Financial and Environmental Impacts of Hypothetical Finnish Dry Port Structure

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Abstract

One main theme of European Union in transport policy statements has been the increased role of railways in reducing environmental impacts and costs of transport activity. One option to increase the modal share of rail transport is to use dry port concept, particularly applicable in general cargo. At Port of Gothenburg (Sweden) increased use of this concept with rail transport has led in decreased CO_2 emissions, and lower transport energy costs. Our main objective and motivation of this research work is to examine through analytical models, how this same dry port concept should be implemented in Finland, with estimates of benefits being gained.

Research method of this study is macro gravitational models of distribution. Main input data for the models are distances and population in the area. Aim of this approach is to research, how the relative transport costs behave by increasing the number of dry port distribution places. For actual computation work we use linear integer programming. Based on the results, we argue that relative transport costs can decrease considerably by increasing the number of dry ports, up to the level of six locations. This is considerably less than what is the current situation in Sweden. Solution also differs from Sweden in a way, that fragmented Finnish seaport system enables the usage of numerous seaports instead of one, which decreases transportation amounts considerably further.

Keywords: Dry port, gravitational models, transport, costs, environment

1. Introduction

Transportation is the only sector with increasing environmental impacts e.g. CO_2 emissions (European Communities, 2009b; UIC, 2009). EU will increase its attention in decreasing the pollution of transportation by using different methods e.g. CO_2 taxing and encouraging environmentally friendlier modes of transport (European Commission, 2001). One of the main objectives of the EU is to increase proportional share of rail transport by increasing the use of intermodal transportation (European Commission, 2001; European Communities, 2009a). Decreasing emission amounts in hinterland transports could be achieved by using dry port concept, which relies on the smooth and coherent operative usage of inland intermodal terminals and transport equipment. In the dry port concept the inland transportation between seaport and dry port is performed in most parts by rail instead of traditional road transport. Only the final leg of transportation is being performed by road from dry ports to the final place of demand. Many studies have found out that rail transport is more inexpensive mode of transport than road transport, especially in terms of environmental friendliness (Bauer *et al*., 2010; Chapman, 2007; Facanha and Horvath, 2006; Forkenbrock, 2001; Henttu *et* al., 2010; Janic, 2007; Winebrake *et al*., 2008). Corollary of rail being environmentally friendlier, the whole transportation system can decrease its environmental impacts by increasing the share of rail transport. There are also many studies with results that intermodal transport on the whole can be used as cost-efficient and environmentally friendly transport mode (Janic, 2007; Macharis and Bontekoning, 2004). In addition, dry ports offer similar services as seaports, but in hinterlands, where value added services of transportation could be lower cost, owning higher flexibility, and being in closer proximity to final customers. In Sweden this kind of dry port network has been used increasingly during the recent decade, and has led in lower environmental emissions, and considerable energy savings. It is possible that same kind of dry port network would increase environmental friendliness of Finnish transportation system too. However, large-scale usage of dry ports in Finland is still in its infancy, and could not be compared by any means that of Sweden.

Main research method used in this research is macro gravitational models of distribution. Models are completely quantitative by their nature, and are based on numerical data concerning populations of chosen main cities (TOP50 of Finland), and distances between chosen used seaports (maximum amount used is four), dry ports (ranging from one to nine), and most important cities of consumption (TOP50 of Finland). Aim of the gravitational models is to compare relative transport costs and environmental impacts with different amounts of dry ports used (ranging from one to nine), and examine, how performance evolves with different configurations. Models use linear integer programming to achieve optimal distribution strategy for each setting.

Structure of this research is as follows: Literature review concerning previous studies is presented in the following Section 2. It mainly concerns the dry port concept and studies that have researched, how to choose optimal locations for inland intermodal terminals. In Section 3 we introduce research environment of Finland, and chosen main seaports, dry port locations and modeling logic. Modeling results are presented in Section 4. Aim of these is to investigate, the possible positive impacts of dry port network implementation in Finland concerning transportation costs and environmental harm caused. Conclusions of this study are represented in Section 5 with consideration of further research in this topic area.

