PLANNING OF PORT CAPACITY IN INTERMODAL TRANSPORT NETWORKS – THE CASE OF ROTTERDAM

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Abstract

Port capacity expansion requires substantial investments and has impact on port competiveness as well as on regional and national economy. Decision-making on port capacity expansion is complex due to conflicting interests associated with the port-commercial and the welfare perspective, and wide margins in the decision space caused by the combined effect of many options and uncertainties. Elaboration of such decision-making indicates that a dynamic duo-perspective decision framework incorporating competition is required. Efficiency, the main guiding principle in the decision-making, needs to address the simultaneous determination of (1) optimum capacity expansion; (2) optimum use of capacity; (3) pricing; and (4) investment recovery, in which self-financing of capacity expansion is an important principle. The basis for the solution of this efficiency problem is supply-demand planning framed into cost-benefit analysis. Exploration of the decision space for the Rotterdam situation indicates potentially large but volatile container flows for the coming 15 years. This emphasizes the need for a systematic framework for the planning of port capacity.

Keywords: Port planning; Capacity planning; Port competition
Topic area: A2 Maritime Transport and Ports

1. Introduction

During the past decade, substantial investments have been made to strengthen the competitive position of the Port of Rotterdam. Examples are the construction of a dedicated rail connection for freight transport between the Port of Rotterdam and Germany, and the plans for a second seaward expansion of the Port of Rotterdam. The main argument for the government to subsidize such investments is the expected positive impact on national economic development.

Planning of port capacity, intended to expand or improve cargo-handling capability, poses a challenge due to many inter-dependencies and uncertainties. Methodologically, port capacity planning can be based on a confrontation of the demand for port services with the supply of capacity. The port constitutes a node in an elaborate network of logistic chains connecting origins and destinations for freight flows. Determination of demand for port services then entails the determination of freight transportation demand in a dynamic network characterized by inter-port competition, and changing transportation routes, modes and technology. The supply of capacity is characterized by many options and economies of scale.

Two basic perspectives should be distinguished in port capacity planning: the port-commercial and the welfare perspective. In this order, they represent an increasing scope in evaluation involving a more complex owner/beneficiary situation. For plans that are funded by the government and/or have considerable impact on society, the indirect and environmental effects should also be accounted for requiring the welfare perspective. These different perspectives may conflict and need therefore to be distinguished to make a proper justification of the associated investment projects (Dekker *et al.*, 2002).

This paper emphasizes the methodology for port capacity planning. It accounts for (1) port-commercial interests such as throughput maximization, efficient facility usage and investment recovery; and (2) welfare interests such as direct and indirect effects. Particularly the various trade-offs and inter-relationships that complicate port capacity planning are discussed. The Port of Rotterdam serves as an illustrative example, particularly since the Italian port Gioia Tauro is a potential additional competitor in serving the German hinterland.

The rest of this paper is divided into five sections. Section 2 briefly reviews relevant backgrounds. Section 3 schematizes the port system and gives an overview of port capacity measures and of the various inter-dependencies in port capacity planning. Section 4 discusses a framework for decision-making on port capacity investment and Section 5 presents a scope on the decision space for the Rotterdam situation. The last section summarizes the findings.

2. Background

2.1 Debate on port investments

The decision-making on a second seaward expansion of the Rotterdam port and other investments, such as the hinterland railway connection with Germany and a newly build container terminal (Ceres) in Amsterdam, has initiated a heated debate in the Netherlands. This debate concerns the potential and desired role of the Dutch ports in international transport, their contribution to regional and national economy and their further enhancement by investments in capacity expansion.

The advocates of such investments (e.g., BCI, 1996) point at the potential attractiveness of hub development for companies and the radiation effect on regional and even national economic development. Some authors criticize, however, these investments. Pols (1997, 1999), for instance, noted the lack of development of policy alternatives and a well founded and coherent policy vision on hub development in the Netherlands. For example, the one-sided focus on scale advantages of increasing vessel size in container transport disregards the logistic disadvantages of lower frequencies, and the increasing distances in both sea and inland transport. It disregards also the high investment and exploitation costs of specialized cargo-handling facilities with relatively low capacity utilization rates. Pols noted further the lack of coordination at a more operational level between transport, spatial and environmental policy.

A most important aspect in the above mentioned debate is the determination of added value for the national economy and, in particular, the indirect effects. An inventory (Kuipers, 1999) of these effects for the Port of Rotterdam suggested that circa 6.8 % of the Dutch Gross Domestic Product and 7.1 % of total Dutch employment would be generated by the Port of Rotterdam. However, a considerable amount of double counting is suspected in calculating such figures (e.g., Pols, 1997).

In decision-making on port investment, an adequate trade off of costs and benefits is necessary. Therefore, a substantial research effort into the estimation of benefits of infrastructure investments has been carried out in the Netherlands (see Eijgenraam *et al.*, 2000). Although the result of this effort presents a clear overview of many types of benefits, there is still discussion on some issues including the formulation of the reference situation/development, the development of alternatives, and the determination of indirect effects for specific projects.

A possible changing competitive position of the Dutch ports in the European transport network depends on the likelihood of route and modal shifts. Various authors (e.g., Roscam Abbing, 1999; Connekt, 2001) mention the opportunities of technological developments in transportation. For example, the introduction of larger inland transport modes can affect route and mode choice, and may serve as an alternative for constructing new hinterland transport infrastructure. The fact that the Dutch ports have excellent connections with inland waterways is an important natural advantage that should receive specific attention.

Another but interrelated aspect in the port investment debate concerns the future demand for port capacity, which is in fact a demand for services consisting of transfer, storage and transport. Some parties propose essentially an extrapolation of past trends, while others point to the (potential) changing structure of the economy and composition of trade flows. The development and choice of economic scenarios has considerable impact on capacity requirements of ports.

The Dutch debate on port investments continues to date. It hinges on aspects that are difficult to resolve, such as an improved utilization of existing capacity, a clear distinction between direct and indirect effects, the potential of developments in transportation technology, and prediction of port demand.

2.2 Port capacity and competition

Ports are critical determinants of supply chain efficiency in that they can facilitate or hinder rapid and cost-effective exchange of cargo between vessels and other transport modes. In modern logistics management, balanced supply chain capacities and unrestricted flows of products, services, and information are crucial factors in cost control and customer satisfaction. In present Just-In-Time systems, inventories are kept to a minimum and goods, moved frequently and in small quantities, are planned to arrive when they are needed. This places pressure on port systems by requiring greater reliability, flexibility and speed.

Delays, inadequate hinterland connections and insufficient information exchange result in competitive disadvantage for ports and suboptimal operation of the supply chains in which they operate. Adequate port capacity expansion enhances the efficiency of the cargo transfer process and, thus, the profitability of exports and the costs of imports. The total transferred cargo can be divided in logistic ‘families’ (Iding *et al.*, 1999) that differ in terms of type, value, origin and destination, route, mode and frequency.

