

# **A Very Long Term Forecast for the Development of the Cargo Flows in the Le-Havre – Hamburg range**

**TRAIL Research School, November 2010**

## **Authors**

**Ir. drs. Cornelis van Dorsser<sup>1</sup>, Ir. Milou Wolters<sup>2</sup>**

<sup>1</sup> Maritime Division, Royal Haskoning and Faculty of Civil Engineering and Geosciences, Delft University of Technology, the Netherlands

<sup>2</sup> Section of Hydraulic Engineering, Delft University of Technology, the Centre of Traffic and Navigation, Rijkswaterstaat and Faculty of Civil Engineering and Geosciences, Section of Hydraulic Engineering, Delft University of Technology, the Netherlands.



# Contents

## Abstract

<b>1</b>	<b>Introduction .....</b>	<b>1</b>
1.1	Background of the Project.....	1
1.2	Relevance of seaports for inland water transport.....	1
1.3	Research questions .....	2
1.4	Outline of the paper.....	2
<b>2</b>	<b>Forecasting Methodology .....</b>	<b>3</b>
2.1	Review of Port Throughput Forecasting Methodology .....	3
2.2	Review of Very Long Term Forecasting Methodology.....	5
2.3	Methodology applied for the 90 year Forecast up to 2100 .....	6
<b>3</b>	<b>Historical GDP and Port Throughput Data .....</b>	<b>6</b>
3.1	GDP development of the Hinterland of the port region.....	6
3.2	Port Throughput data for the Le-Havre – Hamburg range.....	7
<b>4</b>	<b>Relation between GDP and Port Throughput.....</b>	<b>8</b>
4.1	A warning from econometrics.....	9
4.2	Defining the relationship between GDP and Port Throughput .....	9
4.3	Evaluation of findings .....	14
4.4	Ex-post performance of the regression models.....	15
4.5	Combining forecasting models .....	16
<b>5</b>	<b>Probabilistic Population and GDP Forecasts .....</b>	<b>16</b>
5.1	Developing a probabilistic population forecast .....	16
5.2	Developing a probabilistic GDP forecast.....	17

<b>6</b>	<b>Very Long Term Forecast for Le-Havre – Hamburg Range .....</b>	<b>20</b>
6.1	Preparation of forecast based on levels approach .....	20
6.2	Preparation of forecast based on differences approach.....	21
6.3	Final forecast based on a combined approach .....	21
6.4	On the subject of reliability.....	22
<b>7</b>	<b>Conclusions .....</b>	<b>24</b>
	<b>Acknowledgements .....</b>	<b>25</b>
	<b>References.....</b>	<b>25</b>

## **Abstract**

The development of the Dutch ports and waterways has historically gone hand in hand since the waterways have always provided a primary access route to the Hinterland. Any vision on the development of the Dutch waterway system will therefore require a vision on the developments of the ports in the region and vice versa.

The Dutch waterway system contains hundreds of hydraulic structures such as storm surge barriers, sluices, ship locks, and bridges. The projected lifetime of these structures is generally about 100 years and the total replacement costs are estimated at about 15 billion Euros. Rijkswaterstaat, the responsible waterway authority, now desires to develop a replacement strategy that takes the possible developments over the lifetime of the infrastructure into account in their asset management process.

In March 2009 a project commenced to, amongst others, develop a model that provides insight in the possible developments of (and on) the main waterway network in the Netherlands up to the year 2100. On the basis of this model a methodology will be developed for the evaluation of various replacement strategies.

Insight in the future use of the inland waterways depends on the development of continental and port related cargo flows as well as on the competitiveness of river barge transportation versus other modes of transport. The port related import/export flows can be based on a very long term forecast for the Le-Havre – Hamburg range in combination with some assumptions on the market share of the various ports within this range.

This paper discusses the challenges related to the preparation of a very long term forecast for the development of the overall cargo flows in the Le-Havre – Hamburg Range up to the year 2100. Special attention is given to the reliability of the forecast and the interpretation of the results.

## **Keywords**

Very Long Term, Probabilistic Forecast, Population, GDP, Port Throughput, Le-Havre – Hamburg Range.



# 1 Introduction

## 1.1 Background of the Project

The Dutch waterway system contains hundreds of hydraulic structures such as storm surge barriers, sluices, ship locks, and bridges. The projected lifetime of these structures is generally about 100 years and the total replacement costs are estimated at about 15 billion Euros. One-by-one substitution will result in, metaphorically speaking: “*replacing all parts of an old car, and delivering a good as new old timer*” (Heijer et al., 2010). Clearly it makes no sense to provide a 21<sup>st</sup> century waterway network on the basis one hundred year old specifications. The world has changed and will be changing. Transport demand will further increase, climate change will have an effect on the height and fluctuation of the water levels, and new vessel types may enter the waterways. In order to meet future challenges Rijkswaterstaat now desires to develop a very long term substitution strategy. In March 2009 a project commenced to, amongst others, develop a model that provides insight in the possible developments of (and on) the main waterway network up to the year 2100. Such a model requires insight in the potential development of barge transportation, a subject closely related to the development of the main cargo flows in the Dutch and Belgium seaports.

## 1.2 Relevance of seaports for inland water transport

The development of the ports and waterways has historically gone hand in hand since the waterways have always provided a primary access route to the European Hinterland. The importance of the main West-European ports for the European inland waterway transport sector can be evaluated by comparing port statistics with EU statistics on inland water transport. In 2006 and 2007 the total volumes transported on the inland waterways were respectively 503 and 515 million tonnes (De La Fuente Layos, 2007 and 2009). The total volumes of cargo loaded and unloaded in barges in the ports of Rotterdam, Amsterdam and Antwerp have been compared to the total transport volumes in the EU. The findings are listed in Table 1.

