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CONCEPTS FOR INTEGRATED PLANNING OF PORT CAPACITY – APPLICATION TO ROTTERDAM EXPANSION PLANS

ABSTRACT

Port planning is complicated due to many factors, including the existence of economies of scale in port expansion and the fact that ports operate under competition. The port planner should provide an overview of all potential strategies to enhance port competitivness. Choices should be made with tailored design concepts within a framework comprising supply-demand planning and cost-benefit analysis. Port expansion is a strategy to enhance port competitiveness and can be characterized as a structural port capacity measure. Non-structural alternatives comprise supply and demand management measures and aim at efficient capacity utilization. In the design of port expansion, a certain level of traffic congestion should be accepted. Full integration of port-commercial and public interests by combining structural and non-structural capacity measures is essential for planning of port capacity. Efficiency, the main guiding principle for such planning, addresses the simultaneous determination of 1) optimal expansion size, and 2) investment recovery period.

KEY WORDS

port planning, port expansion, capacity planning, investment planning

1. INTRODUCTION

In recent years, substantial investments have been made in the Dutch seaports. Examples are the construction of a rail connection between the Port of Rotterdam and Germany (the Betuwe line project), a newly built high-performance container terminal (CERES) in Amsterdam, and the planned second seaward expansion of the Port of Rotterdam (the Maasvlakte 2 project). These investments aim at enhancing the competitive position of the Dutch ports in order to support the national economic development.

Planning of port capacity – essentially decision-making on port investment - is more complicated than planning for 'standard' transport infrastructure. For example, port expansion is characterized by economies of scale, and ports operate under competition making demand volatile. The port planner should provide an overview of all the potential alternatives to enhance the port competitivness such as specialization, pricing strategies and expansion. Choices should be based on tailored design concepts.

This paper presents an inventory of measures to improve port capacity and the scope of planning for such improvement. The planning is applied to the set of planning issues for the Port of Rotterdam. Port expansion is widely considered as an important strategy to enhance port competitiveness; design concepts for port expansion are reviewed and developed. The ultimate goal of this paper is to contribute to concept development for planning of port capacity.

The remainder of this paper is divided into four sections. Section 2 illustrates the issues in the Maasvlakte 2 project and in planning of port capacity. In Section 3, design concepts for port expansion are reviewed and further developed. This leads to a capacity planning that integrates port-commercial and public interests to address the full scope of design, which is applied to the Port of Rotterdam in Section 4. Section 5 summarizes the findings.

2. BACKGROUND: ISSUES IN PORT INVESTMENT

2.1. The Maasvlakte 2 Project

Figure 1 presents the planned location of the so-called Maasvlakte 2 project at the North Sea coast comprising an extension of the Rotterdam port area with about 1,000 hectares. According to the present plans, sixty percent is reserved for container activities and the rest for other activities such as chemical industries.

Originally, two main alternatives were proposed for the Maasvlakte 2 project: Alternative A with access via the existing port entrance and facilities of Maasvlakte 1 (see Figure 1), and Alternative B with a separate entrance for ocean vessels. The estimated total investment cost for A is € 1.8 billion compared to € 2.3 billion for B. The difference originates from the extra dams to protect the port entrance and by the costs to dredge the entrance channel. Alternative B is selected due to the improved port accessibility.

The Dutch national government helps to fund the project. However, the effectiveness and necessity of such large-scale (public) investments can be questioned for three reasons. First, the one-sided focus on more and bigger port facilities to facilitate large container vessels disregards logistic disadvantages of larger vessels due to longer hinterland connections and lower frequencies. This may lead to lower attractiveness of ports for transport-logistic chains. Second, port expansion increases potential over-capacity. Non-structural alternatives, based on efficiency improvements should be considered too. Third, ports are in fact club goods or public goods with external effects rather than pure public goods. Private funding or financing based on pricing according to usage should then be pursued.