Port capacity is the combined product of port facilities and associated services. Port facilities consist of port land, infrastructure, superstructure, and maritime and hinterland access infrastructure. Port services comprise mainly cargo handling services. The cargo handling process can be schematized as several inter-dependent stages or links. When the capacity of one link has been expanded and has become bigger than the capacity of other links, the other links should also be expanded in order to realize the full potential of the original investment (see also Jansson and Shneerson, 1982). An efficient port system includes therefore a chain of mutual balanced link capacities.

Port capacity planning needs to strike a balance between (occasional) shortages and over-capacity. A shortage will lead to delays and associated congestion for users. Further, if there is competition shortages may lead to a decreased demand. Over-capacity is a time-varying phenomenon if demand is increasing. In view of demand growth and economies of scale in developing capacity expansion strategies, there will be a relatively substantial over-capacity after implementation of a new capacity increment that decreases into the future. Uncertainty in the realization of the future demand is involved in the decision to establish new capacity.

From an overall welfare perspective, port capacity could best be determined such as to minimize the combined cost of capacity investment and generalized transportation costs including congestion costs. However, a realistic planning also has to consider the individual decision-making, based on different commercial interests, of the users and competitive port operators.

Government subsidy may disturb an efficient match of port service demand and capacity supply; it causes an investment cost (to society) that does not reflect the 'real' investment cost for the port manager/operator, which ultimately results in capacity shortage. A combination of over-capacity and port competition causes price wars between ports as can be observed in the North Sea region (Chlomoudis and Pallis, 2002). This results in collapsing port tariffs, which makes it difficult to recover investments. Furthermore, a reduction in employment can be observed due to cost savings and automation.

Port competition can be divided into six categories (Goss, 1990; Meersman and Van de Voorde, 1994; Robinson, 2002): (1) competition between whole ranges of ports or coastlines; (2) competition between ports in different countries; (3) competition between individual ports in the same country; (4) competition between operators or providers of facilities within the same port; (5) competition between different modes of transport; and (6) competition between supply chains. This study focuses on the last category.

2.3 Developments in transportation technology

Ports operate as firms embedded in supply chains making their competitiveness highly dependent on the attractivity of the chains. Technological developments in freight transportation enhance supply chain attractivity due to increased transport efficiency. Developments that increase transport efficiency in container transportation are summarized below.

Containerization. More than 50% of all general cargo in international liner trade (measured by volume) is currently being moved in containers. By 2010, it is predicted that 90% of all liner freight will be shipped in containers (US DOT, 1998).

Increasing vessel size. Blue prints exist for 15,000 TEU vessels (McLellan, 1997) and even 18,000 TEU (Malacca-Max) vessels (Wijnolst, 1999). Lim (1998) estimated the reduction in operational costs of increasing vessel size from 4000 to 6000 TEU at about 21%. Assuming that the maritime transport component accounts for about 30% of total intermodal costs, this represents a 6.3% reduction of total transportation costs (Lim, 1998).

Horizontal chain integration (mergers and alliances). As a result of horizontal integration of ocean carrier operations, volume and capital available for developing dedicated terminals is increasing. The advantages of running a dedicated terminal are: 1) guaranteed availability of berths; and 2) controlling planning and operation (Connekt, 2001).

Vertical chain integration of maritime and inland transport. Ocean carriers began offering intermodal services aiming at shorter transit times at competitive rates (e.g., Foggin and Dicer, 1985; Brooks, 1992). For example, many shipments between the East Coast of the USA and East Asia are transported by rail using the so-called *landbridge* from the East Coast, via inland terminals, to ports along the West Coast from where they are shipped to their final destinations in East Asia and vice versa.

In Europe, the German rail freight carrier *DB Cargo* and the Italian terminal operator *Contship Italia* recently started a joint venture (*Hannibal*) to offer services between Hamburg-Bremen and the Italian ports Gioia Tauro and La Spezia. Daily rail services for container transport over the Alps will be offered (Elliot, 2002). This development is a potential threat for the competitive position of Rotterdam and other ports in the Hamburg-Le Havre range serving the industries in the southern part of Germany (see Figure 1).

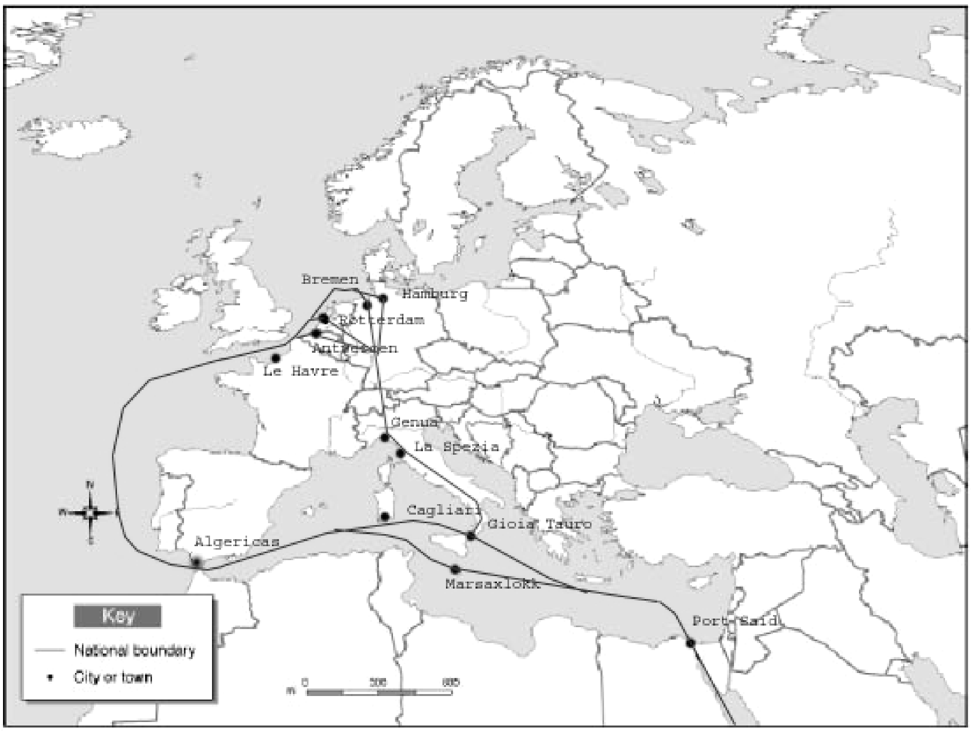

Figure 1. Gioia Tauro as a potential threat for ports in the Hamburg-Le Havre range.

