EJTIR

Issue 12(3), 2012
pp. 310-331
ISSN: 1567-7141
www.ejtir.tbm.tudelft.nl

Combining Models and Commodity Chain Research for Making Long-Term Projections of Port Throughput: an Application to the Hamburg-Le Havre Range

Peter W. de Langen[1]
Department of Corporate Strategy, Port of Rotterdam Authority, Rotterdam, The Netherlands, and Department Industrial Engineering and Innovation Science, Eindhoven University of Technology, Eindhoven, The Netherlands

Jaco van Meijeren[2]
Sustainable Transport and Logistics, TNO, Delft

Lóránt A. Tavasszy[3]
Sustainable Transport and Logistics, TNO, Delft, and Faculty of Technology, Policy and Management, Delft, Delft University of Technology

Long term projections of cargo throughput are indispensable for port development plans. Although commodity flow projections are useful for governments, port authorities, terminal operating companies and port users, scientific research on commodity flow projections for ports is limited. Existing studies generally use econometric models that assume stable relationships between growth of port throughput and such variables as GDP growth and trade growth. This paper presents a method that was developed as part of the Port Vision 2030 project of Port of Rotterdam Authority. The method combines a model with expert judgement and commodity specific research. This combination enables incorporating disruptions of past growth patterns.
The contribution of this paper is the description of this method, its application to the volumes in 2030 of all major commodities handled in the Hamburg – Le Havre range, with four different scenarios, while most studies deal with a few commodities in one port, and often for a shorter period and with less scenarios. The results show that in all scenarios, total throughput is expected to rise, although in three scenarios not as fast as in the previous two decades. Furthermore, intermediates and container flows are expected to continue to grow, while throughput of raw materials (iron ore, crude oil) may decline.

Key-words: commodity flows; Hamburg-Le Havre range; port demand; projections; scenarios

[1] P.O. box 6622, 3002 AP Rotterdam, T: +31102521010, E: P.W.d.Langen@tue.nl
[2] P.O. box 49, 2600 AA Delft, T: +31888668404, E: Jaco.vanMeijeren@tno.nl
[3] P.O. box 49, 2600 AA Delft, T: +31888660888 , E: Lori.Tavasszy@tno.nl

1. Introduction

Long term projections[4] are indispensable for port development plans, for two main reasons. First, investments in port infrastructure are fixed investments, with a long pay-back period. Analysing the financial viability of such investments requires long term projections of port throughput (see Dekker et al, 2011, for a model to optimise port expansion that assumes linear growth of freight volumes). Even though flexibility in port planning is called for, to cope with uncertainty (see Taneja et al, 2012), projections with the use of different scenarios are required for a sense of direction. Second, port authorities develop strategies, for instance regarding redeveloping port areas, the selection of promising markets and the development of terminal sites. These choices benefit from a long term projection of commodity flows. Furthermore, port developers need to keep in mind that it takes a period of about 5-15 years between initial port development plans and their (final) approval (Notteboom, 2006). This increases the need for long run projections.

For these reasons, all major ports, especially when drafting long term development plans, rely on projections[5]. Even though commodity flow projections are widely used, mainly by governments, port authorities (PAs), and terminal operating companies (TOCs), scientific research on commodity flow projections for ports is limited. Our literature search shows that a) surprisingly little has been published in the literature on port forecasting and b) that the models reported in the literature are simplified to such an extent that additional research is needed to make forecasts useful for ports. Relevant works include Fung (2002), who created a projection model of container throughput for Hong Kong, and Hui et al (2004), who apply an error correction method to Hong Kong and compare it with the projection of the port planners. Both papers extrapolate historical trends, based on an econometric model. For a more detailed review of papers that use models for projections, see Van Dorsser et al, (2012). Our main critique on the approaches reported in the literature is that most forecasts rely uniquely on trend forecasts and trend based models. Typically, models do not capture disruptions of historical patterns, especially for specific commodities. However, disruptions do occur in practice, with implications for long term planning, as illustrated by the following cases.

- Port of Rotterdam Authority (PoR) made projections shortly before the oil crisis in 1973[6]. Based on the fast growth in the 1950s and 1960s, the projections foresaw a crude oil throughput of more than 200 mln ton in 1980 and more than 300 mln ton in 1990 (PoR, 1974). The realised throughput of crude oil peaked in 1976, with almost 150 mln ton, and declined to slightly less than 100 mln ton in 1990.
- Projections for conventional breakbulk in Port of Antwerp that were made in 2005. In 2004, conventional breakbulk volumes in Antwerp were around 20 million ton. The projections for 2015 were roughly between 17 million in a low growth scenario and 22 million in a high growth scenario (ESCA, 2005). However, partly due to rapid containerisation of flows, breakbulk throughput declined to about 12.8 million ton in 2011 (Port of Antwerp, 2012).
- Many port authorities and TOCs underestimated the surge in container volumes between 2000 and 2008. In these years, average annual growth in the Hamburg-Le Havre (HLH) range was 9%, higher than most firms in the industry expected, and higher than the growth in previous years. This led to capacity shortages in various parts of the world (see Maloni and Jackson, 2005 for the case of the US ports).

This paper presents a forecasting approach that uses a model, in combination with expert judgement and commodity specific research. This combination enables incorporating disruptions

[4] We use the term projections, instead of forecasts, to highlight the uncertainty of future developments. These projections provide a sense of direction. But they certainly cannot be taken for granted.
[5] See for example the port plan for Hong Kong: http://www.pdc.gov.hk/eng/plan2020/pdf/annex.pdf.
[6] The report is officially published in 1974, but projections were based on the throughput in 1970.

of past growth patterns. The approach was developed for a project at Port of Rotterdam Authority, to develop long term projections of commodity flows for the HLH range. We provide the main results, but emphasise that the main aim of these projections is to provide a 'sense of direction', The precise figures are less relevant.

Practical approaches to make long term forecasts in combination with expert judgement have been developed before but were generally not as broad and systematic as this study (most studies deal with a few commodities, one port, a shorter period and two or three scenarios). In addition, strangely enough, these approaches are not published in the academic literature. Given the importance of getting investments right in infrastructures (Skamris and Flyvbjerg, 1997), forecasting approaches require better coverage in the literature. The contribution of this paper is an account of a combined, model and expert based, forecasting effort, its application to forecasts for 2030 of volumes of all major commodities (16) handled in the Hamburg – Le Havre range, in four different scenarios. The paper is built up as follows. First, we provide a short general description of the HLH range. This is relevant because it explains some of the choices regarding projections. Second, we briefly describe previous experiences of Port of Rotterdam with projections. Third, we detail the method used and fourth we present the main findings. A short concluding section finalises the paper.

2. The Hamburg-Le Havre range

The Hamburg Le Havre range consists of ports in France, Belgium, the Netherlands and Germany, that all serve North-West European hinterlands. The three largest ports in Europe (Rotterdam, Antwerp and Hamburg) are located in this range. The throughput volumes of the large ports in this range are given in Table 1[7].

Table 1. Throughput volumes 2011 Hamburg – Le Havre range

Port	Dry bulk	Liquid bulk	Containers	Others	Total
Hamburg	25647	13.964	90.129	2.476	132216
Bremen	8036	1.465	62.683	8.401	80585
Wilhelmshaven	3345	19.620	0	18	22984,27
Amsterdam	46450	39.446	606	6.384	92886
Rotterdam	87326	198.526	123.556	25.143	434551
Zeeland Seaports	13169	12.778	189	9.382	35518
Antwerpen	19086	46.016	105.109	16.940	187151
Gent	17130	4.451	545	5.069	27195
Zeebrugge	1652	8.281	22.743	14.281	46957
Duinkerken	23789	8.064	2.387	13.283	47523
Le Havre	3058	41.386	21.629	1.465	67538
Total	248.689	393.997	429.576	102.842	1.175.104
Growth rate 1991-2000	0,6%	2,4%	7,6%	N.A.	2,4%
Growth rate 2001-2010	-0,1%	2,3%	6,6%	N.A.	2,8%

Gross weight x 1 million metric tons Source: PoR (2012A)

[7] Table 1 shows that Rotterdam is market leader for liquid and dry bulk. The large market shares for dry and liquid bulk are mainly explained by two factors. First, because of the large draft (depth of entrance channels and port basins) and open access to the sea (no locks), Rotterdam can accommodate the largest bulk tankers. This is not the case in Hamburg and Antwerp (draft problems for the largest bulk vessels) and Ghent and Amsterdam (behind a lock that is too small for the largest bulk vessels). Second, Rotterdam is well connected to sites of 'bulk consuming industries' (oil refining, the petrochemical industry, steel production and energy production). Most of these industries receive bulk goods by river and/or pipeline. Pipeline infrastructure connects Rotterdam to the main oil refineries in North West Europe, including Antwerp. Dry bulk (especially coal and iron ore) is mostly shipped by barge to inland destinations. This gives the 'ARA ports' (Amsterdam, Rotterdam, Antwerp), that are well connected to the river Rhine, a competitive advantage over German and French ports.