**Table 1: Barge loading/unloading in main ports compared to EU figures for IWT**

Port Data	Loaded on Barges		Unloaded from Barges	
	million tonnes	% of IWT in EU	million tonnes	% of IWT in EU
Rotterdam (2007)	133.0	25.8%	55.4	10.8%
Amsterdam (2006)	37.8	7.5%	21.6	4.3%
Antwerp (2007)	49.4	9.6%	39.9	7.7%
Total		42.9%		22.8%

Source: Eurostat bulletin 132/2007 and 27/2009; Port of Rotterdam Website (2010); Port of Amsterdam Website; Port of Antwerp Statistical Yearbook 2008.

Note: IWT stands for Inland Water Transport.

From the table it can be expected that over 50% of all inland water transport in the EU is port related (listed ports indicate at least 43-66% market share<sup>1</sup>). Therefore a vision on the development of the inland waterway system should take the development of port throughput volumes into account. This paper discusses the challenging task of providing a very long term forecast for the Port Throughput in the Le-Havre – Hamburg range<sup>2</sup> (LHR) up to the year 2100.

### 1.3 Research questions

Normally a long term port forecasts looks 20 to 30 years ahead. Providing a 90 year forecast represents a different league. To develop a very long term forecast for the port throughput volumes in the Le-Havre – Hamburg range the following research questions have been defined:

1. What techniques are common in port forecasting and to what extend are these techniques suitable for the very long term?
2. What techniques are common in very long term forecasting and how suitable are these techniques for forecasting port throughput volumes?
3. What would be a sensible approach for the development of a very long term forecast of the port throughput volumes in the Le-Havre – Hamburg range up to 2100?
4. Is there sufficient historical data available to develop such a very long term forecast?
5. Is it possible to identify a causal relationship that can be used to develop a valid forecast or at least a reasonable estimate of the order of magnitude?
6. Does the forecast methodology require input from other forecasts (such as a GDP forecast) and how can this input data be obtained?
7. What is the expected development of the port throughput in the Le-Havre – Hamburg range up to the year 2100?

The answers to each of these questions are discussed in the various sections of this paper. A summary of the conclusions is provided in the last section.

### 1.4 Outline of the paper

The aim of this paper is to discuss the questions listed above. Section 2 discusses the available techniques applied in the fields of port forecasting (Q1) and very long term forecasting (Q2). Finally section 2 will conclude with a discussion of the methodology applied in this paper (Q3). As will be concluded later in this paper there is a long term relation between GDP and Port Throughput. Section 3 discusses the availability of historic data required to understand this very long term relationship

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<sup>1</sup> Exact figures can not be given without knowing the amount of the cargo volumes shipped between the ports.

<sup>2</sup> The Le-Havre – Hamburg range contains the West European ports located between Le-Havre and Hamburg.



(Q4). The functional shape of the forecast relation is not clear from forecasting literature. For this reason section 4 discusses a number of different causal relationships between GDP and Port Throughput. For each of these causal relationships the challenges with the statistical (or econometric) and theoretical validity of the forecast relation will be discussed. Finally it will be indicated if a valid forecast can be developed (Q5). The evaluated causal relations require a probabilistic very long term GDP forecast as input. Section 5 discusses how the probabilistic very long term GDP forecast has been obtained (Q6). Section 6 uses the GDP forecast and causal relation to develop a very long term forecast of the Port Throughput in the Le-Havre – Hamburg range up to 2100 (Q7). A summary of the conclusions is provided in section 7.

## 2 Forecasting Methodology

How to provide a 90 year forecast for the Le-Havre – Hamburg range? In an attempt to answer this question a benchmark study on forecasting literature and articles related forecasting has been carried out. Section 2.1 discusses common practice and available literature on port forecasting, section 2.2 indicates the availability literature on very long term forecasting techniques, and Section 2.3 concludes with the methodology applied in this paper.

### 2.1 Review of Port Throughput Forecasting Methodology

On the basis of a library search and various discussions with experts in the field of port economics, econometrics and forecasting it had to be concluded that most likely there does not exist a handbook on port throughput forecasting. Port throughput forecasting is generally applied by port authorities and specialised consultants. In practice forecasts are, to our best knowledge, usually based on causal relationships between port throughput volumes and demographic, economic, or industrial developments. There is sufficient support for the use of causal relationships. Economic textbooks indicate the existence of a relationship between economic activity (measured in GDP) and freight transport (measured in tonnes or tonne kilometres). For example Meersman and van de Voorde (2008, p. 67-92) recently discussed the relation between economic activity and internal transport within the European Union.

A review of port throughput forecasting articles has revealed that the subject has not received much attention. A search on Scopus and Google Scholar provided seven relevant articles of which full text documents were accessible<sup>3</sup>. Quite interesting is to observe that most of these articles do not relate to the causal models applied in practice. Instead they refer to methods that are somehow based on mere trend extrapolation of historic data such as *autoregressive integrated moving average models* (Klein, 1996), *vector autoregressive models* (Veenstra and Haralambides, 2001), *grey models* (Guo, Song and Ye, 2005), and *neural networks* (Weiqun and Nuo, 2003; Li, Chen and Cui, 2008; S.H. Chen and J.N. Chen, 2010). By definition models based on mere trend extrapolation are not suitable for very long term

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<sup>3</sup> Most of the research on port throughput forecasting is recently published by Asian universities. Not all of these documents are accessible from the Delft University Library. There were for example some articles published in the *Journal of Wuhan University of Technology* and *Journal of Shanghai Jiaotong University* which have not been included in this study.

predictions. The same is also likely to hold for models based on a combination of autoregressive and causal relationships such as the *vector error correction model* applied by Fung (2001).