Hinterland transport. Innovations in road transport include more efficient fuels and engines, self-loading semi-trailers, and increasing capacity by introducing longer trucks (4 TEU) (Connekt, 2001). Another trend is the development of various traffic management techniques to enable more efficient use of existing road capacity. The introduction of double-stack railcars in the US resulted in cost savings of 30-40% per container unit carried (Fleming, 1989). Inland (container) shipping is a more energy-efficient and cost-effective alternative for road and rail freight transport. An important innovation is the development of larger inland container barges. An example is the Jowi with a transport capacity of 408 TEU, a length of 135 m and a speed of 23 km/h or more. A reduction of transport costs of 15-20% per container unit, compared with smaller inland container barges, can be reached (Roscam Abbing, 1999). In contrast, new small 32 TEU barges are developed that are more suitable to penetrate inland navigation networks (Connekt, 2001).

Information technology. Examples are Electronic Data Interchange (EDI) and Data Base Management (DBM) for the provision of real-time information on shipments, arrival date and time, and infrastructure and service performance; and Geographic Information Systems (GIS) and Global Positioning Systems (GPS) for tracking-and-tracing systems. Such applications enable more responsive, efficient, safe and reliable freight transportation systems, and lead to better communications within supply chains.

Container handling. Innovations in container handling increase port productivity and include fast quay cranes, Automated Guided Vehicles (AGV's), vehicle routing control and efficient terminal layout.

3. Schematization for decision making

3.1 Port System Schematization

Figure 2 presents a schematization of the components and their inter-relationships, relevant for port capacity planning. This schematization essentially identifies the different capacity investments and follows the cargo flows through a port system including its hinterland connections. The volumes of the cargo flows through a port are highly determined by a port's position within the service networks of ocean carriers. When ports have an important hinterland function, the cargo flows depend also on the performance of their hinterland connections. Some ports, such as Singapore, mainly depend on transhipment flows.

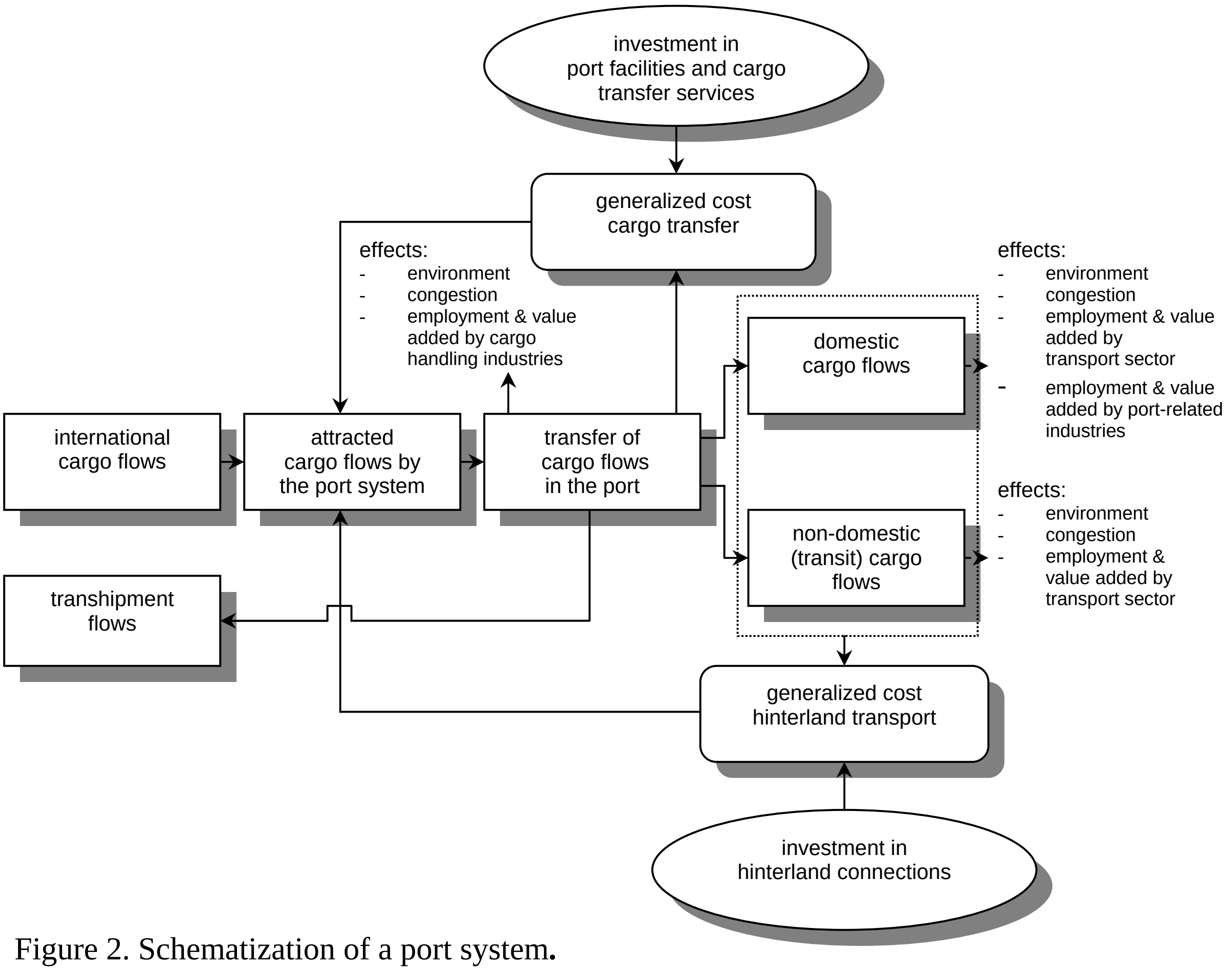

Figure 2. Schematization of a port system**.**

The impacts of port capacity investment depend on:

- *investment in port facilities and cargo transfer services* aiming at reduced generalized cost of vessel calls and cargo handling in the port; and
- *investment in hinterland connections* aiming at reduced generalized cost of hinterland transport.

Reduced generalized cost in the port system enhances the attractivity of the associated logistic chains and increases the volume of cargo flows through the port.

The changes in the different logistic chains affect the environment, cause traffic congestion, and create employment and value added by the cargo handling industries. For hinterland transport, a major differentiation should be made into domestic cargo flows (i.e. cargo flows with the country in which the port is located as destination) and non-domestic flows (i.e. transit flows to foreign countries). They have a strongly different impact on national welfare. Both flows have impact on the environment and traffic congestion. The domestic flows, however, have a strong relation with the creation of employment and value added in port-related industries while the non-domestic flows contribute primarily to an increase in employment and added value in the national transport sector. Particularly the non-domestic and transhipment flows occur in competition with other ports and constitute, therefore, a relatively volatile part of the total flows. At the same time, these flows are crucially important to maintain the hub-status of ports. The Port of Rotterdam, for instance, has a relatively high proportion of non-domestic transit and transhipment container flows (in 1998 about 39% and 24%, respectively, of total container throughput volume; NHR, 2001).

3.2 Structural and non-structural capacity measures

Port capacity measures comprise~~s~~ structural measures leading to facility expansion, and non-structural measures leading to a more efficient utilization of existing facilities. Examples of structural measures are land reclamation, dredging works and the removal of obstacles (e.g., low bridges) above waterways. Such measures are usually capital-intensive and may activate latent demand (i.e., demand that is deterred by congestion itself) due to improved accessibility (Small, 1995).