3. Long term projections at Port of Rotterdam Authority

Port of Rotterdam Authority has a long tradition in making projections. So called 'commodity flow models' were developed in the 70s and further refined in the 80s and 90s. The latest projections with these models were made in 1996 (PoR, 1998) and updated afterwards for some market segments. The projections of total throughput made in 1996 (with 1993 as base year) and real throughput volumes until 2010 are given in figure 1. Figure 1 shows the projects for two scenarios: the most optimistic one (Global Competition) and the most pessimistic one (Divided Europe). These figures show the volume growth in this period exceeded the most optimistic scenario of Port of Rotterdam Authority (PoR), rather exceptional for demand projections (Skamris and Flyvbjerg, 1997). This was mainly caused by higher than expected growth of container volumes and mineral oil products. This does not imply that the latest projections will also be exceeded, as indicated in section two, forecasts have been too optimistic as well.

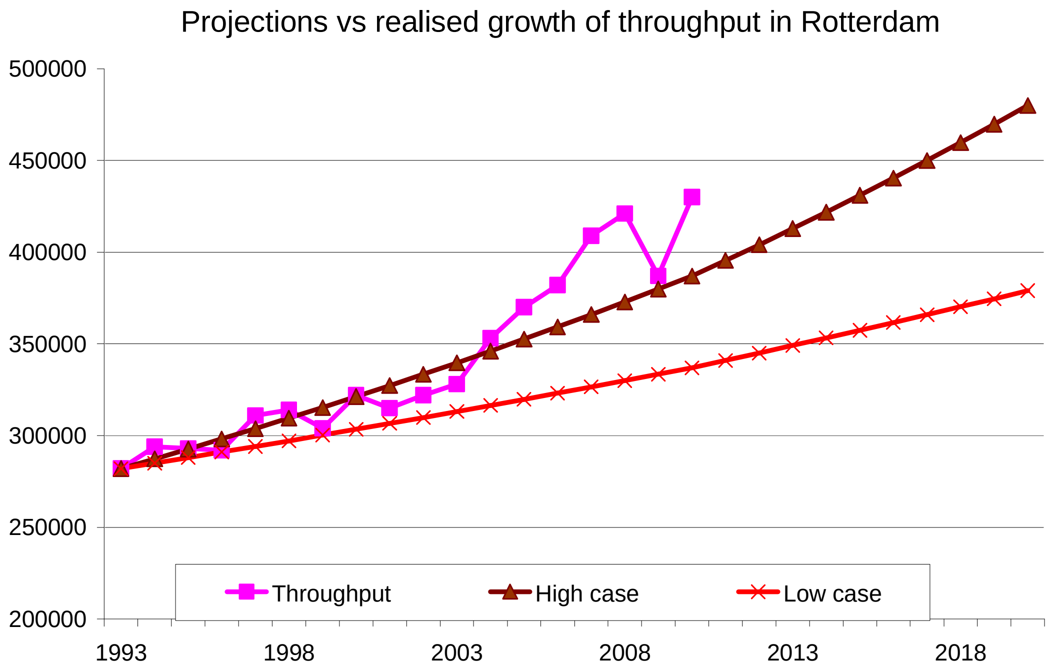

Figure 1: PoR 1996 projections vs real throughput development (until 2010)

Source: authors, based on Port of Rotterdam (2010A and 2010B)

The use of long term projections by PoR

The long term projections are used, first, to develop an overall vision for the long term development of the port (see Port of Rotterdam, 2012). Projections are an important requirement for developing such a vision. Second, especially since corporatisation, PoR makes investment decisions based on business cases. This applies to large port development projects (such as Maasvlakte 2), for new terminal concessions and for investments for established customers (e.g. construction of additional jetties). Given the long depreciation periods of these investments, long term projections are used[8]. Third, PoR is actively involved in efforts to secure hinterland access

[8] These projections are thus mainly used for strategic choices in port development. As PoR makes these investments itself, (roughly €180 mln per year, on top of the € 2 billion investments in the Second Maasvlakte

(see Van der Horst and De Langen, 2008), through investments in road and rail infrastructure and through infrastructure management organisations aimed to improve the utilisation of existing infrastructure. Projections of the demand for transport of different hinterland modes are an important input for decisions in this area.

4. Long term projections for 2030: method

This section discusses the main choices made in the projection project. The most important characteristic of the method is a combination of a freight transport model and commodity specific research and expert judgement to validate or modify the model results. Most studies either use the outcomes of freight transport models or expert based methods to project cargo throughput. The latter type of studies is frequently made by consultants and may include methods such as a 'multiple' (or multiplier) of freight growth over GDP. However, such a multiple is not derived from a freight transport model.

Long term port flow projections require a systematic treatment of the effect of global economic developments on world trade and port throughput, a key capability of large scale freight flow models. Freight demand models distinguish several levels of analysis and can be implemented using different modelling methods and techniques (see for a recent review Chow et al, 2010). Currently, freight models have limited capabilities to address new logistic developments (Tavasszy et al., 2012). The ongoing globalisation and changing supply chain structures are not captured in models, which can result in substantial differences between projections and actual freight growth. Large scale freight modelling approaches rely on publicly available statistics of production and trade and are insufficiently detailed to capture strategic developments in production networks, such as the effects of global mergers & acquisitions, hub formation, port choice, technological innovation, scarcity of resources and green logistics (see e.g, Dicken, 2003; Tavasszy et al, 2003; Rodrigue, 2006). As these models provide insufficient detail, analyses of breaks in industry trends and their implications for projections are needed, to improve and detail generic projections. This is especially the case when forecasts are made for specific commodities, instead of freight transport in general. By looking in detail at different segments, specific developments that can have substantial impact on the results of the projections can be taken into account. Examples are different developments for container segments and different developments for dry bulk segments. For specific commodities, disruptions of past growth patterns are more likely (e.g. through containerisation, changing supply chains or changing manufacturing technologies).

Virtually all the relevant previous academic work on throughput projections deals with container traffic only and takes a pure modelling approach (see Klein, 1996; Veenstra and Haralambides, 2001; Seabrooke et al, 2003; Lam et al, 2004, Guo et al, 2005; Peng and Chu, 2009; Chen and Chen, 2010). For a more detailed review see Van Dorsser et al, (2012). These authors develop a forecast with a very long horizon (2100), based on a model that relates throughput to GDP growth, but do not distinguish between commodity flows and also do not include transhipment. In summary, the current state of the art in forecasting models mostly rests on cyclical and linear trend analyses, supported by (mostly aggregate forms of) discrete choice modelling for trade and mode choice. As models are validated on time series or cross-sectional data from the past, the capability of these models to take into account the effects of disruptions is limited.

Our method combines of a freight transport model and commodity specific research and expert judgement to validate or modify the model results. Recently, a combined method was used for projections in the Dutch rail market (see Van Meijeren and Hofker, 2009). This study

---

project), there is no drive to develop unrealistically high forecasts, as may be the case when investments in port development are publicly funded (see Van Wee, 2007).

demonstrated that an added benefit of such a specific analysis is that it substantially improves the stakeholders' acceptance of the results. A systematic overview of the steps in our method is given in Figure 2.

