are very few ports that have so many functioning close intermodal terminals, or metropolitan intermodal terminals, as they are referred to in Australia. The other reason for choosing these sites is due to a 10 year delay for the implementation of the planned intermodal terminal despite obvious benefits that this terminal would bring to different actors of the system. The choice of case studies in Paper V is a result of the previous research on dry port. Virginia Inland Port was chosen due to its reputation as a successful inland port for the Port of Virginia but also due to the fact that it fits into the concept of dry port. On the other hand, Falköping terminal is still in the process of development into a dry port for the Port of Göteborg and therefore is still not in full bloom. The idea behind the study is, partially, to learn from the best and apply locally. This may be described as best practice case versus beginner. According to Abrahamson (2003), in logistics, proof that a certain case is a best practice case can be done both in qualitative descriptions of what they have done and with quantitative key figures such as logistics cost or delivery service. In this study, cases are discussed from both perspectives, qualitative and quantitative.

Survey as a research strategy has been applied for Papers III and VI, however, with different purposes. The purpose of the survey in Paper III was to map dry ports in Sweden and therefore the data for this study were collected by a questionnaire sent by e-mail and conventional mail to 25 road-rail terminals in Sweden. However, the response was weak and the data insufficient with different reference years; therefore, additional data was collected through archival records and interviews. A preliminary survey encompassed 19 intermodal (road-rail)
terminals that handled containers and were connected by rail to the Port of Göteborg, but only 15 were addressed in this study due to their relevant characteristics. Due to inconsistency of the collected data as well as to a small sample, the analysis was qualitative. On the other hand, the survey in Paper VI had for purpose to test the previous findings. As a result of a review of trade journals and internet based documents, a list of existing dry ports across the world was established. Furthermore, the data collection was performed through interviews, both personal and telephone, and through questionnaires sent by mail. Personal interviews can play a valuable role in surveys but over the years the use of the same has declined significantly, partly due to the cost of fielding a survey and the logistical problems involved (Cotugno and Wood, 2003). Therefore, personal interviews in this study were opportunistic, i.e., performed during site visits to relevant ports or during attended conferences or similar logistics research-related gatherings. The phone interviews became the data gathering process of choice for the rest of interviewees; however, many interviewees preferred questions to be e-mailed. Some empirical gaps, such as general technical data, were covered by information gathered from the reviewed dry ports’ web sites or other secondary sources. The research strategy intended for this study was not a typical statistical survey on a large sample of a certain population, in which the data is analyzed through the systematic use of statistical methodology (Marriot, 1990); rather, the aim was a qualitative, or even more appropriately, analytical survey with respect to the number of participants and the questions asked, which is a combination of the two types of questions. According to Fink (2002), a qualitative survey that provides information of a descriptive nature is particularly useful when one doesn’t have or want a large number or participants, as was the case here.

Observation as a data collection method has also been used during the whole research process, in particular for studies in Papers II, IV and V, but not in such a range as a literature study; therefore, it may be considered to be of secondary importance or supplementary. It was mainly unstructured participant observation during the study visits as well as jointly with the interviews. It has contributed to the understanding of practical issues in the subject related industry. Observation during the visit to the seaport container terminal, as an example, provided an insight into terminal processes such as truck arrivals, loading and unloading of vehicles and vessels.

Data collection methods and research strategies discussed above are all summarized in Table 3 giving an overview of the same in connection to the papers. This table also gives insight into all different methods and combination of research strategies applied for this study.
Table 3 Summary of data collection methods and research strategies applied in the papers.

<table>
<thead>
<tr>
<th>The paper</th>
<th>Data collection methods</th>
<th>Research strategy</th>
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<tbody>
<tr>
<td><strong>Paper I</strong></td>
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<tr>
<td>The dry port concept: connecting container seaports with the hinterland</td>
<td>Literature study</td>
<td>Conceptually based</td>
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<tr>
<td><strong>Paper II</strong></td>
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<tr>
<td>Evaluation of the dry port concept from an environmental perspective</td>
<td>Literature review, archival records, interviews, observation</td>
<td>Modelling and simulation</td>
</tr>
<tr>
<td><strong>Paper III</strong></td>
<td></td>
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<tr>
<td>Emergence and significance of dry ports - The case of the Port of Göteborg</td>
<td>Literature review, archival records, questionnaires, interviews</td>
<td>Survey study</td>
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<tr>
<td><strong>Paper IV</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factors influencing implementation of a dry port</td>
<td>Literature review, interview, secondary sources</td>
<td>Case study</td>
</tr>
<tr>
<td><strong>Paper V</strong></td>
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<tr>
<td>The dry port concept - Moving seaport activities inland?</td>
<td>Literature review, interview, observation, secondary sources</td>
<td>Case study</td>
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<tr>
<td><strong>Paper VI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A review of dry ports – Characteristics, driving forces and impediments</td>
<td>Literature review, questionnaires, interviews, secondary sources</td>
<td>Survey study</td>
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3.4 Validity and reliability

The validity and reliability of the research provides confidence in the collected data as well as confidence in the successful application of the results. The research applied here was both qualitative and quantitative; consequently, the validity and the reliability techniques differ to a certain extent.

The validation of the model, created in Paper II, is done by a subjective method, i.e., the model is validated with the help of the experts in the field using a structured walkthrough of the model. Additionally, some simulation results were analysed for validation purposes. Although “a three step approach” for validation (Law and Kelton, 1991) is not applied here, the model might be considered valid enough for the purpose of this paper. The model is quantitative in its nature as well as descriptive in its purpose. It is stable – some input data can be altered, but
it is not flexible – i.e., it cannot simulate another seaport by a simple change of input data.

According to Riege (2003), few scientific techniques have been developed to address how to enhance validity and reliability of qualitative research, in particular case study research. Furthermore, the author implies that case study research is perceived as more subjective than qualitative methodologies in general because researchers usually have close contact with the organization or people examined. The case studies in this research were not of a longitudinal nature nor were they over a longer period of time; therefore there was no need for the researcher to make extra efforts to refrain from subjective judgements due to lasting or multiple contacts. In accordance with recommendations by Stuart et al. (2002), for the case study research in this thesis a case study protocol consisting of a semi structured interview, based on a research question, has been developed in order to ensure reliability. Semi-structured open-end interviews were chosen as the appropriate method to explore the issues as the same allowed the interviewees to introduce new issues and the interviewer to follow up topics more fully. A checklist of issues was used to ensure that every pre-decided topic was covered and to give a sequence of questions, starting with factual queries on site and leading into more research question related issues. During the interview, the interviewer recapped what the interviewees had said, inviting them to develop their original statements. Data for the case studies is collected primarily through face-to-face interviews with interviewees representing different actors of the transport system who were of relevance for the research. In addition, the interviews were supported by site visits. In order to ensure validity, triangulation (Voss et al., 2002; Stuart et al. 2002) with multiple means of data collection has been done. Therefore, apart from having interviewees from different sectors of the transport system, secondary data sources have been used, such as internal company reports, Internet based documents and archival records. Some additional phone interviews as well as e-mail correspondence were done in order to fill the gaps.

The surveys applied in this research are of a qualitative nature and as such used the case study applicable methods for validation. A preliminary literature review on the subject of dry ports provided good insight into the existing and planned dry ports in Sweden and in the world. Once the list of dry ports was established for both studies - mapping of dry ports in Sweden and a review of dry ports in the world - the data collection was performed through interviews, both personal and telephone, and through questionnaires sent by mail. Some empirical gaps, such as general technical data, were covered by information gathered from the reviewed dry ports’ websites or other secondary sources; therefore, this triangulation ensured validity.
4 SUMMARY OF THE APPENDED PAPERS

This chapter summarizes the appended papers and gives an overview of the interrelationship between the papers. For each paper, the purpose and the most important findings are given.

4.1 Interrelationship between the papers

Paper I is conceptual as it introduces the dry port concept; and as such it provides a core for the papers that came later. Therefore, the main findings from this paper are integrated in all of the subsequent papers. It was considered indispensable since the concept is not widely known and any further discussion on the concept’s application or evaluation was not possible without an adequate explanation of the same. Based on the outcome from the research related to Paper I, which is about dry port principles, the areas of interest for the next paper were identified; that was the principle for all subsequent papers, i.e., the work on each paper inspired and gave ideas for new research. Papers II, III and V are about the impact the dry ports are making once implemented into the system, while Paper IV is about the influence the different actors of the transport system may have on the implementation of the dry port into the system. Finally, the last paper, Paper VI, has the purpose to test findings from all previous papers and as such covers all previously mentioned areas of study. The interrelationship between the papers regarding the research areas covered in each of the papers is illustrated in Figure 14.

![Figure 14 Interrelationship between the papers](image-url)
4.2 Overview of the papers

4.2.1. Paper I - The dry port concept: connecting container seaports with the hinterland

Purpose

The framework developed in this paper provided a basis for an overview of the dry port concept, its terminology, as well as on the actors involved in the system and their benefits from implementation of a dry port. The hypothesis behind this paper is that the problems related to increased container flows are best approached from a joint seaport and hinterland perspective. Hence, it is here argued that a well applied dry port concept can shift freight volumes from road to more energy efficient traffic modes that are less harmful to the environment, relieve seaport cities from some congestion, make goods handling more efficient in seaports and facilitate improved logistics solutions for shippers in the port’s hinterland.

The main purpose of the paper is to define the dry port concept and different types of dry ports: close, midrange and distant. For each category the benefits are defined from the perspectives of actors involved such as seaports, rail and road operators, shipping lines, shippers, local authorities and the society as a whole. After a theoretical part regarding the role of terminals in freight transport networks, the dry port concept is presented. In addition, examples of applications of the dry port concept are presented regardless of whether these are officially denoted as dry ports.

Findings

It is here asserted that the dry port concept goes beyond the conventional use of rail shuttles for connecting a seaport with its hinterland. Being strategically and consciously implemented jointly by several actors, it also goes beyond the common practice in the transport industry. Besides the general benefits to the ecological environment and the quality of life by shifting flows from road to rail, the dry port concept mainly offers seaports a possibility to secure a market in the hinterland, increasing the throughput without physical port expansion as well as better services to shippers and transport operators. The seaport cities, often also the principal of the port authority, benefit from less road congestion.

The real-world examples also show that dry ports can be introduced and are being introduced by several ports. The immediate reasons may vary, but a common denominator is that rail has a role to play as an intermediate traffic mode between sea and road. For implementation, however, costs and benefits must be carefully evaluated and distributed between the actors.
4.2.2. Paper II - Evaluation of the dry port concept from an environmental perspective: a note

Purpose

The following hypothesis was formulated in the first paper: “A carefully implemented dry port concept can shift freight volumes from road to more energy-efficient and less environmentally harmful rail, reduce road congestion in seaport cities, and facilitate improved logistics solutions for shippers in the seaport’s hinterland.” Therefore the purpose of this paper was to partially test this hypothesis explicitly to evaluate the dry port concept from an environmental perspective using modelling and simulation.

A model of a transport system, with and without a midrange dry port, was created and the results of the simulations were compared. The reference situation represents the transport of loading units from the seaport to the chosen inland destinations by truck. In other words, it represents seaport inland access conducted by truck without an implemented dry port. The scenario demonstrates the system with an implemented dry port, which means that the transport of the loading units from the seaport to the dry port is by rail, and from the dry port to the inland destinations by road. Thus, the transport of containers is shifted from road to rail on the link from the seaport to the dry port. The objective was to show that there is a way to improve the operations involved in the container flow in order to achieve better productivity, and with that to lower the environmental impact. The benefits of the dry port implementation are defined from an environmental perspective, specifically by reduction of CO₂ emissions and congestion at the terminals.

Findings

With dry port implementation, CO₂ emissions should decrease; the calculated CO₂ emissions during simulation of the transport between terminals as well as during queuing (very low speed driving) at the terminals were approximately 25% lower in the model with the dry port. Furthermore, queues and long waiting times at seaport terminals should be avoided, and the risk of road accidents reduced. Although it is obvious that the movement of containers from road to (electrified) rail will result in lower CO₂ emissions, a dry port is not merely an implementation of rail – it is a set of efficient services such as transhipment, storage, depot, maintenance of containers, customs clearance, and tracing and tracking. Moreover, the quality of access to a dry port and the quality of the road–rail interface also determines the dry port’s performance. It is therefore necessary to have scheduled and reliable rail transport between the seaport and the dry port.

4.2.3. Paper III - Emergence and significance of dry ports - The case of the Port of Göteborg

Purpose

This paper summarizes the research from the first two papers and applies the same to the situation in Sweden.
As container transport volume continues to grow, seaport inland access becomes a critical factor for the seaports’ competitive advantage. Therefore, progress only in the maritime part of the transport chain and in seaport terminals, without improvements in seaport inland access by means of intermodal terminals, is not sufficient for the entire transportation chain to function. Consequently, the emphasis of this paper is on the importance of efficient seaport inland access that would be obtained through implementation of dry ports. Therefore, the purpose of the paper is to present the dry port concept as well as to identify and categorize existing dry ports for the Port of Göteborg.

The scope of the paper is the seaports’ inland access with intermodal terminals, as a part of the intermodal transport chain. Moreover, the transport of containers from the seaport to inland destinations in Sweden, mainly by rail and only a short leg by road, was of interest.

Findings

The findings show that only Stockholm-Årsta and Karlstad-Vänerterminalen with extra services offered at the terminals may be categorized as advanced inland intermodal terminals for the Port of Göteborg, or, given their rail connection to the seaport, as simple dry ports. However, as described earlier, even without these extra services some of the surveyed terminals fulfil the role of a dry port for some actors in the transport system. In addition to the general benefits to the ecological environment and the quality of life by shifting flows from road to rail, the dry port concept mainly offers seaports a possibility to increase the throughput without physical expansion at the site. However, this study indicates the expected difficulties with the implementation of the concept since intermodal transport itself has many hindrances.

4.2.4. Paper IV - Factors influencing implementation of a dry port

Purpose

With an increase in the volumes of maritime container traffic to/from Australia, seaports and their inland access are becoming critically strained. Although inland access is important for the competitiveness of seaports, the competitiveness is not a critical issue for Port Botany, Australia’s second largest container port. The most urgent issue to deal with for the port and the city, Sydney, is congestion due to inappropriate seaport inland access, which is mainly done by road on road arteries already reaching their capacity. Although a concept of a close dry port should bring numerous benefits to the actors of the transport system, and would relieve the congested roads, there are still many impediments to the implementation of the same. Therefore, the purpose of this paper is to investigate and define impediments to a close intermodal terminal – dry port implementation through case studies. Empirical data for the case studies are collected at Port Botany and its existing and proposed close intermodal terminals, or metropolitan intermodal terminals as they are referred to in Australia. The idea behind the study is to contribute to better understanding of the concept of close dry port through the
factors that influence the implementation of the same and by that to improve the knowledge on implementation of the concept.

In Sydney the truck industry is obligated to take greater volumes of freight in and out of the Port. These movements lead to other secondary movements which must interact on increasing congested roads. Furthermore, transport operators don’t have many options but to go by road because of the poor rail infrastructure from one side and lack of awareness of the problem from the other. Sydney’s Port Botany handles more than 1.6 million TEUs a year (2006/07) and the figure is just growing; however, the state does not have a dedicated freight strategy. One potential solution is with the concept of dry ports for Port Botany.

Findings

Land use, infrastructure, environmental and institutional impediments are identified as the most common ones for the cases. A dry port must fit into a complex system where the necessary supporting infrastructure (roads, railways) is in place, maintenance is assured, and the legislative, regulatory, and institutional systems are properly designed to optimize the involvement of both the public and the private sector. The case permits us to assume that transport issues might be closely related to psychological and behavioural issues and if actors involved are not well-informed on the matter problems might arise. That was the case with Enfield project; the public wants the transport services but doesn’t want the traffic.

4.2.5. Paper V - The dry port concept - Moving seaport activities inland?

Purpose

Transport systems have always been designed according to geographical conditions as well as the demand for transportation, which was determined by the goods quantity and service quality. Currently, environmental issues play an important role in the design as well. One way to accomplish those demands is to employ rail through intermodality. The shipping companies strive towards economies-of-scale for the maritime part of their transport chain and that derives a demand for efficiency, capacity and short lead time in the transit through the seaports and further transport to the seaports hinterland. To stimulate the development of those seamless intermodal transport chains the concept of dry ports is established.

The purpose of this paper is to further develop the dry port concept and to analyze the same through comparison of physical flows and administrative activities at the seaport terminal from time perspective in the transport system with and without a dry port, theoretically and through case studies. The data for the analysis is obtained through literature review and interviews with relevant actors of the transport system.
Findings

The results of the comparison of the cases show two different approaches regarding the seaports’ competitive advantages by improvement of the seaport inland access through dry ports. The Port of Virginia is ready to invest in development of inland terminals because the competition between ports is the fact that expansion inland into new markets brings competitive advantage. Faster movement of containers from the port to the final destination also increases the port’s capacity. On the other hand, the Port of Göteborg has sufficient volumes with no fierce competition and does not strive towards the expansion of its hinterland, so far; problems of congestion at seaport gates and potential delays have not reached a critical point yet. Therefore, the port does not invest in inland transport development as long as there are others such as rail operators, terminal operators and belonging municipalities eager to do so. However, the Port of Göteborg’s role is of a supportive nature when it comes to the development of inland terminals and rail shuttles by other actors of the transport system. Implementation of a dry port into the seaport transport system, that is seaport’s hinterland, should create a seamless transport chain, smooth transport flow with one interface in the form of a dry port concept instead of two interfaces, one at the seaport and the other one at the inland destination. In other words, two nodes in the transport chain, seaport and inland terminal, should be replaced with one “dry port concept” node. However, the significant time savings, as well as the financial savings, could be made only by avoiding the queues at seaport gates and by moving container storage inland. Evidently, expansion inland into new markets improves seaport’s access to areas outside its traditional hinterland, resulting in new customers generating more profit and promoting the regional economic activity.

4.2.6. Paper VI - A review of dry ports – Characteristics, driving forces and impediments

Purpose

Environmental problems have received increasing attention during the last decade and with them also the role that logistics systems can play in reducing those problems. However, logistics concepts in the role of decreasing environmental impacts have not been extensively researched until recently. One of these concepts is a concept of dry port that, apart from reducing the environmental impact, has the potential to create numerous benefits for the actors of the transport systems.

The objective of the paper is to present the theory behind the dry port concept and to review the existing dry ports in the world, i.e., freight terminals that use the term “dry port” in their name. Therefore, the purpose of the paper is to clarify the concept by showing potential discrepancies or agreements between the theory and practice. Starting from a literature review on the dry port concept, this study presents a review of existing dry ports in the world. The data collection was conducted by means of interviews or by questionnaires sent by email to the dry port managers.
Findings

The findings are analyzed with the intention of clarifying the concept by showing the similarities and differences between reviewed dry ports and existing definitions of the same. The dry port concept, when defined as an inland intermodal terminal directly connected to seaport(s) by rail, where customers can leave/pick up their units as if directly to a seaport, ideally represents the dry ports reviewed in this study. Even the extra services offered at the studied dry ports, such as customs clearance and storage, correspond to those previously identified. Other services, such as the maintenance of containers or forwarding, were not available at all the dry ports; therefore, they do not have to be considered as essential for the dry ports’ viability. Regarding the advantages resulting from the dry ports’ implementation in the transport system, all of the reviewed dry ports brought at least two advantages for the actors of the system. Improved customer service and the creation of new jobs in the area, advantages both closely related to regional growth, were the most recognized advantages, and particularly so for landlocked countries. Closely related to all the advantages are the impediments, or the lack of the same; the reviewed dry ports have not experienced significant impediments, and some faced no impediments at all. In other words, many had a smooth path on their way to realization. This paper contributes to the study of dry ports by synthesizing a literature review on the subject of dry ports; moreover, it provides an overview of dry ports in the world through their characteristics, driving forces and impediments; and as such makes a contribution to the scarce research on the dry port concept.
5 ANALYSIS

In this chapter the findings from the papers are analysed with regard to the research questions; additionally, the chapter gives an overview of the main findings as well as an overview of the papers’ contributions to answering the research questions.

5.1 The dry port concept

This section tends to give answers to the primary research question:

**PRQ:** What key principles characterize the dry port concept?

The ambiguous frame of reference regarding the specific subject of dry ports formed the first issue to be discussed, and that is the clarification of the concept of dry port. Therefore, the very first task was to define the concept, i.e. to define the principles that characterize the concept. Hanappe (1986) relates to dry ports as multifunctional logistics centres with a variety of firms operating at the same site. This description corresponds to the concept of freight villages, according to the Economic Commission for Europe (2001), since this definition does not emphasize a connection to seaports nor does it specify the range of services offered at the terminals. Beresford and Dubey (1990), in their extensive survey of dry ports in Africa, use a dry port definition that corresponds to the definition of an Inland Clearance Depot, according to UN ECE (1998). Their definition is very specific regarding ownership and services, in particular customs clearance, although with no specification of the type of connection to a seaport. Furthermore, Beresford and Dubey (1990) emphasize the importance of a dry port as a common user facility that would promote the transfer of goods from origin to destination without an intermediate customs examination, the so-called through-transport concept.

Terminals as physical plants that meet the business needs of a specific marketplace may take many forms, depending on the characteristics of the landscape, their proximity to the seaport and their location relative to the main rail infrastructure. This conscious and strategic development of intermodal terminals in the seaport’s hinterland is approaching what we denote as dry ports. Based on the research findings, the following definition was formed:
A dry port is an inland intermodal terminal directly connected to seaport(s) by rail where customers can leave/pick up their units as if directly to a seaport.

Throughout the study the definition emphasized the use of high capacity transport means, which includes rail and/or barge. The same has been done so because some existing dry ports or advanced intermodal terminals use both means of transport. However, the word “dry” has raised many discussions which in the case of use of barges would be contradictory. On the other hand there is a concept of inland port which is defined by the use of barges. Therefore this dry port definition emphasizes the use of rail.

Essentially, four functions take place at the freight terminal: transfer of cargo, mostly unitized, between two modes; the assembly of freight in preparation for its transfer; the storage of freight awaiting pick-up; and delivery and the logistical control of flows (Slack, 1999). In addition to all functions mentioned above, services such as maintenance of containers, customs clearance, and other value-added services should take place at a dry port terminal in accordance with customers’ needs. Furthermore, dry ports are categorized into distant, midrange and close dry ports, based on their function and the location. The benefits of these categories are discussed in the next chapter. Therefore, this approach to the dry port concept might be characterized as one step towards a clarification of the concept, compared to Beresford and Dubey (1990). Although the two approaches share a common background, the former emphasizes a connection to a seaport as well as the environmental benefit and promotion of intermodal transport, while the latter’s approach is more about transit cost savings and promotion of regional economic activity, among other advantages.

The quality of the access to a dry port and the quality of the road–rail interface determines the dry port’s performance. Scheduled and reliable high-capacity transportation to and from the seaport is therefore necessary. To summarize the main features of a dry port:

- Intermodal terminal
- Situated inland
- Rail connection to a seaport
- Offers services that are available at seaports, such as container maintenance, storage of containers, forwarding, depot and customs clearance

Thus, dry ports are used much more consciously than conventional inland terminals, with the aim of improving the situation resulting from increased container flows, and a focus on security and control by the use of information and communication systems. The dry port extends the gates of the seaport inland, with shippers viewing the dry port as an interface to the seaport and shipping lines. A simplified explanation of a dry port concept would be: movement of seaport’s interface inland.

The purpose of the last paper was to test previously formed conclusions and therefore the results of that paper may serve as a conclusion here. The dry port concept is based on a seaport directly connected by rail to inland intermodal
terminals, where shippers can leave and/or collect their goods in intermodal loading units as if directly at the seaport; this definition ideally represents the dry ports reviewed in this study. Even the extra services offered at the studied dry ports, such as customs clearance and storage, correspond to those previously identified by various researchers. Other services, such as the maintenance of containers or forwarding, were not available at all the dry ports; therefore, they do not have to be considered as essential for the dry ports’ viability.

Although this section is labelled as the answer to the primary research question, the one that was necessary as a base in order to further develop the concept, the same has an additional purpose as well. The idea behind this first part of the study related to the definition of the dry port was to make a step towards the standardization of the definitions for logistics terms related to different types of freight terminals.

5.2 Impacts resulting from dry ports

By discussing different types of dry ports and the potential benefits they bring for different actors of the transport system, this section tends to give answers to research question one:

RQ1: What impacts does the dry port concept create for actors of the transport system?

Conventional hinterland transport is based on numerous links by road and only a few by rail, which is generally limited to serving major conurbations at relatively large distances from the seaport, as shown Figure 1a.

![Comparison of conventional hinterland transport and an implemented dry port concept](image)

*Figure 15 Comparison of conventional hinterland transport and an implemented dry port concept*

Dry ports are divided into close, midrange, and distant dry ports; a seaport and all three types of dry ports are presented in Figure 1b.

The benefits from distant dry ports derive from the modal shift from road to rail, resulting in reduced congestion at the seaport gates and its surroundings. Since one train can substitute for about 35 trucks in Europe, the external environmental effects along the route are reduced. Today, seaports compete not only on tariffs and transhipment capability, but also in the quality of inland access. This competition requires seaports to focus on transport links, on the demand for
services in its traditional hinterland, and on development in areas outside their immediate market (Notteboom and Rodrigue, 2007). Consequently, apart from environmental benefits, a distant dry port also brings a competitive advantage to a seaport since it expands the seaport’s hinterland, i.e., improves the seaport’s access to areas outside its traditional hinterland by offering shippers low cost and high quality services. Rail operators benefit from distant dry ports simply by the movement of containers from road to rail, which increases the scale of their business. From the shippers’ perspective, a well-implemented distant dry port offers a greater range of logistics services in the dry port area. For environmentally conscious shippers it gives the option of using rail rather than road, thus reducing the environmental impact of their products.

The benefits of a midrange dry port are comparable to those of a distant dry port since the same serves as a consolidation point for different rail services, implying that administration and equipment specific to sea transport are needed at only one terminal away from the seaport. The high frequency achieved by consolidating flows, together with the relatively short distance, facilitates the loading of containers for one container vessel in dedicated trains. Hence, the dry port can serve as a buffer, relieving the seaport’s stacking areas.