Non-structural alternatives relate to technological, economic and regulatory measures that (1) increase the throughput capability of the port system, or (2) affect port users' behavior. The first group is referred to as supply management and the second as demand management. Examples of supply management are higher stocking of containers, application of faster cargo handling systems, and spreading of logistic activities (e.g., warehousing) to other regions. Demand management measures include pricing and redirection of (parts of) cargo flows to secondary ports.

Some port capacity measures may interact with each other. For example, if a port seeks spreading of its activities to other regions, it is less likely to seek land reclamation works. If the port already benefits from land reclamation or redirection to secondary ports, investments in faster cargo handling systems would be less likely to be supported.

Structural and non-structural measures may have to be combined to effectively reduce port capacity problems. Pricing, for instance, could help to decrease activated latent demand and the extra revenues from pricing could be used to finance expansion works. The latter is justified on the grounds that the incremental cost of providing additional facilities to accommodate peak demand ought to be paid for by those demanding and benefiting from these facilities.

3.3 Complexities in port capacity planning

In this study, the strategy of a single port is considered. The effect of capacity expansion on a port's competitiveness can then be evaluated with a partial equilibrium model and port pricing can be based on marginal user costs. This represents a standard approach in transportation systems analysis, but produces biased results for three reasons (see, e.g., Johansson, 1991; Venables and Gasiorek, 1999; Haralambides, 2002). First, it assumes that changes induced in other ports and elsewhere in the network (general equilibrium effects) are of no social value. Second, it assumes that the potential users of the port considered are representative for all users of the network. Third, it neglects the potential existence of imperfections in the port market due to, for instance, over-capacity.

Competition between ports focuses on hinterlands, which are overlapping or "contestable". Cargo flows associated with these areas constitute a relatively uncertain part of total port throughput (see above). Since investment cost is a considerable component in the total cost of port facilities, it is obvious that ports will strive to increase their share of the "contestable" flows in order to obtain a high capacity utilization, which can justify the large port investments.

High capacity utilization can affect handling charges due to economies of scale and scope by the bundling of different cargo flows. These different flows use joint facilities for handling and transport, which assures cost sharing. For example, for container flows it can be cheaper to go through an existing port that has already been equipped with sufficiently deep entrance channels for crude-oil vessels, than a newly build "dedicated" port. At the same time, introduction of additional cargo flows or simply the growth of existing cargo flow volumes may induce diseconomies of scale such as traffic congestion and land shortage causing the switch of carriers to other ports.

The effects that can be expected from a large-scale port capacity investment project include effects on existing network flows: redistribution of cargo flow volumes among ports and, in addition, network effects. Changes in capacity for one port will, therefore, not only affect cargo flow volumes through the particular port but also the cargo flows through other ports in the network. Furthermore, the different alternatives for capacity investment are interdependent (see above). The here-mentioned inter-dependencies strongly increase the dimensionality of the port capacity-planning problem, as many combinations of measures, and of measures and effects, have to be considered.

4. Framework for port capacity planning

4.1 Decision analysis for port capacity expansion

The decision analysis for port capacity expansion, based on supply-demand planning framed into cost-benefit analysis, can be schematized by a number of steps as presented in Figure 3.

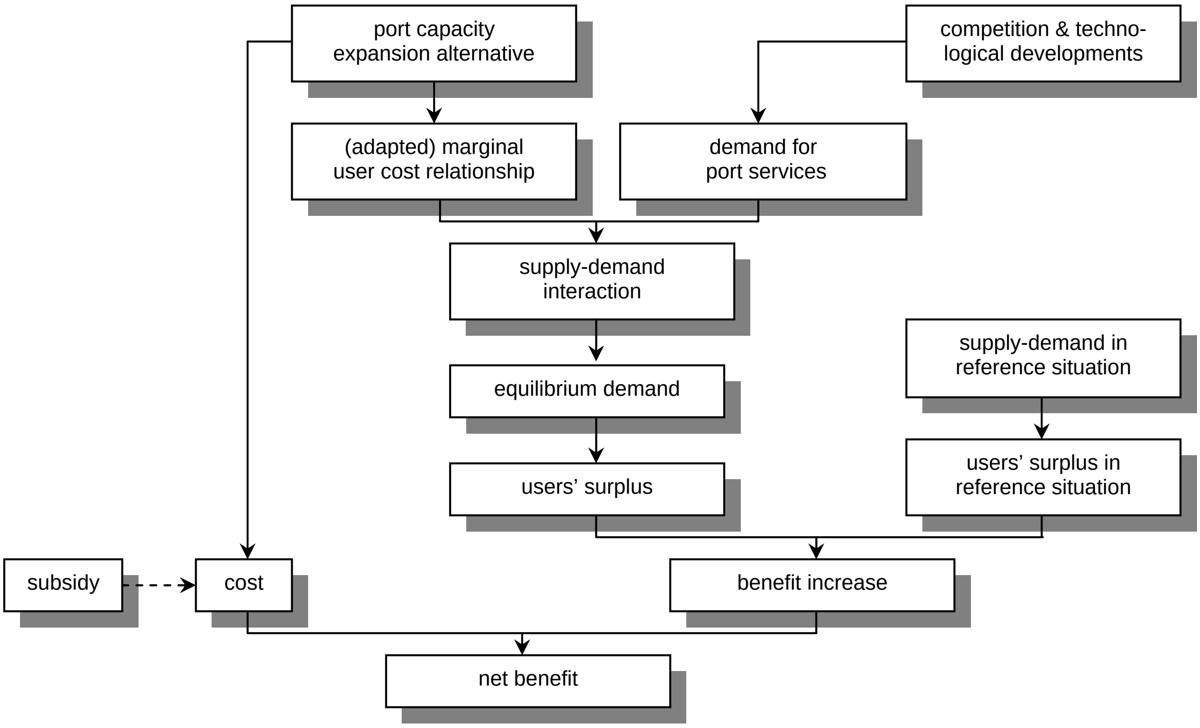

Figure 3. Decision analysis for port capacity expansion.

For a reference equilibrium demand, the users' surplus can be estimated. Competition and technological developments in freight transportation affect the demand for port services. Any port capacity expansion changes the existing marginal costs to the users; thus for each port capacity expansion alternative, the supply-demand interaction should be reconstructed, and equilibrium demand and users' surplus should be recalculated accordingly. An alternative in this sense can be defined as a set of (inter-related) capacity measures in a port system. Comparison of the users' surpluses (benefits) before and after expansion (i.e. the direct effects) is a measure for improvement of port competiveness and provides a main input to evaluation.