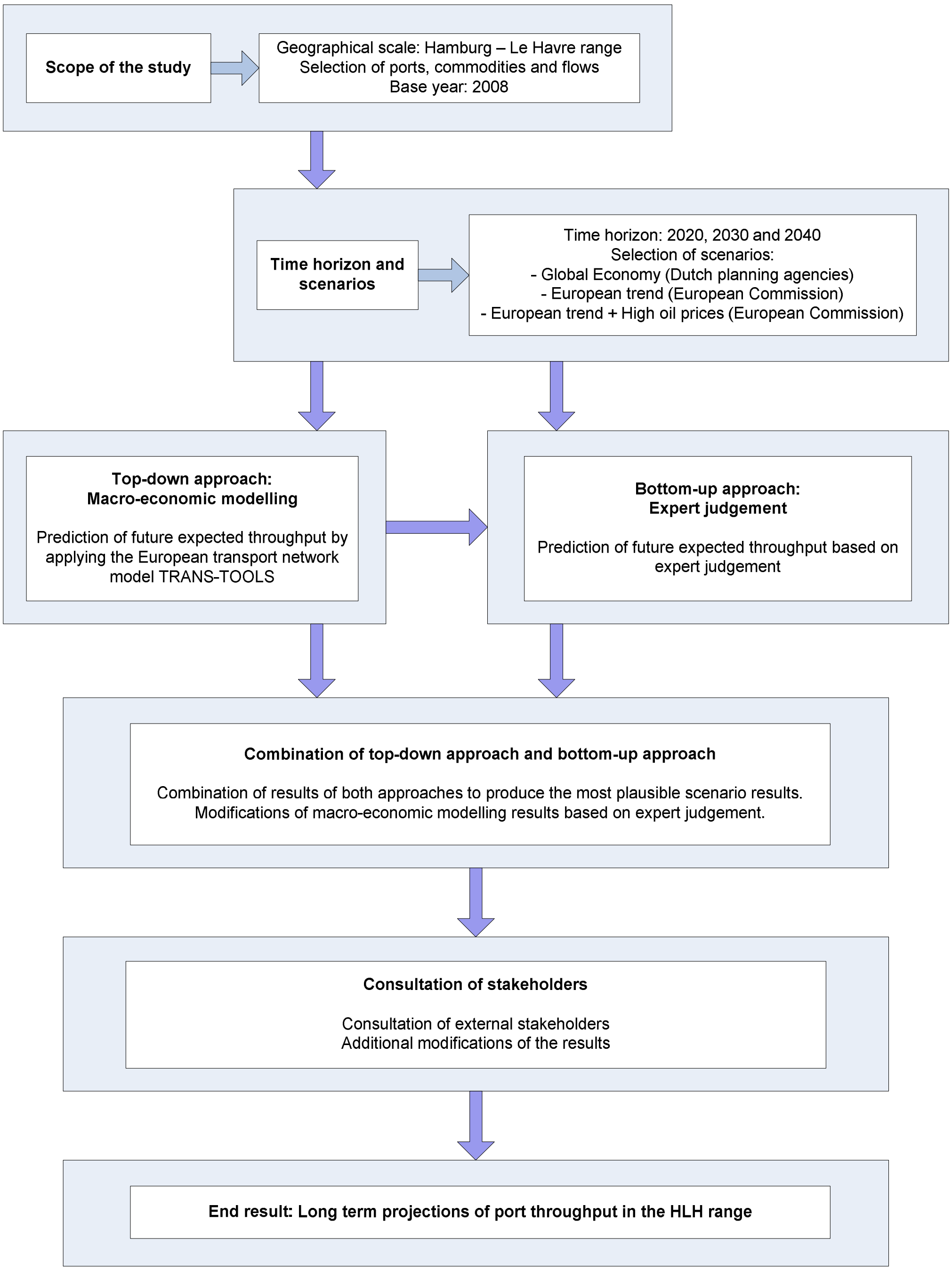

Figure 2. Schematic overview of the method

Analysis of the market in North West Europe

Given the fact that Rotterdam competes with other ports and market shares change over time, it was decided to make a projection of throughput for the relevant market – not just for Rotterdam. Making a projection for a range instead of just one port reduces the sensitivity of shocks. For instance, the closure of a large plant in the proximity of a specific port will have a huge impact on the throughput of that port, but the impact on the throughput of a complete range is much more limited. Thus, total volumes for the relevant market, the Hamburg Le Havre range (see Veldman and Buckmann, 2003 and Notteboom, 2006) were projected[9]. For efficiency purposes, only the volumes of the 11 largest ports were taken into account, not the very small volumes of the other ports in the range[10]. The ports in the Hamburg Le Havre range that have been taken into account are the ones listed in table 1.

The study takes into account all maritime transport arriving in or departing from these ports. The distribution of these 'maritime' freight flows to different hinterland transport modes is not included in this study. Furthermore, the projections do not distinguish between import and export flows.

Distinction between commodity flows

As the second step, the commodity flows for the projections were identified. Ports collect data on different levels of detail (e.g. liquid bulk, further divided in mineral oil products, crude oil etc.). The definition of commodity groups was driven by first, the need to define coherent commodity groups, with distinct throughput drivers and distinct terminal requirements. For this reason, dry bulk was not used: the underlying throughput drivers of coal (mainly energy) differ substantially from the throughput drivers of iron ore (steel mill capacity). For the same reason, three types of container flows are distinguished: direct deepsea, shortsea and transhipment flows. The throughput drivers for these flows differ, which led to a different method. This approach is in line with the study of the Institute of Shipping and Logistics (ISL) for a container forecast (ISL, 2011). Transhipment flows differ from 'direct deep sea' and shortsea because they arrive and depart by ship, while direct deepsea and shortsea flows either arrive or depart from the port by truck, train or barge. So feeder flows are driven by scale economies in container shipping, while shortsea flows are driven by intra EU trade and a shift from road to sea.

Second commodity groups were aligned with the categories in the TRANS-TOOLS model as much as possible (we elaborate on the model further on in this section). Third, small commodity flows were not studied in depth, as their relevance for port development plans and investment decisions is limited. For instance, 'other general cargo' was used as a commodity group, consisting of different commodities such as non-containerised paper, cars and fruit. The total volumes are so small, about 1.5% of the overall throughput in Rotterdam (PoR, 2010A), that further divisions are not warranted. Table 2 shows the commodity groups for which projections were made.

---

[9] There is some competition between the Hamburg Le Havre range and ports in other parts of Europe (e.g. ports in the Mediterranean or Black Sea area (see Medda and Carbonaro, 2007). However, this competition is very limited for most commodities. The growth of ports in the Mediterranean is mostly due to economic growth in 'their' hinterland, not to shifts in hinterlands. The first effect is included in the TRANS-TOOLS model.

[10] The 11 included ports account for more than 97% of all throughput in the HLH range. The 'cut –off point' at eleven was chosen as there is a huge gap between the 11th largest port, Ghent, with over 20 million ton and the next largest port (Groningen. Moerdijk, Kiel and Oostende all handle less then 10 million ton).

Table 2. Overview of commodity groups

Type of goods	Commodity groups
Dry bulk	Coal
	Iron ore
	Agribulk
	Dry biomass
	Other dry bulk
Liquid bulk	Crude oil
	Chemical products
	Vegetable oil products
	Mineral oil products
	LNG
General cargo	Ro-Ro
	Steel products
	Other general cargo
Containers	Short sea (excluding feedering)
	Direct deep sea (excluding feedering)
	Feedering

Time horizon and base year

Given the fact that port development requires long term investments, insight in the development of freight flows is needed for time horizons up to 2030[11], a period of 20 years. While port infrastructure is used even longer, 20 years is sufficient for investment decisions, as the impact of revenues and costs of the infrastructure after the first 20 years have a minor impact on the net present value (NVP). This period was similar in previous projections at Port of Rotterdam, and is sufficiently long for making port development plans not too long for making a detailed projection (see Petersen et al, 2009). An important basis for the projections is the base year data of the throughput in the Hamburg Le Havre range. In this study, 2008 was used as base year for two reasons. First, 2008 was the latest year for which throughput data of all relevant ports was available. Second, provisional data for 2009 could not be considered as a representative base year because of the – temporary – strong decline in throughput for several segments (in some cases over 30%), due to the huge economic crisis that deeply affected port throughput in 2009[12].

Scenarios

As uncertainties surround economic development, trade flows and logistics patterns, scenarios are used to create different forecasts. A scenario consists of a number of (plausible and coherent)

---

[11] Many Dutch public planning initiatives deal with 2040 (see e.g. VROM, 2008). As the time horizon of the port vision is 2030, the projections are for 2030. An indicative projection for 2040 was included. In line with Petersen et al (2009), we use our approach with a model and detailed expert opinions for a 20 year time horizon. For longer time-horizons, this approach may be too detailed and a more general (meta-) model may be more appropriate.

[12] The economic crisis affected the last quarter of 2008, but nevertheless the highest throughput ever in the Hamburg Le Havre range was realised. For general cargo and containers the decline in throughput because of the economic crisis was expected to have a structural impact. Thus, the long term growth rates for 2009 and 2010 were modified downwards. For 2009, half of the expected decline in throughout was taken into account. The argument was that 2008 was a peak and 2009 a bottom, so that it would be sensible to work on the basis of an average. For 2010, a 0% volume growth was assumed, in line with the modest 2010 economic growth prospects. For 2011- 2030 the projected long term growth rates were used. For bulk commodities the impact of the economic crisis on volumes was not expected to be structural, so no modifications have been made for the bulk products. As an alternative, we could have used a de-trended value of the 2008 throughput as a starting point. This was not done as it would be complex to explain the use of 'wrong' figures' for 2008, but may be appropriate from a methodological point of view.

assumptions about future developments. By using scenarios, uncertainty is taken into account. For cargo throughput the two most important uncertain factors were identified as:

- Economic development. Economic development is an important driver of cargo throughput. Many commodities handled in ports are raw materials or intermediates. These flows are strongly related to industrial production (see Pallis and de Langen, 2010) and economic growth.
- The speed of a transition towards a sustainable economy. Many commodities handled in ports (crude oil, oil products, coal, liquid natural gas) are non-renewable and energy-related. The transition towards sustainability requires changing the energy mix (more renewable energy), with potentially huge consequences for ports.