Implementation of a dry port in the seaport’s immediate hinterland enables the seaport to increase its terminal capacity and hence manage the problem of lack of space or inappropriate inland access. With increased terminal capacity comes the potential for increased productivity, since bigger container ships may call at the seaport. Road hauliers lose a marginal market share in terms of road-kilometres, but would still benefit from shorter waiting times at dry port terminals. In cities not allowing long or polluting road vehicles, calling at a close dry port is an alternative to splitting up road vehicles or replacing them with less polluting vehicles.

Identification and categorization of dry ports in Sweden resulted in the following conclusion: several intermodal terminals in the study could be categorized as advanced inland intermodal terminals for the certain seaport, or, given their rail connection to the seaport, as simple dry ports. However, even without all the extra services usually available at the dry ports some of the terminals might fulfil the role of a dry port for some actors in the transport system. At the time the study was performed none of the surveyed terminals used the term dry port, nor had the complete dry port features been previously described.

Dry port implementation generates set of advantages for the actors of the transport systems; these are summarized in Table 4. The most obvious benefit from environmental perspective comes from movement of containers from road to rail which results in less congestion on the roads as well as at seaport terminals, reduced emissions; and by that in reduced environmental effects.

There is a general perception that environmentally friendly solutions involve high cost and therefore hinder economic growth; therefore green logistics has always been seen as some sort of trade-off. However, lately, sustainable logistics solutions/concepts have become more important in everyday business, partially
due to regulations but also due to customers’ environmental awareness. One can see from Table 4 that dry ports have the potential to generate environmental benefits on all levels and eventually those benefits can be translated into cost reductions, as, for example, less congestion on the road generates time and consequently cost savings for road carriers. Although a dry port implementation, as a sustainable logistics solution, involves significant investments for the owners, one should keep in mind that the same has the potential to gradually generate much higher total revenue for all actors of the system, not just for direct investors. Therefore, the dry port concept should be arranged as a joint venture of all beneficiary stakeholders, of which the biggest one eventually is society.

Table 4 Impacts generated by dry ports for the actors of the transport system.

<table>
<thead>
<tr>
<th></th>
<th>Distant</th>
<th>Midrange</th>
<th>Close</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seaports</strong></td>
<td>Less congestion</td>
<td>Less congestion</td>
<td>Less congestion</td>
</tr>
<tr>
<td></td>
<td>Expanded hinterland</td>
<td>Dedicated trains</td>
<td>Increased capacity</td>
</tr>
<tr>
<td></td>
<td>Interface with hinterland</td>
<td>Depot</td>
<td>Depot</td>
</tr>
<tr>
<td><strong>Seaport cities</strong></td>
<td>Less road congestion</td>
<td>Less road congestion</td>
<td>Less road congestion</td>
</tr>
<tr>
<td></td>
<td>Land use opportunities</td>
<td>Land use opportunities</td>
<td>Land use opportunities</td>
</tr>
<tr>
<td><strong>Rail operators</strong></td>
<td>Economies of scale</td>
<td>Day trains</td>
<td>Day trains</td>
</tr>
<tr>
<td></td>
<td>Gain market share</td>
<td>Gain market share</td>
<td>Gain market share</td>
</tr>
<tr>
<td><strong>Road operators</strong></td>
<td>Less time in congested</td>
<td>Less time in congested</td>
<td>Less time in congested</td>
</tr>
<tr>
<td></td>
<td>roads and terminals</td>
<td>roads and terminals</td>
<td>roads and terminals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Avoiding environmental</td>
</tr>
<tr>
<td><strong>Shippers</strong></td>
<td>Improved seaport access</td>
<td>Improved seaport access</td>
<td>Improved seaport access</td>
</tr>
<tr>
<td></td>
<td>“Environment marketing”</td>
<td>“Environment marketing”</td>
<td>“Environment marketing”</td>
</tr>
<tr>
<td><strong>Society</strong></td>
<td>Lower environmental impact</td>
<td>Lower environmental impact</td>
<td>Lower environmental impact</td>
</tr>
<tr>
<td></td>
<td>Job opportunities</td>
<td>Job opportunities</td>
<td>Job opportunities</td>
</tr>
<tr>
<td></td>
<td>Regional development</td>
<td>Regional development</td>
<td>Regional development</td>
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</table>

The study concerning environmental evaluation of the dry port concept has been twofold, with regard to queues at the seaport terminal gates and CO₂ emissions. The results for terminal queuing which are based on a simulation of four (peak) hours show that there is a 72-minute longer waiting time at the seaport terminal in the model without a dry port. Although it might not seem like a very long waiting time, one should bear in mind that this difference comes as a result of four hours of simulation or approximately 70 trucks, while the seaport has an average throughput of approximately 700 trucks per day (both for loading and unloading). Not maintaining a predetermined schedule for the arrival of trucks at a busy seaport terminal has been shown to be the major cause of congestion at a terminal. Long waiting times, apart from financial loss for carriers increases the risk of road.
accidents since truck drivers become anxious and might also avoid regular rests during transportation in order to arrive at the destination on time.

The results for CO\textsubscript{2} emissions are based on a simulation for 35 trucks, which is equal to the average number substituted by one train in Sweden. The calculated CO\textsubscript{2} emissions during simulation of the transport between terminals as well as during queuing (very low speed driving) at the terminals are approximately 25% lower in the model with the dry port. This translates to approximately 1300 kilograms of CO\textsubscript{2} less per train/35 trucks, and for the chosen case there should be two trains per day, i.e., about 70 trucks a day should pass through the dry port. In view of the fact that a major part of these CO\textsubscript{2} emissions occurs during the transport between the terminals, and only about 4% comes from queuing, the benefit from the dry port implementation can be translated into road-kilometres reduced.

Some seaport activities can easily be moved to dry ports; however, seaports that do not face a lack of space at their terminals will not gain by moving their storage area to an inland terminal. On the contrary they might lose a significant portion of the profit like in the case of the Port of Göteborg. The Port is located outside the city centre and has a sufficiently large storage area with the possibility for expansion, and at present, the storing of containers brings in a significant amount of revenue for the Port. This usually is not the case with big container ports and dry port as a depot is seen as the solution for the problem of lack of space. Since the inland terminal in this case is not owned by the Port, moving the storage from the Port to the dry port would imply giving away the profit. Therefore, the Port was not financially involved in the establishment of its inland terminals; however, the administrative part of the establishment as well as some adaptations at the port terminals had to be done in order to introduce one extra shuttle train. This is not the case with the Port of Virginia, which owns the dry port and therefore, moving activities inland does not imply loss of profit. The dry port with direct rail to the seaport gained a valuable space at the seaport terminals, i.e., increased capacity that resulted in increased productivity. Furthermore, the dry port also brought a competitive advantage to a seaport since it expanded the seaport’s hinterland, i.e., improved the seaport’s access to areas outside its traditional hinterland.

When it comes to time savings that result from implementation of a dry port into a seaport transport system, one can see that the same can be obtained by eliminating queues at the seaport’s gates or by eliminating storage at the seaport. The latter does not represent a certain gain for the actors of the system since the containers need to be stored anyway; whether at the seaport terminal or at the dry port makes no difference as long as the seaport does not face lack of storage space. The former, on the other hand, makes significant gains, not only for the seaport that would perform better with no congestion at the terminals, but for the carriers who suffer from financial loss due to delays caused by the congestion. At the Port of Göteborg gates there are several hours-long queues at peak times. VIP can have trucks in and out in just 30 minutes; truck drivers never have to leave their vehicles.
To summarize how the implementation of a dry port into a seaport’s transport system influences physical and administrative flows at the seaport and by that the system; well, one does not need a case study to realize that some activities like ship loading/unloading cannot be moved to an inland terminal. However, there is a whole range of administrative activities that would be moved inland with implementation of a dry port, specifically those related to handling truck related paperwork. Moreover, some physical activities would take less time, such as storage; while some could be reduced completely, such as inevitable queuing at the seaport gates. In an ideal situation with direct loading/unloading of a ship to/from a train would result in a significant reduction of internal vehicle transport. Implementation of a dry port could create seamless seaport inland intermodal access, i.e., smooth transport flow with one interface in the form of a dry port concept instead of two, one at the seaport and the other one at the inland destination.

The survey on dry ports in the world identified the most common impacts in the form of advantages resulting from dry ports and the same fit into the previous findings on potential benefits from dry ports. Some advantages the dry ports bring to different actors in the transport system may easily be related to the impediments, or lack of the same. For instance, local environmental issues were not recognized as impediments by any reviewed dry port, and at the same time, as a majority of them are situated in rural areas, many dry ports stated regional growth and new jobs in the area as the most important advantages. Increased port capacity is the least-recognized advantage, since the reviewed dry ports are mostly implemented by local municipalities or in cooperation with them, and their foremost intention is regional development through the attraction of new industries to the area, once logistic solutions are available. The most important advantage resulting from dry ports is better customer service, which is recognized differently by the reviewed dry ports but might be summarized as the following: lower transport cost, more value-added services at the customers’ doorstep, faster transport of units to/from the seaports, faster customs clearance, simplified documentation and lower storage rates.

![Advantages resulting from the implementation of surveyed dry ports, from dry port managers’ perspectives](image-url)
5.3 Factors influencing implementation of a dry port

Although a concept of a dry port should bring numerous benefits to the actors of the transport system there are still many impediments to the implementation of the same. Therefore this section tends to give an answer to research question two:

RQ2: What factors influence implementation of dry ports into seaports’ hinterland?

With an increase in the volumes of maritime container traffic to/from Australia, seaports and their inland access are becoming critically strained. Although inland access is important for the competitiveness of seaports, this is not a critical issue for Port Botany, Australia’s second largest container port. The most urgent issue for the port and the city, Sydney, to deal with is congestion due to inappropriate seaport inland access, which is mainly done by road on road arteries already reaching their capacity. Beavis et al. (2007) indicate that poor harmonization of the system resources (including storages, train path access and positioning of empty containers) under conditions of an increasing flow avalanche from the port is adding to Sydney’s hinterland congestion. To ease pressure on Sydney’s roads, moving a larger portion of containers by rail is proposed for Port Botany’s basin, and a network of intermodal terminals that should be located in proximity of the served market and within the industrial area is crucial to achieve this. Although a concept of a close dry port should bring numerous benefits to the actors of the transport system, there are still many impediments to the implementation of the same. Therefore, the purpose of the study was to investigate and define impediments to a close intermodal terminal – dry port implementation through case studies. Different actors of the transport system such as the terminal manager, seaport managers, rail and road operator as well as ministry of transport personnel familiar with the current transport issues identified four impediments for implementation of the needed terminal: regulations, environment, land use and infrastructure. Interviewees agree that it is not just about general awareness on benefits from rail freight transport or environmental issues coming from it to start with changes; it is about regulations and policies. There are no direct subsidies for rail from the government and one reason for weak involvement of the government in support of rail is very strong road lobby that impedes any actions towards increased use of rail and by that, intermodal transport, as explained by some interviewees. The other identified impediment was fear from environmental impacts in the area due to potential for increased road traffic, which was overstated by local politicians’ struggling for votes. The fact is that road traffic from the port already runs through the area because it is located next to major roads. The residents see it as a trade off between congestion at the seaport and at the Enfield area and their major concern was environmental effects from generated road traffic as well as from rail. Therefore, an environmental assessment has been done on effects of road and rail traffic and finally it was approved to build the intermodal terminal with smaller operating capacity. The question of environmental impact is closely related to the issue of land use; the closer the potential site for an intermodal terminal is to a metropolitan area the higher the price as well as demands regarding the environmental impacts. Functionality of the seaport depends on its inland access, which in this case
depends greatly on a close intermodal terminal situated within the metropolitan area but the residents want parks and not transport facilities. However, the site is already highly disturbed by ruined rail buildings and stockpiles and therefore substantial investments within the project are planned to transform the site into a green space and a valuable community asset with buffer planting and acoustic moulding and walling. This case permits us to assume that transport issues might be closely related to psychological and behavioural issues as even Engström (2007) discuses that shippers sometimes make decisions on not using a specific mode of transport based on soft variables such as feelings or resistance to change or lack of know-how instead of facts and data. Rail infrastructure is already a concern since the existing passenger and freight shared rail network is getting more constrained by passengers, and passenger transport has priority, and there are very few free slots for eventual new rail operators. Road congestion is an urgent issue; seaport terminals as well as city roads are congested with trucks, but improvements to the rail network with dedicated freight lines would require considerable investments to which government is not ready to commit.

The impediments identified in the survey on dry ports in the world (Figure 17) generally correspond to those above, which relate to implementation of a dry port into seaport’s immediate hinterland, with one exception: none of the reviewed dry ports experienced problems due to local environmental issues. This could have been anticipated since all reviewed dry ports are located in rural areas or are not very close to residential areas, which was the case in the previous study where dry ports were situated within or very close to metropolitan areas. In general, the surveyed dry ports have not experienced impediments to a large extent; regulations were the most frequently identified impediment in the study, but by less than 30% of reviewed dry ports. Only one dry port experienced a land use problem, and not in the early phase but rather in future plans for expansion.

![Figure 17 Impediments experienced by the dry ports in the study, from dry port managers’ perspective](image)

The second diagram in Figure 17 shows that the reviewed dry ports have not experienced a significant number of impediments; in other words, many of them had a smooth path on their way to realization. One impediment, previously not identified, was the financing of dry ports; this is rather self-evident since the
implementation of a dry port requires substantial financial resources. If one neglects financing as an impediment, since the same should be assumed as a precondition for such matters, it turns out that more than 50% of reviewed dry ports have not experienced any impediments to implementation and operation.

5.4 Summary of the papers' findings and contributions

The main findings from the papers with regard to the research questions are summarized in Table 5.

Table 5 Summary of the papers’ main findings

<table>
<thead>
<tr>
<th>Main findings</th>
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<tbody>
<tr>
<td><strong>Paper I</strong> Defined dry port principles; identified three types of dry ports: close, midrange and distant; identified potential impacts</td>
</tr>
<tr>
<td><strong>Paper II</strong> Evaluated reduction of environmental impacts; i.e., congestion and CO2 emissions; identified impacts for seaports, road operators and society</td>
</tr>
<tr>
<td><strong>Paper III</strong> Identified and categorized dry port applications in Sweden and their impacts</td>
</tr>
<tr>
<td><strong>Paper IV</strong> Identified factors that impede implementation of dry ports</td>
</tr>
<tr>
<td><strong>Paper V</strong> Identified impacts for seaports and transport chain as a whole</td>
</tr>
<tr>
<td><strong>Paper VI</strong> Dry port principles, impacts resulting from dry ports and factors influencing implementation of dry ports</td>
</tr>
</tbody>
</table>

The overview of the contribution from each paper to answering the research questions is presented in Table 6. The primary research question has a comprehensive answer in Paper I and although this paper defines the dry port concept and different types of dry ports, each of the appended papers contributed to a better understanding of the concept, and by that may be considered as a partial answer to the primary research question regarding the characterization of the dry port. The purpose of research question one regarding identification and elaboration of different impacts the dry port creates is covered in Paper I as well as in Paper III, however as an overview. Papers II and V cover more specific impacts the dry port makes, such as environmental benefit through reduction of local congestion and CO2 emissions, and changes in physical and administrative flows at the seaport once the dry port is implemented into the system. Research question two has an answer in Paper IV which covers the factors that influence the implementation of the concept.
Table 6 Contribution from the papers to answering the research questions

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<tbody>
<tr>
<td>RQ1</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>RQ2</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
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<td>x</td>
</tr>
</tbody>
</table>

Additionally, the last paper, Paper VI, with its purpose of testing all previous findings further contributes to the clarification of the concept and therefore may be considered as a partial answer to all research questions.

Furthermore, from Table 4 and Table 5, the single contributions from the papers when summarized lead to completion of the purpose where the concept is defined through the principles and developed through different impacts dry ports generate as well as through the factors that influence the implementation of the concept.
6 CONTRIBUTION AND FURTHER RESEARCH

Here, the contribution of the thesis is discussed and some ideas for future research are given.

6.1 Thesis contribution

Interrelation between the papers together with the contribution from the papers in relation to the research questions is shown in Figure 18, which is developed and modified from Figure 12, which represents the flow of initial ideas. The two figures give an overview of the research, from the initial ideas that resulted in different studies presented in the papers as well as papers’ contributions regarding the research questions.

Figure 18 Contribution from the papers

According to Reilly (1993), words such as requirements, management, logistics support, structure, and systems engineering have surprisingly diverse meanings to most people who routinely use them, and therefore there is a need to decide upon the precise meanings of certain words used by systems engineers. This
phenomenon of vague conception, as defined by Reilly (1993), is treated in this thesis as well, in particular at a very begging of the search for the proper definition of the dry port concept. There are many different terms used for a certain inland terminal facility, in this case for a dry port; sometimes the same term is used for different types of facilities or different terms are used for the same facility, creating chaos of understanding. Hanappe (1986) refers to dry ports as multifunctional logistics centers with a variety of firms operating at the same site. Hanappe’s description corresponds to the concept of freight villages, according to the Economic Commission for Europe (2001), since this definition does not emphasize a connection to seaports nor does it specify the range of services offered at the terminals. Beresford and Dubey (1990), in their extensive survey of dry ports in Africa, use a dry port definition that corresponds to the definition of an Inland Clearance Depot, according to the Economic Commission for Europe (2001). Their definition is very specific regarding ownership and services, in particular customs clearance, although with no specification of the type of connection to a seaport. Furthermore, Beresford and Dubey (1990) emphasize the importance of a dry port as a common user facility that would promote the transfer of goods from origin to destination without an intermediate customs examination, the so-called through-transport concept. The existing definition on dry port from the European Commission for Europe (2001) is developed by specification of the type of the connection to a seaport and by a range of services offered at a dry port. The dry port concept may be best understood by an explanation of benefits the concept brings for different actors of the transport system. Besides the general benefits to the ecological environment and the quality of life by shifting flows from road to rail, the dry port concept mainly offers seaports a possibility to secure a market in the hinterland, increasing the throughput without physical port expansion, as well as better services to shippers and transport operators. Moreover, the dry port contributes to the development of rural areas once implemented in the area as discussed by Höltgen (1995) and Bergqvist (2008), where the author emphasises the role intermodal terminals have in the promotion of regional development. The regional development is identified through the attraction of new industries to the area, once logistic solutions are available.

When discussing the influence a dry port has on physical and administrative flows at the seaport and by that, the system, it is rather obvious that some activities like ship loading/unloading cannot be moved to an inland terminal. However, there is a whole range of administrative activities that would be moved inland with the implementation of a dry port, specifically those related to handling truck related paperwork. Moreover, some physical activities would take less time, such as storage, while some could be reduced completely, such as inevitable queuing at the seaport gates.

In the transport system where the node is equivalent to a stop in the flow (Lumsden, 1998), and although a dry port is a node in the system, the idea behind the concept is to make the flow smooth; in other words, not to stop the flow in the node but to make all node activates seamless and by that to make the part of the intermodal transport chain seamless (see Figure 19). The problem of needless long
stops in the nodes is also discussed by Woxenius (1997), where the author questions the functionality of intermodal terminals and even sees them as such as barriers to intermodality. Implementation of a dry port could create seamless seaport inland intermodal access, i.e., smooth transport flow with one interface in the form of a dry port concept instead of two, one at the seaport and the other one at the inland destination. The same can be compared to the case of an increased level of functional integration of supply chains (Notteboom, 2006) (Figure 8), where many intermediate steps in the transport chain have been removed and therefore enabled so-called one-stop-shop, enabling many shippers to have a single contact point on a regional or even global level.

Features of a dry port concept as such are:
- Seamless transportation and transhipment points
- Scheduled and reliable rail connection between a seaport and a dry port
- Dry port equipped for the handling of intermodal units
- Services at a dry port: transhipment between road and rail, customs clearance, maintenance of containers, long and short time storage, road haulage and forwarding.

![Transport network with and without a dry port.](image)

*Figure 19 Transport network with and without a dry port.*

Although a concept of a dry port should bring numerous benefits to the actors of the transport system there are still impediments to the implementation of the same. The findings of the study regarding the factors that influence the implementation of the dry port are compared against the concept of the dry port, which is a modified extract from the referenced intermodal transport model developed by Woxenius (1998), which represents the whole intermodal transport
chain (see Figure 20). The new model illustrates actors, activities and resources that congregate at the dry port as well as factors that directly influence the implementation of a dry port or an intermodal terminal with direct rail connection to a seaport. Land use, infrastructure and regulations are identified as the most common factors that impede the implementation of dry ports in seaports distant hinterland. Furthermore, the cases of implementation of dry ports into seaports’ immediate hinterland show an additional impediment in a form of local environmental impact. However, those are the factors that might have an influence on dry port implementation in a positive or negative way depending on the circumstances. For example, if infrastructure is in place and in good shape it should just facilitate implementation of a dry port, not impede. The gray area in the figure represents the dry port terminal system while items outside the box represent the system’s surroundings consisting of factors that influence the dry port.

A dry port must fit into the transport system where regulations are designed to optimize the use as well as development of existing infrastructure and its belonging modes of transport. The case in this study permits us to assume that transport issues might be closely related to psychological and behavioural issues and if actors involved are not well-informed on the matter, problems might arise.

**Figure 20 Reference model of intermodal transport from Woxenius (1998) applied on the dry port – generated from the findings**

This thesis with its comprehensive overview of the subject of dry ports contributed to a better understanding of the dry port concept and as such the thesis tends to cover, to a certain extent, research gap on the dry port concept.
6.2 Issues for further research

A lot has changed since this research on the dry port concept started; some of the studied terminals do not exist anymore, some have developed from simple transhipment points into intermodal terminals; and some are on their way to develop into a dry port. Some seaports from the study have faced drastic changes. And, compared to six years ago, there are many more dry port related research projects going on. The concept has become quite popular in that time, and there are many more dry ports in operation now; however, still not enough. Findings from the study show that it is a long way from the idea to the realization, even despite obvious benefits that the realization of the concept would bring there are still many impediments to the same, such as environment, infrastructure, regulations or land use, depending on the dry port location. To further study the impediments, more case studies in different countries are necessary, in particular, to find about if there are other impediments than those previously defined. Furthermore, for practitioners it would be of interest to find out how to overcome those impediments, or even better, how to avoid them.

Legal issues during the process of dry port implementation

Furthermore, studying legal as well as practical issues during the process of dry port implementation would be of interest. The same were not the scope of the thesis, nor was the economical perspective; however, the same always raises an interest among the practitioners. However, it is obvious that the legal issues depend on the country where the dry port is implemented and practical issues depend very much on each specific case even within the same country or region. Each case differs in available infrastructure, in interested parties, in volumes needed, in available operators, etc.; therefore, it is impossible to generalize. However, with more cases on dry ports implemented in different locations, regions, and countries, the set of rules would be interesting to establish.

Design and layout of a dry port

An interesting area for research about dry ports would be the design and layout of a dry port; however, the same is specific to each location and therefore it is not possible to give one generally accepted design. There are numerous factors to consider prior to implementation, such as: traffic flows, traffic modes available, existing transport infrastructure and network capacities, possible reduction in tonne-km with the introduction of the dry port, and services offered at the dry port. Those factors and their significance for each type of dry port (close, midrange and distant) should be studied through case studies. Data for the case studies can be obtained through field observation with internal data collection or through secondary sources like seaports. However, the combination of both would be more appropriate since it would give insight into the problem from two perspectives.
Ownership

The ownership as well as funding of dry port implementation is always an issue of interest, in particular among practitioners. The issue was touched on during the research for Paper III, where it was noticed that the even terminals belonging to the same network and group do not follow the same pattern regarding the ownership or the terminal operators. The dry port implementation may be funded by the public sector, the private sector, or a combination of the two. Each way brings it own advantages and disadvantages. A publicly owned dry port may give an impression of a greater security to the actors involved in the operations since chances for malpractice or unreasonable tariffs are minimized. Alternatively, privately owned dry ports can be more flexible to negotiate with when changes in tariff structure or, for example, changes in daily operations, are needed. Related to the issue of ownership is also the organizational structure of a dry port: should there be a controlling body, general manager, accountant, or security?

Seaports’ role in relation to dry ports

A conclusion of the study for Paper V is that the implementation of a dry port into a seaport transport system should create a seamless transport chain. However, the significant time savings, as well as financial, could be made only by avoiding the queues at seaport gates and by moving container storage inland, apart from savings from the movement of containers by rail instead of road considering rail tariffs to be lower. Evidently, expansion inland into new markets improves seaport’s access to areas outside its traditional hinterland, resulting in new customers, and generating more profit and promoting the regional economic activity. The question is whether this expansion should be in a form of ownership or collaboration; if the latter, then on what level? Therefore, the results presented here may serve as a basis for further research on the concept and different forms of collaboration between the actors, focusing on practical experiences of the concept in the world. Furthermore, related to this issue of collaboration, it would be interesting to investigate the situation in landlocked countries that benefit significantly from dry ports. What form of collaboration is of interest in those cases? Should seaports play a vital role in the implementation of dry ports in those countries or should this be a matter of the region or country where the dry port is implemented?

Dry port advantages from customers’ perspectives

Throughout the study, impacts of dry ports, and in particular the positive ones have been discussed; however, mostly from the perspective of dry ports or seaports. One can assume that if a dry port manager states that one of the advantages is improved customer service, the same is not just his own perception of the situation but is confirmed by the dry port customers. However, in order to avoid bias and o find out what dry port users/customers consider as advantages or disadvantages resulting from dry ports, a new survey or case studies aiming this group of actors are needed.
Feasibility of intermodal transport on shorter distances

Results of the study in Paper IV on Port Botany, Australia’s second largest container port, open an interesting area for research. To ease pressure on Sydney’s roads, moving a larger portion of containers by rail is proposed for the Port since the existing network of intermodal terminals servicing Sydney’s catchment area will not be able to cope with the capacity required; therefore, a network of close intermodal terminals is crucial to achieve this. There is an apparent need for new intermodal terminals that, apart from having direct access to both road and rail, should be located in the proximity of the served market and within an industrial area. The Port already has rail shuttle connections to 6 terminals in a 45 km radius. With these facts this study raises important questions about viability of intermodal transport on shorter distances. This issue is heavily argued between academics; for example, van Klink and van den Berg (1998) claim that rail services are generally competitive at distances above 500 km. However, the case of Sydney’s port Botany, with its close intermodal terminals, shows feasibility of intermodal transport on shorter distances and as such offers a new area for research.
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APPENDIX I – MODELLING APPLIED IN PAPER II

“Evaluation of the dry port concept from an environmental perspective” – explanation of the modelling

Due to technological changes of traffic modes and handling equipment, and differences in operating conditions at each terminal, past experiences from other seaports may not be applicable for the modelling of one certain seaport (Ballis and Abacoumkin, 1995). The empirical data that enabled the modelling were collected through archival records from the Port of Gothenburg and through an interview with the seaport rail manager. Data regarding the seaport activities were obtained through the seaport visit and through the interview; the same were used to define processes in the model.