A major justification for government subsidy can be found in the contribution to national welfare. The government may then contribute a portion in the capacity measure equivalent to the investment (cost), which balances the discounted environmental and indirect effects (benefits) over the project's lifetime. The proportions of direct effects, and external and indirect effects respectively in the total economic effects will then determine the appropriate ratio of private to public investment (Dekker *et al.*, 2003). Government subsidy could be used to fund the first phase of a port expansion project in order to attract a so-called launching customer.

Many uncertainties exist in the above-sketched decision analysis; there is uncertainty associated with most of the design and evaluation parameters, in particular with the demand. The various uncertainties combine and propagate through the many options and inter-relations, and therefore strongly increase the dimensionality of the decision analysis. Uncertainty has the effect of diffusing the decision analysis by diffusing the differences between alternatives.

4.2 Efficiency concepts

Optimum capacity expansion means in economic terms that capacity expansion is such that the marginal expansion cost is equal to the marginal benefits. Similarly, optimum use of existing capacity means that the rate of capacity utilization is such that the marginal benefits of further use is equal to its marginal cost of congestion. Pricing according to capacity usage contributes to financing capacity expansion as well as improving capacity utilization.

Efficiency, the main guiding principle for the decision-making, needs to address the simultaneous determination of (1) optimum capacity expansion; (2) optimum use of capacity; (3) pricing; and (4) investment recovery. The main concepts for solving this efficiency problem are discussed below.

Supply-demand interaction

The basis for efficiency comprises the interaction between the port service demand curve and the marginal user cost curve, representing port capacity supply. Both curves can be expressed in terms of the generalized cost. Investments will change the supply-demand interaction; a description of this interaction can be used to evaluate the impact of the investment. A typical form of this interaction is presented in Figure 4.

For a starting situation with a capacity K_0 the supply curve MC (i.e. the service curve) increases when the throughput increases, due to traffic congestion. Equilibrium between the demand curve D(Q) and the supply curve MC(Q,K_0) exists at equilibrium demand Q^* (Figure 4a).

When a competing port succeeds in increasing its market share or when a new chain through an other port enters the network, the demand for port services of the port considered decreases due to a redistribution of the cargo flows. The demand curve shifts then from D(Q) to D'(Q) and, consequently, equilibrium demand decreases to Q^*_0. Consider further a port capacity expansion from the present capacity K_0 to K_i, resulting in a new supply curve. Capacity expansion reduces the generalized cost associated with using the facility, resulting in turn in a changed equilibrium demand (Q^*_i). When the port is confronted with a decreasing market share due to investments by other ports, it can react with capacity expansion. The lost throughput may then be reduced, as demonstrated in Figure 4b.

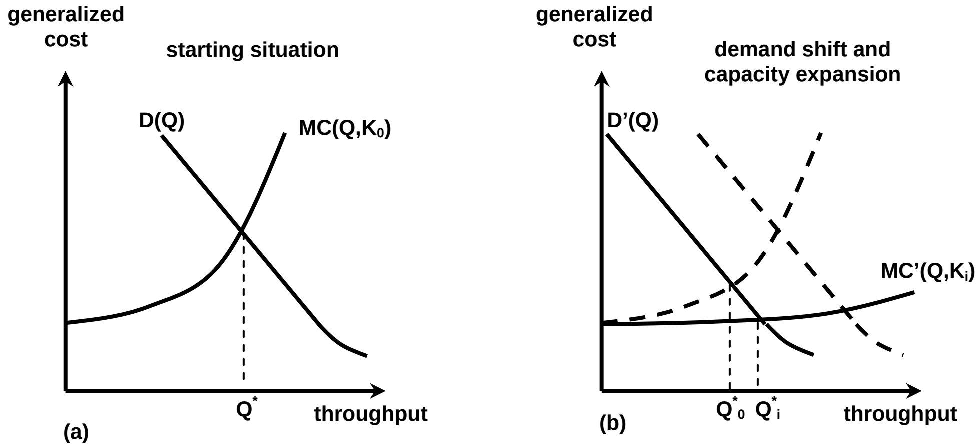

Figure 4. Supply-demand interaction.

The situation directly after the demand shift represents the reference situation. If D'(Q) represents the demand curve for the improved and reference situation, and if MC'(Q,K_i) and MC(Q,K_0) respectively represent the supply curve for the improved and reference situation, then the benefit~~s~~ increase due to port capacity investment (in terms of direct effects) can be expressed as the area between the vertical axis, the demand curve D'(Q) and the supply curve MC(Q,K_0) in Figure 4b minus the similar area between the demand curve D'(Q) and the supply curve MC'(Q,K_i), also in Figure 4b.

This comparison represents a standard approach, which incorporates competition in the port capacity planning problem. It could be applied straightforward to relatively simple situations such as the design of a port for a single cargo flow. The situation for ports with more than one cargo flow is more complex. Furthermore, there are considerable uncertainties in the estimation of both the demand for port services and the effectiveness of capacity measures.

Optimal pricing

In the above elaboration on supply-demand interaction, the difference between short run and long run is neglected. It needs, however, to be considered when pricing is incorporated in the decision problem. The price that leads to the maximum users' surplus as well as internalized (external) congestion costs (i.e. the optimal price; Jansson and Shneerson, 1982) is determined by the difference between the short-run marginal social cost (SRMSC) and the short-run marginal private cost (SRMPC). The latter is equal to the short-run average social cost (SRASC) and includes for port usage port dues, cargo-handling charges and time costs. For the optimal price holds further that at equilibrium demand, Q^*_i, SRMSC is equal to the long-run marginal social cost (LRMSC), which assures long-run efficiency for the users (see, e.g., Jansson and Shneerson, 1982). Figure 5 illustrates this concept.

An interesting balance between optimal pricing and investment was established by Mohring and Harwitz (1962). They showed that the additional revenues from road pricing due to additional capacity recover precisely the cost of highway expansion if constant returns to scale exist in traffic congestion as well as in capacity expansion cost. Application of such self-financing principle to port capacity investment is complicated, because considerable economies of scale in investment cost and time-dependent system changes are to be expected.

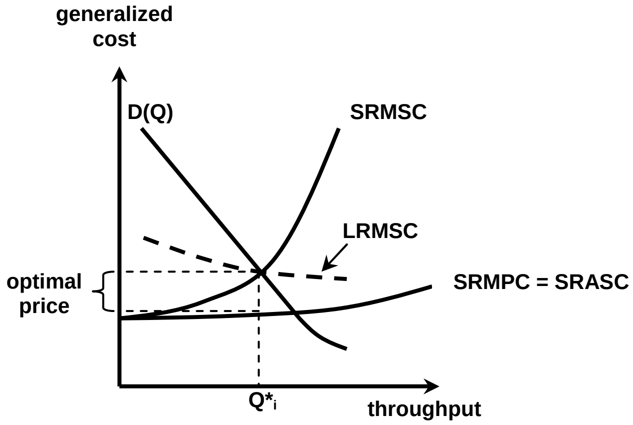

Figure 5. Derivation of the optimal port price

Application is nevertheless attractive. The advantages include: (1) achievement of an efficient port system in terms of efficient capacity utilization; and (2) improvement of the acceptability of port pricing by the users, because port pricing may be perceived as fair - only the users of the port pay for the capacity - and transparent - there are no “hidden” transfers surrounding capacity financing (Verhoef and Rouwendal, 2003).