2. Environmental Issues of Transport, and Dry Port Concept

One of the largest global sources of pollution is transportation activity fuelled by increased globalization and trade. In fact, transportation is the only sector that has not been able to decrease or even maintain its level of pollution (European Communities, 2009b; UIC, 2009). All the other sectors (energy industries, industry, households, services etc.) have at least halted the increase of their pollution levels (European Communities, 2009b). The EU has pointed out that it will increase its participation in trying to decrease pollution levels that originate from transportation (European Commission, 2001). One way to decrease emissions from transportation activity is to use environmentally friendlier modes of transport, namely rail instead of road (European Commission, 2001; European Communities, 2009a). Therefore, usage of dry ports fits this situation well, since it aims to increase modal share of rail transport instead of road transport, and uses de-centralized dry ports located in hinterland to achieve its objectives (Henttu *et al*. 2010).

Most of the dry port research has been conducted during the last decade time period. Roso (2009a, b), Roso *et al*. (2008) and Woxenius *et al*. (2004) have made considerable research about the dry port concept, impacts resulting from it and factors influencing its implementation. Roso (2009b) has defined the dry port concept as:

"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 transshipment 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 concept is part of intermodal transportation system. The dry port itself is an inland intermodal terminal with additional services located inlands. It is directly connected by rail to seaport or in some cases two or more seaports. In a dry port concept, the maximum possible amount of freight transportation is accomplished by rail between the dry port and the seaport. Only the final leg of the door-to-door transportation is carried out by road transport from hinterland dry port terminal. In the most desirable situation of dry port implementation whole freight transportation between seaport and dry port is carried out by rail. However, that is not usually possible due to capacity constraints of rail connection, and flexibility required. (Roso, 2009a, b)

A flawless connection between road, rail and seaport enables fast and reliable movement of freight. The performance of a dry port is measured from the quality of access to the dry port and the quality of the road-rail interface (*Roso et al*., 2008). The dry port offers value-creating services (e.g. consolidation, storage, depot, maintenance of containers and customs clearance) to actors, which operate within the transportation system i.e. there is a whole range of administrative activities that could be moved inland with implementation of a dry port. Outsourcing activities from seaport to dry port relieves seaport, and hence seaport can concentrate in its core tasks and competencies.

In order to meet greater demands from shipping lines, ports are forced to respond by enlarging hinterland areas, with the creation of inland terminals such as dry ports, to enhance or sustain their relative competitiveness (*Lee et al*., 2008). As container transport volume continues to grow, seaports' inland accesses become more critical factors for the seaports' competitive advantage, because inland access easily becomes a constraint for a seaport, if it is not developed enough (Roso, 2009b).

Because the implementation of dry ports increases the use of intermodal transport, especially rail transport, it can decrease the environmental impacts of the whole transportation system. Many studies support the assumption that rail transport is environmentally friendlier mode of transport than road transport (Bauer *et al*., 2010; Chapman, 2007; Facanha and Horvath, 2006; Forkenbrock, 2001; Henttu *et* al. 2010; Janic, 2007; Winebrake *et al*., 2008). By implementing one or more dry port solutions, it is possible increase regional transportation efficiencies (Rahimi *et al*., 2008).

There are differences in dry ports according to their geographical location. Woxenius et al. (2004) and Roso et al. (2008) have categorized different dry ports according to their functions and distances from the seaport. There are three different definitions for different kinds of dry ports, and they are: close, midrange and distant dry port. All the dry ports are located at the seaport's hinterland areas, because they serve them. It is possible that different dry ports serve more than one seaport. In that case seaports share areas of their hinterland with other seaports.

All dry port categories share many common benefits. First of all, properly implemented dry port reduces congestion at the seaports immediate closeness by modal shift from road to rail. The congestion is also reduced at the seaport cities and roads connecting cities as road transportation considerably decreases, while transportation at rails increase. Rail operators gain more market share, because more freight is being transported by rail. Shippers gain a greater range of logistics services, thanks to dry ports. For the entire society the dry port enables lower environmental impacts, job opportunities and regional development. The most apparent benefit from environmental perspective comes from the modal shift from road to rail, which results in less congestion and less pollution. (Woxenius et al., 2004; Roso et al., 2008)

Distant dry ports are located over 500 kilometers from the seaport. The main advantage of distant dry port is its capability to provide vital transportation over long distances from a strict cost perspective i.e. rail transport is more cost-efficient transportation mode than road transport, especially at long distances. Part of the benefits relate to the modal shift from road to rail that results in reduced congestion and environmental impacts. Distant dry ports improve seaports’ ability to offer a more efficient inland access. (Roso et al., 2008; Roso 2009b)

Midrange dry ports are situated between close and distant dry ports. The distance from the seaport is approximately 100 – 500 kilometers. Midrange dry ports usually offer depot facility. All the other advantages are similar to distant dry ports. (Roso et al., 2008; Roso, 2009b)