Definition of inputs

The Port of Gothenburg is the largest container seaport in Scandinavia, handling more than 750 000 TEUs per year, about 70% of which is transported by truck to inland destinations (Port of Göteborg AB, 2006). However, none of the seaport’s official documents relating to containers includes information on the inland destinations of the containers. Therefore, in 2002 the seaport conducted a study (Johansson, 2005), interviewing truck drivers at the seaport gates regarding inland destinations of containers being transported. The findings showed that about 70 inland destinations throughout Sweden were served by trucks from the seaport. However, the current study addresses only the transport of containers by truck to 19 inland destinations in the seaport’s hinterland, see Figure 21. Container transport to other inland destinations, return of empty trucks or trucks arriving to the seaport to unload containers are disregarded due to the report’s scope and delimitations.

Today, shuttle trains run from the seaport to some of the chosen destinations, with the shuttle train to Nässjö a good example of the successful link. However, other destinations with small flows that do not merit the implementation of direct trains would benefit from an intermodal rail/road terminal – dry port in their vicinity.
The first set of input data are distances [km] to the inland destinations together with the number of TEUs (expressed here as the percentages of TEUs for each destination) per day transported from the seaport to the same inland destinations, see Figure 22 for the inputs into the model without the dry port. The same set of input data for the model with the dry port differs only in the distances travelled by trucks from the dry port to the same inland destination, which are generally shorter, as expected. This is clearly explained by Figure 26 and Figure 27.

The city of Borås was chosen as the location for the dry port due to its vicinity to the seaport and existing railway infrastructure, as well as its convenient position and good road infrastructure regarding the other inland destinations. Another reason for having the dry port in Borås is the fact that more than 20% of the containers in this study are destined to Borås. The position of Borås as the dry port in relation to the seaport as well as to inland destinations is shown in Figure 21. No software tool for the optimal location of the dry port was used since the purpose of the paper was not to find the optimal location for the dry port nor to support any decisions regarding financial investments of any kind.
Preliminary event logic (Figure 23) shows the type of input data as well as the type of processes in the models.

![Figure 23 Preliminary event-logic diagram of the model](image)

Based on the practice at the terminals (Johansson, 2005), some assumptions are made regarding processes in the models, and according to Law and Kelton (1991) triangular distribution should be used for a rough model in the absence of data.
Thus, trucks arrive randomly at the seaport and dry port, with a triangular distribution with an interval of 4 min, to pick up containers intended for the chosen inland destinations. It is assumed that the containers are already at the seaport terminal and are ready to be loaded onto the trucks, i.e. unloading from ship to the dock is not taken into account. It is also assumed that each truck carries two containers. The seaport’s capacity regarding handling equipment is three straddle carriers (see Figure 24) for the stated amount of containers, i.e. stated inland destinations; nevertheless, the seaport has eight straddle carriers.

Figure 24 Screenshot in Planimate™ of the flow panel of the model without the dry port

The dry port has four straddle carriers for handling trucks. Figure 25 shows a Quality Based Modelling (Lind, 1997) diagram for the dry port model with the switch determining which of the four reach stackers is not occupied, i.e. available for loading the next truck. The truck loading time as well as the administrative service time follow a triangular distribution; at the seaport an interval of 12 min per truck plus an interval of 6 min for administration is used; the dry port has an interval of 8 min per truck plus an interval of 4 min for administration. The assumption of faster dry port services is based on dry port characteristics defined by Woxenius et al. (2004).
Since the trucks used for the inland transportation of containers are of different types, dates of manufacture, fuel consumption, loads etc., it is very difficult to estimate average fuel consumption for the case. Therefore, as discussed above we assume an approximate CO$_2$ emission from the trucks of 1.1 kg/km, while CO$_2$ emission during queuing or very low speed driving is approximately 6 kg/hour. For this study, only CO$_2$ emissions that occur during transportation and queuing are taken into account; CO$_2$ emissions that occur during the production of energy, needed to power certain traffic modes, are disregarded. Approximately 95% of Swedish state railway transport is by electric trains. As the electricity used for the trains derives from hydro power, emissions from the electric trains are reduced to an absolute minimum (www.ntm.a.se). Therefore, CO$_2$ emissions from trains in this study are treated as zero.

This model is quantitative in its nature as well as descriptive in its purpose. It is stable – some input data can be altered, but it is not flexible – i.e. it cannot simulate another seaport by a simple change of input data. The validation of the model is done by a subjective method, i.e. the model is validated with the help of the experts in the field using a structured walkthrough of the model. Additionally, some simulation results were analysed for validation purpose. Although “a three step approach” for validation (Law and Kelton, 1991) is not applied here, the model might be considered valid enough for the purpose of this paper.

**Definition of the reference situation and the scenario**

The reference situation represents the transport of units from the seaport to 19 inland destinations by truck. In other words, it represents seaport inland access conducted by truck without an implemented dry port – see Figure 24 for the flow panel of the model and Figure 26 for the illustration of the reference situation. The scenario demonstrates the system with an implemented mid-range dry port (Figure 27), which means that the transport of the units from the seaport to the dry port is by rail and from the dry port to the inland destinations by road. Thus, the transport of containers is shifted from road to rail on the link from the seaport to the dry port. The objective is to show that there is a way to improve the operations involved in the container flow in order to achieve better productivity and with that to lower the environmental impact.
Figure 26  Illustration of the reference situation – the transport system without a dry port

Figure 27  Illustration of the scenario with a dry port

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APPENDIX II – ADDITIONAL PUBLICATIONS BY THE AUTHOR RELATED TO THE RESEARCH AREA

2009

Roso, V. and Lumsden K. “The dry port concept - The case of Falköping terminal” –Maritime Transportation proceedings, Barcelona, April 2009, pp. 7-17.

2008

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Woxenius, J; Roso, V; Lumsden, K. “The Dry Port Concept - Connecting Seaports with their Hinterland by Rail”, First International Conference on Logistics Strategy for Ports 2004 proceedings.
2003

APPENDIX III – APPENDED PAPERS

Paper I


Paper II


Paper III


Paper IV


Paper V


Paper VI

PAPER I

The dry port concept: connecting container seaports with the hinterland.
The dry port concept: connecting container seaports with the hinterland

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ABSTRACT

The dry port concept is based on a seaport directly connected by rail with inland intermodal terminals where containers can be dealt with in the same way as if they were in a seaport. The main purpose of the article is to extend the theory behind the dry port concept and to define three dry port categories: close, mid-range and distant. The findings show that the dry port concept can help identify ways of shifting freight volumes from road to more energy efficient traffic modes that are less harmful to the environment, relieve seaport cities from some congestion and facilitate improved logistics solutions for shippers in the port’s hinterland.

1. Introduction

Since it appeared on a large scale in the 1960s, the container shipping industry has improved its performance at an impressive pace. It is the backbone of global trade estimated to account for 13% of seaborne trade and 49% by value (Cullinane and Khanna, 2000). Its importance for the ongoing space/time collapse relates more to cost reductions than to increased speed (Rodrique, 1999). The maritime part of the intermodal transport chains has employed ever larger ships to cope with increasing transport demand and for facilitating lower unit costs as discussed by Cullinane and Khanna (2000). With latest vessels on order reaching 14,000 TEU (World Cargo News, 2006), progress in ports and hinterland operations must improve similarly to fully realise the economies of scale (McCalla, 2007).

Despite heavy investments in container terminal capacity, larger ships and larger flows of containers severely strain seaport operations (see Mourão et al., 2002; McCalla, 2007). Port capacity can be increased by physically expanding existing ones (McCalla, 1999), but this is at considerable cost and effort (Pellegram, 2001). Other options include adding conventional equipment or improving the productivity by new forms of technology as analysed by Ballis et al. (1997), work organisation as suggested by Paixão and Marlow (2003) or by information systems such as elaborated by Henesey (2006).

Also the transport services to the ports' hinterland, defined by van Klink and van den Berg (1998) as the “the interior region served by the port”, are strained by the increasing flows. According to European Union Road Federation (2008), in the period of 1996–2006, European hinterland transport market share for road increased by about 5%; while for rail it decreased by 4%. Furthermore, road transport has the biggest market share of 76% (European Union Road Federation, 2008). Besides the introduction of double-stack trains in the US in the 1984 (DeBoer, 1992), productivity in the land part of the transport chains has generally not followed the progress at sea. Nevertheless, double-stack containers are already being run on electric traction routes in China (Cheng, 2004) and are being discussed in Sweden and the Netherlands.

The hypothesis behind this article is that the problems related to increased container flows are best approached from a joint seaport and hinterland perspective. The idea of dry ports is certainly not new, and the notion of ports’ role and spatial coverage is dealt not new, and the notion of ports’ role and spatial coverage is dealt with, e.g., by Heaver et al. (2000, 2001), Notteboom (2002), Notteboom and Winkelmans (2001), Robinson (2002) and van Klink and van den Berg (1998). In addition, the tradition of land-bridges, mini-bridges and micro-bridges has a long history in the US (Mul-ler, 1999). Previously, however, the use of dry ports has not generally been seen as a tool for consciously solving problems of a multitude of actors with somewhat contradictory goals. Hence, it is here argued that a well applied dry port concept can help identify ways of shifting freight volumes from road to more energy efficient traffic modes that are less harmful to the environment, relieve seaport cities of some congestion, make goods handling more efficient in seaports and facilitate improved logistics solutions for shippers in the port's hinterland.

The main purpose of the article is to extend the idea of the dry port concept and to define three dry port categories; close, mid-range and distant. For each category the benefits are defined from the perspectives of actors involved such as seaports, rail and road operators, shipping lines, shippers, local authorities and society as a whole. The article takes a logistics, technological, economic as well as environmental perspective.
After a theoretical part regarding the role of terminals in freight transport networks, the dry port concept is presented. In addition, examples of applications of the dry port concept are presented regardless of whether these are officially denoted dry ports.

2. Freight transport networks

Freight transport systems are characterised by sequential transfers of goods between points of origin and destination, generally defined as nodes. Activities, such as consolidation, sorting, storage and transhipment between vehicles and traffic modes, are carried out in nodes. The globalisation of supply chains implies that it is often attractive for shippers to outsource value adding services such as customs, packaging or sequencing to logistics service providers at strategically placed nodes (Cheung et al., 2003; Notteboom and Winkelmans, 2001; Paixão and Marlow, 2003; Robinson, 2002).

A node can be defined as a source, a sink or a transhipment node, depending on the transport assignment. Links represent transport and transfer activities connecting nodes, and together with the nodes the links compose the transportation network. Links and nodes are abstract terms used for modelling. In the real system, links are served by vehicles and vessels using infrastructure. For the physical unit corresponding to transhipment nodes, the word terminal is used although the traffic mode specific terms airport, seaport and station are more common in colloquial speech. Transhipment nodes with a central role in a network are, varyingly and often inconsistently, called hub, dock, gateway and turntable in the transport industry. To avoid confusion, a gateway is defined here as a link between different networks, while Fleming and Hayuth (1994) restricted the meaning to nodal points transhipping between intercontinental transport flows and continental axes.

In an intermodal gateway (see Fig. 1), networks based on different traffic modes are linked, while intramodal gateways link networks using the same traffic mode. Traditional examples of intermodal gateways are seaports, airports and intermodal road–rail terminals. Intramodal gateways include consolidation terminals where lorries operate over long-distances and pick-up and delivery routes respectively are coordinated, and seaports offering transhipment between trans-ocean container vessels and feeder vessels or barges. Intra-European rail services are still commonly operated by use of intramodal gateways which compensate for incompatible legislation, electric power supply systems, signalling systems, loading profiles and sometimes also rail gauge between neighbouring countries.

An intermodal road–rail terminal can simply be described as a place equipped for the transhipment and storage of intermodal loading units (ILUs) between road and rail. There are intermodal terminals in a great variety of shapes and sizes (see, e.g., Woxenius, 1998) and a number of value-added services such as stuffing and stripping, storing and repair of ILUs might be offered. As suggested by Höltingen (1995), intermodal terminals can be classified according to some basic functional criteria like traffic modes, transhipment techniques, network position or geographical location. Nevertheless, the transhipment between traffic modes is the characterising activity.

A specific class of terminals has evolved around the need for connecting inland conurbations with seaports. Depending on the role and the offered services, the transport industry operates this kind of terminals under different names. From a legal point of view, it is of particular importance if customs services are provided. The UN Economic Commission for Europe (UN ECE, 1998) defines an Inland Clearance Depot as:

A common-user inland facility, other than a port or an airport, with public authority status, equipped with fixed installation...
and offering services for handling and temporary storage of any kind of goods (including container) carried under Custom transit by any applicable mode of inland surface transport, placed under Customs control and with Customs and other agencies competent to clear goods for home use, warehousing, temporary admission, re-export, temporary storage for onward transit and outright export.

India introduced Inland Container Depots (ICDs) in 1983 and the Indian Customs (2004) bases its definition of an ICD on the UN ECE definition above, but restricts it to containers. India also uses the term Container Freight Station (CFS), which differs from an ICD since containers are stuffed and stripped there. Hence, an ICD is a consolidation node for containers whereas a CFS aggregates individual consignments into containers. A CFS function might be added to an ICD. ICDs are normally located outside the port towns but there are no site restrictions regarding CFSs. CONCOR, the intermodal branch of Indian Railways, currently operates a network of ICDs of which the ICD Tughlakabad in Delhi alone has a capacity of 500,000 TEU (Thorby, 2004).

In Europe there has been a focus on business areas offering a wide range of logistics services. In a survey, Cardebring and Warnecke (1995) define an Intermodal Freight Centre as:

A concentration of economically independent companies working in freight transport and supplementing services on a designated area where a change of transport ILUs between traffic modes can take place.

Tsamboulas and Dimitropoulos (1999) also discuss the term freight nodal terminal that, although similar in concept, varies in definition among countries; Gueterverkehrscentren in Germany, Plateformes Multimodales Logistiques in France, Freight villages in the UK or Interporti in Italy. They all provide transshipment from one mode to another as well as auxiliary services such as warehouses, customs, maintenance workshops, insurance offices and other.

An Inland Freight Terminal is, according to UN ECE (1998), “any facility, other than a port or an airport, operated on a common-user basis, at which cargo in international trade is received or dispatched”. An Inland Port is located inland, generally far from seaport terminals; they supply regions with an intermodal terminal offering value-added services or a merging point for different traffic modes involved in distributing merchandise that comes from ports (Harrison et al., 2002). The term dry port is used synonymously. Finally, according to the Economic Commission for Europe (2001, p. 59), a dry port is simply “an inland terminal which is directly linked to a maritime port”. However, Beresford and Dubey (1990) use a dry port definition that corresponds to the definition of an Inland Clearance Depot cited above. Since the former definition of dry port is rather broad in its meaning, all the above mentioned terminal facilities might use the term dry port due to their links to seaports. The Beresford and Dubey definition is very specific regarding ownership and services, in particular customs clearance, although with no mention of any kind of connection to a seaport. Therefore, a more operational and precise definition of the dry port concept is provided in the next section.

3. The dry port concept

As mentioned, the steeply rising container flows have resulted in crowded terminals, congestion and prolonged dwell times for containers. An option for relieving the main ports of such congestion on the land side is to shift from routes where the trans-ocean vessels call at a few ports in each continent to call at a single hub port while feeder vessels connect to many smaller ports (Baird, 2002). The individual main ports, however, try to attract as much flow as is economically feasible and the size and shape of a port’s hinterland is not statically or legally determined but varies dynamically due to developments in technology, economy and society (see van Klink and van den Berg, 1998), Notteboom and Rodrigue (2007) define three types of hinterland: the macro-economic, the physical and the logistical hinterland; explaining that all three types are subject to complex spatial and functional structures.

Among others, Heaver et al. (2000), Notteboom (2000, 2002) Notteboom and Winkelmans (2001), state that many seaports as well as shipping lines integrate vertically to also control hinterland transport. The vertical integration must be done cautiously and respect anti-trust legislation since slot-sharing alliances and conferences are accepted at sea but have been disputed by competition authorities (Slack et al., 2002), even in court by the European Commission. With new port networks emerging (Notteboom, 2002) and different actors integrating vertically, the competitive situation needs continuous attention by port operators (Heaver et al., 2001; Notteboom and Winkelmans, 2001).

Conventional hinterland transport is based upon numerous links by road and a few by rail such as the example of ten shippers outside the seaport city shown in Fig. 2. Rail transport is generally limited to serving major conurbations at rather long-distances from the port and the interface towards containers arriving by rail is comparable to that for those arriving by road.

The traditional division of labour in the transport industry together with monopolies or other regulation is now loosened. In addition to rail shuttles, ports have also shown interest in starting

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Fig. 2. A seaport with connections to its hinterland.
inland terminals in order to control and optimise a larger part of the intermodal transport chain. The importance of well functioning inland terminals is stated by van Klink (2000, p. 134):

Another way in which ports can exploit know-how in order to pursue their strategic goals is to participate in the development of a network of inland terminals within Europe. Developing and rationalizing intermodal transport operations places great demands on the structure and operation of inland terminals. By investing in inland terminals and participating in their operation, a sea port can establish itself in inland regions. Inland terminals may be considered as “extended gates” for sea ports, through which transport flows can be better controlled and adjusted to match conditions in the port itself. In this way, inland terminals can help to improve land access to ports in both physical and psychological terms.

According to Zimmer (1996) an ideal terminal is not a certain physical configuration of pavement and tracks, but an organisation of services integrated with a physical plant that meets the business needs of a specific marketplace. These physical plants may take many forms, which are influenced by the characteristics of the landscape, their proximity to the seaport or major industrial complex, their location relative to the main rail infrastructure, and their distance from the country’s highway network. This conscious and strategic development of intermodal terminals in the hinterland is approaching what we denote as dry ports.

Based on earlier research on the terminal facilities using the dry port notion, the following definition was formed by Leveque and Roso (2002):

A dry port is an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardised units as if directly to a seaport.

Apart from the basic service, transshipment, that a conventional inland terminal provides; services like storage, consolidation, depot-storage of empty containers, maintenance and repair of containers and customs clearance should be available at full-service dry ports. The quality of access to a dry port and the quality of the road/rail/waterway interface determines the quality of terminal performance; therefore, it is necessary to have scheduled, reliable, transport by high capacity modes to and from the seaport. Thus, dry ports are used much more consciously than inland terminals with the aim of improving the situation caused by increased container flows and the focus on security and control by use of information and communication systems. The real difference is that the gates of the port are extended as described by van Klink and van den Berg (1998) and that the shipper or forwarder sees the dry port as an adequate interface with the port and the shipping lines. Hence, the dry port concept goes beyond just using rail for high capacity transportation in the hinterland. Between the seaport and the dry ports, relatively large goods flows are being concentrated, giving room for other traffic modes than road. For a fully developed dry port concept the seaport or shipping companies control the rail operations, but it does not mean that the terminal itself must be dedicated to serving only one port and it can also be part of a network for continental services.

3.1. Distant dry ports

Based upon the function and the location of a dry port, they can be categorised as distant, midrange and close dry ports. A distant dry port is the most conventional of the three and has the longest history. The main reason for implementing it is simply that the distance and the size of the flow make rail viable from a strict cost perspective. Fig. 3 shows a seaport and its hinterland with the implementation of a distant dry port.

Compared to conventional rail shuttles to and from ports, the difference refers mainly to the functions offered at the distant dry port and the move of the interface with shippers. The more structured approach increases the competitiveness of rail against road and the shippers 3, 6 and 7 are now served by the dry port (see Fig. 3). Parts of the benefits of distant dry ports relate to the modal shift from road to rail that result in reduced congestion at the seaport gates and its surroundings. One train can substitute for 35 lorries in Europe and more than 100 in the US, and reduce external effects along the route. The main reason for the seaport to engage with a distant dry port is that a wider hinterland can be secured by offering shippers low cost and high quality services.

Hence, the main benefit is attributed to seaports and the shippers using it. Van Klink (2000) states that the pressures for good inland accessibility come from various directions. In addition, shippers and carriers increasingly rate ports on their accessibility, for example the frequency of inland transport services and transit times, or because of society’s demand for more environmentally friendly transport. To benefit from the opening up of new markets, ports need to improve their access to areas outside their traditional hinterland. Mourão et al. (2002) agree and argue that ports compete not only in terms of transshipment efficiency and tariffs, but also in terms of speed and reliability of shipments to destinations on the continent. That competition requires seaports to focus on transport links, on the demand for services in its traditional hinterland and also on development in areas outside their immediate market. A good example, according to van Klink (2000), is the...
introduction of a block train service between Rotterdam and Barcelona, which makes it possible for time-critical products from Asia, destined for North-West Europe, to be transhipped in Barcelona and transported over the final leg of the transport chain by rail instead of ship.

Rail operators obviously benefit from distant dry ports because it increases the scale of their business in a comparatively lucrative segment. This is particularly important for rail transport depending on economies of scale and can make continental services viable although ports are reluctant to bring in containers not relating to shipping. At least, the fixed costs of the intermodal terminal itself can be distributed between transshipments when adding the dry port flows. Road transport operators do not benefit from this configuration directly since the aim is to move transport of containers from road to rail, but they are still involved in the intermodal transport chains. As they are not particularly paid for waiting in congestion or at crowded gates at the port, they can serve the dry port surroundings with shorter hauls and with better total revenues.

From the shippers’ perspective, a well implemented distant dry port offers a greater range of logistics services in the dry port area. For environmentally conscious shippers it offers the possibility of using rail instead of road and thus decreases the environmental impact of their products. The seaport city benefits from decreased road traffic saturating the streets which increases the quality of life for the citizens. Less traffic might also liberate valuable areas around the city centre for other purposes than traffic.

One example of a distant dry port is Isaka Dry Port in Tanzania, which used to be a conventional intermodal terminal which acquired the Dry Port status in 1999, and now all the customs documentation may be done at Isaka instead of Dar es Salaam Port (Tanzania Railways Corporation, 2004). The Isaka facility is very profitable because of the increasing exchange of containers with the neighboring land-locked countries of Rwanda and Burundi. Formerly shippers had to undertake custom and port clearance directly in the seaport of Dar es Salaam some 800 km away; instead of a week it now takes only two days to send a container to the seaport.

3.2. Midrange dry ports

Besides the price–quality ratio of competing traffic modes, the competitiveness of intermodal road–rail transport depends on geographical and demographical conditions. Continental services are generally competitive at distances above 500 km (see, e.g. van Klink and van den Berg, 1998). A midrange dry port is then situated within a distance from the port generally covered by road transport as shown in Fig. 4. Here shipper 2, 3 and 9 are served directly by the dry port while shippers 7 and 8 are served by a closer conventional intermodal terminal. The midrange dry port here serves as a consolidation point for different rail services, implying that administration and technical equipment specific for sea transport, for example X-ray scanners needed for security and customs inspections, are just needed in one terminal. The high frequency achieved by consolidating flows together with the relatively short distance facilitates loading of containers for one container vessel in dedicated trains. Hence the dry port can serve as a buffer relieving the seaport’s stacking areas. If this is a severe constraint, shippers with comparable distance to the seaport and the dry port (e.g., shipper 9) can then be directed to the dry port if it is made cost neutral to them. In other dimensions, the benefits are similar to those of a distant dry port.

The Virginia Inland Port (VIP) is an example of a midrange dry port that moves the interface between lorry and rail for the transport of containers to and from the Port of Virginia, mainly their terminals in Hampton Roads. The VIP is located at Front Royal some 330 km from Hampton Roads and serves as a “US customs designated port of entry” where the full range of customs services is available to shippers. It has been consciously developed in order to increase the hinterland of the Port of Virginia (Bray, 1996) serving the Ohio valley in competition with Port of Baltimore (Woodbridge, 2004a). The VIP has attracted investments of some $100 million in distribution centers for Home Depot and Sysco thereby securing import container flows for the seaport (Woodbridge, 2004b).

3.3. Close dry ports

Transport hubs are significant generators of freight traffic both between and within major cities impacting ever more severely on local communities (Slack, 1999). Solving the local traffic problems related to ports is of particular interest to public bodies that most often also control the port authorities although the private sector is increasingly involved in port operations (Cullinane et al., 2002 and Notteboom, 2002). Of measures for mitigating congestion, long-distance road operators and those using intermodal rail services seem to favour arterial priority schemes, dedicated streets for port access and longer operation hours by ports (Golob and Regan, 2000). In addition, most ports suffer from a lack of space and capacity, problems for which conventional mitigation measures were outlined in the introduction to this article.

Another option is to introduce a close dry port at the rim of the seaport city. The close dry port consolidates road transport to and from shippers outside the city area offering a rail shuttle service to
the port relieving the city streets and the port gates as shown in Fig. 5.

In this case, shippers 1–3 and 7–10 use the dry port and the seaport generates no urban road transport or gate congestion from shippers at long or midrange distances. Compared to the other types of dry ports, a close dry port offers larger possibilities for buffering containers and even loading them on the rail shuttle in sequence to synchronise with the loading of a ship in the port. This obviously requires a very reliable rail service to avoid the risk of increased dwell times of container vessels and then a dedicated track is probably required initially. In the longer run, direct transhipment between trains and ships can be implemented or whole container terminals can be specialised for rail–sea.

The 32 km long Alameda Corridor connects the ports of Los Angeles and Long Beach to intermodal terminals near downtown Los Angeles. It can be referred to as an example of a close dry port project since the containers were previously trucked between the terminals and the ports or used degraded small railway lines. Some 200 street-crossings were eliminated by letting the tracks run in a trench. Road congestion is significantly decreased and the containers move at more than double the speed than before (World Cargo News, 2002).