Other social cost components such as environmental costs can be added to the above-described principle of optimal port pricing. This will influence, however, the self-financing principle. Another expansion can be made if the marginal private benefits (represented by the demand curve) are not equal to the marginal social benefits due to the existence of external benefits.

Optimum capacity expansion

The typical patterns of the marginal cost, C^k_K, and the marginal benefits, represented by the product of the optimal equilibrium demand, Q^*_i, and the (short run) average social cost reduction, $-ASC^q_K$, of port capacity investment, are presented in Figure 6. Similar conceptual figures have been presented by Verhoef (2001).

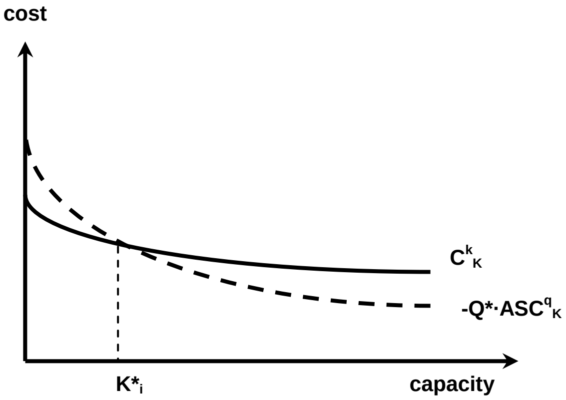

Figure 6. Optimal capacity given the optimal equilibrium demand.

The marginal benefit curve as well as the marginal investment cost curve show diminishing returns (costs) to scale for expanding port capacity. The maximum net benefit can be observed corresponding the optimal port capacity K^*_i. The net benefit can be expressed as the present value of a future stream of annual benefits (users’ surplus increase or direct effects) $B(K_i,K_0)$ minus the investment cost $C(K_i,K_0)$ for a particular capacity K_i.

Investment recovery

The principle of investment recovery is discussed above. To establish the investment recovery, the growth of demand has to be incorporated. In this study, this is implemented by a shift of the demand curve according to an exogenously determined growth rate of trade flows.

Optimization of port capacity is then based on three welfare components: (1) the total user benefits from the demand for port services; (2) the user costs; and (3) the investment cost. From this follows the optimum capacity expansion strategy including the size of the expansion and the investment recovery period. Because the investment shows economies of scale, such strategy results in a positive financial result (see, e.g., Small, 1995).

Potential future subsequent expansion strategies can be expected to be different due to investment strategies by other competitors, developments in transportation technology, changing port tariffs, and decreasing investment cost due to innovative construction technologies.

4.3 Demand for port services

Estimation of the demand for port services is a key component in decision analysis for port capacity investment. Various studies (e.g., Huybrechts *et al.*, 2002; Luo and Grigalunas, 2003) make clear that estimation of port demand is a difficult task due to the complexities of international trade, the dynamics of port competition, and potential strategic behavior by several parties. Methodologically, it represents a challenge to address the major data requirements and the computationally intensive nature of the problem.

A distinction should be made between “demand estimation” and “demand prediction”. *Demand estimation* is basically the determination of the demand curve as shown in Figure 4. There is a need to differentiate the demand for transhipment flows and the demand for transit flows: container transhipment flows usually have lower storage requirements than transit flows due to shorter dwell times and less rehandles.

An example of demand estimation for transit flows is the simulation model by Luo and Grigalunas (2003), in which they simulated port demand for a number of North-American container ports by changing the tariff for one port. In this model, each route is assumed to use only one port. The model determines the distribution of container flows on the basis of least-cost routes. The aggregation of all containers, associated with all the origin-destination pairs, going through a particular port gives the simulated demand for container transit flows of that port. The model comprises a generalized cost function in which total transportation costs are represented by the sum of maritime and land transportation costs, and port-related cost. The time cost is represented by the opportunity cost of time as a function of travel time (duration), cargo value and the daily unit cost of capital.

An adapted version of the model by Luo and Grigalunas (2003) will be used to estimate the demand for the Port of Rotterdam. In this application, demand for container flows from Asia to South-Germany, Switzerland, Austria and North-Italy will be analyzed in which intermodal competition with other ports in the European network, particularly ports in the Hamburg-Le Havre range as well as in Italy (Gioia Tauro), will also be incorporated. The impact of transport-technological innovations (see Section 2.3) can be simulated by reduced durations and/or transportation costs. A logit-type assignment modeling will be used to incorporate uncertainty on the route choice, because route choice is only partly explained by generalized cost. Other uncertainties (e.g., on transportation costs and demand) can be analyzed by varying tariffs and origin-destination flows (Monte Carlo simulation).

Demand prediction represents the development of equilibrium demand in time, which is relevant to judge on long-term capacity adjustments. Changes in port equilibrium demand directly influence the expected results of the associated industries.

Experts of the Rotterdam port authority make long-term predictions for port equilibrium demand. These predictions, made with a cargo prediction model, are based on three scenarios for economic development until 2020 (proposed by the Netherlands Bureau for Economic Policy Analysis; see, e.g., CPB, 2001): Divided Europe (DE; gross domestic product (GDP) growth of 1.5% per year), European Coordination (EC; GDP growth of 2.75%) and Global Competition (GC; GDP growth of 3.25%). These scenarios reflect different assumptions on global economic growth and technological and socio-economic development, and varying degrees of European integration, and represent different growth paths of Dutch GDP. The expected market shares for each cargo flow through the port are determined for each GDP-growth scenario. Results of these forecasts for the Rotterdam container throughput are presented in Figure 7.

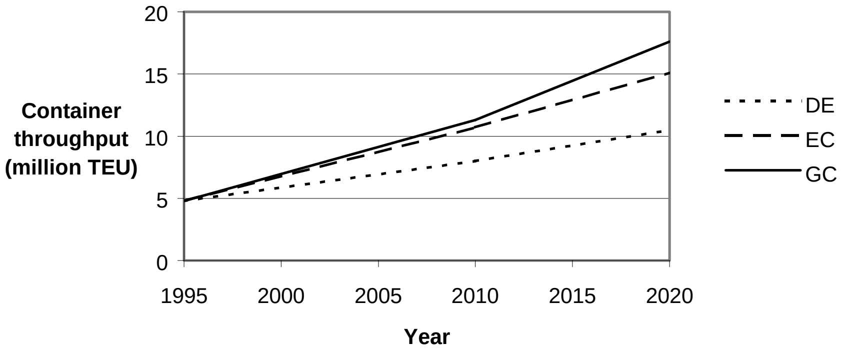

Figure 7. Rotterdam container throughput prediction for three scenarios (Source: CPB, 2001).