Close dry ports are located near the actual seaport. Distance between seaport and dry port is less than 100 kilometers. Close dry ports offers seaports a place for depot and also an increased terminal capacity. The close dry port offers consolidation for road transport to and from the seaport. Straight rail link between dry port and seaport relieves the seaport cities’ streets. (Roso et al., 2008; Roso, 2009b)

This study aims at choosing the amount of dry port implementations with most cost-savings, if cost-savings are possible. In addition, this research studies, which dry ports locations should be saved, if the amount of dry ports is decreased. There are other researches that have studied how to choose location for inland intermodal terminals. Difference with earlier research compared to this research is that we have used alternative method on choosing the number and location of different dry ports. There is a short literature review below concerning different studies that have researched how to choose a specific location for inland intermodal terminal or how to expand seaports.

There are several studies on how to optimize the location of one or more inland intermodal terminals to create the transportation system more cost-efficient. Rahimi *et al*. (2008) have used location-allocation methodology (methodology aims at minimizing truck-miles) to choose one or more optimal locations for regional inland intermodal terminals to support seaport. In their study, Racunica and Wynter (2005) represented an optimization model, which has been developed for hub location problem. Agent-based modeling has been used to optimize the geographic location of inland intermodal terminal (Ackchai *et al*., 2007). In addition, agent-based modeling has been used to research flow of containers in container terminal (Gambardella *et al*., 2002). Limbourg and Jourquin (2009) have used p-hub median problem to solve optimal locations for European inland intermodal terminals for a hub-and-spoke network. Heuristic methods have also been used to research optimal locations for regional inland intermodal terminals (Arnold *et al*., 2004). Bergqvist and Tornberg (2008) included GIS-T (Geographic Information Systems for Transportation) in their modeling method to research optimal location for inland intermodal terminal in regional area in Sweden. In their study, van der Horst and de Langen (2008) have analyzed the coordination problems in hinterland transportation. They have also analyzed different procedures how to resolve problems concerning hinterland transportation. Dekker and Verhaeghe (2008) have used optimal control theory to estimate how to expand seaport. In addition, there is a research that uses modeling on how the shippers could optimally select the seaports (Magala and Sammons, 2008).

3. Research Environment

Research environment concerns Finland with its 50 largest cities. Also four different seaports and nine different dry port locations are chosen (see Figure 1 for details). Idea was to select four most suitable seaports to support larger dry port structure, all over the Finland, which is large country as compared to its population, and has long coastal line as well as numerous seaports. Port of Kotka is one of the east most port in Finland (among Hamina), Port of Helsinki is approx. 140 km from Kotka to west, while Port of Pori is located in the west coast, and Port of Oulu in north. Dry port cities were selected based on their location to serve TOP50 cities as well as with appropriate access to railway network as well as preparedness for needed basic infrastructure.

Seaports	TEU vol. (2009)	Share
Kotka	345,939.00	30.7%
Helsinki	357,204.00	31.7%
Pori	29,087.00	2.6%
Oulu	30,224.00	2.7%
Total	1,125,450.00	

Shortest distance to dry port as selection criteria (railway network).

Dry ports
Kouvola
Kotka
Vantaa
Tampere
Oulu
Turku
Jyväskylä
Kokkola
Rovaniemi

Shortest distribution cost as selection criteria for dry port's distribution cities - uses linear integer programming (road network).

TOP50 Cities	Population
Helsinki	583,995.00
Espoo	244,695.00
Tampere	211,643.00
Vantaa	198,203.00
Turku	176,310.00
Oulu	139,379.00
Jyväskylä	129,749.00
Lahti	101,022.00
Kuopio	92,663.00
Kouvola	88,175.00
Pori	82,859.00
Joensuu	72,753.00
Lappeenranta	71,929.00
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Figure 1. Modelled hypothetical dry port structure of Finland using four seaports, nine alternative locations for dry ports and 50 largest cities as consumption places. Source: (TEU volume): Finnports (2010)

Main difference between Finnish and Swedish logistical structure is that in Sweden there is more or less only one seaport (Port of Gothenburg) that is mainly used for container traffic as in Finland there are four or five different seaports that mainly are used for container traffic (among numerous smaller ones). Main reason for using Port of Gothenburg as the main container port in Sweden is its geographical location and short access to deep seas. This study uses macro gravitational models of distribution to research, if similar dry port network improves the level of Finnish inland transport network.