Moreover, a close dry port is planned at Enfield some 18 km from Sydney’s Port Botany (Sydney Ports Corporation, 2006). Although the port has rail connection to 6 close intermodal terminals in a radius of less than 50 km, Enfield Intermodal Terminal
should facilitate more effective clearance of containers from the port and increase the productivity and capacity of existing port lands (Sydney Ports Corporation, 2006). A special dimension is that the expansion of the port is questioned for local ecological reasons and the dry port is one of many measures to mitigate the consequences. However, the road hauliers lose a marginal market share in terms of road-kms but would still benefit from speedier operations. In cities not allowing long or polluting road vehicles, calling at a close dry port is an alternative to operating more smaller lorries or changing to less polluting ones.

4. Implications of a fully implemented dry port concept

With a combination of the three types of dry ports (Fig. 6) the port and its surrounding city can be relieved of all road connections to locations outside the city area. In the example the shippers closest to the port (1, 2, 9 and 10) call at the close dry port, two at medium distances (7 and 8) call at the midrange dry port through another intermodal terminal while the shippers furthest away from the port (3–6) use the distant dry port. Previously only the shippers very close to the distant conventional intermodal terminal used rail services.

The distant dry port is here directly connected to the port since the flows were already large enough to ensure a full train service. If any of the midrange or close dry ports are used as a consolidation point coordinated with ship calls by dedicated trains, then the distant dry port would be served by a shuttle to the consolidation point. The same principle applies for the midrange dry port if the close dry port is used for coordination or sequenced loading related to individual ships. Regardless of whether the containers pass several dry ports, they can obviously use the same railway line into the port.

It is not only the number of direct road connection that changes. There are opportunities to transfer activities currently causing congestion at the seaport gates to the dry ports. These activities include customs clearance, security checks and information handling. Also physical handling such as stuffing and stripping as well as buffering laden and empty containers can be done at the dry port, thus saving precious space in the port.

The benefits, however, obviously come at a cost and they require that certain conditions are met. The most significant one is that the flows are large enough to facilitate efficient terminal and rail operations, the latter with satisfactory speed and frequency. Midrange and distant dry ports also come with distance requirements. In some cases implementation of the dry port concept requires some new thinking from authorities; if immensely expensive infrastructure projects can be avoided at seaports and their cities, why not take some of the money saved to relieve some of the costs of the rail services? Hence, the costs and benefits must be analysed at an aggregate level and be divided equitably between the actors involved. This is obvious in theory and makes common sense, but in practice shortcomings in this field have stalled numerous theoretically viable projects. One example of these difficulties is the Enfield project for Sydney’s Port Botany that was initiated in 1997 in order to relieve the seaport terminals and adjacent roads from congestion, as well as to increase the port’s capacity (Sydney Ports Corporation, 2006). However, due to land use issues as well as regulations, it was not until 2007 that the project finally received approval.

5. Conclusions

This paper contends that the dry port concept goes beyond the conventional use of rail shuttles for connecting a seaport with its hinterland. Being strategically and consciously implemented jointly by several actors, it also goes beyond the common practice in the transport industry.

Besides the general benefits to the ecological environment and the quality of life by shifting flows from road to rail, the dry port concept mainly offers seaports the possibility of securing a market in the hinterland, increasing the throughput without physical port expansion as well as better services to shippers and transport operators. The seaport cities, and also often the port authority, benefit from less road congestion and/or less need for infrastructure investments.

The real-world examples also show that dry ports can be introduced and are being introduced by several ports. The immediate reasons may vary, but a common denominator is that rail has a role to play as an intermediate traffic mode between sea and road. For implementation, however, costs and benefits must be carefully evaluated and distributed between the actors.

Acknowledgements

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PAPER II

Roso, V. (2007)
Evaluation of the dry port concept from an environmental perspective - A note
Notes and comments

Evaluation of the dry port concept from an environmental perspective: A note

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Abstract

This study evaluates the dry port concept from an environmental perspective using modelling and simulation. A model of a transport system, with and without a dry port, is created and the results of the simulations compared. The benefits of the dry port implementation are defined from an environmental perspective; calculated CO₂ emissions are approximately 25% lower with an implemented dry port for the chosen case, while congestion and truck waiting times at the terminal are significantly reduced.

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Keywords: Seaport inland access; Dry port; CO₂ emissions; Traffic congestion

1. Introduction

As maritime containerised transport continues to increase, functional seaport inland access is important for the efficiency of the transportation chain as a whole. Inland intermodal terminals are important nodes in the transport network and have attracted considerable attention. In particular, research has been conducted on how to find the optimal location for inland intermodal terminals (Rutten, 1998; Macharis and Verbeke, 1999; Arnold et al., 2004) and how to improve the efficiency of rail–road terminals (Ballis and Golias, 2002; Kozan, 2000). Findings on the effects of dry port implementation, as well as on benefits for the actors involved is, however scarce.

The dry port concept is based on a seaport directly connected by rail with inland intermodal terminals where shippers can leave and/or collect their goods in intermodal loading units as if directly at the seaport (Woxenius et al., 2004). Services such as storage, consolidation, depot, maintenance of containers, track and trace, customs clearance, etc. should be available at the dry port. The quality of the access to a dry port and the quality of the road–rail interface determines the dry port’s performance. Scheduled and reliable high-capacity transportation to and from the seaport is therefore necessary. Thus, dry ports are used much more consciously than conventional inland terminals, with the aim of improving the situation resulting from increased container flows, and a focus on security and control by the use of information and communication
systems. The dry port extends the gates of the seaport inland, with shippers viewing the dry port as an interface to the seaport and shipping lines.

Conventional hinterland transport is based on numerous links by road and only a few by rail, which is generally limited to serving major conurbations at relatively large distances from the seaport, as shown in Fig. 1a. Dry ports are divided into close, mid-range and distant dry ports (Woxenius et al., 2004). A seaport and all three types of dry port are presented in Fig. 1b.

The figures show that implementation of a dry port reduces the number of transportation links from/to the seaport. Implementation of a dry port in a seaport’s immediate hinterland increases seaport’s terminal capacity and with it comes the potential to increase productivity since bigger container ships will be able to call at the seaport. With dry port implementation seaport’s congestion from numerous lorries is avoided because one train can substitute some 35 lorries in Europe. With reduced number of lorries on the roads congestion, accidents, road maintenance costs and local pollution are reduced as well. A dry port may also serve as a depot, empty containers storage. Road carriers would lose some market share but in some countries where long trailers are not allowed to pass through cities for safety reasons a dry port implementation is a good solution, if not indispensable, from their perspective as well. The benefits from distant dry ports derive from the modal shift from road to rail, resulting in reduced congestion at the seaport gates and its surroundings as well as reduced external environmental effects along the route.

2. Modelling

The Port of Gothenburg is the largest container seaport in Scandinavia, handling more than 750,000 TEUs per year, about 70% of which is transported by truck to inland destinations (Port of Göteborg AB, 2006). However, none of the seaport’s official documents relating to containers includes information on the inland destinations of the containers. Therefore, in 2002 the seaport conducted a study (Johansson, 2005), interviewing truck drivers at the seaport gates regarding inland destinations of containers being transported. The findings showed that about 70 inland destinations throughout Sweden were served by trucks from the seaport. However, the current study addresses only the transport of containers by truck to 19 inland destinations in the seaport’s hinterland (Fig. 2). Container transport to other inland destinations, return of empty trucks or trucks arriving to the seaport to unload containers are disregarded due to the report’s scope and delimitations.

2.1. Inputs

The first set of input data are distances to the inland destinations together with the number of TEUs (expressed here as the percentages of TEUs for each destination) per day transported from the seaport to the same inland destinations, for the inputs into the model without the dry port. The same set of input data for the model with the dry port differs only in the distances travelled by trucks from the dry port to the same inland destination, which are generally shorter, as expected.

The city of Borås was chosen as the location for the dry port due to its vicinity to the seaport and existing railway infrastructure, as well as its convenient position and good road infrastructure regarding the other
inland destinations. Another reason in choosing the location is that more than 20% of the containers are destined to for the city. The position of Borås as the dry port in relation to the seaport as well as to inland destinations is shown in Fig. 2. No software tool for the optimal location of the dry port was used because the purpose was not to find the optimal location for the dry port nor to support any decisions regarding financial investments.

Based on the practice at the terminals (Johansson, 2005), assumptions are made regarding processes, and according to Law and Kelton (1991) triangular distribution should be used for a rough model in the absence of data. Thus, trucks arrive randomly at the seaport and dry port, following a triangular distribution with an interval of 4 min, to pick up containers intended for the chosen inland destinations. It is assumed that the containers are already at the seaport terminal and are ready to be loaded onto the trucks, i.e. unloading from ship to the dock is not taken into account. It is also assumed that each truck carries two containers. The seaport’s capacity regarding handling equipment is three straddle carriers for the stated amount of containers, i.e. stated inland destinations; nevertheless, the seaport has eight straddle carriers. The dry port has four straddle carriers for handling trucks. The truck loading time as well as the administrative service time follow a triangular distribution; at the seaport an interval of 12 min per truck plus an interval of 6 min for administration is used; the dry port has an interval of 8 min per truck plus an interval of 4 min for administration. The assumption of faster dry port services is based on dry port characteristics defined by Woxenius et al. (2004).

Since the trucks used for the inland transportation of containers are of different types, dates of manufacture, fuel consumption, loads, etc., it is difficult to estimate average fuel consumption. An approximate measure is used in this study; CO₂ emission from the trucks of 1 kg/km, while CO₂ emission during queuing or very low speed driving is approximately 6 kg/h (Blinge, 2005). Only CO₂ emissions that occur during transportation and queuing are taken into account; CO₂ emissions that occur during the production of energy, needed to power certain traffic modes, are disregarded. Approximately 95% of Swedish state rail transport is by electric trains. As the electricity used by the trains comes from hydro power, emissions are minimal and CO₂ emissions are thus treated as zero.

This model is quantitative in nature as well as descriptive in its purpose. It is stable – some input data can be altered – but not flexible – it cannot simulate another seaport by a simple change of input data. Validation is subjective making use of experts in the field via a structured walkthrough of the model. Additionally, some simulation results are analysed. Although “a three step approach” for validation (Law and Kelton, 1991) is not applied, the model might be considered valid for the purposes.

2.2. The reference situation and the scenario

The reference situation represents the transport of units from the seaport to 19 inland destinations by truck. In other words, it represents seaport inland access conducted by truck without an implemented dry port – see
Fig. 3a for an illustration of the reference case. The scenario demonstrates the system with an implemented dry port (Fig. 3b) whereby the movement of the units from the seaport to the dry port is by rail and from the dry port to the inland destinations by road. Thus, the transport of containers is shifted from road to rail on the link from the seaport to the dry port. The objective is to show that there is a way to improve the operations involved in the container flow in order to achieve better productivity and with that to lower the environmental impact.

3. Results

The results for terminal queuing are based on a simulation of four peak hours. The reference situation results show that after 4 h the number of trucks waiting or queuing at the seaport terminal increased to 23; Fig. 4a. This gives an average waiting time of 85 min. The dry port model, after the same simulation, shows five trucks waiting, Fig. 4b, with an average wait of 13 min. A 72-min longer waiting time at the seaport might not seem like sufficient reason for establishing a dry port; however, this difference comes as a result of 4 h of simulation or approximately 70 trucks, while the seaport has an average throughput of some 700 trucks per day loading and unloading. Not maintaining a predetermined schedule for arrival of trucks at a busy seaport terminal has been shown to be the major cause of congestion at a terminal. Long waiting times, apart from financial loss for carriers, increase the risk of road accidents since truck drivers become anxious and might also avoid regular rests during transportation in order to arrive at the destination on time.

Results for CO₂ emissions are based on a simulation for 35 trucks; equal to the average number substituted by one train in Sweden. The main characteristic of a dry port is the rail link to a seaport; a simulation for 35 trucks is thus more suitable than a simulation for a certain number of hours, as using a specific number of trucks enables easier and more appropriate comparison. Consequently, the calculated CO₂ emissions during simulation of the transport between terminals as well as during queuing at the terminals are approximately 25% lower with the dry port. This translates to approximately 1300 kg of CO₂ less per train/35 trucks, and for the chosen case there should be two trains per day, i.e. about 70 trucks a day should pass through the
dry port. In view of the fact that a major part of these CO\textsubscript{2} emissions occurs during the transport between the terminals, only about 4\% comes from queuing, the benefit from the dry port implementation can be translated into road-kilometres reduced. Thus, two trains a day would result in a reduction of approximately 2000 road-km per day.

4. Conclusions

It would be an exaggeration to claim that dry port implementation is a straightforward solution for seaport terminal congestion or for better seaport inland access; however, it could be part of the solution. With dry port implementation CO\textsubscript{2} emissions should decrease, queues at seaport terminals should be avoided, and the risk of road accidents reduced. Although it is obvious that the movement of containers from road to electrified rail will result in lower CO\textsubscript{2} emissions, a dry port is not merely an implementation of rail – it is a set of efficient services such as transhipment, storage, depot, maintenance of containers, customs clearance, and tracing and tracking. Furthermore, the quality of access to a dry port and the quality of the road–rail interface also determines the dry port’s performance.

Some factors, such as more accurate information on trucks and the type of fuel used, the weight of containers, and transport and transhipment costs, have not been taken into account in this research since data were not available. However, these factors should not been neglected if the results of simulation are to be used for final project implementation decisions.

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Emergence and significance of dry ports - The case of the Port of Göteborg.
World Review of Intermodal Transportation Research, Vol.2, No.4. pp. 296-310.
The emergence and significance of dry ports: the case of the Port of Göteborg

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Abstract: The dry port concept is based on a seaport directly connected by rail to inland intermodal terminals, where shippers can leave and/or collect standardised units as if directly at the seaport. The purpose of this paper is to present the dry port concept, to identify and categorise existing dry ports for the Port of Göteborg and to evaluate the concept from an environmental perspective. The conclusions indicate that implementation of a dry port in the seaport’s hinterland enables the seaport to increase its terminal capacity; the modal shift from road to rail results in a reduced congestion at the seaport gates and its surroundings and consequently in improved inland access, as well as in a lesser environmental effect. Only two of the surveyed intermodal terminals can be categorised as simple dry ports for the Port of Göteborg.

Keywords: dry port; environment; intermodal terminal; intermodal transport; seaport inland access; Sweden.

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1 Introduction

Over the years, maritime containerised transport has increased its performance significantly (Cullinane and Khanna, 2000; Mourão et al., 2002). The size of containerships doubled in the last ten years, with the latest vessels in the order of 14 000 Twenty-foot Equivalent Units (TEU) (World Cargo News, 2006). To meet market demands, seaports have tried to increase their capacity within the seaport area; but the demand is still growing and the environmental concerns of the regulators and the public over the consequences of seaport activities often hinder seaport terminal expansion.
Moreover, the transport services to the seaports’ hinterlands are strained by increasing flows (van Klink, 2001). As container transport volume continues to grow, the links with the hinterland will become a critical factor for the seaports’ competitive advantage, therefore progress only in the maritime part of the transport chain and in seaport terminals, without improvements in seaport inland access, is not sufficient for the entire transportation chain to function.

Parola and Sciomachen (2005) modelled and simulated the potential growth of container flows. Their findings show that the modal imbalance between road and rail results in increased road traffic congestion, since a growth in the sea flow implies an almost proportional increase in the road flow. According to the European Commission (2000), the volume of European hinterland transport related to trans-ocean maritime transport will double in the period from 2000 to 2010. And, the road transport has the biggest portion of market share, 76.3%, in that modal split (European Union Road Federation, 2007). Therefore, Parola and Sciomachen (2005) imply that the only strategic decision would be the implementation of rail for connecting seaports with hinterland through inland terminals. Those inland terminals are of major importance for the efficiency of the intermodal transport as well as for efficient access from/to seaports.

The transport sector is the largest energy-consuming sector in the EU and road transport consumes approximately 70% of that energy (European Environmental Agency, 2003), resulting in external effects such as emissions, noise, road accidents and congestion in the seaport cities and further inland. Transport policies at different levels advocate rail and barge as being more sustainable traffic modes (European Commission, 2001a) and therefore propose a shift of volumes from road to more energy-efficient traffic modes, which are less harmful to the environment and reduce congestion at seaport terminals as well as in seaport cities. The problems related to the substantial growth in the last 20 years of containerised maritime transport should be approached from a joint seaport and hinterland perspective. The idea of dry ports, i.e., advanced intermodal terminals (offering additional services such as customs clearance, storage and maintenance of containers) with rail links to seaports, is certainly not new, and the seaport’s role in hinterland transportation has been dealt with (e.g., Slack, 1999; Notteboom, 2002; Notteboom and Winkelmans, 2001; van Klink and van den Berg, 1998). In addition, the tradition of land-bridges, mini-bridges, and micro-bridges has a long history in the USA (Slack, 1990; Coyle et al., 2000); while Eurasian land-bridge potentials are well elaborated by Hilletoff et al. (2007). However, it has not been seen as a tool for solving problems such as congestion, delays or lack of space, which the actors of the transport system meet today.

This paper emphasises the importance of efficient seaport inland access that would be obtained through implementation of advanced inland intermodal terminals – dry ports, which would make goods handling more efficient – and a shift of freight volumes from road to more energy-efficient traffic modes that are less harmful to the environment. Therefore the purpose of the paper is to present the dry port concept through elaboration of the dry port benefits from the perspectives of the different actors of the system; to evaluate the concept from an environmental perspective using modelling and simulation; and to identify and categorise existing dry ports for the Port of Göteborg. Therefore, the following research question has been formulated: What different principles and impacts can be identified in relation to the dry port concept?
The scope of the paper is the seaports’ inland access with dry ports, i.e., advanced intermodal terminals, as a part of the intermodal transport chain. Considering intermodal transport as the transport of standardised units involving at least two different traffic modes, only transport processes involving containers were analysed in the studies. Moreover, the transport of containers from seaports to inland destinations in Sweden, mainly by rail and only a short leg by road, was of interest.

This paper is a result of an extensive study (literature review, survey, and modelling and simulation) on the dry port concept. The modelling and simulation part of the study is elaborated and presented in more detail in the paper ‘Evaluation of the dry port concept from an environmental perspective’, published in 2007 as a note in Transportation Research Part D (Roso, 2007).

The paper starts with a description of the research strategy, followed by a literature review on inland access to seaports and the environmental effects of transportation. The findings from the study are presented with respect to the purposes; the elaboration of the dry port concept with its benefits is followed by the environmental evaluation of the concept, which is done for the case of the Port of Göteborg, with identification of its dry ports. Finally, the conclusions are presented.

2 Research strategy

The literature study was a method applied during the whole research process. It started as a broad literature study on the subject of intermodal transportation, which was gradually narrowed to inland access to seaports and inland intermodal terminals; and it resulted in the description of the dry port concept and its benefits for the actors of the transport system. An additional literature study on transportation-related modelling and simulation and on the environmental effects of transportation was done for the part of the study related to the evaluation of the concept. Scientific journals, conference proceedings, dissertations, theses, EU projects and business-oriented publications were considered as the literature. The business-oriented publications were of particular importance at the very beginning of the research; they served as a source of practical information for initial exploration on the dry port subject. Published materials such as information published on the internet or annual reports were useful, especially in filling some empirical gaps.

Observation as a data collection method was also used during the whole research process, but not in the same range as the literature study; therefore, it may be considered of secondary importance or supplementary. It was mainly unstructured participant observation during the study visits as well as jointly with the interviews. It contributed to the understanding of practical issues in the related industry. Observation during the visit to the seaport container terminal provided insight into terminal processes such as truck arrivals, loading and unloading of vehicles and vessels, which was very useful for the modelling.

Evaluation of the concept from an environmental perspective was conducted by modelling and simulation through a case study. Due to technological changes in traffic modes and handling equipment, and differences in operating conditions at each terminal, past experiences from other seaports may not be applicable for the modelling of a certain seaport (Ballis and Abacoumkin, 1995). The empirical data that were used as input data into the model and that enabled the modelling were collected through archival records.
The emergence and significance of dry ports

from the Port of Göteborg and through an interview with the seaport rail manager. Data regarding the seaport activities were obtained through the seaport visit, as mentioned above, and through the interview; the same were used to define processes in the model. The validation of the model was done by a subjective method; *i.e.*, the model was validated with the help of experts in the field using a structured walkthrough of the model. Additionally, some simulation results were analysed for validation purposes. The software tool Planimate™ was used for modelling and simulation.

The empirical data for the identification of intermodal road-rail terminals in Sweden were collected by a questionnaire sent by e-mail and conventional mail to 25 road-rail terminals in Sweden. The response was weak and the data insufficient with different reference years, and therefore additional data were collected through archival records and interviews. A preliminary survey encompassed 18 intermodal (road-rail) terminals that handled containers and were connected by rail to the Port of Göteborg, but only 15 were addressed in this study due to their relevant characteristics, though seven are in seaport cities but not in dock areas. Due to inconsistency of the collected data as well as to a small sample, the analysis was mainly qualitative; however, cluster analysis was applied to get a better overview of the situation, since one of the purposes of the study is the categorisation of the terminals.

3 Inland access to seaports

The main problems seaports face today, as a result of growing containerised transport, are lack of space at seaport terminals and growing congestion on the access routes serving their terminals. Parola and Sciomachen (2005) modelled and simulated the potential growth of container flows. Their findings show that the modal imbalance between road and rail results in increased road traffic congestion, since a growth in the sea flow implies an almost proportional increase in the road flow. A study by the Transport Research Board (1993) also indicated that total seaport commerce was projected to triple over 30 years; consequently, seaport efficiency was threatened by increased bottlenecks in the landside transportation system serving the seaports. For some seaports, the weakest link in their transportation chain is their back door, where congested roads or inadequate rail connections cause delays and raise transportation costs. According to the authors, the strategic decision would be the implementation of rail or improved inland intermodal terminals serving seaports. However, the Transport Research Board (1993) survey identified infrastructure, land use, and environmental and institutional impediments that reduce the efficiency of freight movements on land. Short-term impediments in the form of privatisation of rail have been elaborated by Hilmola *et al.* (2007).

As elaborated by van Klink and van den Berg (1998) and McCalla (1999), seaports can generate scale economies to operate cost-effective intermodal transport with high frequency to different destinations beyond their traditional hinterland, *i.e.*, to use rail to enlarge their hinterland and at the same time to stimulate intermodal transport. The individual seaports try to attract as much flow as is economically feasible and the size and shape of a seaport’s hinterland is not statically or legally determined, but varies dynamically due to developments in technology, economy and society. Despite the advantages stated above, there is a relatively low share of rail in the transport of containers from seaports to the hinterland; the modal split for the transport by rail is, on
average, 17.4%; by barge, less than 5.8% (European Union Road Federation, 2007). However, there are seaports that transport significant volumes of containers, up to 30%, by rail, such as Hamburg and Bremerhaven; and Antwerp by barge.

The concept of a hinterland changes constantly and it is generally accepted today that serving seaport hinterlands is more competitive than before containerisation and intermodality (McCalla, 1999). There is a strong interdependency between a seaport’s foreland and hinterland, which is particularly apparent in intermodal transportation. Seaports are competing not only with seaports in their local area, but also with distant seaports attempting to serve the same hinterland (Notteboom and Rodrigue, 2004). Notteboom (2001) and van Klink and van den Berg (1998) state that many seaports, as well as shipping lines, integrate vertically to also control hinterland. However, the vertical integration must be done cautiously and must respect antitrust legislation, since slot-sharing alliances and conferences are allowed at sea but have been disputed by competition authorities (Slack et al., 2002). Even van Klink and van den Berg (1998) discuss EU regulations on competition, since the same frustrate the role of seaports in intermodal operations and hamper the realisation of the EU transport policy’s central goal to make transport more efficient and sustainable.

3.1 Inland intermodal terminals

Inland intermodal terminals, as important nodes in the transport network, have gained substantial attention in transportation literature. Considerable research has been conducted on how to find the optimal location for inland intermodal terminals (Rutten, 1998; Macharis and Verbeke, 1999; Arnold et al., 2004) and how to improve the efficiency of road-rail terminals (Ballis and Golias, 2002; Kozan, 2000). Earlier research by Slack (1990) on inland load centres shows the importance of their development for intermodal transportation; in his later research (1999), he emphasises the inland terminal’s (satellite terminals) role in reducing environmental effects. Seaports are among the most space-extensive consumers of land in metropolitan areas and their expansion often generates environmental and land use conflicts; therefore, satellite terminals (inland intermodal terminals in remote areas) are seen as an alternative to seaport expansions (Slack, 1999). In his work on terminals, Woxenius (1997) discusses whether or not the terminals are barriers for intermodality. Despite their important role in transport networks, terminals sometimes impede the development of intermodal transport with additional transhipment costs at road-rail terminals or due to a shippers’ lack of freedom in choosing traffic modes once they move their business to intermodal freight centres (Woxenius, 1997, p.15).

In his comprehensive study, Rutten (1998) has the objective of determining the interrelationships between terminal locations, number of terminals, shuttle train length and system performance. He suggests the movement of transport from road to intermodal rail over distances longer than 100 km, when the quality and service of the intermodal transport is comparable to or better than the road. Moreover, the intermodal transport cost should be lower than or equal to the road transport cost (Rutten, 1998, p.281). According to van Klink and van den Berg (1998), rail services are generally competitive at distances above 500 km. However, the critical distance varies due to the portion of transhipment costs, which varies depending on the combination of traffic modes. Distance is not the only prerequisite for the success of intermodal transport, but also the volume of goods
and the frequency of the service provided. The case of the Port of Hamburg, where container cargo already travelling 150 km enters or leaves the seaport by rail, shows that intermodal transport is viable even at shorter distances (HHVW, 1997).

Höltgen (1995), in his doctoral thesis, deals with the basic problem of differentiation between ‘conventional’ transhipment terminals and the various types of large-scale intermodal logistics centres, as well as trying to find a unique definition for the same. The problem is that the concept for intermodal logistics centres varies from country to country, although there is a common background: it should contribute to intermodal transport, promote regional economic activity, and improve land use and local goods distribution. Furthermore, the author suggests classification of intermodal terminals according to some basic functional criteria like traffic modes, transhipment techniques and position in the network or geographical location. Nevertheless, the transhipment between traffic modes is the characterising activity.