In planning of container port capacity, the total values for demand and costs, which are built up from the contributions of different container flows (transshipment, domestic and non-domestic flows), can be conceived. The selection of an optimal equilibrium demand and capacity with the above-described method should then be based on the net benefit of an optimal composition of the different container flows. Furthermore, the generalized cost concept is but one factor in the selection of a particular route; full port demand estimation should also incorporate factors such as port reliability (e.g., chance on strikes), the risk of accidents and losses by cargo-handling activities, and the quality of auxiliary services.

5. Indications on the decision space

Within the framework of the above-described approach for port capacity planning, two studies have been carried out at the Delft University of Technology to identify and clarify parts of the framework. The results of these studies enable to make an assessment of the uncertainty range in the decision-making, which can be expected. The wider the decision space, the more relevance should be attached to a rational and systematic scanning of the many options.

In the first study, by Van der Hoest (2003), total transportation costs and travel times of nine different intermodal transport chains from Asia to the hinterland between Stuttgart and Milan were compared. The total selected hinterland consists of Baden-Württemberg (represented by Stuttgart), Bayern (Munich), Switzerland (Basel) and North-Italy (Milan). Furthermore, three modalities for hinterland transport were analyzed: inland shipping, short sea shipping and train. The selected transport chains comprise 3 chains with Rotterdam as first port of call, and 5 chains with the Italian ports Gioia Tauro (3 chains), Genoa (1 chain) and La Spezia (1 chain) as first port of call. All transport chains were analyzed by comparing total transportation costs and time costs using the generalized cost expression of Luo and Grigalunas (2003) in which the different cost components included depreciation and interest for facility investment.

The results for Rotterdam and Gioia Tauro are presented in Table 1, representing the least-transportation cost chains from Gioia Tauro to the four destinations. The chains with Rotterdam as first port of call include the transportation cost (about 50 €/TEU) and duration (about 5 days) of the maritime leg between Gioia Tauro and Rotterdam for a 5000 TEU container vessel. The columns representing the proportion of port-related costs and duration are expressed as proportions of total transportation costs and total duration, respectively.

Table 1. Least-cost transport chains through Rotterdam and Gioia Tauro

Destination	First port of call	Hinterland transport modes	Total transportation cost (€/TEU)	Proportion of port-related costs (%)	Total duration (days)	Proportion of port-related duration (%)
Stuttgart	Rotterdam	inland shipping/train	372	31	13.5	31
	Gioia Tauro	short sea shipping/train	627	15	11.1	36
Munich	Rotterdam	train	446	27	10.7	31
	Gioia Tauro	short sea shipping/train	524	18	10.6	38
Basel	Rotterdam	inland shipping/train	319	34	16.4	26
	Gioia Tauro	short sea shipping/train	512	18	10.4	38
Milan	Rotterdam	inland shipping/train	536	24	17.3	24
	Gioia Tauro	short sea shipping/train	295	27	9.6	42

It can be concluded that the turning point, in terms of total transportation costs, is somewhere between Basel and Milan. The total durations particularly differ for Basel and Milan as destination. It can further be observed that port-related costs and duration contribute significantly to total chain costs and duration, emphasizing the sensitivity of the relative position of ports within transport chains for the effects of capacity investment. Sensitivity of the results for the choice of hinterland transport modes should be analyzed.

In the second study, by Op het Veld (2003), the impact of competitiveness on the market share of ports was analyzed. This was applied to container throughput in Rotterdam in mutual competition with Antwerp; focus of this application was the increase of port-related costs due to the Maasvlakte 2 land reclamation project (estimated costs: €2.3 billion) in Rotterdam. The results of this study indicate that passing on the full investment costs to the port users would decrease total annual container throughput with about 1.25 million TEU, representing 20% of present Rotterdam container throughput. It can therefore be concluded that subsidy for facility expansion has substantial impact on port demand.

The above-presented results contribute to the arguments of those supporting port expansion and the traditional role of the government in funding such investments. It further highlights the impact of port capacity investment on total transportation costs and duration and, therefore, on port competitiveness.

6. Observations and conclusions

Port capacity expansion requires substantial investments and has impact on port competiveness as well as on regional and national economy. Decision-making on port capacity expansion is of considerable complexity due to conflicting issues of port-commercial and national welfare interests, and wide margins in the decision space caused by the combined effect of many options and uncertainties (e.g., growth of international trade, potential shifts in the intermodal network, and strategic behavior by competitors).

Exploration of the decision space, applied to the Rotterdam situation, indicates that in the coming fifteen years major decisions will need to be made in port development to accommodate an expected strong increase in container flows. It is further shown that container transit flows are volatile due to port competition, associated route and modal shifts, and developments in transportation technology. These observations emphasize the need for a systematic framework for planning of port capacity.

In this paper, a framework for decision-making on port capacity expansion has been presented. Considering the two perspectives (port-commercial and welfare) from which port capacity expansion can be viewed, and the strong impact of competition, a duo-perspective decision framework incorporating competition is required. Due to the expected strong increase in demand and the capital-intensive nature of the investments, phasing is indicated; a dynamic approach for the decision framework is thus required.

Efficiency, the main guiding principle in the decision-making, needs to address the simultaneous determination of (1) optimum capacity expansion; (2) optimum use of capacity; (3) pricing; and (4) investment recovery, in which self-financing of capacity expansion is an important principle. The basis for the solution of this efficiency problem is supply-demand planning framed into cost-benefit analysis.

Estimation of the demand for port services is a key component in decision-making on port capacity expansion. In ongoing research by the authors, an application is being worked out to simulate the demand for the Port of Rotterdam. In this application, demand for container transit flows will be sought, particularly with Central Europe as origin/destination, which is the contestable hinterland for ports in the Hamburg-Le Havre range as well as for Italian ports.

References

BCI, 1996. De economische betekenis van de luchtvaart. Rapportage in opdracht van TNLI (The economic significance of aviation. Report under the authority of TNLI). Buck Consultants International, Nijmegen/the Hague, the Netherlands. [in Dutch]

Brooks, Mary, 1992. Issues in North American container port competitiveness. Journal of the Transportation Research Forum, 32 (2), 333-343.

Chlomoudis, Constantinos I., Pallis, Athanasios A., 2002. European Union Port Policy – The Movement Towards a Long-term Strategy. Edward Elgar, Cheltenham, UK/Northampton, Massachusetts, USA.

Connekt, 2001. International State-of-the-Art in Container Logistics and Performance Requirements for Mega-Hubs – A Vision for Container Logistics in the Port of Rotterdam. Connekt, Delft, the Netherlands.

CPB, 2001. Welvaartseffecten van Maasvlakte 2 – Kosten-batenanalyse van uitbreiding van de Rotterdamse haven door landaanwinning (Welfare effects by Maasvlakte 2 – Cost-benefit analysis of an extension of the Port of Rotterdam by land reclamation). Centraal Planbureau, the Hague, the Netherlands. [in Dutch]

Dekker, S., Verhaeghe, R.J., Pols, A.A.J., 2002. Expansion of the Port of Rotterdam – Framework for Evaluation. Transportation Research Records 1782, 49-55.