In our approach first gravitational model created is the one with nine different dry port cities (all potential dry port cities of Figure 1). It is the largest model. Next gravitational model uses eight different dry ports, and following one seven, until we have only one dry port location to serve entire country. Logic in selecting, which dry port location "drops from the list" at each time, is relatively straight forward: dry port, which is serving lowest amount of TOP50 cities, and has least transportation activity (distance times population).

Rail network distances from four different seaports to different dry ports are gathered from Finnish Transport Agency sources (Ratahallintokeskus, 2009). Distance to each dry port is from nearest seaport. Road network distances from chosen dry ports to 50 largest Finnish cities are gathered from Google Maps (2010) and ViaMichelin (2010). Populations of the 50 largest Finnish cities are gathered from Finnish population register centre (Väestörekisterikeskus, 2010).

The first gravitational models consider only distances between seaports, dry ports and TOP50 cities added with population of the TOP50 cities. In addition, two different types of gravitational models were created. The second type of gravitational models includes total costs for both the road and rail transport. In their research, Henttu *et al*. (2010) calculated total costs of road and rail transport in Finnish transport network. Costs are 0.0506 Euros per ton-kilometer for road transport and 0.0270 Euros per ton-kilometer for rail transport. Increasing use of rail transport can decrease total costs of the transportation, because total costs of rail transport are less than same costs of road transport. These costs are used in the second type of gravitational models.

The final type of gravitational models is based on similar costs as previously explained models. The final type of models includes external costs calculated by Henttu *et al*. (2010) for both the road and rail transport. External costs include CO_2 emissions, congestion, noise and accidents. External costs used in this research for road transport are 0.007 Euros per ton-kilometer and 0.0007 Euros per ton-kilometer for rail transport. With this type of gravitational models, the difference in environmental impacts with different number of dry port solutions can be researched in terms of relative external costs.

4. Modeling Results of Hypothetical Finnish Dry Port Structure

Results of the first gravitational models concerning relative transport costs are illustrated in Figure 2 below. In y-axis we describe the amount of relative transport costs incurred by varying number of dry ports being used (relative due to fact that transportation amounts are measured by multiplying population and distance with each other). The lightest line represents similar relative costs between seaports and dry ports, which has continuously increasing tendency, if additional dry ports are being added into system. It means that by increasing the number of dry ports, the amount of rail transport increases. Basically, the lightest line represents, the amount of rail transportation with different number of dry port implementations. However, reward from this is shown in the darkest line, where road transportation costs decrease by adding closer distribution terminals. By increasing the number of dry ports, the amount of road transport decreases. The line in the upper part of Figure 2 represents total relative transport costs of the dry port system implemented with varying number of inland terminals. It is the relative transport costs of rail transport added with same costs of road transport. As can be seen from Figure 2, total relative costs decrease significantly with first added dry ports, but the proportional decrease in relative transport costs becomes lower by adding more dry ports in the system. At around four to six dry ports, the decrease in relative transport costs is not considerable anymore. By increasing the number of dry ports further from six, relative transport costs will not decrease significantly – implying some sort of asymptote for transportation costs.