Established economic scenarios were used as a basis for the forecasts as these are more acceptable for stakeholders. Given the uncertainties described above, the following four scenarios were used:

- European trend scenario

The European Trend (ET) scenario (European Commission, 2006) – developed for the European Commission – is a reference scenario that is used to analyse the impact of European policy measures. ET is a scenario with moderate economic growth without major disruptions of existing trends. For instance, the share of renewables remains relatively low, and existing patterns of industrial production hardly change.

- Global Economy scenario

The Global Economy (GE) scenario is one of the four scenarios developed by the Dutch planning agencies (CPB, MNP and RPB, 2006). The main drivers of this scenario are strong international cooperation (further globalisation) and strong development of the private sector. Compared to the other three scenarios and ET this scenario can be characterised as a high economic growth scenario, with a slow transition towards sustainability.

- Alternative energy and sustainability scenario

The alternative energy and sustainability scenario is based on the European trend scenario, but in addition, shifts in the energy market are assumed, due to high oil prices, (therefore the abbreviation HOP (see Schade et. al, 2008)) and increased attention and priority for sustainability. Compared to the European trend scenario, the economic growth is similar, but because of the shifts in energy markets, a number of commodities have different growth/decline patterns. This scenario is not the result of a 'backcasting approach' (see Hickman and Banister, 2007, for such an approach to improving the sustainability of transport, also with the time horizon 2030) but assumes a significantly higher share of renewables in the energy mix.

- A 'low growth' scenario.

This low growth (LG) scenario is based on a CPB scenario and had been previously used in TRANS-TOOLS. It assumes a very modest economic growth in Europe, combined with maturing of the growth in global trade.

The ET, GE and LG scenario have been applied in several other studies. The alternative energy and sustainability scenario is less common and was further elaborated in this project.

Method: combining modelling and industry analysis based on expert judgement

Our method is a combination of a quantitative model and an expert based approach. Experts assessed critically the plausibility of model outcomes and to suggest modifications to model use, inputs, or results. Currently, most academic research uses regression analysis to define relationships between the flows of specific (containerised) commodities (the dependent variable), and a set of economic indicators, such as GDP (independent variables). Occasionally, these studies compare their outcomes with expert views and evaluate or correct the predictions directly using the expert's growth estimates (as was the case in Seabrooke et al, 2003 and Ke et al, 2009). We are not aware of any academic publications in the field of freight transport that combine modelling and expert knowledge.

In the remainder of this section we describe the model based analysis and the expert based analysis employed in this forecasting study. We explain how both were used for the different commodity segments and provide some detailed examples of numerical differences between the model-based and expert based results.

Modelling: the TRANS-TOOLS model

Few freight transport models cover all Europe. TRANS-TOOLS is an European network model that covers transport in Europe by mode of transport (road, rail, inland waterways and maritime transport) and by commodity (according to the NSTR 1 classification). It is developed for and owned by the European Commission (TRANS-TOOLS, 2006)[13].

Table 3: the TRANS-TOOLS models

Step in calculation (sub-model)	Methods used
Regional freight generation and interregional distribution of flows (output: interregional trade table: tons/year)	Interregional freight flows by commodity in tons are based on regional freight generation functions for production and demand. Flows are distributed spatially with a doubly constrained gravity model taking account of trends in supply and demand, including changes in trade impediments between countries. This method first determines how much freight transport will leave a region (where it is produced) and how much freight transport will enter in a region (where it is consumed). In a next step, the production and consumption regions are linked resulting in freight flows between regions.
Mode choice (output: interregional transport table by mode of transport; tons/year)	Aggregate multinomial logit model based on transport times and tariffs. Logistic chain model based on trade volumes and networks (optional). No intermodal transport.
Network assignment (output: network flows in vehicles per year)	Equilibrium assignment to network. Transport flows in tons are translated in number of transport units (trucks, trains, vessels) and assigned to the infrastructure network. The result consists of intensities of traffic on the network including additional information such as type of vehicles or fuel use. In the assignment limited infrastructural capacity is taken into account (alternative routes are chosen if the preferred route is too much congested). Port choice is not included in the assignment.

[13] More general information about TRANS-TOOLS can be found on the website of the Joint Research Center of the European Commission: http://energy.jrc.ec.europa.eu/transtools. The model is IPR free (Intellectual Property Right free) meaning that anyone can download and apply the model (although in-depth knowledge is necessary to run the model). This model was built in a 6th framework project for the European Commission coordinated by TNO. The model was applied for many European studies and TNO has applied the model in several national and regional studies as well. Examples of these studies are a social cost benefit analysis of the lock at Terneuzen (TNO, 2009) or a social cost benefit analysis of the Iron Rhine rail corridor between Antwerp in Belgium and the Ruhr area in Germany (TML and TNO, 2009).

The structure of the TRANS-TOOLS model is as follows. The main input of the TRANS-TOOLS model consists of socio-economic data (economic structure and population) on regional level (NUTS 2 regions) and transport data on network level. The projections for freight flows are made between regions and per commodity group, based on socio-economic variables in both regions (e.g. regional production, growth in specific industries and regional consumption growth in specific sectors). Next, shifts in modal-split are projected based on changes in level-of-service (generalised transport costs) and the results are assigned to the infrastructure networks per transport mode. The models used are summarized in Table 3.

The above sub-models are run after one another. By doing so, the model translates the macro-economic scenarios (such as the European trend scenario) into developments of freight flows in terms of projected annual growth rates for different commodities. TRANS-TOOLS does not take capacity restrictions, competition between ports or industry specific developments into account. For the projections of the throughput in the Hamburg – Le Havre range, mainly the sub-model dealing with regional freight generation and interregional distribution of flows has been applied since the projections focus on maritime transport flows. The sub-model on mode choice and network assignment – have only been applied for specific analyses, as will be elaborated below.

The sub-model freight generation and distribution

For the estimation of the trade flows a gravity model is used in which the trade between countries/regions is explained by the supply factors of the exporting country/region and the demand factors of the importing country/region.

The underlying theory is that trade is the result of specialization of countries/regions. This means that a country/region produces and exports goods for which it has a comparative advantage. Besides the supply and demand factors in the gravity model a 'resistance' on the trade is assumed because of impediments to trade such as transport costs, imposed tariffs and cultural differences. It is expected that, all other things being equal, the larger the distance between countries, the less trade will take place. In addition, cultural and fiscal factors impact trade flows between regions. Expressed mathematically, the above-described relations lead to a functional form of the trade model as follows:

$$T_{ijg} = \alpha 1 * P_{ig}^{\alpha 2} * A_{jg}^{\alpha 3} * D_{ij}^{\alpha 4} * e^{\alpha 5 * DUMMY} \quad (1)$$

Wherein,

Tijg:	the trade of commodity group g between country/region i and j in tons;
Pig:	the added value of the sector that supplies commodity g in country/region i;
Ajg:	the added value of the sector that consumes commodity g in country /region j;
Dij:	the deterrence variable representing generalized costs between capital cities of country/region i and j as a proxy for the resistance on the trade;
DUMMY:	a dummy variable that captures economic co-operation between countries/regions or a specific position of (a group of) countries/regions;
α1, α2, α3, α4, α5:	the model parameters.

A recognized weakness of this model (Monzón et al, 2010) is that it does not incorporate effects of potentially disruptive developments, such as climate change and energy scarcity. In addition, commodity specific trends are not incorporated in the model. Thus, disruptions of past growth patterns are not incorporated in TRANS-TOOLS and the outcomes, like the outcomes of all forecasting models, need to be confronted –and in some case modified- with expert judgement. This incorporation of expert judgement affected the calculations in different ways. In some cases, economic inputs (expected production of goods in specific regions, for instance oil refining in the Ruhr area) were deemed unrealistic, in other cases intermediate model results (e.g. new trade flows between regions were added because of ongoing investments in plants or terminals) were modified and as a third option, final results were modified (for instance because of a changing share of transhipment).

In the case of changes in inputs or intermediate results, the models were re-run, in the case of changes of final results, alternative methods to develop a forecast were developed. In the next section we describe how the forecasting process was influenced by expert judgement and draw lessons from this process for future forecasts.