Hui, Seabroke and Wong (2004, p.196) discuss that the “*classical regression*” (as usually applied in many practical forecast studies) identifies causal relationships by measuring the co-movement between variables. They warn that this approach “... is only valid if the data used are stationary and not displaying any trend over time. When the classical model is used to estimate relationships of, say, certain economic variables which show distinct upward trends, the strength of the relationship is likely to be inflated. This is because for trending variables, even if they are completely independent, they often move in the same direction under the common trend, creating an illusion of causal relationships. Spurious regression refers to instances where unrelated variables are estimated to hold a causal relationship, which can happen when the regression is fitted with trending time series”. They also discuss that a common approach to avoid problems with spurious regression is the use of a first-differences model. Such a model for example relates the annual change of GDP to the annual change of the Port Throughput. However, “a first-differenced model considers only short-run adjustments which relate how changes in one variable correlate with changes in another. It neglects the underlying long-run relationship linked by the levels or the original (nondifferenced) values of the variables”. Under certain conditions the regression of two non-stationary series does not result in spurious regression. If this is the case the error term of the regression is stationary and the variables are referred to as co-integrated. For co-integrated series an alternative model approach can be applied which is referred to as the error correction model (ECM). The error correction model combines the advantages of the long term levels approach and the short term differences approach. Suppose the long term model is defined as:

$$\bullet \quad Y_t = \alpha + \beta X_t + e_t \quad (\text{Long-Term Model})$$

Then the corresponding error correction model can be defined as:

$$\bullet \quad \Delta Y_t = \alpha' + \beta' \Delta X_t + \lambda e_{t-1} + u_t \quad (\text{Error Correction Model})$$

The error correction model is developed by a two step approach. The first step consists of regression of the parameters of the long-term model and estimation of the error terms. In the second step the error correction model is developed. By adding the error term to the equation of the short-term differences model the obtained error correction model is forced to follow the long-term trend. Important is that this approach is only valid if the variables in the long term equation are co-integrated. In other words, if a true relationship between these variables exists. In the case of the forecast discussed by Hui, et al. (2004, p.197) this was not the case, but they managed to “make” the forecast co-integrated by taking the natural logarithms.

## 2.2 Review of Very Long Term Forecasting Methodology

An evaluation of ten mainstream forecasting textbooks with a general or wide coverage<sup>4</sup> has revealed that the subject of (very) long term forecasting has, despite its importance, received almost no attention in textbooks. Makridakis et al. (1998) is the only author writing a full chapter on the subject. In this chapter reference is made to the construction of scenarios and the use of analogies. However, scenarios are not predictions (Schwartz, 1996, p.6). Armstrong (2001, p.517) advocates the use of scenarios to gain acceptance for forecasts but warns not to use scenario techniques to provide forecasts because “*If you do, you are likely to be both wrong and convincing*”. Other long term forecasting methods include causal relations, long term (economic) trends, qualitative estimates (such as expert judgements, panel consensus, Delphi, and nominal group process), analogies, technological s-curves, Bayes’ theorem, and systems dynamic modelling. Surprisingly the use of probabilistic (or Bayesian) forecasts was not mentioned once in textbooks. A review of articles published in the ‘*Journal of Forecasting*’ and ‘*International Journal of Forecasting*’ has also indicated that hardly anything has been written on the subject<sup>5</sup>. This has been confirmed by Fildes (1986, p.4; and 2006, p.420) who concluded twice that hardly anything has been published on the subject of (very) long term forecasting.

The fact that hardly anything is written on very long term forecasting in general forecasting literature is probably related to the fact that it will be inevitable to bring insight into the forecast and move beyond mere trend extrapolation techniques. The “*Strategic Foresight Group*” defines *foresight* as “*forecasting with insight*” (www.strategicforesight.com, 2009). To bring insight into the forecast use can be made of a less common subfield of forecasting referred to as Bayesian forecasting<sup>6</sup>. In Bayesian forecasting probabilistic forecasts are developed on the basis of system dynamic models and Bayesian statistics. M. West and J. Harrison (1999, p.20) indicate that “*Bayesian statistics is founded on the fundamental premise that all uncertainties should be presented and measured by probabilities*”. Bayesian input can be either based on ‘*hard*’ data or ‘*soft*’ judgemental estimates. In this paper the term *Bayesian forecast* refers to all forecasts that contain subjective elements. However, in practice the field is much richer and covers various techniques for updating forecasts in case new information becomes available. To avoid disappointment of Bayesian statisticians it is intended to avoid the word Bayesian in this paper and to use the term probabilistic instead. Probabilistic techniques have been successfully applied to develop probabilistic very long term population forecasts and are also suitable for the preparation of probabilistic GDP forecasts. Probabilistic methods will be applied in this paper to develop a probabilistic forecast of the cargo throughput volumes in the Le-Havre – Hamburg range.

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<sup>4</sup> Evaluated textbooks included: Armstrong, J.S., ed. (2001), Bails et al. (1993), Bowerman et al. (2005), DeLurgio S.A. (1997), Diebold (2004), Hanke et al. (2008), Levenbach et al. (2005), Makridakis et al. (1998), Mentzer et al. (1998), and Wilson et al. (2009).

<sup>5</sup> Except for a special section on: “Global Income Growth in the 21st Century: Determinants and Forecasts” in the *International Journal of Forecasting* (Vol. 23, issue 4, 2007).