An intermodal road-rail terminal can simply be described as a place equipped for the transhipment and storage of intermodal loading units between road and rail (European Commission, 2001b). There are many different terms used for an inland terminal facility, such as Inland Clearance Depot, Intermodal Freight Station, Inland Freight Terminal, Inland Port or Advanced Port. Sometimes the same term is used for different facilities or different terms are used for the same facility (Woxenius et al., 2004).

4 Environmental effects of transportation – CO$_2$ emission and congestion

The environmental impacts of the transport sector have increased significantly in the last decade, contributing 45% of total CO$_2$ emissions, and within the EU the road sector is responsible for almost 90% of the emission compared to other modes of transport (European Environmental Agency, 2003). With CO$_2$ being the main contributor to transport Greenhouse Gas (GHG) emissions, policies targeting the reduction of CO$_2$ emissions are imperative.

CO$_2$ emissions are directly proportional to fuel consumption. Therefore, establishing the CO$_2$ emission of a certain vehicle relies on an estimation of a vehicle’s fuel consumption. However, estimating fuel consumption is complex since it is a function of many parameters such as speed, acceleration, traffic volume, driving style, weather, vehicle age and fuel type, and road condition, to name just a few. A study by Palmer (2005) has shown a fuel consumption difference of up to 40% depending on whether a constant or variable speed is used in a link. Due to the complexity of estimating CO$_2$ emissions, an approximate measure is used in this study: according to Albrecht (2001), the CO$_2$ emission from a truck during transport with an average speed and average load is 1.2 kg/km; an average of 1 kg/km might be applied. CO$_2$ emission during queuing or driving at very low speed is approximately 6 kg/h.

The paper by Léonardi and Baumgartner (2004) shows the results of the implementation of the proposed CO$_2$ efficiency measures taken by randomly chosen operators; the measure of moving transport from road to rail or ship is found in only 15% of the companies, to a very small extent and is not expected to rise. The same study showed that the most commonly implemented measures were drivers’ training and technical improvements, such as low-resistance tyres and improved motor oils.
Congestion as a major social and environmental cost of urban transport is targeted by a wide range of policies. Moreover, it involves personal costs such as loss of time, additional vehicle maintenance costs, indirect health effects and stress. Congested traffic produces more air pollutants than smooth traffic flow, generates greater noise and consumes more energy (Salomon and Mokhtarian, 1997). Considering these facts and a growing concern for the environment, a focus is emerging on reducing congestion. The main cause of congestion in urban areas is private cars; however, trucks, on their way to or from seaports, usually passing through the seaport cities, also increase the problem. Shifting the transport of containers from road to rail is the political objective, which, with electrically powered rail, would also lower CO₂ emissions.

5 The dry port concept – findings from the study

According to Zimmer (1996), an ideal terminal is not a certain physical configuration of pavement and tracks, but an organisation of services integrated with a physical plant that meets the business needs of a specific marketplace. These physical plants may take many forms, which are influenced by the characteristics of the landscape, their proximity to the seaport or major industrial complex, their location relative to the main rail infrastructure, and their distance from the country’s highway network. This conscious and strategic development of intermodal terminals in the seaport’s hinterland is approaching what is regarded here as dry ports. A dry port is an inland intermodal terminal directly connected to a seaport, with high-capacity traffic modes, preferably rail, where customers can leave and/or collect their goods in intermodal loading units, as if directly to the seaport (Woxenius et al., 2004). As well as transhipment, which a conventional inland intermodal terminal provides, services such as storage, consolidation, depot, track and trace, maintenance of containers and customs clearance should be available at dry ports. The quality of the access to a dry port and the quality of the road-rail interface determines the dry port’s performance. Scheduled and reliable high-capacity transportation to and from the seaport is therefore necessary. Thus, dry ports are used much more consciously than conventional inland terminals, with the aim of improving the situation resulting from increased container flows, and a focus on security and control by the use of information and communication systems. The dry port extends the gates of the seaport inland, with shippers viewing the dry port as an interface to the seaport and shipping lines. The main features of a dry port are as follows:

- intermodal terminal
- situated inland
- rail connection to a seaport
- offers services that are available at seaports, such as container maintenance, storage of containers, forwarding, depot and customs clearance.

Conventional hinterland transport is based on numerous links by road and only a few by rail, which is generally limited to serving major conurbations at relatively large distances from the seaport, as shown in Figure 1(a). Dry ports are divided into close, midrange and distant dry ports; a seaport and all three types of dry ports are presented in Figure 1(b).
The benefits from distant dry ports derive from the modal shift from road to rail, resulting in reduced congestion at the seaport gates and its surroundings. Since one train can substitute for about 35 trucks in Europe, the external environmental effects along the route are reduced. Today, seaports compete not only on tariffs and transshipment capability, but also in the quality of inland access. This competition requires seaports to focus on transport links, on the demand for services in its traditional hinterland and on development in areas outside their immediate market (Notteboom and Rodrigue, 2004). Consequently, apart from environmental benefits, a distant dry port also brings a competitive advantage to a seaport since it expands the seaport’s hinterland, i.e., it improves the seaport’s access to areas outside its traditional hinterland by offering shippers low-cost and high-quality services. Rail operators benefit from distant dry ports simply by the movement of containers from road to rail, which increases the scale of their business. From the shippers’ perspective, a well-implemented distant dry port offers a greater range of logistics services in the dry port area. For environmentally conscious shippers, it gives the option of using rail rather than road, thus reducing the environmental impact of their products.

The benefits of a midrange dry port are comparable to those of a distant dry port since the former serves as a consolidation point for different rail services, implying that administration and equipment specific to sea transport are needed at only one terminal away from the seaport. The high frequency achieved by consolidating flows, together with the relatively short distance, facilitates the loading of containers for one container vessel in dedicated trains. Hence, the dry port can serve as a buffer, relieving the seaport’s stacking areas.

Implementation of a dry port in the seaport’s immediate hinterland enables the seaport to increase its terminal capacity and hence manage the problem of lack of space or inappropriate inland access. With increased terminal capacity comes the potential for increased productivity, since bigger container ships may call at the seaport. Road hauliers lose a marginal market share in terms of road-kilometres (road-km), but would still benefit from shorter waiting times at dry port terminals. In cities not allowing long or polluting road vehicles, calling at a close dry port is an alternative to splitting up road vehicles or replacing them with less polluting vehicles.

Dry port implementation generates a set of advantages for the actors of the transport systems; these are summarised in Table 1, which is the result of the extensive literature study and the survey. The most obvious benefit from the environmental perspective comes from the movement of containers from road to rail, which results in less congestion on the roads as well as at seaport terminals, in reduced emissions and, with that, in reduced environmental effects.
Table 1  The dry port’s advantages for the actors of the transport system

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5.1 Evaluation of the concept from an environmental perspective

For the purpose of evaluation of the concept, a model of a transport system, with and without a midrange dry port, is created and the results of the simulations are compared. (See Figure 2 for illustration of the two systems, with and without the dry port.) The benefits of the dry port implementation are defined from an environmental perspective, specifically by the reduction of CO\(_2\) emissions and congestion at the terminals.

Figure 2  Illustration of the transport system (a) without a dry port and (b) with a dry port

Evaluation of the dry port concept from an environmental perspective was conducted for the case of Port of Göteborg and its hinterland, i.e., on the transport of containers from the seaport to 19 inland destinations. The city of Borås was chosen as the location for the dry port due to its vicinity to the seaport and existing railway infrastructure, as well as its convenient position and good road infrastructure regarding the other inland destinations.
Another reason for having the dry port in Borås is the fact that more than 20% of the containers in this study are destined for Borås. No software tool for the optimal location of the dry port was used since the purpose of the paper was neither to find the optimal location for the dry port nor to support any decisions regarding financial investments of any kind. The first set of input data are distances (km) to the inland destinations together with the number of TEUs per day transported from the seaport to the same inland destinations, for the inputs into the model without the dry port. The same set of input data for the model with the dry port differs only in the distances travelled by trucks from the dry port to the same inland destination, which are generally shorter, as expected.

The reference situation (see Figure 2a) represents the transport of loading units from the seaport to the chosen inland destinations by truck. In other words, it represents seaport inland access conducted by truck without an implemented dry port. Based on the practice at the terminals, some assumptions are made regarding the processes in the models, and according to Law and Kelton (1991), triangular distribution should be used for a rough model in the absence of data. Thus, trucks arrive randomly at the seaport and dry port to pick up containers intended for the chosen inland destinations. It is assumed that the containers are already at the seaport terminal and are ready to be loaded onto the trucks, i.e., unloading from ship to the dock is not taken into account. It is also assumed that each truck carries two containers. This model is quantitative in its nature as well as descriptive in its purpose. It is stable – some input data can be altered, but it is not flexible – i.e., it cannot simulate another seaport by a simple change of input data. The validation of model is done by a subjective method, i.e., the model is validated with the help of experts in the field using a structured walkthrough of the model. Additionally, some simulation results were analysed for validation purposes.

The scenario demonstrates the system with an implemented dry port (Figure 2b), which means that the transport of the loading units from the seaport to the dry port is by rail, and from the dry port to the inland destinations by road. Thus, the transport of containers is shifted from road to rail on the link from the seaport to the dry port. The objective was to show that there is a way to improve the operations involved in the container flow in order to achieve better productivity, and with that to lower the environmental impact.

The results for terminal queuing are based on a simulation of 4 (peak) h. The reference situation results show that, after 4 h, the number of trucks waiting or queuing at the seaport terminal increased to 23, giving an average waiting time of 85 min. The dry port model, after the same simulation, shows that the number of trucks waiting at the terminal is five, with an average waiting time of 13 min. Not maintaining a predetermined schedule for the arrival of trucks at a busy seaport terminal has been shown as the major cause of congestion at a terminal. Long waiting times, apart from financial loss for carriers, increase the risk of road accidents since truck drivers become anxious and might also avoid regular rests during transportation in order to arrive at the destination on time.

The results for CO$_2$ emissions are based on a simulation for 35 trucks, which is equal to the average number replaced by one train in Sweden. The main characteristic of a dry port in this case is the rail link to a seaport; a simulation for 35 trucks is thus more suitable than a simulation for a certain number of hours, as using a specific number of trucks enables easier and more appropriate comparison. Consequently, the calculated CO$_2$ emissions during simulation of the transport between terminals as well as during queuing
(very low driving speed) at the terminals are approximately 25% lower in the model with the dry port. In view of the fact that a major part of these CO$_2$ emissions occurs during the transport between the terminals, only about 4% comes from queuing; the benefit from the dry port implementation can be translated into road-kilometres reduced. Thus, the implementation of the dry port at the chosen location, having two trains a day, would result in a reduction of approximately 2000 road-km per day.

5.2 Identification and categorisation of dry port applications for the Port of Göteborg

There are five different types of rail freight terminals in Sweden: Intermodal Freight Centres (IFC), conventional intermodal terminals, light-combi terminals, wagon-load terminals and freeloading sites. The differences between them are location, services offered, type of traffic modes and goods handled. Fifteen intermodal (road-rail) terminals that handle containers and are connected by rail to the Port of Göteborg were included in the study. The Port of Göteborg is the largest container seaport in Scandinavia, handling more than 750 000 TEUs per year, about 70% of which is transported by truck to inland destinations (Port of Göteborg AB, 2006). Figure 3 shows the analysed terminals with respect to volumes handled per year and distance to the Port of Göteborg. Categorisation of the terminals was not straightforward since the volume handled, as well as types of goods, differed significantly between the terminals with no apparent pattern; and in many cases the terminal operators had no knowledge of the types of goods transported in the containers.

Figure 3  Inland road-rail terminals with volumes handled per year and distances to the Port of Göteborg
There are few terminals in Sweden that can be categorised as dry ports. All terminals surveyed for the study have rail connection to the seaport, handle containers and offer transhipment service; however, those characteristics do not make them different from the conventional intermodal terminals. Figure 4 shows the clustering of those terminals based on volumes handled and distances from the seaport. Two groups of terminals were identified: midrange and distant (I and II in the figure, respectively). Midrange terminals may be further divided into (Ia) midrange terminals with low volumes, up to 20 000 units; and (IIb) terminals with high volumes, above 20 000. The majority of these terminals can be described as simple intermodal road-rail terminals. What would make a distinction from the simple intermodal terminals and make them more advanced are the extra services offered at the terminals as well as the quality of their rail access.

Figure 4  Diagram based on distance from the port and volumes handled

Stockholm-Årsta is the largest of all the surveyed terminals, in number of loading units handled per year as well as in terminal area, and also the most advanced in services offered. The terminal provides customs clearance and storage of containers; moreover, there are several forwarders, hauliers and shipping agencies situated in the area. Karlstad-Väneterminalen also offers a range of services that inland ports usually offer, such as customs clearance, storage of containers and handling of dangerous goods.

Considering the findings above on distances to the Port of Göteborg and the characteristics of the surveyed terminals, only two terminals can be categorised as having the role of a dry port for the Port of Göteborg: Stockholm-Årsta and Karlstad-Väneterminalen. The latter has the role of a midrange dry port for the Port of Göteborg because of the distance from the seaport that is generally covered by road, as well as the quantity of units handled at the terminal and destined for the seaport. The terminal also serves as a consolidation point for goods from different traffic modes and offers the full range of services that inland ports usually offer. Stockholm-Årsta is situated approximately 470 km from the Port of Göteborg, which is precisely at the edge
for classifying it as a midrange or a distant one; it also offers the full range of services expected of a dry port. This terminal also serves as a consolidation point for different rail services.

Therefore, at present, only Stockholm-Årsta and Karlstad-Vänerterminalen, with the extra services offered at the terminals, may be categorised as advanced inland intermodal terminals for the Port of Göteborg – or, given their rail connection to the seaport, as simple dry ports. However, as described earlier, even without these extra services, some of the surveyed terminals fulfil the role of a dry port for some actors in the transport system.

6 Conclusions

The dry port concept is based on a seaport directly connected by rail to inland intermodal terminals, where shippers can leave and/or collect their goods in intermodal loading units as if directly at the seaport. In addition to the transhipment that a conventional inland intermodal terminal provides, services such as storage, consolidation, depot, maintenance of containers and customs clearance are also available at dry ports. The dry port implementation itself certainly is not a straightforward solution for seaport terminal congestion or for better seaport inland access; however, it could be part of the solution. The quality of access to a dry port and the quality of the road-rail interface also determines the dry port’s performance; it is therefore necessary to have scheduled and reliable rail transport between the seaport and the dry port. With dry port implementation, CO₂ emissions should decrease, queues and long waiting times at seaport terminals should be avoided and the risk of road accidents reduced. Besides the general benefits to the ecological environment and the quality of life by shifting flows from road to rail, the dry port concept mainly offers seaports a possibility to increase the throughput without physical expansion at the site. However, this study indicates the expected difficulties with the implementation of the concept since intermodal transport itself has many hindrances. The real-world examples show that dry ports are successfully implemented by several ports (Woxenius et al., 2004). The immediate reasons may vary, but a common dominator is that rail has a role to play as an intermediate traffic mode between sea and road. For implementation, however, costs and benefits must be carefully evaluated and distributed between the actors.

To conclude, here is an interesting observation by Vandervoort and Morgan (1999): “A dry port must fit into a complex system where the necessary supporting infrastructure (roads, railways) is in place, maintenance is assured, and the legislative, regulatory, and institutional systems are properly designed to optimise the involvement of both the public and the private sector.” This might serve as a good answer to the question of whether a dry port implementation will result in success or failure.

The conclusions drawn from the research indicated the importance dry ports have for efficient seaport inland access and therefore for the entire intermodal transport chain. Despite the advantages that the dry port concept brings to different actors of the transport system, there are still impediments to the implementation of the same. The next step in the research would be shifting the perspective to the impediments that reduce the efficiency of seaport inland access routes and their terminals.
References


PAPER IV

Roso, V. (2008)
Factors influencing implementation of a dry port
International Journal of Physical Distribution and Logistics Management
Factors influencing implementation of a dry port

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Abstract

Purpose – A close dry port with direct rail connection to a seaport is a potential solution for seaport terminal congestion as well as for better seaport inland access. The purpose of this paper is to investigate and define impediments to a close advanced intermodal terminal – dry port implementation.

Design/methodology/approach – Comparative case studies through face-to-face interviews and a literature review have been carried out in order to accomplish the purpose. In addition, secondary sources such as reports, internal documents and web pages were used.

Findings – The most common factors that impede dry port implementation are infrastructure, land use, environment and regulations. Hence, the same reduce the efficiency of freight movements on land access routes to and from seaports. An advanced intermodal terminal must fit into a complex system where the necessary infrastructure is in place and the regulatory systems are properly designed to optimize the involvement of both the public and the private sector.

Research limitations/implications – Empirical data for the case studies are collected at Port Botany, Sydney, and its close intermodal terminals. A more comprehensive view of the problem could be obtained through additional case studies on other countries’ seaports’ intermodal terminals.

Originality/value – The idea behind the study is to contribute to a better understanding of the concept of close dry port through the factors that influence the implementation of the same and thereby to improve knowledge of the implementation of the concept.

Keywords Docks, Rail transport, Australia

1. Introduction

Population growth and increased economic activity result in growth of maritime container transport consequently creating growth of land surface freight transport. Intermodal transport through dry ports as advanced intermodal terminals would play a key role in enabling the most appropriate mode of transport to be used for different legs of container transport chain (Woxentius et al., 2004). Intermodal (road and rail) transport combines the line haul efficiency of rail and flexibility of road, for inland access to/from the seaports. Viability of intermodal transport on long distances is argued by many academics, for example van Klink and van den Berg (1998) and McCalla (1999). The authors elaborate that seaports can generate scale economies to operate cost effective intermodal transport with high frequency to different...
destinations on long distance beyond their traditional hinterland. However, research on viability of intermodal transport on short distance is rather scarce, despite some successful examples in practice.

With increase in the volumes of maritime container traffic to/from Australia, majority of containers originate from Asia (Sydney Ports Corporation – SPC, 2007a), seaports and their inland access are becoming critically strained. Although inland access is important for the competitiveness of seaports (Notteboom, 1998; Slack, 1999; de Langen and Chouly, 2004), this is not a critical issue for Port Botany, Australia’s second largest container port. The most urgent issue to deal with for the port and the city, Sydney, is congestion due to inappropriate seaport inland access which is mainly done by road on road arteries already reaching their capacity. Beavis et al. (2007) indicate that poor harmonization of the system resources (including storages, train path access and positioning of empty containers) under conditions of an increasing flow avalanche from the port is adding to Sydney’s hinterland congestion. And, with average annual growth of 10 per cent (in last five years) for containerized transport through the port (SPC, 2007a), the urgency is obvious. Although a concept of a close dry port should bring numerous benefits to the actors of the transport system still there are many impediments to the implementation of the same. Consequently, plans for development of an intermodal terminal on the Enfield site, located 18 km from Port Botany and adjacent to existing rail lines that would eliminate the movement of up to 300 trucks per day between the two sites (SPC, 2007a), were still on hold at the initiation of this study. Finally, in September 2007, the plans for Enfield intermodal terminal received approval from Department of Planning, ten years after the first proposal.

The purpose of this paper is to investigate and define impediments to a close intermodal terminal – dry port implementation through case studies. Therefore, the following research question is formulated: “Which impediments may be identified during the process of implementation of advanced intermodal terminals-dry ports in the seaports immediate hinterland?” Case studies have been carried out primarily through face-to-face interviews and literature review, combined with site visits. Some additional phone interviews as well as e-mail correspondence were done in order to fill the gaps. Empirical data for the case studies are collected at Port Botany and its existing and proposed close intermodal terminals, or metropolitan intermodal terminals as they are referred to in Australia.

The paper starts by brief literature review on intermodal transport and intermodal terminals; and explanation of dry port concept. Chapter on methodology used for the study is followed by two case studies on close intermodal terminals that are first described and then discussed with focus on what were the impediments to their implementation. Finally, from the analysis the conclusion is made as well as suggestions for the further research.

2. Frame of reference
Intermodal transportation refers to freight transport chain using at least two different modes of transportation for the transport of intermodal units (containers, semi trailers or swap bodies) between origin and destination with one bill of lading, i.e. without handling freight itself during transhipment (Rutten, 1998; van Klink and van den Berg, 1998; Niérat, 1996). Reduced energy consumption, optimization of the usage of the main
strength of different modes (European Commission – EC, 2000; Rutten, 1998), reduction of congestion on road networks, and low-environmental impacts (Woxenius et al., 2004; Kreutzerberger et al., 2003) are considered as the advantages of intermodal (road-rail) transport.

2.1 Seaports inland access with intermodal solutions
The model in Figure 1 shows actors, activities, resources as well as factors that influence the intermodal transport. The gray area in the Figure 1 shows the intermodal transport system while items outside the box represent the system’s environment consisting of factors that influence the system. The links between actors, activities and resources are not made explicit in the model since the same cannot be determined on a general level; however those links are horizontal across the figure, i.e. the haulier performs road haulage with a lorry.

The viability of intermodal transport on long distances is argued by many academics, for example by van Klink and van den Berg (1998) and McCalla (1999). Those authors elaborate that seaports can generate scale economies to operate cost effective intermodal transport with high frequency to different destinations beyond their traditional hinterland; i.e. to use rail to enlarge their hinterland and at the same time to stimulate intermodal transport. Rutten (1998) proposes movement of goods transports from road to intermodal rail over distances longer than 100 km when the quality and service of the intermodal transport is comparable or better than the road. Moreover, the intermodal transport cost should be lower than or equal to the road transport cost (Rutten, 1998, p. 281). Distance is not the only prerequisite for the success of intermodal transport, but also the volume of goods and the frequency of the service provided (Woxenius, 1998).

Figure 1.
A reference model of intermodal transport

Despite the advantages stated above there is relatively low share of rail in transport of containers from seaports to the hinterland; the modal split for the transport by rail for Australian major ports is approximately 18 per cent (VFLC, 2007) and in Europe it is less than 10 per cent (EC, 1998). Apart from lack of sufficient rail infrastructure or free slots, according to Engström (2007) there are many obstacles that prevent transport buyers from using the railway as a major mean of transportation; lack of flexibility (in time and space) and damaged goods being the most significant. Furthermore, the author discuses that shippers sometimes make decisions on not using specific mode of transport, rail in this case, based on soft variables such as feelings or resistance to change or lack of know-how instead of facts and data. Short transit time and high reliability are significant criteria of successful logistical structure as they reduce the shippers’ need for safety stocks (Coyle et al., 2000). Survey on landside access problems identified that infrastructure, land use, environmental and regulatory impediments reduce the efficiency of freight movements on land access routes to and from seaports (Transport Research Board, 1993).

2.2 Inland intermodal terminals

Regarding intermodal terminals, substantial research has been done on how to find the optimal location for inland intermodal terminals (Rutten, 1998; Macharis and Verbeke, 1999; Arnold et al., 2004) and how to improve the efficiency of road-rail terminals (Ballis and Golas, 2002; Kozan, 2000). Earlier research by Slack (1990) on inland load centres shows the importance of their development for intermodal transportation; in his later research (Slack, 1999) he emphasizes the inland terminal’s role in reducing environmental effects and harmonising flows as satellite terminals. Woxenius (1997) discusses that despite their important role in transport networks, terminals sometimes impede the development of intermodal transport with additional transhipment costs at road-rail terminals or due to a shippers’ lack of freedom in choosing traffic modes once they move their business to an intermodal freight centre.

Höltgen (1995), in his doctoral thesis, deals with the basic problem of differentiation between “conventional” transhipment terminals and the various types of large-scale intermodal logistics centres, as well as aims on finding a unique definition for the same. The problem is that the concept for intermodal logistics centres varies from country to country, although there is a common background: it should contribute to intermodal transport, promote regional economic activity, and improve land use and local goods distribution. These features may also be applied to a dry port which is an inland intermodal terminal that has direct rail connection to a seaport, where customers can leave and/or collect their goods in intermodal loading units, as if directly to the seaport (Woxenius et al., 2004). As well as transhipment, which a conventional inland intermodal terminal provides, services such as storage, consolidation, depot, track and trace, maintenance of containers, and customs clearance are available at dry ports. The basic idea behind the concept of dry port is shown with Figure 2 that shows shift of flows from road to rail resulting in reduction of road transports to/from the seaport once a dry port is implemented in the transport system. The quality of the access to a dry port and the quality of the road-rail interface determines the dry port’s performance. However, the quality of inland access depends on the behaviour of a large variety of actors, such as terminal operators, freight forwarders, transport operators, and port authorities (de Langen and Chouly, 2004). Scheduled and reliable
Figure 2.
Basic idea behind the concept: seaport's inland access (a) without a dry port; (b) with a dry port.
high-capacity transportation to and from the seaport is a bare necessity (Woxenius et al., 2004) obtained partially through interorganizational arrangements of the actors of the transport system (de Langen and Chouly, 2004). Implementation of a close dry port in a seaport’s immediate hinterland increases seaport’s terminal capacity and with it comes the potential to increase productivity since bigger container ships will be able to call at the seaport. With dry port implementation seaport’s congestion from numerous lorries is avoided because one train can substitute some 35 lorries in Europe (Roso, 2007a, b). With reduced number of lorries on the roads congestion, accidents, road maintenance costs and local pollution are reduced as well.

A dry port may also serve as a depot, empty containers storage. Road carriers would lose some market share but in some countries where long trailers are not allowed to pass through cities for safety reasons a dry port implementation is a good solution, if not indispensable, from their perspective as well. The benefits from distant dry ports derive from the modal shift from road to rail, resulting in reduced congestion at the seaport gates and its surroundings as well as reduced external environmental effects along the route. The distant dry port extends the gates of the seaport inland, with shippers viewing the dry port as an interface to the seaport and shipping lines. The implementation of the dry port is not the only factor in relieving seaport congestion or improving seaport inland access; however, it is a significant component in improving seaport productivity. With dry port implementation CO₂ emissions should decrease, congestion at seaport terminals and seaport city roads should be avoided, and the risk of road accidents reduced (Roso, 2007a). Besides, the general benefits to the environment and the quality of life by shifting flows from road to rail, the dry port concept mainly offers seaports a possibility to increase the throughput without physical expansion at the site.

Figure 3 shows the basic relation between a dry port, factors that might have influence on a dry port implementation in the system and the actors that might benefit from the dry port.