Non-structural (and less capital-intensive) alternatives relate to technological, managerial, economic and regulatory measures that 1) improve the handling capability of the port (e. g., improved cargo-handling technology), or 2) affect port users' behaviour (e. g., peak pricing). The first group is referred to as supply management measures and the second as demand management measures.

2.2. Planning of a port capacity

In deciding on the port capacity, there is a need to strike a balance between (occasional) shortages and over-capacity, which are strongly affected by the dynamics of competition. Furthermore, there is a need to focus on the main bottlenecks in the total transfer process.

Shortages will lead to congestion and associated delays for users. In case of competition, this may lead to a decreased demand. Economies of scale and an increasing demand lead to an expansion strategy with substantial capacity increases; over-capacity is then a time-varying phenomenon. Uncertainty in the realization of the future demand needs to be accounted for in the decision to establish new capacity.

From a public perspective, port capacity should be determined by maximizing the net economic benefit of capacity investment. A realistic planning has further to consider the private decision-making covering the commercial interests of competitive ports (mainly investment recovery/profit making).

Planning of port capacity should address the following six questions (Dekker, 2005): 1) what is the expected demand of services in terms of types and volumes of the transport flows, 2) what are the required supply of capacity in terms of physical characteristics (sizes and numbers) and service characteristics (tariffs and productivities), 3) what is the utilization rate and equilibrium demand, 4) what are the investment cost and service prices, 5) what are the economic benefits, and 6) what is the overall viability of the port investment project.

Port investment aims at affecting supply of capacity and/or demand for services. The interaction between supply and demand leads to a certain utilization rate and equilibrium demand that determine, together with the investment cost, the service price. The service price affects, in turn, the competitive position of the

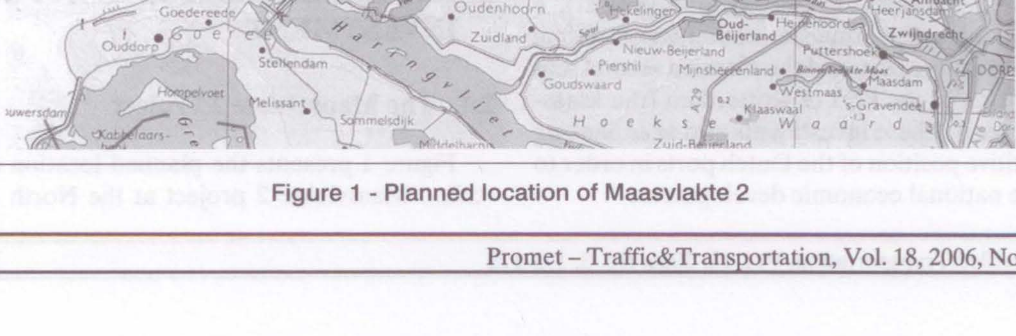

Figure 1 - Planned location of Maasvlakte 2

port in the transportation network. Ideally, the service price should balance port investment cost.

Government subsidy may disturb an efficient match of port demand and supply; it involves an investment cost (to the port) that does not reflect the 'real' investment cost, which may result in over-capacity. The combination of over-capacity and port competition gives cause to price wars between ports as can be observed in the North Sea region. This spirals into collapsing port service prices making investment recovery difficult.

3. DESIGN CONCEPTS FOR PORT EXPANSION

3.1. Strategic design

In the design of port expansion, three levels of decision-making can be distinguished: strategic, tactical and operational levels. At the strategic level, the focus of this paper, decisions are made on the size, the location and the implementation timing of the port expansion works.

Many port designs are based on expansion of the existing ports that may have undesirable impacts: unique landscapes (coast lines) may disappear and morphological processes along the coast may be disturbed. Alternative port development concepts can be used to overcome these impacts and to reduce the need for land reclamation works.

The process of strategic design for port expansion plans can be represented by a two-step procedure, involving a conditional forecast of the demand, followed by determination of the port expansion strategy to satisfy this demand. Concepts to support strategic design of port expansion are discussed below.