Industry specific analysis and expert judgement

In TRANS-TOOLS –like in other freight models, industry specific developments are not taken into account. This disadvantage can be dealt with by commodity specific research and expert information concerning expected market developments. Based on their in-depth knowledge of specific market segments, experts from PoR as well as other companies and institutes were consulted. The conversations with experts focused on identifying and understanding throughput drivers of commodity flows (see Pallis and De Langen, 2010)[14] and potential disruptions of past growth patterns related to these throughput drivers. The experts were also asked to assess the plausibility of the model results. In total, over 50 experts were consulted, a minority from Port of Rotterdam Authority and the majority from firms operating in the 16 commodity segments. Most of these experts work with multinational firms, so even though the majority is based in the Netherlands, a ´country bias´ is unlikely. And based on the modifications made (see later), there was no common 'bias' of being more or less positive than the model results about throughput growth. Furthermore, the projections were also discussed with some leading international experts. The model results have also been discussed with governmental agencies such as the independent economic bureau engaged in various scenario studies (CPB), the agency for environmental studies (ECN) and the agency for mobility studies (KIM). The response by KIM (see KIM, 2010) led to the inclusion of the low growth' scenario, the other meetings resulted in modifications of the preliminary results.

This process is visualised in Figure 3. The process starts with the input (I) of the model (scenarios), the model run (TT) and the output (O) of the model (forecasts). Then the results have been assessed by experts and an investigation has been made of important additional developments. The expert ideas were taken into account either by changing the input of the model, or by changing the output. This loop of model results and expert ideas has been iterated a number of times to come to the final results of the combined approach of modelling and expert opinions.

[14] Conceptually, this approach is somewhat related to the Global Production Networks (GPN) research stream in economic geography. This research analyses (changing) structures of production-distribution-consumption chains (see Coe et al. 2008).

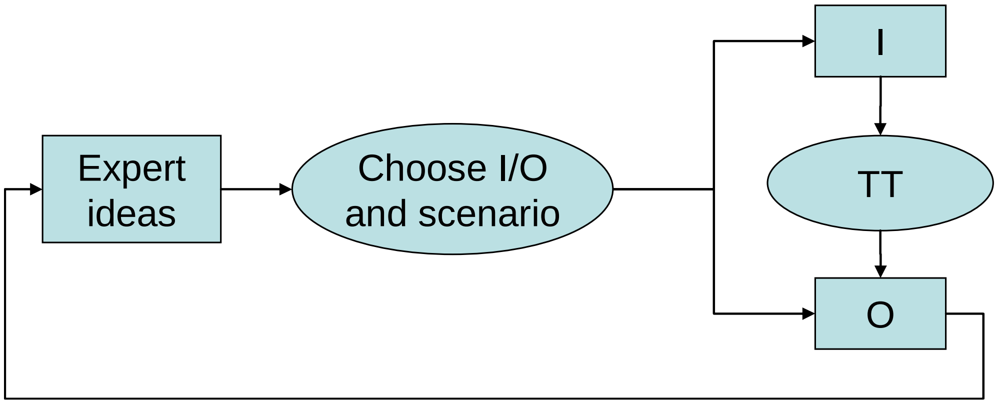

Figure 3. Combination of model results and expert judgement.

For most commodities, the expert judgement led to either modification of the TRANS-TOOLS results, or new projections, based on specific developments that are not taken into account in the TRANS-TOOLS model, but drive throughput volumes. Liquid natural gas (LNG) is an example. LNG is a potential new freight flow for many ports. As TRANS-TOOLS projects growth rates for 'existing' flows, the model does not work well for flows where various ports have either huge investment in new cargo handling equipment, or plans to develop such capacity. These 'disruptions' are not captured in the model. Therefore, the LNG projection is completely based on expert judgement.

Another example concerns the increased use of biomass in power plants. This is a disruption of past growth patterns, resulting in less flows of coal and more flows of biomass. This disruption is also not incorporated in TRANS-TOOLS. Thus, the biomass projection is based on expert judgement of the share of biomass-usage in coal fired power plants.

As a third example, a disruption of iron ore volumes is widely expected by industry experts. This disruption is mainly explained by the foreseen reduction of blast-furnace capacity for steel production in North-West Europe. This reduction is expected due to stable steel demand, combined with an increased re-use of steel products and a reduced competitiveness of steel production in North-West Europe, resulting in lower export volumes. Again, these disruptions are not incorporated in TRANS-TOOLS. Therefore, expert judgements were used to project the development of blast furnace capacity and resulting projections of 'steam-coal' (coal used in blast furnaces) and iron ore. Table 4 indicates to what extent modelling results have been modified or re-done.

A complete quantitative overview of all modifications is beyond the scope of this paper. For the two largest commodities (containers and crude oil, together around 40% of total throughput in the range), we describe the commodity specific analysis in more detail below[15].

[15] A complete quantitative description of all expert-based modifications is too detailed to be included in the paper. More details are available –in Dutch- from Port of Rotterdam (2012).

Table 4. Approach for projections for all commodities

Commodity	Approach	Disruption and adaption
Containers	modified TRANS-TOOLS outcomes	-Increasing containerisation (shift of non-containerised goods to containers). Higher containerisation rates (for instance for bulk metals) added to the TRANS-TOOLS model. -Growth of transhipment, higher transhipment volumes in United Kingdom added to results. -Maturing of globalisation of supply chains. Modification of 'multiplier' for container growth from TRANS-TOOLS.
Ro-Ro	TRANS-TOOLS outcomes	No disruptions. The model results were deemed plausible by industry experts and are in line with a UK projection (MDS Transmodal, 2007).
Iron ore & steel	New projections, based on industry insights	-Shift of steel mills to other regions in the world. Thus, the blast furnace capacity implicitly assumed in TRANS-TOOLS is too high. The projection is based on expert judgement of blast furnace capacity.
Coal & dry biomass	New projections, based on industry insights.	-The closing of German mines, leading to higher overseas imports. -Increased use of biomass in energy plants. -Lower blast furnace capacity (see above), resulting in lower volumes of coal. The projections were based on an overview of all coal fired energy plants, with expert judgement of the share of biomass.
Crude oil	New projections, based on industry insights.	-Closure of refineries in North West Europe. This is highly likely, as the region exports refinery products. The projections were based on expert judgement of future refinery capacity.
Mineral oil products	modified TRANS-TOOLS outcomes	- An increase in sea-sea transhipment of mineral oils flows. Expert based estimate of the sea-sea volume.
Chemical products	TRANS-TOOLS outcomes	Model results are plausible.
LNG	New projections, based on industry insights.	-Import of LNG by sea. Expert assessment of future investments in LNG terminals and utilisation in different scenarios.
Vegetable oils	New projections, based on industry insights.	-Increased use of biofuels in transport. Expert judgement of market for vegetable oil use as energy source.
Agribulk	New projections, based on industry insights.	-Reduced livestock and fertiliser use. Expert judgement of agribulk volumes.
Other dry bulk	modified TRANS-TOOLS outcomes	The growth rate was derived from projected growth rates of coal, chemical products and agribulk.

Containers

For containers, TRANS-TOOLS has incorporated a 'multiplier' between GDP growth and container volumes. This multiplier was derived from data for the past two decades, when container growth was very high. However, the analysis of throughput drivers suggests a lower multiplier in the coming decades. A detailed discussion of these trends is beyond the scope of this paper, but the main reasons are:

1. Container volumes are for a substantial part intermediates. The growth of intermediates has been very high due to increased global sourcing. However, for the future, intermediate flows are largely driven by industrial production in North West Europe, which is widely expected to be moderate.

2. In the past decades consumer goods were also increasingly imported from low wage countries. However, this is also a temporary trend: most consumer goods such as toys, furniture or textiles are now predominantly imported overseas.

3. Increased containerisation is part of the explanation of the huge container growth in the past decades. Ongoing containerisation is expected (e.g. for chemicals), but to a lesser extent as in the past decades.

Specifically for containers an analysis of the future of sea-sea transhipment is also required. Such transhipment is not incorporated in the transport model, but constitutes roughly 30% of all container volumes in the HLH range. In the projections, two regions are distinguished: UK & Ireland and Scan Baltic (Scandinavia and Baltic regions, combined). Both the Scan Baltic and Ireland receive more than 95% through feedering, this is assumed to remain the case. For the UK, container flows are currently about 70% direct calls and 30% transhipment through ports in the HLH range. The share of transhipment is assumed to increase to 35% in 2020 and 40% in 2030. Reasons for the assumed growth of transhipment share to/from the UK are:

- Increasing ship sizes and reduction of number of ports called by deepsea vessels (see Ng, 2006).
- Continued shift of distribution centres to Central UK (MDS Transmodal et al., 2006), while the UK deepwater ports are located in the South. The development of new 'port centric' distribution facilities (see Mangan et al, 2008), for instance in the Humber area are illustrations of this shift.
- Increasing attractiveness of feedering compared to transport through the UK by road and rail.