<sup>6</sup> Bayesian forecasting refers to the use of statistical methods in forecasting. It has been named after Bayes’ theorem of conditional probabilities. This field has been almost completely ignored by mainstream textbooks. Journals pay somewhat more attention to the subject. A special issue on “Bayesian Forecasting in Economics” was recently published in the *International Journal of Forecasting* (Vol. 26, issue 2, 2010).

## 2.3 Methodology applied for the 90 year Forecast up to 2100

*Port throughput forecasting* and *very long term forecasting* methodology have not received much attention in literature and no article has been found that refers to a combination of both issues. Nevertheless current practice and available literature points in the direction of causal relations and leading indicators. Therefore the following approach has been applied:

1. Define the very long term causal relation between Port Throughput and GDP,
2. Develop a very long term probabilistic forecast for the GDP of the Hinterland,
3. Estimate Port Throughput on the basis of the GDP forecast and causal relation.

The first step is complicated by the fact that the reviewed literature does not indicate the type of relationship that should be applied. For this reason a number of options has been evaluated in order to define a suitable long term forecast relation. The second step is complicated by the fact that no probabilistic GDP forecast of the Hinterland is available. A first simplification can be made by assuming that the GDP of the countries in the combined Hinterland (defined as the Netherlands, Belgium, Germany, and France) move along quite similar. This allows the Dutch GDP to be used as an estimator for the GDP of the combined Hinterland. However, no probabilistic GDP forecast was available for the Netherlands either. The forecast has therefore been developed by multiplying the following variables:

- The population in the working age class of 20-65 years old;
- The labour participation fraction of the working class of 20-65 years old;
- The annual number of hours worked per employee;
- The development of the GDP output per employee per hour.

The required very long term probabilistic forecast of the Dutch population was also not available and has been obtained by combining various sources. For the other variables assumptions have been made on the type, mean and variance of the distribution function. The final step is straightforward but requires advanced statistical methods to perform the calculations. For this purpose use has been made of the Excel Add-on @Risk.

## 3 Historical GDP and Port Throughput Data

In order to evaluate the existence of a long term causal relation between GDP and Port Throughput a long term data range is required. This section discusses the available long term GDP and Port Throughput data series applied in this study.

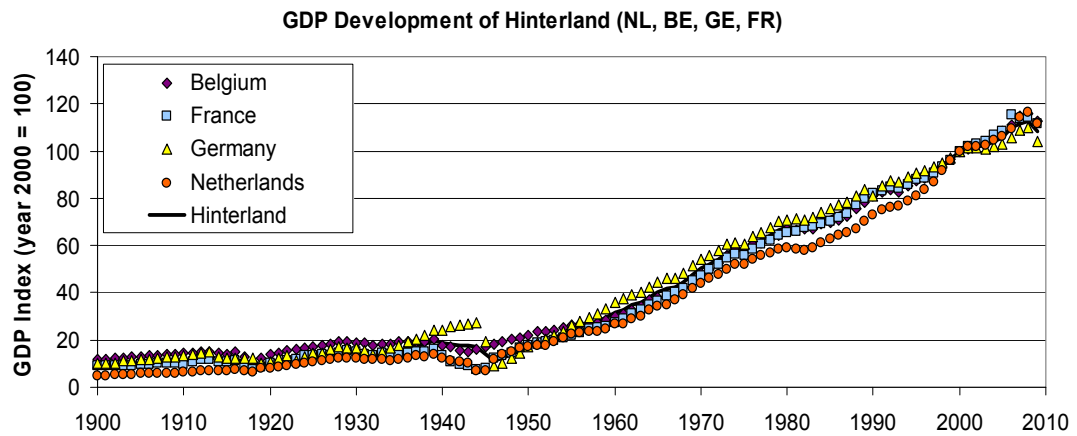
### 3.1 GDP development of the Hinterland of the port region

The Le-Havre – Hamburg range does not serve a distinct number of countries exclusively. The actual boundaries of the region are vague and contain overlap with other port regions. For the purpose of this paper a pragmatic approach has been obtained in which the Hinterland is defined as The Netherlands, Belgium, Germany and France<sup>7</sup>. This simplification is acceptable because integrated economic regions

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<sup>7</sup> Luxembourg has not been included due to its small size and unavailability of sufficient long data series.

tend to move simultaneously – and we are not interested in the actual throughput of the ports per unit of GDP, but in the way that GDP and Port Throughput move along together. To allow for comparison between countries the GDP of the Hinterland has been measured as an index of the year 2000. Figure 1 shows the historic development of the GDP in the assumed Hinterland.



Source: GDP Index derived from Real GDP data provided by Maddison (2010)

**Figure 1: Historical development of GDP in the Hinterland of the Le-Havre – Hamburg range**

From the figure it can be observed that the GDP of the selected Hinterland areas follows a similar trend. Growth has generally been quite stable though a trend breach can be observed at the instance of the Second World War.

### 3.2 Port Throughput data for the Le-Havre – Hamburg range

The Le-Havre – Hamburg range includes many ports of various sizes. The Rotterdam Port Authority includes the ports of Le-Havre, Dunkirk, Zeebrugge, Antwerp, Gent, Zeeland Seaports, Rotterdam, Amsterdam, Wilhelmshaven, Bremen, and Hamburg in their statistics but provides only a few years of data on their website ([www.portofrotterdam.com](http://www.portofrotterdam.com); 2010).

Long data series from 1936 onwards (excluding 1939-1947) have been obtained from the Antwerp Port Authority for the ports of Le-Havre, Dunkirk, Antwerp, Gent, Rotterdam, Amsterdam, Hamburg and Bremen (refer Table 2).