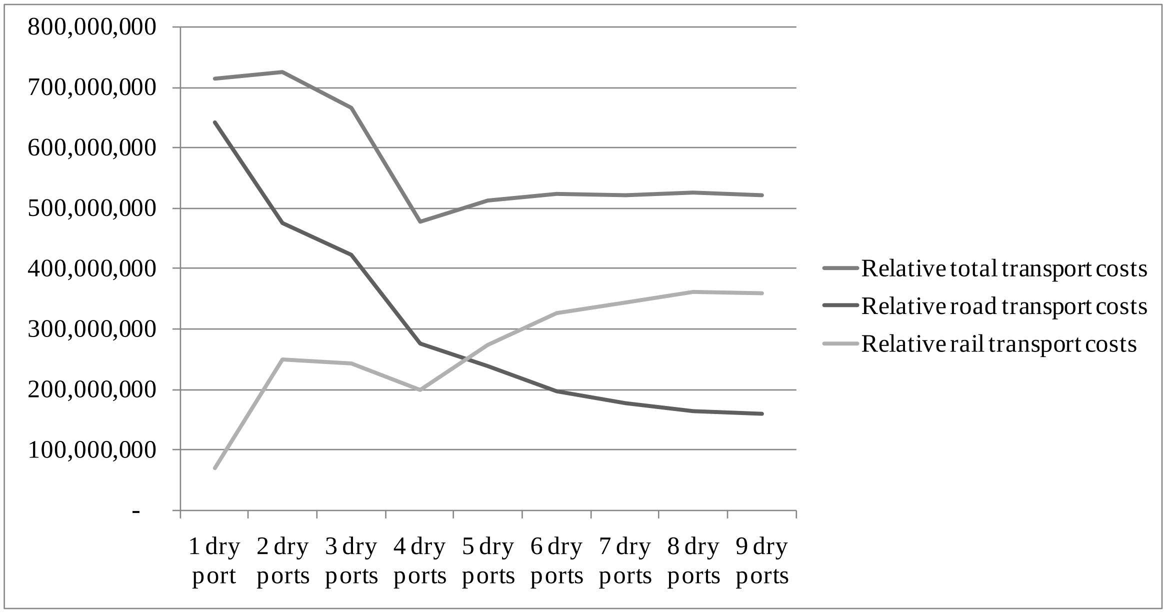

Figure 2. Relative transport costs with different number of dry ports in Finland.

Results shown in Figure 3 are based on same input values as previous results in Figure 2 added with the difference in total costs of road and rail transport. As can be noted, total costs of rail transport decrease if compared to total costs road transport, when compared to previous results in Figure 2. It is a consequence of rail transport being more inexpensive mode of transport than road. Difference in total costs of transport is though somewhat similar than in previous results shown in Figure 2. If the difference in costs of road and rail transport is taken into account, the optimal number of dry port implementations in Finland seems to be at the number of four to six dry ports.

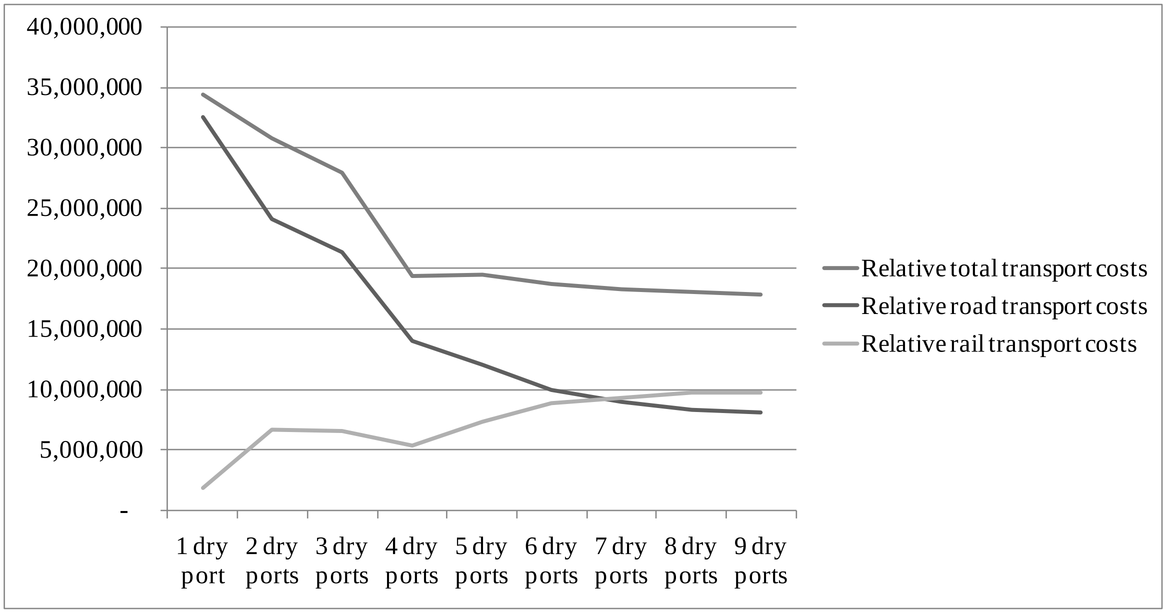

Figure 3. Relative transport costs with different number of dry ports added with the difference in total costs of road and rail transport in Finland.

Figure 4 represents the results on how the external costs of the whole dry port network evolve by using different amount of dry ports. The external costs consider CO_2 emissions, congestion, noise and accidents. With only few dry ports, road transport creates almost all the external costs. With nine dry port solutions the external costs seem to be minimized i.e. by adding over nine dry ports the environmental impacts can be decreased only slightly more. External costs with nine dry ports are still mainly caused by road transportation. This is due to road being significantly more expensive mode of transport in terms of external costs. The external costs of rail transport remains considerably low by adding up to nine dry port implementations into the transportation system. So, basically ecology here argues that we ought to use increasingly more dry port terminals, in order to reduce environmental impacts of the whole transportation system. This differs a bit from typical analytical tradeoff situation shown in total costs (see Figures 2 & 3).