The incorporation of these assumptions in the model results leads to an additional feedering volume in the HLH ports.

Crude oil

Crude oil is input for refineries in North Western Europe. TRANS-TOOLS implicitly assumes a slight decrease of the refinery capacity. Industry experts expect a more severe decrease. Therefore, for each plant in North Western Europe, industry experts provided insights to make an assumption on whether it will still be in operation in 2030, based on the age of the site, and the accessibility of the site, and the integration in a petrochemical cluster. These assumptions are then used for a crude oil forecast that is substantially lower than the TRANS-TOOLS results.

Table 5. Differences between TRANS-TOOLS model results and final projection, for the ET scenario

Commodity	TRANS-TOOLS projection 2030, European Trend HLH range (mln. ton)	Modified projection 2030 HLH range, European Trend (mln ton)	Difference TRANS-TOOLS model and final outcome (%)	Short explanation of differences
Coal	64	67	+6%	The closure of coal mines in Europe (especially Germany) is not incorporated, but will lead to additional coal flows.
Crude oil	187	154	-21%	Industry experts foresee closure of refineries in NW Europe
Mineral oil products	199	217	+8%	Experts expect an increase in sea-sea transhipment of mineral oils flows.
Containers	1101	815	-35%	Industry experts expect a lower 'multiple' between GDP and container throughput.

These examples show that incorporating expected disruptions of past growth patterns has led to significantly modified forecasts. Table 5 shows the initial TRANS-TOOLS results and the final projections for the four largest commodities.

5. Long term projections for 2030; main results

This section presents the main findings on the projections[16]. The complete projections are given in appendix 1. First, in all scenarios, cargo volumes keep growing but in three of the four scenarios average annual growth is lower than in the past two decades (see McKinnon, 2007 for a similar conclusion regarding the growth of road freight). Figure 4 shows the overall projected cargo volumes (all commodities) in the four scenarios.

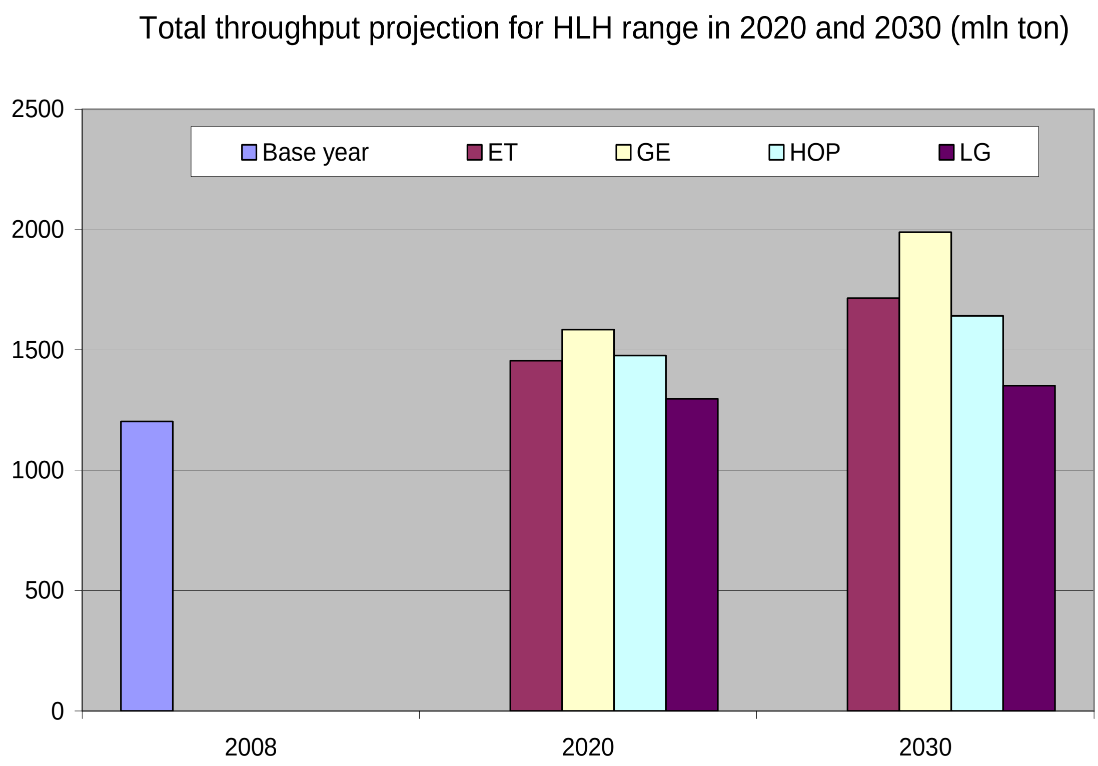

Figure 4. Overall projected cargo volumes in the HLH range

Source: authors, based on projections project at Port of Rotterdam Authority

Second, there are substantial differences between the different commodity groups. Table 6 shows the scenario projections for dry bulk, liquid bulk and containers. Containers are expected to

[16] The projections have been compared with other projections, but projections presented in this paper were more detailed and complete than other projections. Compared with scenarios developed by the Dutch planning agencies, *total growth figures* are similar, but, the results by *commodity group* differ. These differences can be explained by the fact that contrary to our approach, the WLO scenarios do not make a distinction between commodities and do not incorporate industry specific developments. For RoRO, the results are in line with an UK forecast (MDS Transmodal, 2007), while for containers, the forecasts are lower than the ISL forecasts (ISL, 2011). The projections are in line with the very long term projections based on a throughput to GDP relation by Van Dorsser et al (2012).

remain the fastest growth market segment. However, the projected growth in the container market is substantially lower than in the past decades[17].

Third, the commodity mix handled in ports is expected to change. This applies to all scenarios. Containerised goods become more important: while their share was 25% in 2008, this is projected to growth to 38% in HOP, 41% in ET and 42% in GE in the year 2030. Furthermore, a shift from primary commodities (crude oil, iron ore, coal) to intermediates (oil products, steel slabs) is to be expected.

Fourth, the energy mix has a very substantial impact on port throughput for specific commodities. Figure 5 shows the projected differences in throughout in 2030 for different energy commodities between the ET and HOP scenarios. Both scenarios have very similar socio-economic developments, so the main explanation of the differences is the different energy mix in both scenarios.

Table 6. HLH range compound annual growth rates (CAGR) per commodity group, for the past decades and projections until 2030

	Actual growth		Projection CAGR 2010-2020				Projection CAGR 2020-2030			
	CAGR 1990-2000	CAGR 2001-2010	ET	GE	HOP	LG	ET	GE	HOP	
liquid bulk	2,4%	2,3%	1,0%	1,7%	1,8%	-0,8%	0,7%	1,2%	0,1%	-0,4%
Dry bulk	0,6%	-0,1%	0,3%	0,7%	0,2%	0,0%	-0,2%	0,0%	-2,3%	-1,9%
Containers	7,6%	6,6%	3,2%	4,2%	2,8%	2,2%	3,1%	3,8%	3,0%	1,8%

Source: authors, based on projections project at Port of Rotterdam Authority

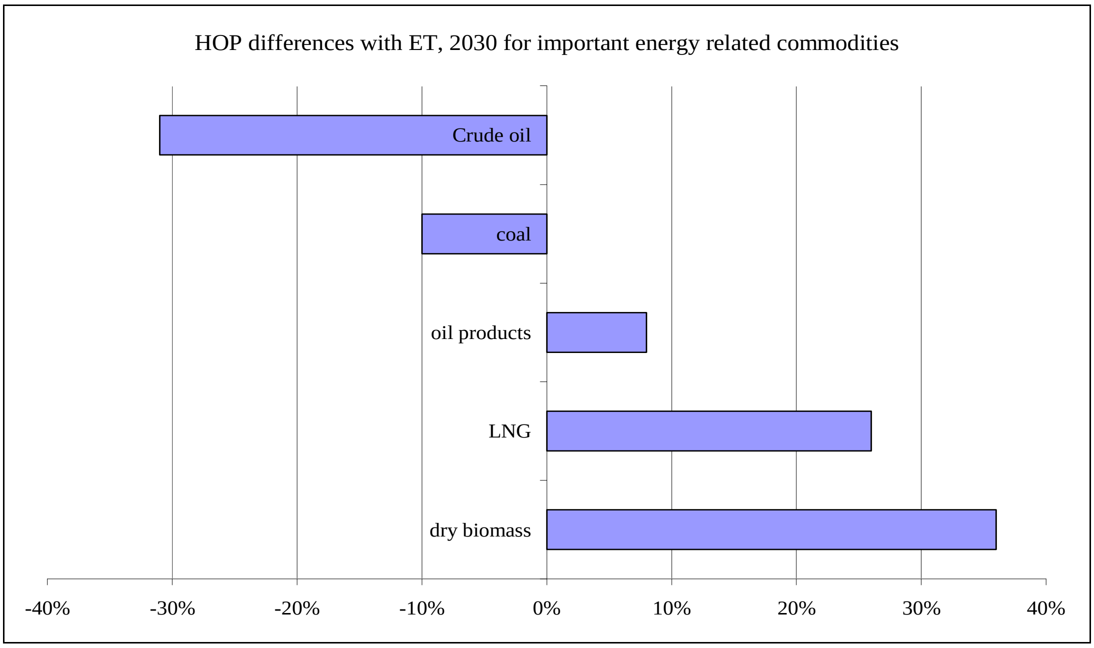

Figure 5. Differences between ET and HOP throughput in 2030, for important energy commodities

Source: authors, based on projections project at Port of Rotterdam Authority

[17] The projected growth of intermodal container transport is beyond the scope of the paper, but given the modal split ambitions of PoR and the inclusions of modal split targets in concession contracts for the container terminal operators in Rotterdam (see de Langen et. Al, 2012), intermodal container transport is expected to grow faster than maritime container transport.