## 4.1 A warning from econometrics

Regression of two time series, that follow an upward or downward trend, can result in a virtual correlation that in reality does not exist. Granger and Newbold (1974, p.111) provided a bold statement and warned for “*spurious*” (meaningless) regression as they wrote that: “*It is very common to see reported in applied econometric literature time series regression equations with an apparently high degree of fit, as measured by the coefficient of multiple correlation  $R^2$  or the corrected coefficient  $*R^2$ , but with an extremely low value for the Durbin-Watson statistics. We find it very curious that whereas virtually every textbook on econometric methodology contains explicit warnings of the dangers of autocorrelated errors, this phenomenon crops up so frequently in well-respected applied work*”. The standard methodology for hypothesis testing and goodness of fit is only valid if the regression parameters are stationary, or in a special case where the time series are co-integrated (i.e. the error term is stationary). In practice many time series are non-stationary and referred to as following a random walk or containing a unit root. If a time series follows a random walk the effects of a temporary shock will not dissipate after several years, but instead remain. To avoid unnecessary misspecification and misinterpretation of the regression model it is important to test for stationarity of the error term.

Granger and Newbold mentioned the danger of (positive) autocorrelation in time series. Durbin-Watson<sup>8</sup> provided a test for autocorrelation of which the test statistics lie in the range of 0 to 4. A value of 2 indicates that there is no autocorrelation. High values indicate negative correlation. Low values indicate positive correlation. Low Durbin-Watson statistics are therefore a warning for non-stationary data series. A formal F-test for random walks is provided by Dickey-Fuller. A low F-value indicates a high probability of unit roots. For a sample size of 50 data points one can reject the hypothesis of a random walk at the 95% confidence level if the critical value is above 6.73 (and for 100 data points the critical value is 6.49). For larger samples the critical value will be lower. Apart from stationarity it also is important to test for normality of the error term. This because the standard theory<sup>9</sup> for the calculation of prediction intervals is only valid if the error term is normal distributed. Normality can be tested by using the Jarque-Bera (JB) statistics that follows a chi-square distribution with two degrees of freedom. If the JB- statistics are greater than 5.99 the null hypothesis of normality can be rejected at the 95% confidence level.

## 4.2 Defining the relationship between GDP and Port Throughput

In order to obtain a useful forecast relation between GDP and Port Throughput three simple linear relations have been considered (refer Equation 1 to 3).

<sup>8</sup> The description of the Durbin-Watson statistics, Dickey-Fuller tests, and Jarque-Bera statistics mentioned in this section is based on Pindyck and Rubinfeld (1998, p. 45-58, 164-166, 507-513).

<sup>9</sup> The standard theory for the calculation of prediction intervals states that the prediction interval can be calculated as:  $\hat{y}_p \pm t_{\alpha/2} \cdot s^2 \cdot [1 + 1/n + (x_p - x_{avg})^2 / \{\Sigma(x_i^2) - [(\Sigma(x_i))^2/n]\}]$  with  $\hat{y}_p$ : the point estimate,  $1-\alpha$ : the confidence belt,  $t_{\alpha/2}$ : the t-statistics for  $\alpha$  based on t-n degrees of freedom, n: the number of points in the dataset, s: the standard deviation of the sample,  $x_p$ : the value of x for which  $\hat{y}_p$  is calculated,  $x_{avg}$ : the average x value of the dataset,  $x_i$ : the individual x values of the  $i^{th}$  point in the dataset.

- $PT_t = \alpha + \beta \cdot GDP_t + \varepsilon_t$  (Equation 1)

- $\ln(PT_t) = \alpha + \beta \cdot \ln(GDP_t) + \varepsilon_t$  (Equation 2)

- $\Delta PT_t = \alpha + \beta \cdot \Delta GDP_t + \varepsilon_t$  (Equation 3)

in which:

$\alpha$  : Intercept value,

$\beta$  : Linear coefficient,

$PT_t$  : Port Throughput level in year t,

$GDP_t$  : GDP index level in year t,

$\Delta PT_t$  : Difference in Port Throughput between year t and year t-1,

$\Delta GDP_t$  : Difference in GDP index between year t and year t-1,

$\varepsilon_t$  : Error term in year t.

For each of these three functions a regression analysis has been applied (refer Figure 2-4). The coefficients and results of the statistical tests are indicated in Table 3.

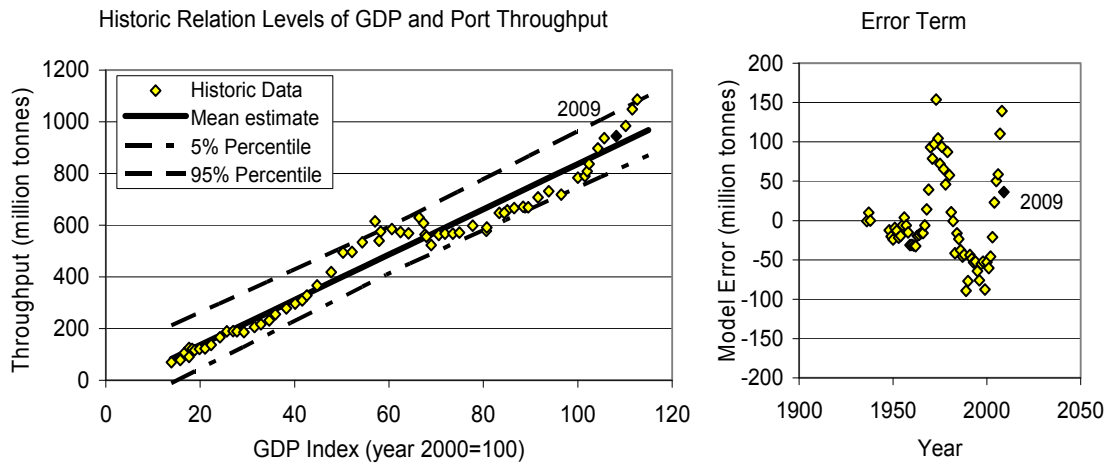
**Table 3: Historic development of cargo volumes in Le-Havre – Hamburg range**