This model, which is a basis for the analysis is made on the results from the previous studies by the author (Roso, 2007b; Woxenius et al., 2004) and on the results from the literature study for this paper. Although all elements in the figure are of importance for the transport system and are considered to some extent in the study; the emphasis is on the factors that influence the implementation of a dry port into the system and the relation is grey shaded.

3. Methodology
The quantitative and qualitative data for this paper come from two case studies on close intermodal terminals for Port Botany in Sydney. One case study is on an existing
intermodal terminal, MIST; and the other is on a planned intermodal terminal, Enfield. Nevertheless, the port is connected by rail to six close intermodal terminals that run shuttles daily to and from the port. However, due to the scope of this paper only one existing intermodal terminal has been chosen for the case. Port Botany and its close intermodal terminals have been chosen due to its distinctiveness which is in the fact that there are very few ports that quite many functioning close intermodal terminals, or metropolitan intermodal terminals as they are referred to in Australia. The other reason for choosing these sites is due to ten years delay for the implementation of Enfield intermodal terminal despite obvious benefits that this terminal would bring to different actors of the system. Consequently, my question was “Why?”. Why is this project on hold for ten years? And case studies are particularly appropriate for the circumstances, according to Yin (1994). Furthermore, apart from aiming to answer why and to identify impediments to an implementation, which could have been done only by a case study on Enfield, the intention is to compare those two case studies and by that to map factors that develop as well those that impede the implementation. In order to accomplish that purpose it is more appropriate to have an existing terminal as a case.

In accordance with recommendations by Stuart et al. (2002) a case study protocol consisting of a semi structured interview, based on a research question, has been developed in order to insure reliability. Semi-structured interview was chosen as the appropriate method to explore the issues as the same allowed the interviewees to introduce new issues and the interviewer to follow up topics more fully. A check list of issues was used to ensure that every pre-decided topic was covered and to give a sequence of questions, starting with factual queries on site and leading into more research question related issues. During the interview, the interviewer recapped on what the interviewees had said, inviting them to develop their original statements. Data for the case studies is collected primarily through face-to-face interviews with interviewees representing different actors of the transport system such as terminal manager, seaport managers, rail and road operator as well as ministry of transport personnel familiar with the intermodal situation in the region as well as with the port activities and future plans. In addition, the interviews were supported by a site visit. In order to insure validity, the triangulation (Voss et al., 2002; Stuart et al., 2002) with multiple means of data collection has been done. Therefore, apart from having interviewees from different sectors of the transport system, secondary data sources have been used, such as internal company reports, internet-based documents and archival records. Some additional phone interviews as well as e-mail correspondence were done in order to fill the gaps.

The case study approach was chosen with the purpose of gaining an understanding of factors in the transport system that influence the implementation of a close dry port.

4. Empirical findings
The cases were carried out at Sydney’s Port Botany and its two inland intermodal terminals with dry port characteristics. The first subchapter gives an insight into Port Botany and situation of it inland access; it is followed by two case descriptions and short summary of the key finding that were the basis for the discussion.
4.1 Port Botany and its inland access

Port Botany, belonging to state-owned SPC, is an integrated cargo precinct with facilities for stevedoring, customs, warehousing, empty container storage and handling bulk liquids. The facility that covers 210 ha is Australia’s second largest container port handling over 1.6 million TEU, in 2006/07 (SPC, 2007a, b) (Figure 4). Export and import of containers are rather balanced in amount of TEU, with East Asia being the leading region for full container imports by almost 45 per cent of the total. About 8 per cent of all import containers are destined to Sydney area. About 60 per cent of the total full container exports are almost equally distributed between East Asia and Oceania. Container trade through the port from 1997/1998 to 2006/2007 is shown in Figure 4 together with volumes of TEUs transported on rail to and from the port, respectively. Rail volumes increased from approximately 16 per cent in 1997/1998 to the top of 23 per cent in 2001/2002, with an average of 19 per cent for the presented period. One can see that 300,000 TEU are transported by rail from/to the seaport in 2006/2007, of which 100,000 TEU are regional units and 99 per cent are for export. Furthermore, the Figure 4 shows an average annual growth of 10 per cent for the total container trade in last five years. With that rate of increment traffic of containers through Port Botany is going to double to a predicted total of more than three million by 2020 (SPC, 2007a, b).

Despite scheduled arrival of trucks for picking or delivering containers, the seaport terminals and gates are quite congested, intensity depending on time of the year and weekday; in peaks there are 40-60 trucks per hour. Congestion creates delays which result in financial loss for the carries; but also effect environment since produces more air pollutants than smooth traffic flow and generates greater noise (Salomon and Mokhtarian, 2004). However, pick up of empty containers is not scheduled and one fourth of export containers are empty.

In order to cope with growing containerized trade Sydney Ports is developing an additional 60 ha five berth container terminal site, among other investments. However, since a growth in sea flow implies almost proportional increase in land flow,
improvements only in seaports are not enough to cater for growing container trade. And, with a target of a 40 per cent share for rail in moving containers to/from Port Botany (SPC, 2007a, b), the port has prepared a Port Freight Logistics Plan to improve road and rail performance through maximization of the use of rail which should result in minimization of growth of truck movements through the port and the city; and by that improve inland access to the port. One of the tools for reaching the goal is implementation of an advanced inland intermodal terminal – dry port at Enfield site. If the plan does not come in action and if the present trend away from rail continues, according to The SMH (2005), total externalities, such as greenhouse gas, air pollution, noise, congestion and accidents, will increase to approximately 74 million A$ by 2021 compared to approximately 54 million for the total externalities if the scenario with the target of 40 per cent by rail is reached.

4.2 Case study I – Minto terminal
The Minto facility operated by Macarthur Intermodal Shipping Terminal (MIST) is intermodal precinct with daily rail shuttle to and from Port Botany situated 45 km from the facility. There is an easy road access to both northbound and southbound ramps of the M5 Motorway and recently completed Orbital Westlink M7.

The terminal handles 40,000 TEU a year (in 2007), of which one third is for export with main customer Kimberly Clark, a paper products manufacturer. Besides, rail connection to the seaport the terminal has rail connection to other inland terminals where empty containers (from the seaport) are sent to be filled with grains for export. At present, it is 12.5 ha site of paved surface, but additional 3.5 ha are acquired on the adjacent area which will allow track extension from today’s 390-600 m. Consequently, the terminal will be able to accommodate longer trains and that will result in increased rail volumes which are expected to grow nevertheless. Terminal expansion is best solution for capacity problem since free slots on the rail are already an issue and to increase rail shuttle frequency would be difficult on shared rail. There is about 25,000 m² covered storage in use and an additional 10,000 m² warehouse under construction. The terminal is entirely privately owned and run by MIST who saw the potential in using rail for transport of containers to the seaport and in agreement with the seaport, but with its own investments, started to transport containers on rail on route to and from the seaport. Previously only trucks were used for transport of containers on this route. Although privately owned, the terminal is open for public, not intended just for certain customers. The principal function of the terminal is container haulage and transhipment between rail and road, in other words door-to-door service. However, the terminal offers a range of ancillary services such as storage, warehousing, maintenance of containers, customs clearance, quarantine, reefer storage, packing/unpacking. The whole area was transport – industry designated and therefore has not experienced the land use conflict that inner city sites may suffer.

The terminal started as a truck company 20 years ago, and in 2002 commenced with intermodal solution. Initially the terminal cooperated with a rail operator but the opportunity of rail transport was soon realized and they bought the rail company. MIST now owns Independent Railways of Australia that specialises in rail movement of containers to and from Port Botany covering Sydney, but also Newcastle, Wollongong, South Western NSW and Western NSW. The implementation of intermodal solutions at the terminal created new job not only at the terminal
(160 employees at MIST) but also in the surrounding area since new industries came in the area due to existing infrastructure. Besides, environmental benefits that came from movement of containers from road to rail, intermodal solutions reduced significantly delays as well as congestion at the seaport terminals.

A train can carry 50 TEU and it is diesel run for the time being, but the company is working on implementation of gas injected diesel, first in world, in order to improve utilization of diesel and lower emissions by 25 per cent. Trucks are used for short haulage run in balanced flow, delivering full containers and picking up empty and transporting them to the industry where the same are to be staffed with export goods, i.e. reuse of empty containers. The MIST facility offers customs clearance and quarantine and therefore is secured with high fence, cameras and guards with dogs. However, customers are not using the customs clearance service mainly due to insurance which changes if custom clearance is done at the terminal instead at the seaport. Additionally there may be a lack of awareness as well as resistance to change by customer.

The biggest obstacle upon implementation of intermodal solutions was not the cost of running rail on such a short distance, or extra infrastructure at the terminal since the state does not give subsides for rail, but intermodal procedure in the seaport, i.e. how to arrange transhipment of units from a ship directly to a train; and administrative work.

4.3 Case study II – Enfield terminal

In September 2007 Sydney Ports received planning approval to develop an Intermodal Logistics Centre at its 60 ha site at Enfield, of which 12 ha are intended for intermodal facility. However, plans for expansion of the former marshalling yard at Enfield and making it into intermodal terminal, started already in 1997. Although the site is located in an industrial and commercial area adjacent to a dedicated freight line to the port within easy access of major roads there, various obstacles hindered the realization of the plans.

Enfield project is initiated by Sydney Ports because road artery is quite congested and the goal was to minimize the growth of trucks on the roads. About 85 per cent of containers originate or are bound for a destination within 40 km of Port Botany, i.e. Sydney area, therefore there is no use of distant terminals, and instead there is a need for few close intermodal terminals. It is imperative that any new infrastructure to facilitate movement of freight by rail is built in the metropolitan area of Sydney.

The intermodal terminal is intended for loading and unloading of containers between road and rail and short-term storage and it is going to be part of a network of intermodal facilities in the area and as such should service around a quarter of the total intermodal demand. The terminal will have a warehouse for packing and unpacking of containers and short-term storage for unpacked cargo; as well as empty container storage facility – depot for later packing or transfer by rail.

Initially the terminal was planned for 500,000 TEU per year but an independent review from 2003 concluded and recommended that it was too large for the site (SPC, 2006). Environmental Assessment Report 2005 (SPC, 2006) suggested total of 300,000 TEU per year to be moved in and out of the site by 2016. The project finally received approval in 2007; the operator will be determined via tender; the port authority will remain a land lord. The future task is to define operations at the terminal. The construction work would be managed by Sydney Ports and is expected
to take approximately two years and would employ 500 temporary workers for building it. Furthermore, the terminal will open 300 permanent new jobs.

According to SPC’s calculations it would be economically viable to use rail even on such a short distance as 18 km to Enfield. Transport cost comparison for all roads versus intermodal transport from the Port Botany to 25 km distant destination in Sydney’s hinterland, Table I, shows that it is 49 A$ cheaper with intermodal transport and almost two hours faster. Assumptions are that, due to congestion on Sydney roads, average road speed is 26 km/h and trucks waiting time at the seaport terminal is at least one hour.

4.4 Empirical synthesis

General info on each terminal, summarized in Table II, allows the comparison between the terminals. Differences are obvious, in size and equipment as in units handled; but the purpose is the same. However, Enfield has potential to provide many more shuttle services per day than Minto due to proximity to the Port and has a dedicated freight line available to utilise. The frequency of services will depend on the turn around time at terminal-dry port and seaport. Minto has a logistical structure based on private ownership of both rail and trucking services, but with open access. A different logistical structure may be required for a more centrally located intermodal terminal such as Enfield with the trade volumes that are expected.

<table>
<thead>
<tr>
<th>Table I.</th>
<th>All road</th>
<th>Intermodal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (km)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Travel time (hours)</td>
<td>4.42</td>
<td>2.43</td>
</tr>
<tr>
<td>Rail cost (A$)</td>
<td>–</td>
<td>50</td>
</tr>
<tr>
<td>Road cost (A$)</td>
<td>287</td>
<td>158</td>
</tr>
<tr>
<td>Transfer at Enfield (A$)</td>
<td>–</td>
<td>30</td>
</tr>
<tr>
<td>Total cost (A$)</td>
<td>287</td>
<td>238</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table II.</th>
<th>Minto</th>
<th>Enfield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from the port (km)</td>
<td>45</td>
<td>18</td>
</tr>
<tr>
<td>Surface area (ha)</td>
<td>16</td>
<td>60</td>
</tr>
<tr>
<td>Traffic (TEU)</td>
<td>40,000</td>
<td>300,000</td>
</tr>
<tr>
<td>Rail frequency</td>
<td>Daily shuttle</td>
<td>Daily shuttle</td>
</tr>
<tr>
<td>Loading rail tracks (m)</td>
<td>390</td>
<td>920</td>
</tr>
<tr>
<td>Lifting equipment</td>
<td>9 container forklifts, 7 warehouse forklifts</td>
<td>3 gantry cranes, 3 container forklifts, 2 reach stackers</td>
</tr>
<tr>
<td>Warehouse (m²)</td>
<td>25,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Container storage area</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Customer service</td>
<td>Integrated door-to-door service</td>
<td>Separate forwarding service</td>
</tr>
</tbody>
</table>

Source: Compiled from the interviews and internal reports
The key findings from the case studies are synthesized in the Table III. Minto’s terminal manager identified regulational and institutional impediments as most critical for the implementation of intermodal solutions, i.e. rail for container transport from/to the seaport. To some extent rail infrastructure is also an issue since the same is quite old as well as shared, with passenger traffic having priority. Minto terminal situated 45 km from the city centre has never experienced land use or environmental problems since the area was intended as an industrial area for more than 20 years ago. Development of transport infrastructure in the area was perceived just as an advantage since it brought new jobs and by that further developed the area.

All interviewees identified regulations and infrastructure as an obstacle to further development of intermodal transport and by that implementation of intermodal terminals. One big obstacle is strong road operators lobby that intimidates any attempt of lowering road sector share for container transport although the same is indispensable for a solution to previously mention transport-related problems. It is apparent that a land use problem, as well as land price, is closely related to distance from the city centre and certainly to vicinity of residential areas. The same is further related to environmental issues and fear of local air pollution, noise, congestion, etc. The seaport, during Enfield project realization, experienced all four obstacles from the Table III; however the port does not consider that all are of the same relevance or justification. All agree that regulations are indispensable for any further development of intermodal transport or solutions to current congestion problem. One will lead to another and with regulations infrastructure should get its share of improvement.

5. Discussion

To ease pressure on Sydney’s roads, moving a larger portion of containers by rail is proposed for the Port Botany’s basin. A network of intermodal terminals is therefore crucial to achieve this. The existing network of intermodal terminals servicing Sydney’s catchment area will not be able to cope with the capacity required to reach the target of 40 per cent containers on rail compared to present 20 per cent. Development of network of intermodal terminals would enable achievement of the target of 40 per cent containers on rail and by that cut number of truck movements on arterial roads by approximately one million per year. This would only last until 2012 after which new intermodal terminals would be needed to capture further 5 per cent increase in container transport through Sydney. There is an apparent need for new intermodal terminals that, apart from having direct access to both road and rail, should be located in proximity of the served market and within industrial area. The terminals should also be environmentally and socially sustainable. Both terminals in this study meet these requirements however one had many impediments on the way to realization, while another had a smooth path.

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Regulations</th>
<th>Environment</th>
<th>Land use</th>
<th>Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table III.
Impediments identified by five interviewees
5.1 Regulations

It is not just about general awareness on benefits from rail freight transport or environmental issues coming from it, to start with changes; it is about regulations and policies. The restructure of NSW rail sector and the open access approach led to a revival of rail transport for import/export of containers. The restructure, occurred in 1996, renewed interest in movement of containerized cargo by rail and by 2003 the share of rail volume had reached approximately 25 per cent; before that act rail market share was less than 10 per cent (SFCNSW, 2004).

The seaport’s proposal for solving congestion problem was by imposing an auction “pay for slot” so that peak hour slots would be most expensive and that would possibly spread truck’s arrival at the seaport avoiding peak hours. With this solution the road market share would not be affected as with increased use of rail, furthermore it would only be a part of the solution for the problem of congestion at the seaport terminal.

There are no direct subsidies for rail from the government. The only act from the governments side was suggestion to impose so-called “infrastructure charge” of 30 A$ for both road and rail; and then rail would be refunded. Revenue from the charge would be intended for financing rail infrastructure and support rail to be more competitive. One reason for week involvement of the government in support of rail might be in very strong road lobby that impedes any actions towards increased use of rail and by that intermodal transport.

5.2 Environment

The Enfield project was delayed due to bureaucracy and politics. Local politicians during the election period went along with the residents in the area and hindered the project due to fear from increased road traffic through the area. The fact is that road traffic from the port already runs through the area because it is located next to major roads. The residents see it as a trade off between congestion at the seaport and at Enfield area and their major concern was environmental effect from generated road traffic as well as from rail. Therefore, an environmental assessment has been done on effects of road and rail traffic such as traffic congestion, noise, air pollution, heavy vehicles use of local roads and consequently increased risk for traffic accidents. Finally, in 2007 it was approved to build the intermodal terminal with smaller operating capacity, 300,000 instead of 500,000 TEU a year. Traffic in and around the terminal is limited by regulations and will be monitored; if an operator increases the volumes the fine will be imposed.

On its way to intermodal realization Minto terminal has not experience environmental issues as obstacle, as previously explained.

5.3 Land use

The question of environmental effects is closely related to the issue of land use; the closer the potential site for an intermodal terminal is to metropolitan area the higher the price as well as demands regarding the environmental impacts. Functionality of the seaport depends on its inland access which in this case depends greatly on close intermodal terminal situated within metropolitan area but the residents want parks not transport facilities. The site is already highly disturbed by ruined rail buildings and stockpiles and therefore substantial investments within the project are planned to transform a 6 ha of the Enfield site into a green space and a valuable community asset.
with buffer planting and acoustic moulding and walling. On the other hand the seaport’s waterfront is threatened as well because of its attractiveness as residential area; consequently the seaport cannot increase its capacity by expanding the existing port terminals at the waterfront area. However, that kind of expansion would only solve the problem of the terminal capacity and by that would contribute to even greater congestion at the seaport gates if rail infrastructure, including intermodal terminals, would not be improved.

5.4 Infrastructure
Rail infrastructure is already a concern since existing passenger and freight shared rail network is getting more constrained by passengers, and passenger transport has priority. Furthermore, on shared rail freight is not allowed between 6-9 am and 3-7 pm, and there are very few free slots for eventual new rail operators. Road congestion is an urgent issue; seaport terminals as well as city roads are congested by trucks; but improvements of intermodal network with dedicated freight lines would require considerable investments to which government is not ready to commit.

The introduction of Enfield intermodal terminal should be a blueprint for the future since older terminals as well as those situated far from the city have not experienced issues like environment or land use or even infrastructure during their implementation. These issues are related to population growth and increased economic activity that results in growth of maritime container transport consequently creating growth of land surface freight transport.

5.5 Inference
The findings of the study are compared against the concept of the dry port; Figure 5 shows the dry port model which is modified extract from the referenced intermodal transport model developed by Woxenius (1998) which represents the whole intermodal transport chain (Figure 1). The new model illustrates actors, activities and resources that congregate at the dry port as well as factors that directly influence implementation of a dry port or an intermodal with direct rail connection to a seaport.

![Diagram of a dry port model](image-url)

**Notes:** * Dry port operator; ** transshipment, storage, customs clearance, maintenance of units, depot

**Figure 5.** Reference model applied on the dry port – generated from the findings
The gray area in the Figure 5 shows the dry port terminal system while items outside the box represent the system’s environment consisting of factors that influence the dry port.

6. Conclusions

In Sydney the truck industry is obliged to take greater volumes of freight in and out of the Port. These movements lead to other secondary movements which must interact on increasing congested roads. Furthermore, transport operators have no many options but to go by road because of the poor rail infrastructure from one side and lack of awareness of the problem from the other. Sydney’s Port Botany handles more than 1.6 million TEUs a year (2006/2007) and the figure is just growing, however the state does not have a dedicated freight strategy. One potential solution is with the concept of dry ports for the Port Botany.

Although a concept of a close dry port should bring numerous benefits to the actors of the transport system still there are many impediments to the implementation of the same. Land use, infrastructure, environmental and institutional impediments are identified as the most common ones for the cases. A dry port must fit into a complex system where the necessary supporting infrastructure (roads, railways) is in place, maintenance is assured, and the legislative, regulatory, and institutional systems are properly designed to optimize the involvement of both the public and the private sector.

The case permits us to assume that transport issues might be closely related to psychological and behavioural issues and if actors involved are not well-informed on the matter problems might arise. That was the case with Enfield project; the public wants the transport services but does not want the traffic.

If nothing is done to increase rail’s deteriorating market share, truck volumes will triple resulting in congestion, delays, rise of air and noise pollution, as well as rise in financial and emotional costs with higher accident rates.

This small study raises important questions about viability of intermodal transport on shorter distances which is heavily argued between academics but shows its feasibility in cases on Sydney’s Port Botany and its close intermodal terminals, i.e. dry ports. A more comprehensive view of the problem could be obtained through additional case studies on other countries seaports’ intermodal terminals.

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Roso, V. and Lumsden, K. (2009)
The dry port concept - Moving seaport activities inland?
THE DRY PORT CONCEPT

MOVING SEAPORT ACTIVITIES INLAND?

Violeta Roso* and Kent Lumsden

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ABSTRACT

The shipping companies strive towards economies-of-scale for the maritime part of their transport chain and that derives a demand for efficiency, capacity and short lead time in the transit through the seaports and further transport to the seaports hinterland. To stimulate the development of those seamless intermodal transport chains the concept of dry ports is established. The purpose of this paper is to develop the concept and to analyze the same through comparison of physical flows and administrative activities at the seaport terminal from time perspective in the transport system with and without a dry port. The data for the analysis is obtained through literature review and interviews with relevant actors of the transport system. The conclusions indicate that implementation of a dry port in the seaport’s hinterland enables the seaport to increase its terminal capacity and therefore manage the problem of lack of space; however, the benefits also derive from the modal shift - road to rail. The paper provides better understanding of the concept of dry ports through its benefits.

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INTRODUCTION

Intermodal container transportation is the dominant technology for container transport overseas. The shipping companies strive towards economies-of-scale for the maritime part of their transport chain and that derives a demand for efficiency, capacity and short lead time in the transit through the seaports (Culiner and Khanna, 2000; Mourão et al., 2002), and further transport to the seaports hinterland. To stimulate the development of those seamless intermodal transport chains and to meet market demands on seaports, the concept of dry ports is established. The dry port concept is based on a seaport directly connected by rail to inland intermodal terminals, where shippers can leave and/or collect their standardized units as if directly at the seaport (Roso et al., 2008). The incentive is to channel freight volumes to fewer transport corridors in order to enhance the opportunities to utilize economies of scale in the hinterland corridor and to increase the capacity in the system as well as decrease transit time through the seaport. This improves the seaport’s access to areas outside its traditional hinterland and therefore expands its hinterland (Roso et al., 2008).

As container transport volume continues to grow, the links with the hinterland will become a critical factor for the seaports’ competitive advantage; therefore, progress only in the maritime part of the transport chain and in seaport terminals, without improvements in seaport inland access, is not sufficient for the entire transportation chain to function. The efficiency of the railway is increasingly needed for the execution of the constantly growing cargo quantities. The demand for seamless hinterland connections to the inland terminals is increasing with the steadily increasing container volumes in the European ports. European hinterland transport market share for road increased for about 5%; while for rail it decreased for 4%. Furthermore, with a 76% market share, road transport dominates the inland freight transport market in EEA member countries (European Union Road Federation, 2008). The modal share of rail and road diverged due to the removal of trade barriers and liberalisation of markets, which resulted in increased utilization of road transport. A change in the geographic orientation of trade (from east to west) has also contributed to the shift because the new markets are not suitably connected by rail links and offer much more flexible road transport connections (European Environmental Agency, 2003). Therefore, the only strategic decision would be the implementation of rail for connecting seaports with hinterland through inland terminals. Those inland terminals are of major importance for the efficiency of the intermodal transport as well as for efficient access to/from seaports. Transport policies at different levels advocate rail and barge as being more sustainable traffic modes than road (European Commission, 2001), and therefore propose a shift of volumes from road to more energy efficient traffic modes, which are less harmful to the environment and reduce congestion at seaport terminals as well as in seaport cities. The problems related to the substantial growth of containerized maritime transport in the last twenty years should be approached from a joint seaport and hinterland perspective (Slack et al., 2002).

This paper emphasizes the importance of functional seaport inland access that might be obtained through implementation of advanced inland intermodal terminals - dry ports, which would make goods handling more efficient, and a shift of freight volumes from road to more energy efficient traffic modes that are less harmful to the environment. The purpose of the paper is to develop the dry port concept and to analyze the same through comparison of physical flows and administrative activities at the seaport terminal from time perspective in the transport system with and without a dry port, theoretically and through case studies. Consequently, the following research question is created:

RQ: How does implementation of a dry port into a seaport’s transport system influence physical and administrative flows at the seaport and, by that, the system?
The literature review allows analysing the concept and giving an overview of the same. However, the data for the analysis of physical and administrative flows at a seaport is obtained mainly through interviews with relevant actors of the transport system. The empirical evidence for the assessment of existing dry ports, i.e., advanced intermodal terminals that play a dry port role for their seaports, is based on case studies.

The scope of the paper is the seaports’ inland access with dry ports, i.e., advanced intermodal terminals, as a part of the intermodal transport chain. Considering intermodal transport as transport of standardized units involving at least two different traffic modes, only transport processes involving containers were analysed in the studies.

**FRAME OF REFERENCE**

Transport systems are characterised by transfers of goods between points of origin and destinations through the transport network; see FIGURE 1. The transport network is made of links and nodes where links represent transport and transfer activities connecting nodes (Lumsden, 1998). Activities such as consolidation, sorting, storage and transhipment between vehicles and traffic modes, are carried out in nodes (Lumsden, 1998). From this point of view a node is equivalent to a stop in the flow or to a point where the flow can be stopped. To ensure that the network will function when it comes to exchanging goods between the different links it is necessary that the links converge in a specific node at certain times or within certain time intervals.