6. Conclusions

Long term projections are indispensable for port development plans. In this paper we have presented the method and results of projections of the Hamburg-Le Havre range port throughput in 2030. This paper is one of the few studies where all major commodities handled in ports have been analysed. The study has led to important conclusions.

First, incorporating expert based analysis has led to important modifications to the assumptions and results of the transport model. A European transport model was used for obtaining a first set of results. These were confronted with expert opinions. Through expert judgement, throughput drivers for various commodities and likely disruptions of past growth patterns were identified and analysed. This led to modified forecasts. In some cases, the results of the TRANS-TOOLS model were used without modifications, in other cases, the model results were modified based on expert judgements and, as a third possibility, a commodity specific analysis and projections replaced the outcomes of the model. These modifications demonstrate the impact of incorporating expert judgement in projections.

Second, the result shows that commodity specific trends are relevant. Disruptions of past growth patterns are likely, according to the involved experts. There is no common denominator in the modifications of the experts: in the case of coal, the model results are too low (due to closure of mines not incorporated in the model) and in the case of crude oil too high (because of an expected shake-out in European refining not incorporated in the model). The relevance of commodity specific trends is an important conclusion, as evaluations of the benefits of investments in infrastructure often rely on results of models alone, even though these do not capture such trends.

Third, the results show that in all scenarios, total throughput is expected to rise, although in three scenarios not as fast as in the previous two decades. Both the model alone and the modified results based on experts suggest lower growth rates than in the previous decades.

Fourth, the results suggest relatively low growth rates or decline for raw materials and moderate growth rates for intermediates and container. Thus, the composition of throughput is likely to change substantially.

Fifth, this study has shown that assumptions about the future energy mix have a huge impact on commodity flows. Given this huge impact, the lack of attention for the relation between the energy mix and freight flows, both academically and in the industry, is surprising. This is an important area for further research.

Future research on port throughput projections is relevant given their importance in port planning and development. Specific issues requiring further attention include ex post evaluations of cargo forecasts of ports as well as comparative analysis of growth patterns of ports, to better understand the relevant throughput drivers. Research on growth patterns of ports in advanced economies vs. ports in emerging economies seems relevant.

References

Anderson, C. Opaluch, J. and Grigalunas, T (2009). The Demand for Import Services at US Container Ports, *Maritime Economics & Logistics*, vol. 11, no. 2, pp. 156-185.

Bröcker, J. (1998). Operational spatial computable general equilibrium modelling. *The Annals of Regional Science*, vol. 32, no. 3, pp. 367–387.

Chen, S.-H. Chen, J.-N. (2010). Forecasting container throughputs at ports using genetic programming, *Expert Systems with Applications* vol. 37, no. 3, pp. 2054–2058.

Chen, T.M., Rudzikaite L., van Leest, E., Tardieu, P., Bröcker, J., Schneekloth, N., Korzhenevych, A, Szimba, E., Kraft, M., Krail, M., Siegele, J., Nielsen, O., Hansen, C., Martino A., Fiorello, D., Christidis, P., Burgess, A., Becker, J.F.F., Snelder, M. (2005). Deliverable 3: Report on model specification and calibration results TRANS-TOOLS (TOOLS for TRansport forecasting ANd Scenario testing). Deliverable3. Funded by 6th Framework RTD Programme. TNO Inro, Delft, Netherlands. Accessed 15 june 2010 from http://energy.jrc.ec.europa.eu/transtools/documentation.html.

Chow, Y.J,. C.H. Yang, Regan, A.C. (2010). State-of-the art of freight forecast modeling: lessons learned and the road ahead, *Transportation* vol 37, no 6, pp. 1011–1030.

Coe, N.M., Dicken, P. and Hess, M. (2008). Global production networks: realizing the potential, *Journal of Economic Geography*, vol. 8, no. 3, pp. 271-295.

CPB, MNP and RPB (2006). Welvaart en Leefomgeving, een scenariostudie voor Nederland in 2040, Den Haag.

Dicken, P. (2003). Global Production Networks in Europe and East Asia: The Automobile Components Industries, GPN Working Paper 7, University of Manchester, accessed 1 June 2012 from http://www.sed.manchester.ac.uk/geography/research/gpn/gpnwp7.pdf.

Dorsser, C. Van, Wolters, M. and Wee, B. Van (2012). A Very Long Term Forecast of the Port Throughput in the Le Havre – Hamburg Range up to 2100, *European Journal of Transport and Infrastructure Research*, vol. 12, no. 1, pp. 88-110.

European Commission (2006). European energy and transport, trends to 2030, update 2005, Brussels.

ESCA (2005). Economische Ontwikkelingsstudie voor de haven van Antwerpen – Eindrapport, Antwerpen.

Fung, M.K. (2002). Forecasting Hong Kong's container throughput: an error-correction model, Journal of Forecasting vol. 21, no. 1, pp 69 – 80.

Hausman, W.H, Lee, Hau, L, Subramanian, U., (2004). Global logistics indicators, supply chain metrics, and bilateral trade patterns, The World Bank, Policy Research Working Paper Series , no 3773.

Hickman, R. and Banister, D. (2007). Looking over the horizon: Transport and reduced CO2 emissions in the UK by 2030, *Transport Policy* vol. 14, no. 5, pp. 377–387.

Schade W., Fiorello D., Beckmann R., Fermi F., Köhler J., Martino A., Schade B., Walz R., Wiesenthal T. (2008).: High Oil Prices: Quantification of direct and indirect impacts for the EU. Deliverable 3 of HOP! (Macro-economic impact of high oil price in Europe). Funded by European Commission 6th RTD Programme. Milan, Italy. Accessed 1 June 2012 from http://www.hop-project.eu/documenti/HOP_Project_D3_Final.pdf.

Hui, E. C. M., Seabrooke, W. and Wong, G.K.C. (2004). Forecasting Cargo Throughput for the Port of Hong Kong: Error Correction Model Approach, *Journal of Urban Planning and Development*, vol. 130, no. 4, pp. 195-203.

Hummels, D., (2001). Time as a trade barrier, GTAP Working Papers 1152, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University, accessed 1 June 2012 from http://www.mgmt.purdue.edu/centers/ciber/publications/00-007Hummels2.pdf.

ISL, Global Insight and Raven Trading (2011). Forecast of handling potential for the Port of Hamburg in 2015, 2020 and 2025, Bremen, accessed 1 June 2012 from http://www.isl.org/projects/2000hafen_hamburg/index.php?lang=en.

Jong, G. de (2004). National and International Freight Transport Models: An Overview and Ideas for Future Development, *Transport Reviews*, vol. 24, no. 1, pp. 103-124.

Jourquin, B. and Beuthe, M. (1996). Transportation policy analysis with a GIS: the Virtual network of freight transportation in Europe, *Transportation Research C*, vol 4, no. 6, pp. 359-371.

Ke, L., Chengcheng, S. and Jiangnan, Y. (2009). The Combination Forecasting of Nanchang port's Cargo Throughput, Procs. Management and Service Science, 2009. MASS '09.

KIM (2010). Second opinion kosten en baten capaciteitsverruiming Maasgeul, Den Haag.

Lam, W. H. K, Ng, P. L. P, Seabrooke, W. and Hui, E. C. M (2004). Forecasts and Reliability Analysis of Port Cargo Throughput in Hong Kong. *Journal of urban Planning and Development*, vol. 130, no. 3, pp. 133–144.