<b>GDP-Throughput Relation</b>	<b>Equation 1</b>	<b>Equation 2</b>	<b>Equation 3</b>
<b>Data</b>			
- DF-test GDP/ln(GDP)/ΔGDP	1.85	49.93	10.05
- Unit Root**	Yes	No	No
- DF-test PT/ln(PT)/ΔPT	1.90	10.68	17.59
- Unit Root**	Yes	No	No
<b>Function</b>			
- F-test	1402*	2390*	65
- R <sup>2</sup>	0.957*	0.974*	0.516
- Adjusted R <sup>2</sup>	0.956*	0.974*	0.508
- Durbin-Watson Statistics	0.23	0.25	2.06
<b>Intercept α</b>			
- t-Stat	-39.92	1.28	-17.46
<b>Linear Coefficient β</b>			
- t-Stat	8.76	1.19	20.76
- t-Stat	37.44*	48.88*	8.06
<b>Error Term ε</b>			
- DF-test on Error Term	1.79	2.82	32.16
- Unit Root**	Yes	Yes	No
- JB-Statistics	7.89	5.20	0.28
- Normal Distributed**	No	Yes	Yes

Note (\*): meaningless value due to non-stationarity of error series,

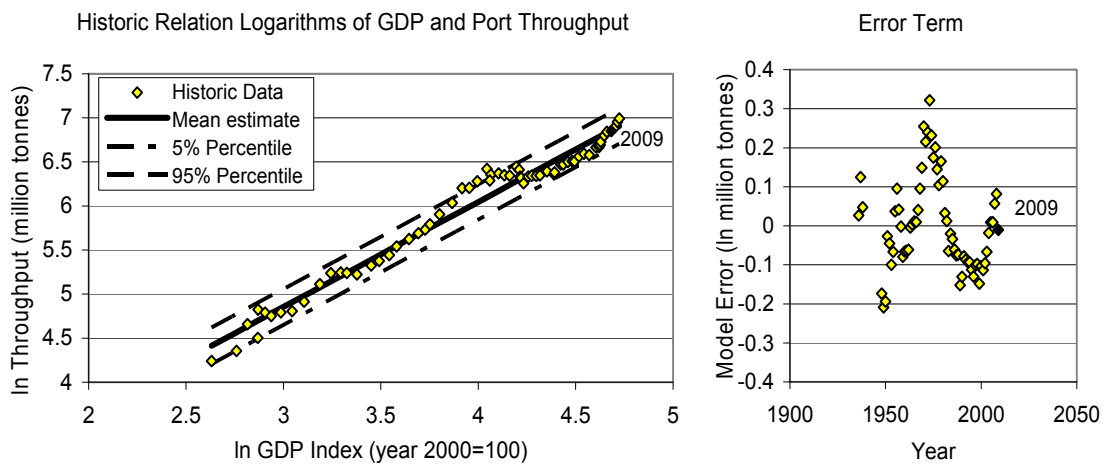
Note (\*\*): the value “Yes” for unit roots in (or normality of) the error term implies that the hypothesis of unit roots (or normality) could not be rejected at the 95% confidence level.





**Figure 2: Simple Linear Regression between levels of GDP and Port Throughput**

Figure 2 shows the results of the simple linear regression between the levels of the GDP and Port Throughput. A clear trend can be observed that holds throughout the data series and that does not even have a trend breach at the Second World War. However from the analysis of the regression statistics it should be concluded that one has to be careful with the interpretation of the model. The error term is highly autocorrelated and likely to contain a unit root. Therefore the model is likely to be misspecified in the sense that it is sensitive to trend breaches of common drivers such as globalisation. Besides this the prediction intervals are too small as a result of the virtually high fit. Finally the error term does not follow a normal distribution and therefore an additional error in the calculation of the prediction intervals will occur if the standard technique for defining prediction intervals is applied (as in Figure 2).



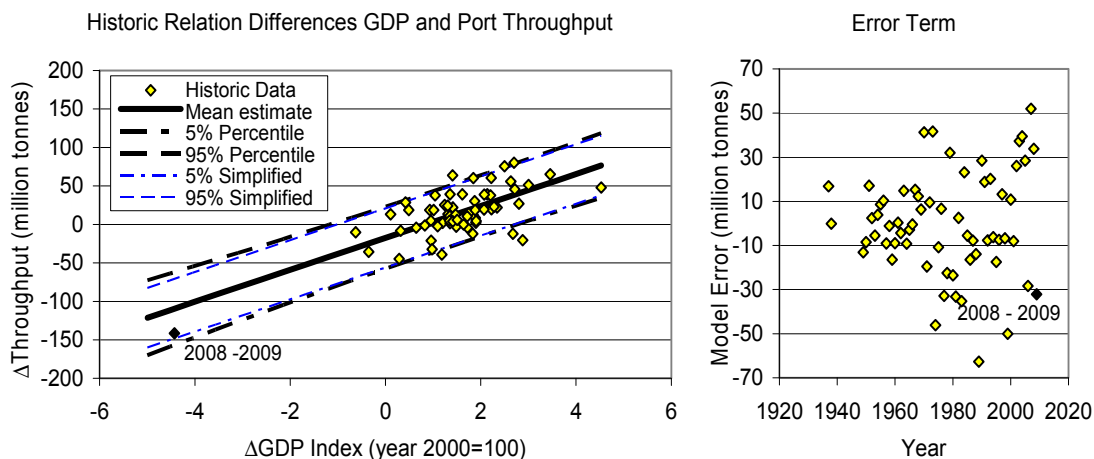
**Figure 3: Linear Regression between logarithm of GDP and Port Throughput**