3.2. Congestion-based design

The premise that port expansion should be designed to accommodate the full demand at all times is unrealistic. Most transportation system designs are based on the acceptance of a certain level of congestion (Bovy, 2001); this is here referred to as congestion-based design.

In determining the design capacity of any transportation system, five design approaches can be distinguished (see Dekker, 2005). The common feature of the approaches is that the decision variable, the design capacity, is chosen in such a manner that the system satisfies the design flow, the design demand or throughput, at a minimum level of service quality. The main differences lie in the type of capacity measure (structural and/or non-structural) and the level of elaboration of costs and benefits. The design approaches are discussed below and lead towards the ultimate goal: integrated planning of port capacity incorporating competition and self-financing of port expansion.

Approach 1: empirically based design standard for structural measures

Approach 1 is based on an empirically based design standard for structural measures. The US Highway Capacity Committee, for instance, translated numerical traffic density results (expressed in vehicles/lane//mile) into a classification of different Levels of Service (LOS) provided by the facility for the prevailing demand conditions. The LOS represents then the design standard, in which 'A' stands for the highest LOS and 'F' for the lowest. Hence, important is the choice of the demand conditions, related to the function of the road, and the associated LOS from which the principal dimensions of the road can be deduced. Approach 1 provides a method for routine (everyday) design practice.

In general, application of design standards can be criticized for several reasons. First, the economic and environmental effects of meeting (some percentage of) a particular standard may not be incorporated. Second, design standards may have been without rational procedures and data. As a consequence, a standard may lead to over- or under-design for a specific situation. Third, standards may not incorporate new knowledge or the latest technology or data. Fourth, design standards hide information about utilization rates, and costs and benefits of alternative solutions and, consequently, bypass the discussion about acceptable congestion and willingness-to-pay for a specific situation.

Approach 2: explicit consideration of supply-demand and congestion effects

Approach 2 is based on finding a balance between supply and demand, incorporating congestion effects. The arrival rates of ocean vessels can be described adequately with the laws of probability. Many decisions on seaside port investment (e. g., quay extension) are therefore based on queuing analysis. The port is then schematized by a queuing system represented by random vessel arrivals, random service times and a service system (queue discipline and number of berths). The aim is to find a balance between the average waiting time of the vessels (demand), the number of berths (supply) and the average berth occupancy rate and service time (congestion effect). Simulation techniques have been developed to deal with more complex queuing problems. Transportation flow modelling considering congestion effects can be regarded as a more elaborated type and can be used for network optimization.

Approach 2 is characterized by application of a criterion for acceptable congestion and does not include a relationship between design capacity and investment costs.

Approach 3: inclusion of investment cost

Approach 3 is an extension of Approach 2 by including the investment cost. For example, the investment cost can be optimized by using the equations of queuing analysis or transportation flow modelling as constraints (see, e. g., Paelinck and Paelinck, 1998).

Since capacity design with Approaches 2 and 3 is based on solving congestion problems with system optimization, it can be characterized as 'transportation system optimization'. It is important to note that the calculation process in Approaches 2 and 3 starts with the given supply and demand characteristics. Consequently, these approaches accept a certain level of congestion.

In port design, over-design implying unnecessary high investment costs may occur due to demand drops making a sound commercial exploitation less likely. On the other hand, under-design leads to a level of congestion that deters potential users causing poor economic performance and leading to congestion costs. The design Approaches 1 to 3 are not applicable for the evaluation of welfare effects or efficiency improvement by non-structural measures. Therefore, in addition to these approaches, further extension is required.

Approach 4: consideration of non-structural measures and welfare effects

Approach 4 considers explicitly the application of non-structural measures and welfare effects such as the external cost of traffic congestion. The design capacity is found by optimizing an objective function such as maximizing some welfare function. For an expansion project, the welfare function in a more restrictive sense can be interpreted as the increase of the consumers' surplus (due to cost savings for the users by, for instance, reduced congestion).