Langen, P.W. de. Berg, R. van den and Willeumier, A. (2012). A new approach to granting terminal concessions: the case of the Rotterdam World Gateway terminal, *Maritime Policy and Management*, vol. 39, no. 1, pp. 79-90.

Maloni, M. and Jackson, E.C. (2005). North American container port capacity: An exploratory analysis, *Transportation Journal*, vol. 44, no. 3, pp. 1-22.

Mangan, J. Lalwani, Ch. And Fynes, B. (2008). Port-centric logistics, *International Journal of Logistics Management*, vol. 19, no. 1, pp.29 – 41.

McKinnon, A. (2007).. Decoupling of road freight transport and economic growth trends in the UK: an exploratory analysis. *Transport Reviews*, vol. 27, no. 1, pp. 37-64.

MDS Transmodal (2007). Update of UK port demand forecasts to 2030 & economic value of transhipment study, Chester.

MDS Transmodal, Roger Tym & Partners and Savills (2006). East Midlands Strategic Distribution Study, Chester, accessed 31 December 2010 from http://www.emda.org.uk/uploaddocuments/EastMidlandsSDStudy2006.pdf.

Medda, F. and Carbonaro, G. (2007). Growth of Container Seaborne Traffic in the Mediterranean Basin: Outlook and Policy Implications for Port Development, *Transport Reviews*, vol. 27, no. 5, pp. 573-587.

Meijeren, J.C. van and Hofker, F. (2009). Long term forecasts of rail freight transport in the Netherlands up to 2040, *European Transport Conference*, Noordwijkerhout.

Minderhoud, M., Tavasszy, L. and Perrin, J.F. (2009). A strategic port choice model for worldwide container flows, *Transportation Research Board*, Washington.

Monzón, A., A.B.Ndiaye, P.C. Pfaffenbichler, and Wegener, M. (2010). Evaluation of TRANS-TOOLS version 2, Sevilla: JRC/IPTS.

Ng, K.YA. (2006). Assessing the Attractiveness of Ports in the North European Container Transhipment Market: An Agenda for Future Research in Port Competition, *Journal of Maritime Economics and Logistics*, vol. 8, no. 3, pp. 234-250.

Notteboom, Th. E. (2006). Traffic inequality in seaport systems revisited, *Journal of Transport Geography* vol. 14, no. 2, pp. 95-108.

Pallis A.A. and de Langen, P.W. (2010).. Seaports and the structural implications of the Economic crisis, Research in *Transportation Economics*, (special issue The Port and Maritime industries in the post 2008 world, edited by Ng A.K.Y. and Liu J). vol. 27, no. 3, pp. 10-18.

Peng, W.-Y. and Chu, C.-W. (2009). A comparison of univariate methods for forecasting container throughput volumes, *Mathematical and Computer Modelling*, vol. 50, no. 7–8, pp. 1045-1057.

Petersen, M.S. Enei, R., Hansen, C.O., Larrea, E. Obisco, O. Sessa, C., Timms, P.M. and Ulied, A. (2009). Report on transport scenarios with a 20 and 40 year horizon. Final Report TRANSvisions. Tetraplan A/S. Copenhagen.

PoR (1974). Voorspelling van de goederenstromen van en naar de havens in het Rijnmondgebied in 1980 en 1990 met behulp van het Goederenstroommodel II, Ekonomisch, Sociologisch en Statistisch Onderzoek Rijnmondgebied (ESSOR). Rotterdam.

PoR (1998). Verkenningen 2020, Rotterdam, 1998.

PoR (2010A). Havenplan 2020, Rotterdam, accessed 10 November 2010 from www.havenplan2020.nl.

PoR (2010B). Port Statistics, Rotterdam, accessed 10 November 2010 from www.portofrotterdam.com/en/port/port-statistics

Port of Rotterdam (2012). Port Vision, available at http://portcompass2030.com/.

Port of Antwerp (2010). Port Statistics, accessed 31 December 2010 from www.portofantwerp.com.

Rodrigue, J.P., (2006). Transportation and the Geographical and Functional Integration of Global Production Networks, *Growth and Change*, Vol. 37, No. 4, pp. 510-525.

Schoemaker, P. J.H. (1995). Scenario planning: a tool for strategic thinking, *Sloan Management Review*, vol. 26 no. 2, pp. 25-40.

Seabrooke, W., Hui, E.C.M., Lam, W.H.K., and Wong, G.K.C. (2003). Forecasting cargo growth and regional role of the port of Hong Kong, *Cities*, vol. 20, no. 1, pp. 51-64.

Skamris, M.K. and Flyvbjerg, B. (1997). Inaccuracy of traffic forecasts and cost estimates on large transport projects, *Transport Policy*, vol. 4, no. 3, pp. 141-146.

Taneja, P., Ligteringen, H. and Walker, W.E (2012). Flexibility in Port Planning and Design, European *Journal of Transport and Infrastructure Research* vol. 12, no. 1, pp. 66-87.

Tavasszy, L.A., Ruijgrok, C.J. and Thissen, M.P.J.M (2003). Emerging Global Logistics Networks: Implications for Transport Systems and Policies, *Urban Growth and Change*, vol. 34, no. 4, pp. 456- 472.

Tavasszy, L.A., (2006). Freight Modelling: an overview of international experiences, in TRB Conference on Freight Demand Modelling: Tools for Public Sector Decision Making. 2006: September 25-27, 2006, Washington DC.

TML and TNO (2009). Social cost benefit analysis Iron Rhine, Leuven.

TNO (2009). Directe transporteffecten kanaal Gent-Terneuzen, resultaten nulalternatief en projectalternatieven, Delft.

Van der Horst, M.R. and P.W. de Langen (2008). Coordination in Hinterland Transport Chains: A Major Challenge for the Seaport Community, *Maritime Economics and Logistics*, vol. 10, no.1-2, pp. 108-129.

Veldman, S.J. and Buckmann, E.H. (2003). A Model on Container Port Competition: An Application for the West European Container Hub-Ports, *Journal of Maritime Economics and Logistics*, vol. 5 no. 1, pp. 3-22.

VROM (2008). Structuurvisie Randstad 2040, Den Haag.

Wee, B. van (2007). Large infrastructure projects: a review of the quality of demand forecasts and cost estimations, *Environment and Planning B: Planning and Design*, vol. 34, no. 4, pp 611- 625.

Appendix one: overview of projection results

HLH-range	Throughput HLH-range	Projections ET		Projections GE		Projections HOP		Projections LG	
Year	2008	2020	2030	2020	2030	2020	2030	2020	2030
Crude oil	179,0	169,0	154,0	185,0	182,0	151,0	118,0	117,0	70,1
Mineral oil products	168,0	191,0	217,0	225,0	265,0	220,0	237,0	184,6	217,1
LNG	4,5	38,0	50,0	15,0	21,0	62,0	68,0	9,0	8,5
Chemical products	48,0	51,0	59,0	64,0	82,0	58,0	69,0	50,9	51,6
Vegetable oils	13,0	15,0	17,0	15,0	19,0	18,0	20,0	14,2	15,0
Total liquid bulk	412,0	464,0	497,0	504,0	569,0	509,0	512,0	375,7	362,3
Agribulk	31,0	25,0	21,0	26,0	23,0	23,0	19,0	21,8	16,5
Iron ore	93,1	76,8	67,2	81,7	71,8	71,8	43,5	76,8	56,4
Coal	90,9	109,0	107,0	116,0	118,0	119,0	97,0	108,5	86,8
Dry biomass	2,1	5,0	7,0	4,0	6,0	7,0	11,0	4,9	8,0
Other dry bulk	55,0	60,0	62,8	62,0	64,3	56,8	49,5	60,7	57,7
Total dry bulk	272,0	275,8	265,0	289,7	283,1	277,6	220,0	272,7	225,4
Containers total	410,2	599,2	814,7	674,9	983,8	572,5	771,2	535,2	639,0
Containers deepsea (excl transhipment)	243,9	360,6	488,1	393,7	566,7	344,0	460,6	319,1	383,9
Containers transhipment	116,6	176,0	249,2	205,3	309,9	169,7	238,9	156,4	189,4
Containers shortsea	49,6	56,7	68,1	67,0	94,5	56,6	67,3	59,7	65,7
Steel	26,8	34,2	43,7	31,6	41,5	34,3	50,4	32,3	42,0
Ro-Ro	56,9	60,1	72,8	64,4	91,4	62,4	72,0	58,8	62,3
Other general cargo	24,9	22,4	20,2	22,4	20,2	22,4	20,2	22,4	20,2
Total general cargo	519,0	710,1	942,1	784,4	1124,2	689,5	909,4	648,7	763,5
Total HLH range	1203,0	1449,9	1704,1	1578,1	1976,3	1476,1	1641,4	1297,0	1351,2