Figure 3 shows the results of the regression between the logarithms of the GDP and Port Throughput. The forecast value can be calculated indirectly by taking the exponent of Equation 2 or directly by applying Equation 4.

$$PT_t = EXP(\alpha + \varepsilon_t) \cdot GDP_t^\beta \tag{Equation 4}$$

From Equation 4 it becomes clear that the coefficient  $\beta$  has a special meaning. It equals the elasticity between the GDP and Port Throughput. For this reason double logarithms are often used in transport literature. However, it is not likely that the elasticity remains constant over a very long time span. This makes the function not very desirable from a theoretical point of view. Now let's look at the statistical performance. Figure 3 (right) indicates that there is still autocorrelation in the error term. This is confirmed by the regression statistics. Though it appears from the Dickey-Fuller statistics that the logarithms of GDP and Port Throughput are stationary, this is not the case as the error term is non-stationary and any linear combination of stationary series would have also been stationary. Unlike the case presented by Hui et al. (2004) taking the natural logarithms does not make the model stationary and the model is therefore still likely to be misspecified. In addition to this the error term does still not fit the normal distribution well. The hypothesis of normality survived at 95% level, but failed at the 90% level. The statistical performance of Equation 2 is therefore also not satisfactory.

Pindyck and Rubinfeld (1998, p.497-499) discuss that *“Probably very few of the series one meets in practice are stationary. Fortunately, however, many of the nonstationary series that are encountered (and this includes most of those which arise in economics and business) have the desirable property that if they are differentiated one or more times, the resulting series will be stationary”*. Therefore Equation 3 relates the annual differences in GDP to the annual differences in Port Throughput (refer Figure 4). The basic statistics indicate that this model no longer contains a unit root and has a normal distributed error term<sup>10</sup>. The fit of the model, as measured by the  $R^2$ , is less satisfactory and leaves room for improvement.



**Figure 4: Linear Regression between differences of GDP and Port Throughput**

There are not many observations related to a decline in GDP. The exception to this is the 2008-2009 value. It is difficult to judge whether this value should be regarded as valuable information or as an unwelcome outlier. For the purpose of this paper it has been argued that there is no reason to exclude the data point. However, if the data point would have been excluded the absolute value of the  $\alpha$  coefficient would have

<sup>10</sup> Though no unit roots can be observed from the test it can be observed from Figure 4 (right side) that it may be possible that there remains some heteroscedasticity in the model. This has not been further investigated.

been 40% lower (at value of -10.42) and the  $\beta$  coefficient would have been 20% lower (at value of 16.72). Therefore, if the 2008-2009 value turns out to be an outlier, the predicted throughput will be too low. Particularly in case of a decreasing future GDP growth as predicted in the next section.

Equation 3 can not be used to derive the throughput value directly from the GDP. In order to obtain a forecast the last observation (at  $t=0$ ) is taken as a starting point. For each succeeding year the annual change in throughput is derived from the annual change in GDP and added to the value of the previous year. The main complication of this approach is that the calculation requires the growth path of the GDP to be known. This is not the case in our probabilistic forecasts. A simplified approach that directly relates the throughput value to the GDP is provided by Equation 5. This equation however still has the less obvious complication that the error term (required in the simulation process) is still path dependant. This complication can be solved by neglecting the variance of the line (i.e. the  $\beta$  coefficient) in the prediction interval. The simplified prediction intervals in Figure 4 indicate that this is an acceptable approach.

$$PT_{t=n} = PT_{t=0} + n \cdot \alpha + \beta \cdot (GDP_{t=n} - GDP_{t=0}) + \sum_{t=1}^n \varepsilon_t \quad (\text{Equation 5})$$

with:

- n : Number of years forecasted ahead,
- $\alpha$  : Annual decrease in throughput at constant GDP,
- $\beta$  : Linear coefficient between throughput and GDP,
- $PT_t$  : Port Throughput in forecast t-years ahead,
- $GDP_t$  : GDP in forecast t-years ahead,
- $\varepsilon_t$  : Stochastic error term of forecast in year t.

Now we have derived a statistically sound relationship the next question is whether it is also valid from a theoretical point of view. The negative  $\alpha$  coefficient indicates that Port Throughputs will decrease with a constant annual value as soon as GDP stabilizes. Theoretical evidence supports the existence of a negative  $\alpha$  coefficient. A possible explanation is the increased share of services and virtual goods in the economy that results in a decoupling of transportation and economic growth. On the contrary it can also be argued that the existence of a constant negative  $\alpha$  coefficient is fundamentally wrong on the very long run as it implies that port throughput drops to zero after the predicted future stabilisation of the GDP output (refer Section 5). This contradicts the fundamental theory of comparative advantage of David Ricardo. There will always be incentives for trade. The very long term perspective therefore requires a model with an  $\alpha$  coefficient that phases out gradually.

To verify if the decline in  $\alpha$  can be observed from the data a multiple regression model containing dummy variables for each decade has been built. Table 6 indicates the model.