Dekker, S., Verhaeghe, R.J., Pols, A.A.J., 2003. Economic impacts and public financing of port capacity investments: the case of Rotterdam port expansion. Transportation Research Records 1820, 55-61.

Eijgenraam, C.J.J., Koopmans, C.C., Tang, P.J.G., Verster, A.C.P., 2000. Evaluatie van infrastructuurprojecten – Leidraad voor kosten-batenanalyse (Evaluation of infrastructure projects – Guideline for cost-benefit analysis). SDU Uitgevers, the Hague, the Netherlands. [in Dutch]

Elliot, Nick, 2002. Full steam ahead? Containerisation International, December 2002, 69-71.

Fleming, Douglas K., 1989. On the beaten track: a view of US West-Coast container port competition. Maritime Policy & Management, 16 (2), 93-107.

Foggin, James H., Dicer, Gary N., 1985. Disappearing hinterlands: the impact of the logistics concept on port competition. Proceedings of the Annual Meeting of the Transportation Research Forum, 26 (1), 385-390.

Goss, R.O., 1990. Economic policies and seaports: 4. Strategies for port authorities. In Maritime Policy & Management, 17 (4), 273-287.

Haralambides, H.E., 2002. Competition, Excess Capacity, and the Pricing of Port Infrastructure. International Journal of Maritime Economics, 4(4), 323-347.

Huybrechts, M., Meersman, H., Van de Voorde, E., Van Hooydonck, E., Verbeke, A., Winkelmans, W. (eds.), 2002. Port Competitiveness- An Economic and Legal Analysis of the Factors Determining the Competitiveness of Seaports. De Boeck Ltd, Antwerp, Belgium.

Iding, M.H.E., Maas, N., L. Verspui, L., Broens, D.F., 1999. Transportefficiency (Transport Efficiency. TNO-INRO, Delft, the Netherlands. [in Dutch]

Jansson, Jan Owen, Shneerson, Dan, 1982. Port Economics. The MIT Press, Cambridge, Massachusetts, USA.

Johansson, Per-Olov, 1991. An Introduction to Modern Welfare Theory. Cambridge University Press, Cambridge, UK.

Kuipers, B., 1999. Flexibiliteit in de Rotterdamse havenregio (Flexibility in the Rotterdam port region). PhD-thesis. Eburon, Delft, the Netherlands. [in Dutch]

Lim, S.-M., 1998. Economies of scale in container shipping. Maritime Policy & Management, 25 (4), 361-373.

Luo, M., Grigalunas, T.A., 2003. A Spatial-Economic Multimodal Transportation Simulation Model for US Coastal Container Ports. Maritime Economics & Logistics, 5 (2), 158-178.

McLellan, R.G., 1997. Bigger vessels: how big is too big? Maritime Policy & Management, 24 (2), 193-211.

Meersman, H., Van de Voorde, E., 1994. Havencompetitiviteit in een Europese omgeving - De nood aan wetenschappelijke instrumenten (Port competitiveness in Europe – The lack of scientific instruments). Tijdschrift voor Vervoerswetenschap, 30 (4), 277-292. [in Dutch]

Mohring, Herbert, Harwitz, Mitchell, 1962. Highway Benefits – An Analytical Framework. Northwestern University Press, Evanston Illinois, USA.

NHR, 2001. Nederland Havenland - De Nederlandse zeehavens in economisch perspectief (The Netherlands as port country— The Dutch seaports from an economic point of view). Nationale Havenraad, the Hague, the Netherlands. [in Dutch]

Op het Veld, J.H.G.P.L., 2003. Capaciteitsplanning onder Havencompetitie – Containeroverslag in de Hamburg – Le Havre Range (Capacity Planning under Port Competition – Container Transfer in the Hamburg – Le Havre Range). MSc-thesis. Delft University of Technology, Delft, the Netherlands. [in Dutch]

Pols, A.A.J., 1997. Internationale concurrentiekracht en mainportstrategie (International competitiveness and mainport strategy). In: Gelok, M.F. and De Jong, W.M. (eds.), Volatilisering in de economie. WRR, serie Voorstudies en Achtergronden, V98, SDU, the Hague, the Netherlands, pp. 37-76. [in Dutch]

Pols, A.A.J., 1999.Alternatieven voor Nederland Distributieland (Beyond physical distribution - Alternative options for economic restructuring). In: Elhorst, J.P. and Strijker, D. (eds.), Het economisch belang van het vervoer – verleden, heden en toekomst. Stichting Ruimtelijke Economie Groningen, REG-publicatie 18, Universiteitsdrukkerij RuG, Groningen, the Netherlands, pp. 91-115. [in Dutch]

Robinson, R., 2002. Ports as elements in value-driven chain systems: the new paradigm. Maritime Policy & Management, 29 (3), 241-255.

Roscam Abbing, M., 1999. Hoe Ontspoort het Water? Ontspoorde Besluitvorming Betuwelijn; Een Analyse van Genegeerde Alternatieven (Betuwe Line Policy; An Analysis of Ignored Alternatives). TU Delft/SISWO, Delft/Amsterdam, the Netherlands. [in Dutch]

Small, Kenneth A., 1995. Urban Transportation Economics. Second printing. Harwood Academic Publishers. Luxembourg.

US DOT, 1998. The Impacts of Changes in Ship Design on Transportation Infrastructure and Operations. U.S. Department of Transportation, Office of Intermodalism, Washington, D.C., USA.

Van der Hoest, A., 2003. Rotterdam en de Italiaanse Concurrentie (Rotterdam and the Italian Competitors). MSc-thesis. Delft University of Technology, Delft, the Netherlands. [in Dutch]

Venables, Anthony, and Michael Gasiorek, 1999. The Welfare Implications of Transport Improvements in the Presence of Market Failure – The Incidence of Imperfect Competition in UK Sectors and Regions. Department of the Environment, Transport and the regions, London, UK.

Verhoef, Erik T., 2001. Optimale congestieheffing en optimale wegcapaciteit (Optimal congestion pricing and optimal road capacity. In: Dings, Jos (ed.), Weg voor je geld? Toepassing van het profijtbeginsel bij de financiering van infrastructuur (Achtergrondrapporten). CE, Delft, the Netherlands. [in Dutch]

Verhoef, Erik T., Rouwendal, Jan, 2003. Pricing, Capacity Choice and Financing in Transportation Networks (version 17/03/03). http://www.tinbergen.nl/discussionpapers/03027.pdf. Accessed 24 November 2003.

Wijnolst, Niko, Scholtens, Marco, Waals, Frans, 1999. Malacca-Max; The Ultimate Container Carrier. Delft University Press, Delft, the Netherlands.