![Transport network diagram](source: Lumsden (1998))

**FIGURE 1  Transport network**

Transport systems have always been designed according to geographical conditions, as well as the demand for the transportation, which is determined by the goods quantity and service quality. Currently, environmental issues play an important role in the design as well. One way to accomplish those demands is to employ rail through intermodality. There is no generally accepted definition of intermodality. Intermodal transport, according to the European Commission (2000), is defined as the following: “There is a consensus that intermodal transport constitutes a transport process in which two following conditions are fulfilled: Two or more different transport modes are deployed; and the goods remain in one and the same transport unit for the entire journey.” Reduced energy consumption, optimization of the usage of the main strength of different modes, reduction of congestion on road networks, and low environmental impacts are considered as the advantages of intermodal (road-rail) transport (European Commission, 2000; Rutten, 1998).
Seaports are important nodes in the intermodal transport; their earlier narrow focus on cargo handling has been replaced with a wide range of logistic activities giving the seaports a more active role in the transportation chain. However, there has been a trend in organizational and technological changes towards offering door-to-door transport solutions rather than port-to-port (Robinson, 2002; Paixão and Marlow, 2003). This has enlarged the seaports hinterland and therefore created a competition among neighbouring seaports.

The main problems seaports face today, as a result of growing containerised transport, are lack of space at seaport terminals and increased bottlenecks in the landside transportation system serving the seaports. For some seaports the weakest link in their transportation chain is their back door, where congested roads or inadequate connections cause delays and raise transportation costs. Therefore, the strategic decision would be the implementation of rail and improved inland intermodal terminals serving seaports.

The concept of hinterland changes constantly and it is generally accepted today that serving seaport hinterlands is more competitive than before containerisation and intermodality (McCalla, 1999). There is a strong interdependency between a seaport’s foreland and hinterland, which is particularly apparent in intermodal transportation. Seaports are not competing only with seaports in their local area but also with distant seaports attempting to serve the same hinterland. Many seaports, as well as shipping lines, integrate vertically to also control hinterland transport (Notteboom, 2001; van Klink and van den Berg, 1998). Van Klink and van den Berg (1998) discuss EU regulations on competition since the same frustrate the role of seaports in intermodal operations and hamper the realization of the EU transport policy’s central goal to make transport more efficient and sustainable.

Inland intermodal terminals have gained substantial attention in transportation literature; considerable research has been conducted on how to find the optimal location for inland intermodal terminals (Rutten, 1998) and how to improve the efficiency of road-rail terminals (Ballis and Golas, 2002). Earlier research by Slack (1990) on inland load centres shows the importance of their development for intermodal transportation; in the later research (Slack, 1999), the author emphasizes the inland terminal’s – the satellite terminal’s - role in reducing environmental effects. Seaports are among the most space-extensive consumers of land in metropolitan areas and their expansion often generates environmental and land use conflicts; therefore, satellite terminals (inland intermodal terminals in remote areas) are seen as an alternative to seaport expansions (Slack, 1999). Despite their important role in transport networks, terminals sometimes impede the development of intermodal transport with additional transhipment costs at road-rail terminals or due to a shipper’s lack of freedom in choosing traffic modes once they move their business to intermodal freight centres (Woxenius, 1997).

The basic problem of differentiation between “conventional” transhipment terminals and the various types of large scale intermodal logistics centres is covered in Höltgen (1995), as well as finding a unique definition for the same. The problem is that the concept for intermodal logistics centres varies from country to country, although there is a common background: it should contribute to intermodal transport, promote regional economic activity, and improve land use and local goods distribution. Furthermore, the author suggests classification of intermodal terminals according to some basic functional criteria like traffic modes, transhipment techniques, and position in the network or geographical location. Nevertheless, the transhipment between traffic modes is the characterising activity.

A dry port definition by Roso et al. (2008) is: “A dry port is an inland intermodal terminal directly connected to a seaport, with high capacity traffic modes, preferably rail, where customers can leave and/or collect their goods in intermodal loading units, as if directly to the seaport.” Moreover, the authors state that services such as transhipment, consolidation, depot, track and trace, maintenance of containers, and customs clearance should be available at dry
ports. The authors’ simplified interpretation of the concept of dry port would be “a movement of seaport interface further inland”. Dry ports are distinguished from conventional inland terminals by services offered at dry ports as well as by its functionality (Roso et al., 2008). Furthermore, the authors divide them into three different categories: close, midrange and distant dry ports.

Implementation of a dry port in a seaport’s immediate hinterland increases the seaport’s terminal capacity and with it comes the potential to increase productivity since bigger container ships will be able to call at the seaport. With dry port implementation, a seaport’s congestion from numerous trucks is avoided because one train can substitute for some 35 trucks in Europe. With a reduced number of trucks on the roads, congestion, accidents, road maintenance costs and local pollution are reduced as well. A dry port may also serve as a depot, empty containers storage. Road carriers would lose some market share but in some countries where long trailers are not allowed to pass through cities for safety reasons, a dry port implementation is a good solution, if not indispensable, from their perspective as well. The benefits from distant dry ports derive from the modal shift from road to rail, resulting in reduced congestion at the seaport gates and its surroundings as well as reduced external environmental effects along the route. Apart from environmental benefits, a distant dry port also brings a competitive advantage to a seaport since it expands the seaport’s hinterland to the area outside its traditional hinterland by offering shippers quality services. New logistics solutions created by a dry port implementation in rural areas make the areas more attractive for the establishment of new businesses resulting directly in development of the area as well as new job opportunities for the local inhabitants (Roso et al., 2008). The dry port benefits are summarized in the TABLE 1.

TABLE 1 Potential benefits from a dry port implementation

<table>
<thead>
<tr>
<th>Potential benefits from dry ports</th>
<th>Seaports cities</th>
<th>Rail operators</th>
<th>Road operators</th>
<th>Shippers</th>
<th>Society</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Less congestion</td>
<td>- Lower road congestion</td>
<td>- Economics of scale</td>
<td>- Less time in congested roads and terminals</td>
<td>- Improved seaport access</td>
<td>- Lower environmental impact</td>
</tr>
<tr>
<td>- Increased capacity</td>
<td>- Land use opportunities</td>
<td>- Gain market share</td>
<td></td>
<td>- “Green” marketing</td>
<td>- Job opportunities</td>
</tr>
<tr>
<td>- Expanded hinterland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: adapted from Roso (2009)

METHODOLOGY

The data collection method performed through the work on this paper was a literature study on seaports and their inland access as well as on inland intermodal terminals. The primary purpose of the literature studies was to generate understanding of the research field, to provide an insight of what research has already been done related to the problem being studied, and to identify areas of interest for further investigation. Observation as a data collection method has also been used and it was mainly unstructured participant observation jointly with the interviews. The interviews were mainly face-to-face, open-end interviews with people directly involved in terminal management - both inland terminals and seaport terminal managers. The interviews were of crucial importance for the understanding of the cases; however, data collection also included secondary sources such as internal reports and archival records which, according to Stuart et al. (2002), should strengthen the reliability. Two case studies are done primarily to draw conclusions from their comparison, not to generalise, what, nevertheless, wouldn’t be appropriate based only on two cases. However, the conclusions make a very good base for further research that might lead to generalization.
The choice of these two case studies is a result of the previous research on dry ports. Virginia Inland Port was chosen due to its reputation as a successful inland port for the Port of Virginia but also because it fits into the concept of dry port according to Roso et al. (2008). On the other hand, Falköping terminal is still in the process of developing into a dry port for the Port of Göteborg, and therefore is still not in its full bloom. The idea behind the study is, partially, to learn from the best and apply locally. This may be described as best practice case versus beginner. According to Abrahamson (2003), in logistics, proof that a certain case is a best practice case can be done both in qualitative descriptions of what they have done and with quantitative key figures such as logistics cost or delivery service. In this study, cases are discussed from both perspectives, qualitative and quantitative. The study took a systems approach to understand the whole picture as well as the components. This approach is often used in logistics to understand how the different components in the system interact in order to improve the effectiveness and efficiency for the system as a whole; the content of the each element and how they are put together is important (Abrahamson, 2003). The system here is a seaport transport system consisting of different actors-elements of the system such as seaport terminals, rail and road operators and inland terminals; however, the same is the subsystem of a whole origin-to-destination transport system (see FIGURE 2). The attention here is on one node in this transport chain, i.e., the element named “inland terminal interface” in FIGURE 2, whose development would influence the system.

FIGURE 2 Origin-to-destination transport system

SEAPORT ACTIVITIES SHOWN ON AN EXPORT CASE

Container’s physical and administrative flows at a seaport’s container terminal may be divided into three interfaces: land side interface (delivery/receipt), container terminal interface (transfer, storage and internal transport) and marine side interface (ship/shore transfer) (Holguin-Veras and Walton, 1997), whereas effectiveness of one interface affects the performance of another; see FIGURE 3. Delivery/receipt represents movements of containers through the gate, i.e., land gate entrance and external vehicle transport in FIGURE 1. The gate is an interface between external modes of transport and a container terminal. Movement of containers from the gate to the storage area, usually with straddle carriers or forklifts, is identified as loading/unloading and internal vehicle transport FIGURE 3. Storage is the area for short or long time storing of units waiting to be loaded on a ship or a train; in the case of ship loading/unloading the same may be identified as transfer ship/shore.
Regarding customs clearance, the same is done almost entirely online; in other words, physical inspection of the goods is rarely performed. Within the EU, a special customs clearance IT system is implemented in order to simplify the activity.

**CASES**

**Virginia Inland Port for the Port of Virginia**

The Port of Virginia, state-owned and established in 1952, is the second largest volume port on the East Coast of the USA in terms of general cargo, with more than 2 million TEU handled in 2006. The seaport inland access is divided into three different traffic modes; 65% of the cargo is moved by trucks, 25% by rail and 10% by barge (Virginia Port Authority, 2007).

The idea of expansion into new market areas, in particular to capture the Ohio Valley area through an inland port, came about in 1984. An inland port was supposed to be an extension of the seaport’s existing way of handling cargo; and the first and the most important step was the selection of the site. After numerous studies, the site was chosen due to its connectivity and potential new market. To adjust terminal into the surrounding area, the site is dug so that the terminal is not noticeable from the roads nearby and therefore doesn’t destroy the landscape. Virginia Inland Port (VIP) started operations in 1989 on a facility on 65 ha, with 5346 m of on-site rail. Rail service operates five times a week between the facility and the seaport; however, Mondays and Tuesdays are the busiest. VIP is situated 350 km from the seaport (FIGURE 4a).
and the total transit time is 12 hours. The procedure at the seaport terminal is rather fast from a vessel by straddle carrier to rail crane to rail. At the beginning, 9,000 TEUs a year were carried by the Detroit train from the seaport but also for other destinations. With increased volumes and involvement of new customers, another train was introduced. In 2006 the facility handled approximately 30,000 TUE (Virginia Port Authority, 2007) although the preliminary study showed potential for 100,000 TEU.

VIP is also known as a US customs designated port of entry where a full range of custom services is available to customers. However, a physical inspection of containers, only 5% of the total TEU, is currently done at the seaport. Customs clearance doesn’t take long time since customs receives information about containers for import about 24 hours prior to unloading of the ship and therefore decides about inspections in advance. There is a so-called 24-hour manifest rule for the clearance but officially, customs has 10 days to do the clearance.

**Falköping terminal for the Port of Göteborg**

The Port of Göteborg is the largest container seaport in Scandinavia, handling more than 840,000 TEUs a year, about 60% of which was transported by truck to inland destinations in 2007 compared to 70% in 2006 (Port of Göteborg, 2008). The Port works on increase of its container rail volumes by cooperating with other actors of the transport systems; today, there are 24 rail shuttles for different destinations that run daily services to/from the port.

In early 2000 came a proposal from the Falköping municipality for the implementation of an intermodal terminal in the area, 124 km rail distance from the port (FIGURE 4b), due to existing volumes already being transported to the port by trucks. The very first and expected problem, apart from financing which always seems to be a problem, was a suitable location for the terminal. However, it was not until the end of 2006, when Swedish biggest forest products company, StoraEnso, showed interest in establishing a terminal in the area, that tangible work on building the terminal started. Once the location was chosen and the terminal built, in 2007 new problems, this time unexpected, arrived. Such problems were deficient volumes, further development issues, competition with another terminal in the area, and collaboration with the Port.

The rail shuttle operates four times a week in both directions, reaching up to 11,000 TEU a year. After further development and extension of rail sidings, an increase in volumes is expected and therefore one more shuttle a week should be introduced. So far, the terminal offers services of transshipment between rail and road, road haulage and storage of containers. Future plans are to develop the terminal from the conventional one to one serving as a dry port, which means offering further services such as customs clearance, maintenance of containers, warehousing as well as some extra services for the forest products company. The customs clearance is feasible since usually there is no need for physical inspections of containers and therefore no need for presence of customs officers at the site, except in special circumstances. However, the same requires extra security measures to be provided at the terminal.

**Synthesis**

Two ports, very different in size but very similar when it comes to their road market share, transport containers to inland destinations - about 60% of the total TEU. One big difference is in ownership of their inland terminals. While the Port of Virginia initiated and financed the implementation, and also owns and operates VIP, the Port of Göteborg had no influence on implementation of Falköping terminal, neither financially or by initiative.
FIGURE 4 a) Virginia state – The Port of Virginia with VIP and b) Southwest Sweden – The Port of Göteborg with Falköping terminal

One can see from FIGURE 5 that the average time needed to handle one container does not differ significantly between the ports in the study. Average internal transport and loading/unloading times at the seaports’ terminals are rather short, are measured in minutes, and therefore cannot influence the internal flow significantly, and by that the whole transport chain.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Port of Gothenburg</th>
<th>Port of Virginia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land gate entrance/exit</td>
<td>varies</td>
<td>varies</td>
</tr>
<tr>
<td>Loading/unloading truck or train</td>
<td>1,5 min</td>
<td>2 min</td>
</tr>
<tr>
<td>Internal vehicle transport</td>
<td>1,5 min</td>
<td>2 min</td>
</tr>
<tr>
<td>Storing</td>
<td>5,5 days</td>
<td>3,5 days</td>
</tr>
<tr>
<td>Internal vehicle transport</td>
<td>1,5 min</td>
<td>2 min</td>
</tr>
<tr>
<td>Loading/unloading ship/shore</td>
<td>1 min</td>
<td>2 min</td>
</tr>
</tbody>
</table>

FIGURE 5 Average time needed to handle one container at the seaports’ terminals

However, land gate entrance time varies notably, from a few minutes to a few hours, depending on the day as well as the time of day. Although a few hours are only a small part of the whole transport chain time scale that might take up to a few weeks, one should keep in mind that those are queuing hours for road carriers which, apart from financial loss for road carriers, also increase the risk of road accidents (Roso, 2007). On the other hand, storage takes up to a few days, on average 5.5 days at the Port of Göteborg and 3.5 days at the Port of Virginia. This
segment of the transport chain might be influenced by moving the storage further inland closer to the final customer, leaving the valuable space at the seaport terminal. The storage of containers wouldn’t be eliminated by that but possibly shortened, due to faster administration inland (Roso et al., 2008), and it would be at a lower cost.

DISCUSSION

Cases

Ports that do not face lack of space at their terminals will not gain by moving their storage area to an inland terminal; on the contrary, they might lose a significant portion of their profit like in the case of the Port of Göteborg. The Port of Göteborg is located outside the city centre and has a sufficiently large storage area with the possibility for expansion, and at present, storing of containers brings in significant revenue for the Port. This usually is not the case with big container ports, and dry port as a depot is seen as the solution for the problem of lack of space (Roso, 2008). Since Falköping terminal is not owned by the Port, moving the storage from the Port to the dry port would imply giving away the profit. Therefore, the Port was not involved financially in the establishment of Falköping terminal; however, the administrative part of the establishment as well as some adaptations at the port terminals had to be done in order to introduce one extra shuttle train. This is not case with the Port of Virginia, which owns the inland terminal; therefore, moving activities inland does not imply loss of profit, but the contrary. An inland port with direct rail to the seaport means gaining valuable space at the seaport terminals, i.e., increased capacity that results in increased productivity. There were no obstacles prior to VIP implementation; infrastructure and market existed, and the municipality approved the arrangement since the implementation of the terminal implied new jobs in the area.

When it comes to time savings that result from the implementation of a dry port into a seaport transport system, one can see that the same can be obtained by eliminating queues at the seaport’s gates or by eliminating storage at the seaport. The latter does not represent a certain gain for the actors of the system since the containers need to be stored anyway; whether at the seaport terminal or at the dry port makes no difference as long as seaport does not face a lack of storage space. The former, on the other hand, makes significant gains, not only for the seaport that would perform better with no congestion at the terminals, but for the carriers who suffer from financial loss due to delays caused by the congestion. At the Port of Göteborg gates there are several hours of long queues at peak times (Roso, 2007). Furthermore, there is an increased risk of road accidents since truck drivers become anxious and might also avoid regular rests during transportation in order to arrive at the destination on time. VIP can have trucks in and out in just 30 minutes; truck drivers never have to leave their vehicles.

Society gains from the movement of containers from road to rail through reduced environmental impact. In Sweden, approximately 95% of state railway transport is by electric trains; as the electricity used for the trains comes from hydro power, emissions from the electric trains are reduced to an absolute minimum (Roso, 2007). One train substitutes for about 35 trucks in Sweden; consequently there are 35 fewer trucks on the roads per full train and there are more than 70 trains a day passing through the Port (Port of Göteborg, 2008), resulting in approximately 2400 trucks less on the roads daily. However, in the USA trains are run by diesel locomotives, but double stacking of containers is feasible and widespread. Double-stack container trains consist of 20 to 25 cars, each carrying 10 TEU, with a total train length of 2000 to 2500 meters, not counting the locomotives (DeBoer, 1992). Currently, about 25% of 2 million
TEU a year are transported by train from the Port of Virginia to inland destinations; considering double-stacking it might result in up to 2000 fewer trucks on the roads daily.

**Deduction**

In the transport system, the node is equivalent to a stop in the flow and although a dry port is a node in the system, the idea behind the concept is to make the flow smooth; in other words, not to stop the flow in the node but to make all node activates seamless, and by that to make the intermodal transport chain seamless (see FIGURE 6).

Features of a dry port concept:
- Seamless transportation and transshipment points
- Scheduled and reliable rail connection between a seaport and a dry port
- Dry port equipped for the handling of standardized units
- Services at a dry port: transshipment between road and rail, customs clearance, maintenance of containers and long and short time storage.

**FIGURE 6** Transport network with and without a dry port.

Finally, to summarize how the implementation of a dry port into a seaport’s transport system influences physical and administrative flows at the seaport and by that system. Well, one does not need a case study to realize that some activities like ship loading/unloading cannot be moved to an inland terminal. However, there is a whole range of administrative activities that would be moved inland with the implementation of a dry port, specifically those related to handling truck related paperwork. Moreover, some physical activates would take less time, such as storage, while some could be reduced completely, such as inevitable queuing at the seaport gates. Implementation of a dry port could create seamless seaport inland intermodal access, i.e., smooth transport flow with one interface in the form of dry port concept instead of two, one at the seaport and the other one at the inland destination (FIGURE 6).
CONCLUSION

Regarding the assumption on which seaport activities could or should be moved to an inland terminal, there is no general answer. The Port of Virginia is ready to invest in development of inland terminals because the competition between neighboring ports is the fact, and expansion inland into new markets brings competitive advantage. Faster movement of containers from the port to the final destination also increases the port’s capacity. On the other hand, the Port of Göteborg has sufficient volume with no fierce competition and does not strive towards the expansion of its hinterland; problems of congestion at seaport gates and potential delays have not reached a critical point yet. Therefore, the port does not invest in inland transport development as long as there are others such as rail operators, terminal operators and belonging municipalities eager to do so. However, the Port of Göteborg’s role is of a supportive nature when it comes to the development of inland terminals and rail shuttles by other actors of the transport system.

Implementation of a dry port into a seaport transport system, that is the seaport’s hinterland, should create a seamless transport chain, smooth transport flow with one interface in the form of dry port concept instead of two interfaces, one at the seaport and the other one at inland destination. In other words two nodes in the transport chain, seaport and inland terminal, should be replaced with one “dry port concept” node. However, significant time savings, as well as financial savings, could be made only by avoiding the queues at seaport gates and by moving container storage inland. Evidently, expansion inland into new markets improves seaport’s access to areas outside its traditional hinterland, resulting in new customers generating more profit and promoting the regional economic activity. The question is whether this expansion is going to be in the form of ownership or collaboration; if the latter then on which level? Therefore, this paper serves also as a basis for further research on the concept, focusing on practical experience of the concept in the world.

ACKNOWLEDGEMENTS

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A review of dry ports - Characteristics, driving forces and impediments.
A REVIEW OF DRY PORTS
CHARACTERISTICS, DRIVING FORCES AND IMPEDIMENTS

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ABSTRACT

Purpose
The objective of the paper is to present the previous research on the dry port concept and to review the world’s existing dry ports, i.e. freight terminals that use the term “dry port” in their name. Therefore the purpose of the paper is to clarify the concept by showing potential discrepancies or agreements between the theory and practice.

Design
Starting from a literature review on the dry port concept, this study presents a review of existing dry ports in the world. The data collection was conducted by means of interviews or by questionnaires sent by email to the dry port managers. The findings are analyzed with the intention of clarifying the concept by showing the similarities and differences between reviewed dry ports and existing definitions of the same.

Findings
A number of qualitative criteria regarding the range of services at dry ports or its features could be theoretically established, although the same may vary depending on the customers’ demand. However, the ultimate purpose of the dry ports is the same, irrespective of that range.

Research limitations
The scope of the paper is seaports’ inland access with dry ports, as part of the intermodal transport chain. The trade journals review allowed identification of numerous dry ports in the world; however, many were not included in the review due to inaccessibility.

Value
This paper contributes to the study of dry ports by synthesizing a literature review on the subject of dry ports; moreover, it provides an overview of dry ports in the world; and as such makes a contribution to the scarce research on dry port concept.

Keywords: Dry port concept, Intermodal transport, Intermodal freight terminals, Dry port services, Review
1. INTRODUCTION

Environmental problems have received increasing attention during the last decade and with them also the role that logistics systems can play in reducing the environmental impact (Aronson and Brodin, 2006). However, logistics concepts in the role of decreasing environmental impacts have not been extensively researched until recently (Aronson and Brodin, 2006). One of these concepts is a concept of dry port that, apart from reducing environmental impact (Roso, 2007), has the potential to create numerous benefits for the actors of the transport systems (Roso et al, 2008). The concept was neglected for many years and recently reborn due to increased interest in environmental issues related to growing containerized maritime transport. As container transport volume continues to grow, seaport inland access becomes a critical factor for the seaports’ competitive advantage. Therefore, progress only in maritime part of the transport chain and in seaport terminals, without improvements in seaport inland access by means of intermodal terminals, is not sufficient for the entire transportation chain to function.

The first mention of dry port in scientific journals dates back to 1986 (Hanappe, 1986) and in transport related trade journals in 1980 (Munford, 1980); it took almost 20 years to revive the interest for the subject among researchers (Leveque and Roso, 2002; Tsilingris and Laguardia, 2007; Roso, 2007 and Roso et al, 2008), as well as among policy makers eager to find solutions to various environmental issues caused by growing containerized transport (European Commission 2000, 2001).

Intermodal terminals have been extensively studied by many researchers. Tsamboulas and Dimitropoulos (1999) as well as Höltingen (1995) discuss the term “freight nodal terminal” that, although similar in concept, varies in its definition among countries; “Gueterverkehrszentren” in Germany, “plateformes multimodales logistiques” in France, “freight villages” in the UK or “interporti” in Italy. They all provide transhipment from one mode to another, as well as auxiliary services such as warehouses, customs, maintenance workshops, and insurance offices. Slack (1999) suggests the implementation of satellite facilities/terminals for container storage in order to relieve congestion at seaport terminals. Furthermore, Höltingen (1995), in his review of different intermodal terminals in Europe, aims to find a unique definition for the same and suggests the classification of intermodal terminals. Considerable research has been conducted on how to improve the efficiency of rail–road terminals (Konings, 1996; Ballis and Golias, 2002 and Koizan, 2006) and how find the optimal location for inland intermodal terminals (Rutten, 1998; Macharis and Verbeke, 1999, and Arnold et al., 2004, Pekin and Macharis, 2007). However, the use of these intermodal terminals has not generally been seen as a tool for solving environmental problems until recently.

The objective of this paper is to present the previous research on the dry port concept and to review the world’s existing dry ports, i.e. freight terminals that use the term “dry port” in their name. Therefore the purpose of the paper is to clarify the concept by showing potential discrepancies or agreements between the theory and practice.

Starting from a literature review on the dry port concept, this paper presents a review of existing dry ports in the world through their characteristics, impediments to their implementation as well as their role as driving forces behind numerous advantages for different actors of the transport system. The data collection has been conducted either by interviews or by a questionnaire sent by
email to the dry ports. The scope of the paper is seaports’ inland access with dry ports as part of the intermodal transport chain.

2. METHODS AND CHOICES

This study started with an extensive literature review on the subject of dry ports which provided good insight into the existing and planned dry ports in the world. Scientific journals were the main source of information regarding the research on dry ports, while trade journals and internet based documents provided support for the identification of existing and future dry ports across the world. Containerization International and World Cargo News were of crucial importance for this identification. Once the list of dry ports was established, the data collection was performed through interviews, both personal and telephone, and through questionnaires sent by mail. Personal interviews can play a valuable role in surveys but over the years the use of the same has declined significantly, partly due the cost of fielding a survey and the logistical problems involved (Cotugno and Wood, 2003). Therefore personal interviews in this study were opportunistic, i.e. performed during site visits to relevant ports or during attended conferences or similar logistics research-related gatherings. The phone interviews became the data gathering process of choice for the rest of interviewees; however, many interviewees preferred questions to be e-mailed. Some empirical gaps, such as general technical data, were covered by information gathered from the reviewed dry ports’ web sites or other secondary sources.

A frame of reference for the study was created through a review of papers available through the Scopus database. The searched term “dry port” gave a hit list of 11 papers, 6 of which were disregarded either due to insufficient information, i.e. no source information available or no author name available, or due to lack of complete records. The narrowed-down hit list of 5 papers is spread among 4 journals, of which 3 are internationally recognized with their editorial scope showing a logistics/transportation focus; the Journal of Transport Geography appeared twice. In three of these papers the term dry port appeared in the title. Additionally, available conference proceedings and UNCTAD records were also reviewed for this study and were invaluable sources of information, both for creating a frame of reference as well as for the identification of dry ports for the survey. Two other databases, Science direct and The Web of Knowledge gave fewer hits than Scopus, two and three journal papers respectively, already available through the Scopus.