Based on Approach 4, further refinement can be made to account for improvement towards the ultimate goal: determining the optimal design capacity by integrating public and commercial interests to obtain overall viability. This is only feasible if the potentials of structural and non-structural measures are combined in determining the design capacity. With a view on the port-planning problem at hand, competition among ports should also be incorporated.

Approach 5: integration of public and commercial interests, and competition

Approach 5 integrates public and commercial interests to obtain overall viability of port expansion projects by combining the full potential of structural and non-structural measures to 1) increase consumers' surplus and to expand transportation systems economic efficiency (public interest), and 2) to recover the investment cost of facility expansion (port-commercial interest). Furthermore, this approach considers the effect of competition among ports on supply-demand interaction.

3.3. Towards integrated planning of port capacity

The above-discussed design approaches have successfully addressed many transport investment problems. Decision-making on port investment is complicated due to the combination of port-commercial and public interests, and the presence of strong competition among ports. This requires a capacity planning based on design Approach 5, which is here referred to as integrated planning of port capacity. This approach applies to infrastructure objects that need to combine their public function with a strong commercial perspective in order to obtain a viable setup.

Commercially sound and welfare-optimal infrastructure expansion and utilization is the ultimate goal that many infrastructure planners want to achieve. Mohring and Harwitz (1962) established an interesting balance between pricing and investment to achieve this goal. They showed that under certain conditions the revenues from congestion pricing are sufficient for financing expansion works, provided that consumers' surplus is maximized. The 'conditions' refer to 1) capacity is adjustable in continuous elements, 2) constant returns to scale in capacity construction, and 3) constant returns to scale in congestion technology.

Application of such self-financing principle to port expansion is complicated due to the presence of competition, economies of scale in investment cost and future growth of transport flows. Application is nevertheless attractive. The advantages include: 1) financial viability of port investments in basic infrastructure that may otherwise be funded with scarce public funds, 2) achievement of an efficient port system in terms of optimal utilization and economic efficiency, 3) improvement of the acceptability of port expansion by society, because self-financing may be perceived as fair - only the users of the port pay for the expansion - and transparent - there are no 'hidden' transfers surrounding investment financing.

4. INDICATIONS ON THE DECISION SPACE FOR ROTTERDAM

Within the framework of integrated planning of port capacity, some indications can be given on the decision space for the Port of Rotterdam. The results enable an assessment of the uncertainty range in the planning, which can be expected. The wider the deci-

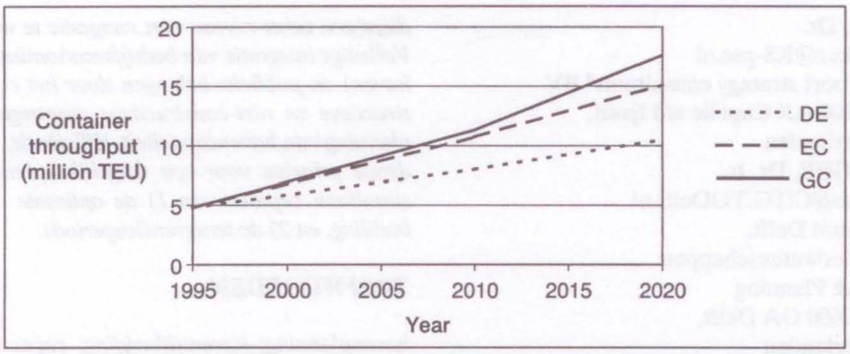

Figure 2 - Rotterdam container demand prediction for three scenarios

sion space, the more relevance should be attached to a rational and systematic scanning of the many options.

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 (*15*): 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 Rotterdam container demand are presented in Figure 2. Potentially large but uncertain container demand is indicated for the coming 10-15 years.