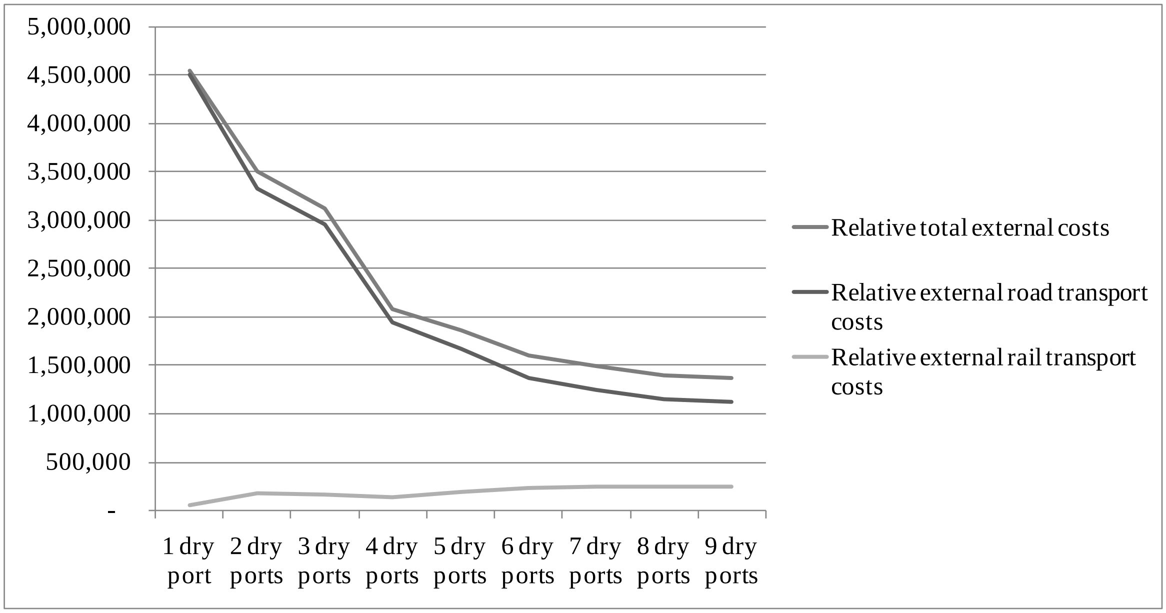

Figure 4. Relative external costs with different number of dry ports in Finland.

According to this research, by implementing dry port solutions and increasing the use of rail transport the total relative costs of transport can be decreased. In addition, the environmental impacts of the transportation can be decreased by using dry port network. There is a optimal area of used dry ports in the system, if the least relative transport costs are taken into account, and most feasible area ranges from four to six inland terminals. By adding dry ports with more than six implementations, the environmental impacts can still be decreased considerable by using up to nine terminals.

5. Conclusions

Hypothetical analytical model supports Finland to use dry port method for inland distribution, it will reduce both, emissions and total transportation costs. Two economical models show typical tradeoff situation between variables examined, and proposes that in Finland amount of dry ports should be around four to six. However, ecological model proposes that even higher amounts should exist in the transportation system, since emissions decline continuously with amount of nodes used in the system (please do note that marginal benefits decrease even in our calculations towards nine dry ports in the system). As a preliminary conclusion, we propose that dry port network is feasible in Finland, and country's transportation system has special characteristics, which should be taken into account, while constructing it. In contract to Sweden, in Finland more seaports are needed to support this system, which in turn leads in a bit lower amounts of dry ports in hinterlands.

As a further research, we would like to enlarge our model in terms of taking into account industrial support of dry ports. Traditionally bulk manufacturing and raw materials have used mostly specific transportation freight structures, and considering their locations and transportation volumes would be vital to further support environmental and economic impacts of dry port system. So, we would therefore like to include chemical factories, pulp and paper mills, and mines in our model to include also industrial aspects of dry port implementation. Our current model is only feasible for consumer items, which are consumed proportionally with amount of people living in particular city (whatever the income level is). To increase the validity of our model, it would be worthwhile to analyze the effects of income and population for optimal amount of dry ports. However, as Finland is known from its northern approach for equality and low income differences, this model would not yield that great difference to the results shown in this research work at hand.

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