According to Fink (2002) qualitative survey is particularly useful when one doesn’t have or want a large number or participants. Furthermore, the author states that a qualitative survey provides information of a descriptive nature, while statistical survey provides information answering questions such as “How many?”. Marriot (1990) defines an analytic survey as a survey where the primary purpose of the design is the comparison between sectors or subgroups of the population sampled. The research strategy intended for this study was not a typical statistical survey on a large sample of a certain population, in which the data is analyzed through the systematic use of statistical methodology (Marriot, 1990); rather, the aim was a qualitative, or even more appropriately, analytical survey with respect to the number of participants and the questions asked, which are the combination of the two types of questions. Unfortunately the response was not as good as expected; hence, the study had to be downgraded from the previous ambition of an analytical survey to a more modest review of dry ports.
Gap analysis involves surveys that seek to detect discrepancies, or gaps, between customer expectations of an organization and that organization's ability to deliver on those expectations (Eldredge, 2004). With respect to this definition, the analysis performed on the findings in this study is not labeled as gap analysis even though it seeks to identify gaps; it examines the gaps between findings on existing dry ports as well between the definitions on the concept of dry ports.

3. THE DRY PORT CONCEPT

Hanappe (1986) relates to dry ports as multifunctional logistics centers with a variety of firms operating at the same site. Hanappe’s description corresponds to concept of freight villages, according to Economic Commission for Europe (2001), since this definition does not emphasize a connection to seaports nor specify the range of services offered at the terminals. Beresford and Dubey (1990), in their extensive survey of dry ports in Africa, use a dry port definition that corresponds to the definition of an Inland Clearance Depot, according to UN ECE (1998). Their definition is very specific regarding ownership and services, in particular customs clearance; although with no specification of the type of connection to a seaport. Furthermore, Beresford and Dubey (1990) emphasize the importance of a dry port as a common user facility that would promote the transfer of goods from origin to destination without intermediate customs examination, the so-called through-transport concept.

Essentially, four functions take place at freight terminal: transfer of cargo, mostly unitized, between two modes; the assembly of freight in preparation for its transfer; the storage of freight awaiting pick-up; and delivery and the logistical control of flows (Slack, 1999). In addition to all functions mentioned above, services such as maintenance of containers, customs clearance, and other value-added services should take place at a dry port terminal in accordance with customers’ needs (Roso et al, 2008). The authors define a dry port as an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), preferably rail, where customers can leave/pick up their units as if directly to a seaport. Furthermore, Roso et al (2008) categorize dry ports into distant, midrange and close dry ports, based upon their function and the location. The benefits of these categories are discussed below. Therefore, the Roso et al (2008) approach to dry port concept might be characterized as one step further towards a clarification of the concept, compared to Beresford and Dubey (1990). Although the two approaches share a common background, the former emphasizes the environmental benefit and promotion of intermodal transport, while the latter’s approach is more about transit cost savings and promotion of regional economic activity, among other advantages.

According to Roso et al (2008), dry ports are used much more consciously than conventional inland terminals, with the aim of improving the situation resulting from increased container flows, and a focus on security and control by the use of information and communication systems. Scheduled and reliable high-capacity transportation to and from the seaport is essential and determines the dry port’s performance (Roso et al, 2008 and Tsilingris and Laguardia, 2007). Furthermore the authors define the benefits, for different actors of the transport system, resulting from all three types of dry ports. Implementation of a close dry port in a seaport’s immediate hinterland increases a seaport’s terminal capacity that might result in increased productivity since bigger container ships will be able to call at the seaport. With dry port implementation seaport’s congestion from numerous trucks is avoided, as well as CO2 emissions, since in Europe one train...
can substitute for some 35 trucks (Roso, 2007). The benefits from distant dry ports derive from the modal shift from road to rail, resulting in reduced congestion at the seaport gates and its surroundings as well as reduced external environmental effects along the route. The distant dry port extends the gates of the seaport inland, with shippers viewing the dry port as an interface to the seaport and shipping lines (Beresford and Dubey, 1990, and Tsilingris and Laguardia, 2007). A midrange dry port is situated within a distance from the seaport generally covered by road transport and serves as a consolidation point for different rail services. The high frequency achieved by consolidating flows, together with the relatively short distance, facilitates the loading of containers for one container vessel in the dedicated trains. Hence the dry port can serve as a buffer relieving the seaport’s stacking areas. However, Ng and Gujar (2008) indicate that the current solution, where shippers often choose dry ports located closest to their production base, is not necessarily the optimal solution in terms of the minimization of transport cost, mainly due to government policies and dry ports’ inability to provide value-added services needed by the shippers. Although a concept of a dry port should bring numerous benefits to the actors of the transport system, there are still many impediments to the implementation of the same; the most common are land use, infrastructure, environmental and institutional impediments (Roso, 2008).

As illustrated in Figure 3.1, implementation of a dry port could create seamless seaport inland access, i.e. smooth transport flow with one interface in the form of the dry port concept, instead of two, with one at the seaport and the other at the inland destination (Roso and Lumsden, 2009).

Figure 3.1 Illustration of a dry port concept shown on a transport network with and without a dry port (Roso and Lumsden, 2009)

Besides the necessity for scheduled and reliable rail connection in the creation of seamless seaport inland access, security at a dry port is also of crucial importance, in particular if it is to perform customs clearance. The implementation of the ISPS (International Ship and Port facility Security) code involves changes in both the physical design of the security in a port area and
adjoining facilities but also changes in general port activities (Mazaheri and Ekwall, 2009). Consequently, it raises the cost of implementation of the dry port.

After studying the failure of a dry port in Egypt, Vandervoort and Morgan’s (1999) recommendation for successful dry ports is that a dry port must fit into a complex system where the necessary supporting infrastructure is in place, maintenance is assured, and the legislative and institutional systems are properly designed to optimize the involvement of both the public and the private sector.

4. FINDINGS ON EXISTING DRY PORTS ACROSS THE WORLD

In this chapter, the reviewed dry ports, arranged by continents and countries, are briefly described with emphasis on the most important features mentioned in the previous chapter. Eleven dry ports are reviewed in this paper; however, the list of identified dry ports - facilities using the term dry port - on four continents was much longer. Many identified dry ports were not included in the analysis for various reasons, such as for being inaccessible, or because a certain terminal facility is referred to as a dry port in informal jargon but the official name of the facility is either ICD or container depot. The reasons for these exclusions are explained below.

In South America, particularly in Brazil, there are 62 facilities named EADI Estação Aduaneira do Interior, meaning Interior Customs Station in Portuguese, sometimes also referred as porto seco, meaning dry port (Ministero de Fazenda, 2009). The facility is defined as a public customs facility located in the secondary zones and offering services such as handling, storage and customs clearance of goods and luggage under customs control (Ministero de Fazenda, 2009). To some extent this definition corresponds to that of an Inland Clearance Depot according to Economic Commission for Europe (2001), but the former does not specify whether it is a freight terminal for intermodal transshipment nor the type of traffic modes used for the connection to seaports. Due to these discrepancies the same does not fit into the scope of the paper.

Asia has a long tradition of ICDs and dry ports and many were identified for the purpose of this study, unfortunately most of them were unreachable either by phone or e-mail; such as Soost, Lahore, Peshawar, Rawalpindi, and Quetta, all in Pakistan; CWT Dry Port in Cambodia; Biratnagar and Bhairahawa in Nepal, The Thar dry port in India, just to name few. Chinese seaports Ningbo, Tianjin and Dalian started to implement terminals with dry port features few years ago and today there are 11 such facilities connected by rail to the seaports offering services of transshipment, customs clearance and forwarding (JC Trans Logistics Inc., 2008). However the facilities are called waterless-ports or inland ports; due to this different terminology, as well as language barrier, they are not included in the survey.

In France there is the seaport Dunkerque which has an on-dock terminal called Dry Port Dunkerque (World Cargo News, 2000a) which as such is not of interest for this study.

After the delimitation, the dry ports below are analyzed in this study.

4.1. Dry ports in Europe

Dry Port Azuqueca de Henares, situated 30 km from Madrid, is jointly owned by the private sector and the state since 1995. The facility has daily rail connections to the ports of Barcelona (600 km), Bilbao (400 km) and Santander (400 km). In 2007 the facility handled 18000 TEU,
which is a significant improvement compared to approximately 3000 TEU handled in 2006. The area of the terminal is 6 ha, of which 1,1 ha are designated for the storage of loaded containers and 1,3 ha are for depot. The units are handled by 1 gantry crane, 3 reach stackers/counterbalanced trucks for loaded containers and one forklift for empty containers. The dry port with its 5 employees offers a wide range of services, such as customs clearance, maintenance of containers, consolidation, road haulage, and the previously-mentioned transshipment and storage. The biggest impediments to its success were the condition of the existing rail infrastructure, as well as regulations (monopoly of the rail), which were eventually overcome. Advantages resulting from the implementation of the dry port are increased volume, better customer service, new jobs in the area due to establishment of new customers, and finally lower environmental impact.

Dry Port Madrid in Coslada is a result of joint efforts and interest of the Spanish Ministry of development, the Municipalities of Madrid and Coslada, the Spanish Port Authority and the Spanish national rail operator, RENFE. The idea for its implementation came in 1995 and the terminal was operational in 2000; however, its dry port status was gained only in 2003. The dry port generates advantages such as increased use of rail, which resulted in increased volume and consequently lower transport costs, as well as lower environmental impact and lower congestion at the seaports. Furthermore, the use of dry port brings competitive advantages to the seaports as well as attracting new business in the area that result in the creation of new jobs. Today the dry ports’ major owners are 4 Spanish ports with the following distances from the dry port: Barcelona at 600 km, Bilbao at 400 km, Algeciras at 660 km and Valenica at 360 km. The dry port is equipped with 3 reach stackers and 3 forklifts, for the handling of 60000 TEUs a year on an area of 14 ha. Services such as customs clearance and forwarding are also available. There is a storage area of 1,6 ha as well as a container depot of 1,8 ha. This facility experienced the same problem as Dry Port Azuqueca de Henares; and that was the condition of the existing rail infrastructure and regulations.

Dry Port Santander-Ebro, jointly owned by the private sector and the Port of Santander, began operation in June 2000. The dry port has rail connections to the ports of Santander (400 km), San Sebastian (260 km), Bilbao (300 km), and Barcelona (300 km). On the terminal’s area of 10 ha, it offers services of transshipment, storage, customs clearance, maintenance and various value added services such as the control of vehicles for new cars waiting for export. The containers are handled by a counterbalanced truck with top lift. The main reason for its implementation was development of the Zaragoza area; the intention was to create a logistics hub for Southern Europe (World Cargo News, 2000b).

Eskilstuna Dry port in Sweden was the very first intermodal terminal in Sweden to start to use the term dry port in its official name. The dry port was realized through cooperation between the Eskilstuna municipality and the two rail operators. The idea for the implementation of the terminal came in the autumn 2002, when the Eskilstuna municipality promised to build a terminal to attract the biggest Swedish apparel manufacturer to the area. The dry port is situated 380 km from the Port of Göteborg and 550 km from the port of Malmö, and handles daily container trains with the ports. Although it is rather new, with operations beginning in 2003, it already handles 45000 TEUs/year, of which 80% are transported on rail. The terminal area is about 2 ha, where 5 employees offer services of transshipment with the use of 2 reach stackers, handling of dangerous goods, storage and depot, customs clearance and road haulage. As the biggest advantage from the implementation of the dry port, the operator pointed out the attractiveness of the municipality for
new activities in the area, which resulted in the establishment of new business and consequently the creation of new job opportunities in the area. Furthermore, the movement of such a large such volumes of containers from road to rail resulted in reduced congestion at the seaports, improved seaport inland access and reduced environmental effects along the transport route.

Swedish Dry Port Hallsberg is jointly owned by the municipality and rail operators, who also initiated the implementation of the combi terminal at the end of the 1990s. The dry port experienced no obstacles to its implementation; today it employs 27 people and has been run by Hallsbergkombiterminallen AB (owned by the dry port owners) since 2003. There are daily rail connections to the ports of Göteborg, 260 km; Trelleborg, 500 km and Malmö, 470 km away. On its 6,2 ha the dry port offers the following services: transshipment with 2 reach stackers, storage and depot of 0,4 ha, customs clearance, maintenance of containers, cross docking, forwarding and road haulage. The terminal handles 65000 TEU a year. The biggest advantage, apart from improved customer service for the customers in the area, is the attractiveness of the region for the establishment of new businesses, which resulted in new jobs in the region. Furthermore, with dry port implementation the rail transport increased and generated increased capacity and volumes at the seaports, as well as improved inland access to the seaports. Consequently congestion at seaport terminals as well as environmental impact decreased.

Dry Port Muizen in Belgium was implemented in 1994 by the national railway and therefore experienced no obstacles during its implementation, as its financing was made available by the government agency. The dry port is run by Inter Ferry Boats and has a daily rail connection to the ports of Zeebrugge. On an area of 4,2 ha the dry port offers services of transshipment by 2 gantry cranes and 3 reach stackers, as well as storage. Today the dry port handles approximately 12000 TEU all of which are transported by rail to the seaports. The biggest advantage is lower environmental effect due to use of rail for the transport of containers.

4.2. Dry ports in Africa

Isaka Dry Port in Tanzania is one of rare facilities to acknowledge gaining the dry port status, in 1999, by offering customs clearance to its customers. For a long time the facility was only a railway station, that in the late 1980s, due to increased freight transport to neighboring Rwanda started to develop into a freight terminal. The dry port has direct daily rail connections to the seaport Dar es Salam some 800 km away, and offers the same services as those available at the seaport, apart from sea-shore transshipment. Th e facility is owned and operated by Tanzania Railways, which handles approximately 13000 TEU a year on an area of 11 ha. The containers are handled by 2 reach stackers and 4 fork lifts for empty containers. The facility is of essential importance for neighboring landlocked countries Rwanda, Burundi and Congo. With the dry port implementation, customer service has been significantly improved, in particular regarding safety of cargo, faster delivery and lower transport cost. Furthermore congestion at the seaport is reduced significantly and with it delays as well.

Matsapha Dry Port in landlocked Swaziland, funded by Swaziland Railway, started operation in 1993 as a response to the growth of country’s containerized exports. The dry port has a daily rail connection to the 500 km-distant seaport of Durban and the 400 km-distant Richards Bay Ports in South Africa, and the 200 km-distant Maputo Port in Mozambique. It offers all the services a seaport should offer, such as transshipment by a reach stacker, tracking, storage and depot, and road haulage; the emphasis is on customs clearance for faster throughput. The main advantage provided by the dry port since its inception is better customer service, i.e. reduced delivery time
and reduced transport cost; consequently the area is more attractive for new businesses/customers. The main obstacle was financing, which was secured from foreign investors.

4.3. Dry ports in Asia

Riyadh Dry Port in Saudi Arabia started to operate in 1982, and in 2003 reached 250000 TEU’s in volume handled and transported by rail to King Abulaziz port (400 km distant) in Dammam. The area of the dry port is 92 ha, of which almost 4 ha are destined for storage. The dry port is run by the Saudi Railway Organization and owned by the Saudi Port Authority. Services available are transshipment by gantry cranes, reach stackers and forklifts; refrigerated storage; customs clearance; maintenance of containers; road haulage and forwarding. The main advantage it provides is improved customer service.

The privately-owned Birgunj dry port in landlocked Nepal has been operational since 2005; however, the process of implementation was not smooth. From the initial idea in 2000, many problems occurred, in areas such as the appointment of appropriate bidders and the evaluation of financial proposals; even after the completion of the terminal, the problem was to reach the service agreement with Indian Railways (World Cargo News, 2001). The terminal has a fixed timetable rail connection to the Port of Kolkata (approximately 700 km away). Although privately owned, the financing was supported by World Bank (World Cargo News, 2005). The containers are handled on an area of 38 ha with 3 reach stackers and one reach stacker for empty containers. To attract more customers the dry port offers reduced tariffs, simplified documentation and increased rail frequency.

Faisalabad Dry Port is the biggest privately owned dry port in Pakistan, considering volume and value. The dry port was implemented and opened for operation in 1994 by a board of trustees whose main intention was to facilitate export for the local textile industry. There are daily road and rail connections to Karachi Port. Annually there are about 33000 TEU for export and 7000 TEU for import, handled by 4 reach stackers and forklifts for empty units. The dry port significantly contributed to the development of the industry and trade in the area. Apart from this the facility enabled lower transport costs and better customer service by offering customs clearance and storage.

5. SYNTHESIS OF THE RESULTS AND THE DISCUSSION

Europe doesn’t have a long tradition of dry ports; some of the reviewed dry ports, such as the two in Sweden, only recently began to operate as dry ports. However, many European intermodal terminals tend to use the term dry port in everyday jargon. Furthermore, some of the dry ports started as conventional terminals and eventually developed into dry ports, offering extra services to their customers.

Asia, in particular Pakistan, has been very agile regarding the development of inland intermodal facilities, many of which are labeled as dry ports. In Pakistan there are privately- and state-owned dry ports, among the oldest ones in the world, some in operation as far back as 1973. Unfortunately, many were not covered in this study due to their inaccessibility.

In Africa and Asia the concept of a dry port is closely associated with the through-transport concept, which is achieved by transfer of containers from origin to destination without
intermediate customs examination (Beresford and Dubey, 1990), i.e. seamless intermodal transport, which is of crucial importance for landlocked countries. Therefore all of these dry ports fit into the concept of distant dry port with distance to the seaports of up to 1000 km, like in the case of Faisalabad.

When it comes to reviewed dry ports’ ownership, there is no apparent pattern; in Table 1 one can observe all three types of ownership: private, state/municipality and the combination of these two. However, there is a continent pattern to a certain extent when it comes to ownership. In Europe most of the dry ports are jointly owned by private sector and municipality or some other state agency, in Africa it is mostly state ownership, and in Asia dry ports are either state or privately owned.

All of the reviewed dry ports, Table 1, differ in volume handled and in the size of their terminals, with no apparent pattern; but there is one common feature for all of them, and that is the daily rail connection to the seaports. When it comes to handling equipment, all of the dry ports are equipped with reach stackers for handling containers of different weights; additionally, some also have gantry cranes or forklifts for empty containers. Customs clearance and storage, besides transshipment, are common services available at all reviewed dry ports; though not at Muizen, which as such might be categorized as a conventional intermodal terminal. Other services available at a majority of the dry ports are maintenance of the containers, forwarding and road haulage. Some of the reviewed dry ports offer more value-added services in accordance with their customers needs.

The impediments identified in this study (see Table 2 and Figure 5.1) generally correspond to those identified by Roso (2008) with one exception: none of the reviewed dry ports experienced problems due to local environmental issues. This could be anticipated since all reviewed dry ports are located in rural areas or are not very close to residential areas, which was the case in the study by Roso (2008) where dry ports were situated within or very close to metropolitan areas. In general, the reviewed dry ports have not experienced impediments to a large extent; regulations were the most frequently identified impediment in the study, but by less than 30% of reviewed dry ports. Only one dry port experienced a land use problem, and not in the early phase but rather in future plans for expansion.

The second diagram in Figure 5.1 shows that the reviewed dry ports have not experienced significant numbers of impediments; in other words, many of them had a smooth path on their way to realization. One impediment, previously not identified, was the financing of dry ports; this is rather self-evident since the implementation of a dry port requires substantial financial resources. If one neglects financing as an impediment, since it is always an issue, it turns out that more than 50% of reviewed dry ports have not experienced any impediments to implementation and operation.
Table 1 General information and range of services offered at the reviewed dry ports

<table>
<thead>
<tr>
<th>Dry Ports</th>
<th>Owner</th>
<th>Started</th>
<th>TEU a year</th>
<th>Area ha</th>
<th>Rail frequency</th>
<th>Transship g, s, r, f*</th>
<th>Customs clearance</th>
<th>Storage</th>
<th>Maintena nce</th>
<th>Forward ing</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>Azuqueca de H mix</td>
<td>1995</td>
<td>18000</td>
<td>6</td>
<td>daily</td>
<td>1g, 3r, 1f</td>
<td>yes</td>
<td>2,4 ha</td>
<td>yes</td>
<td>yes</td>
<td>road haulage, consolidation</td>
</tr>
<tr>
<td></td>
<td>Madrid Coslada mix</td>
<td>2000</td>
<td>60000</td>
<td>14</td>
<td>daily</td>
<td>3r, 3f</td>
<td>yes</td>
<td>3,4 ha</td>
<td>no</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Santander Ebro mix</td>
<td>2000</td>
<td>na</td>
<td>10</td>
<td>daily</td>
<td>1r</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>vehicle control</td>
</tr>
<tr>
<td>Sweden</td>
<td>Eskilstuna mix</td>
<td>2003</td>
<td>45000</td>
<td>2</td>
<td>daily</td>
<td>2r</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>road haulage, dangerous goods</td>
</tr>
<tr>
<td></td>
<td>Hallsberg mix</td>
<td>2003</td>
<td>65000</td>
<td>6,2</td>
<td>daily</td>
<td>2r</td>
<td>yes</td>
<td>0,4 ha</td>
<td>yes</td>
<td>yes</td>
<td>road haulage, cross docking</td>
</tr>
<tr>
<td></td>
<td>Muizen state</td>
<td>1994</td>
<td>12000</td>
<td>4,2</td>
<td>daily</td>
<td>2g, 3r</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>-</td>
</tr>
<tr>
<td>Africa</td>
<td>Isaka state</td>
<td>1994</td>
<td>13000</td>
<td>10</td>
<td>daily</td>
<td>2r, 4f</td>
<td>yes</td>
<td>1,2 ha</td>
<td>yes</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>T²</td>
<td>Matsapha state</td>
<td>1993</td>
<td>na</td>
<td>na</td>
<td>daily</td>
<td>1r</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>road haulage, tracking</td>
</tr>
<tr>
<td>Asia</td>
<td>Riyadh state</td>
<td>1982</td>
<td>250000</td>
<td>92</td>
<td>daily</td>
<td>g, r, f</td>
<td>yes</td>
<td>4 ha</td>
<td>yes</td>
<td>yes</td>
<td>road haulage, refrigerated storage</td>
</tr>
<tr>
<td>S¹</td>
<td>Birgunj private</td>
<td>2005</td>
<td>na</td>
<td>na</td>
<td>timetable</td>
<td>4r</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>-</td>
</tr>
<tr>
<td>N⁵</td>
<td>Faisalabad private</td>
<td>1994</td>
<td>40000</td>
<td>na</td>
<td>daily</td>
<td>4r, f</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>-</td>
</tr>
</tbody>
</table>

Legend: 1 Belgium, 2 Tanzania, 3 Swaziland, 4 Saudi Arabia, 5 Nepal, 6 Pakistan; * g=gantry crane, s=straddle carrier, r=reach stacker, f=forklift truck.
## Table 2 Impediments and advantages identified by reviewed dry ports

<table>
<thead>
<tr>
<th>Impediments</th>
<th>Advantages resulting from dry port implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Land use</td>
</tr>
<tr>
<td>Azuqueca de H</td>
<td>-</td>
</tr>
<tr>
<td>Madrid Coslada</td>
<td>-</td>
</tr>
<tr>
<td>Santander Ebro</td>
<td>na</td>
</tr>
<tr>
<td>Eskilstuna</td>
<td>yes</td>
</tr>
<tr>
<td>Hallsberg</td>
<td>-</td>
</tr>
<tr>
<td>Muizen</td>
<td>-</td>
</tr>
<tr>
<td>Isaka</td>
<td>-</td>
</tr>
<tr>
<td>Matsapaha</td>
<td>-</td>
</tr>
<tr>
<td>Riyadh</td>
<td>-</td>
</tr>
<tr>
<td>Birgunj</td>
<td>-</td>
</tr>
<tr>
<td>Faisalabad</td>
<td>-</td>
</tr>
</tbody>
</table>

Legend: 1 Belgium, 2 Tanzania, 3 Swaziland, 4 Saudi Arabia, 5 Nepal, 6 Pakistan.
Some impediments, or lack of the same, may easily be related to the advantages brought by the dry ports to different actors in the transport system. For instance, local environmental issues were not recognized as impediments by any reviewed dry port, and at the same time, as a majority of them are situated in rural areas, many dry ports stated regional growth and new jobs in the area as the most important advantages (Figure 5.2.). Increased port capacity is the least-recognized advantage, since the reviewed dry ports are mostly implemented by local municipalities or in cooperation with them, and their foremost intention is regional development through the attraction of new industries to the area, once logistic solutions are available. The most important advantage resulting from dry ports is better customer service, which is recognized differently by the reviewed dry ports but might be summarized as the following: lower transport cost, more value-added services at the customers’ doorstep, faster transport of units to/from the seaports, faster customs clearance, simplified documentation and lower storage rates.

Figure 5.1 Impediments experienced by the dry ports in the study

Figure 5.2 Advantages resulted from the implementation of dry ports in the study
6. CONCLUSIONS

The dry port concept, when defined as an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), preferably rail, where customers can leave/pick up their units as if directly to a seaport, ideally represents the dry ports reviewed in this study. Even the extra services offered at the studied dry ports, such as customs clearance and storage, correspond to those previously identified by various researchers. Other services, such as the maintenance of containers or forwarding, were not available at all the dry ports; therefore, they do not have to be considered as essential for the dry ports’ viability.

Regarding the dry ports role as the driving forces behind various advantages for actors of the transport system; all of the reviewed dry ports brought at least two advantages for the actors of the system. Improved customer service and creation of new jobs in the area, advantages both closely related to regional growth, were the most recognized advantages, and particularly so for landlocked countries. Closely related to all the advantages are the impediments, or the lack of the same; the reviewed dry ports have not experienced significant impediments, and some faced no impediments at all; in other words, many had a smooth path on their way to realization.

During the review of trade journals, numerous papers regarding future dry port projects in many developing countries have been encountered. These projects have not been included in the review due to the scope of the study; however, the fact that so many developing countries’ governments have realized the importance of dry ports is promising. However, to further develop the concept and to get better understanding of the drivers for implementation of dry ports or factors that hinder implementation of the same; those planned dry ports should be included in the survey.

REFERENCES