The present capacity utilization rate, estimated at about 70% (e. g., Drewry, 1999), can be increased to obtain a better utilization. A smaller expansion would be needed then. Introduction of marginal cost pricing contributes to this as well as to recovery of the investment. However, this should be traded off against a potential shift of certain container flows to, for instance, the port of Antwerp due to more congestion and higher port tariffs.

The above-presented results contribute to the arguments of those questioning the necessity of port expansion and the traditional role of the government in funding such investments. It further highlights the effect of port expansion on port competitiveness. Application of an integrated capacity-planning framework is called for.

5. OBSERVATIONS AND CONCLUSIONS

Port planning is complicated due to many factors, including the existence of economies of scale in port expansion, the fact that ports operate under competition and the combination of port-commercial and public interests. It puts high requirements on planning. On a scale of increasing complexity of capacity planning, the highest level should then be applied: integrated planning of port capacity. The port planner should provide an overview of all the potential strategies to enhance the port competitiveness. Choices should be made with tailored design concepts within a framework comprising supply-demand planning and cost-benefit analysis.

Port expansion is a strategy to enhance port competitiveness and can be characterized as a structural port capacity measure. Non-structural port capacity measures comprise supply and demand management measures and aim at efficient capacity utilization. Structural and non-structural measures may have to be combined to reduce port capacity problems effectively.

The premise that port expansion should be designed to accommodate demand at all times is unrealistic. A certain amount of traffic congestion should therefore be accepted. Design and optimization of port capacity based on this concept is referred to as congestion-based design. The ultimate level of congestion-based design integrates port-commercial and public interests by combining structural and non--structural capacity measures, and considers competition among ports. This concept is helpful in finding the optimal expansion size for port expansion projects.

Full integration of port-commercial and overall welfare interests is essential for planning of port capacity. Efficiency, the main guiding principle for such capacity planning, needs to address the simultaneous determination of 1) optimal expansion size, and 2) investment recovery period. Port expansion financing should then be based on congestion pricing leading to self-financing of the expansion works.

The concepts as reviewed and developed in this study are used for the development of an analytical framework for planning of port capacity that has been applied to the Port of Rotterdam (Dekker, 2005). The ultimate goal is the development of a generic planning approach for transport hubs in order to be able to evaluate hub development plans.

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SAMENVATTING

CONCEPTEN VOOR INTEGRALE PLANNING VAN HAVENCAPACITEIT – TOEPASSING OP UITBREIDINGSPLANNEN VAN ROTTERDAM

Havenplanning is gecompliceerd door diverse factoren waaronder de aanwezigheid van schaalvoordelen in havenuitbreiding en het feit dat havens opereren onder concurrentie. De havenplanner dient een overzicht te geven van alle mogelijke strategieën die leiden tot een versterking van de concurrentiepositie. Keuzes moeten worden gemaakt met speciale ontwerpconcepten binnen een raamwerk bestaande uit vraag-aanbodplanning en kosten-batenanalyse. Havenuitbreiding is een strategie om de concurrentiepositie van een haven te versterken en kan worden beschouwd als een constructieve havencapaciteitsmaatregel. Niet-constructieve alternatieven zijn gebaseerd op vraag- en aanbodmanagement en zijn gericht op een efficiënte capaciteitsbenutting. Bij het ontwerp van havenuitbreiding dient een zeker niveau van congestie te worden geaccepteerd. Volledige integratie van bedrijfseconomische belangen (van de haven) en publieke belangen door het combineren van constructieve en niet-constructieve maatregelen is essentieel bij planning van havencapaciteit. Efficiëntie, het belangrijkste leidende principe voor een dergelijke planning, adresseert het simultaan bepalen van 1) de optimale omvang van de uitbreiding, en 2) de terugverdienperiode.

TREFWOORDEN

havenplanning, havenuitbreiding, capaciteitsplanning, investeringsplanning

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