**Table 6: Multiple Regression Model with Dummy Variables**

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	-17.69	6.86	-2.58	0.01
$\Delta$ GDP	21.25	2.42	8.80	0.00
Dummy 1960-1969	1.63	9.33	0.17	0.86
Dummy 1970-1979	-0.76	9.33	-0.08	0.94
Dummy 1980-1989	-17.72	9.24	-1.92	0.06
Dummy 1990-1999	-2.05	9.26	-0.22	0.83
Dummy 2000-2009	12.63	9.23	1.37	0.18

Unfortunately the empirical evidence of the dummy model does not support the theory of a declining  $\alpha$  coefficient (intercept + dummy). As it is not possible to estimate the rate of decline it will also not be possible to develop a sound model with a declining  $\alpha$  coefficient.

### 4.3 Evaluation of findings

From the above discussion it has to be concluded that none of the evaluated regression functions is completely satisfactory from both a theoretical and a statistical point of view. There remain drawbacks related to the use of each of the equations taken into consideration:

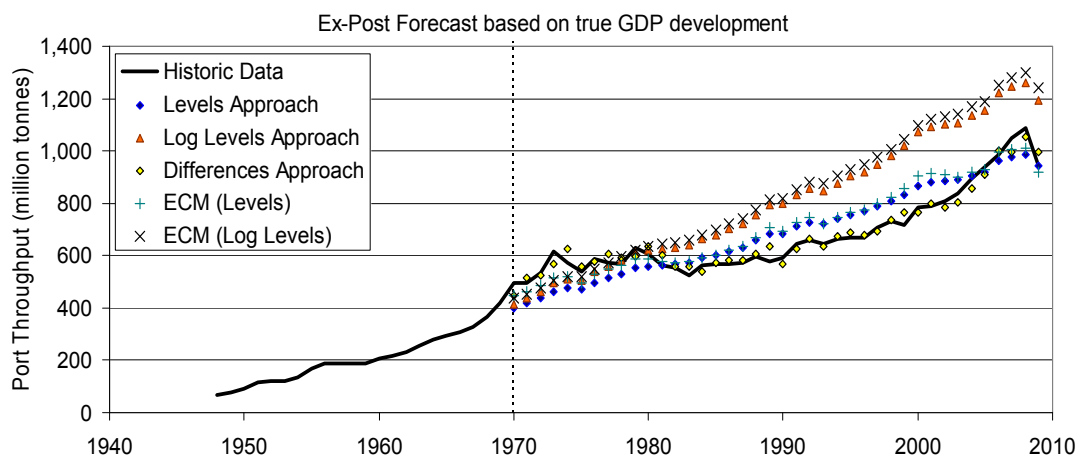
- Equation 1 refers to a simple linear model that is non-stationary and therefore likely to be misspecified. This means that it is sensitive to trend breaches (most likely downwards) and has a prediction interval that is based on a virtual high fit caused by (common) driving factors not specified by the model (such as globalisation).
- Equation 2 refers to a model based on the natural logarithms of both data series. The model therefore assumes an exponential relation between Port Throughput and GDP. Such a relation is however not supported by theory and unlikely to hold on the very long term. The error term indicates that the model still contains a unit root.
- Equation 3 refers to a model based on a differences approach that is statistically sound in the sense that the error term it is stationary and normal distributed. However the fit of the model leaves room for improvement. The constant  $\alpha$  coefficient has proved to be fundamentally wrong. Particularly in case of decreasing economic growth the model is likely to produce outcomes that are structurally too low on the very long run.

Considering the fact that Equation 1 and 2 are not statistically sound (misspecified model) and that Equation 2 and 3 are not sound from a theoretical point of view (wrong model) the question raises how to proceed. A possible option is to consider the (ab)use of the error correction model as this model is likely provide more realistic prediction intervals for Equation 1 and 2 and solves the issue with the zero cargo flows on the very long term in Equation 3. However the correct use of the error correction model requires the variables of the levels model to be co-integrated which is not the case. This approach is therefore misleading because the model looks sophisticated while in fact it is misspecified.

It appears that there is no easy solution to solve the issues with the statistical and theoretical validity of the regression models. For this reason the question raises what model to select and how to proceed. Since the models are statistically unsound the measures of fit do not provide any guidance. A more convenient way to evaluate the performance is to compare them by means of an ex-post evaluation of the regression models.

#### 4.4 Ex-post performance of the regression models

An ex-post forecast has been derived for each of the models referred to in the previous section. The forecast assumes that someone back in 1970 had perfect foresight on the development of the GDP and was asked to develop a forecast of the Port Throughput up to 2009 on the basis of post war data. The results of this forecast as well as the real development of the Port Throughput over the past four decades are indicated in Figure 5.



**Figure 5: Ex-Post forecast from 1970 to 2009 for various forecast approaches**

From the results indicated in Figure 5 it can be concluded that the difference approach has performed remarkably well as it shows almost no deviation from the true development of the Port Throughput. The use of a linear model is also not bad from the perspective of the very long term as it appears to be unbiased towards the long term trend. The use of an exponential model derived from the natural logarithms of GDP and Port Throughput should be avoided as this approach deviates significantly from the real trend<sup>11</sup>. The (ab)use of an error correction model is likely to improve Equation 1 in the sense that it follows the trend slightly closer. Besides this it was also expected to provide more realistic prediction intervals. The downside of this approach is however that it gives the impression of a highly sophisticated and sound approach while in fact the model is still misspecified. This is not a desirable property. An alternative approach that does not create the illusion of a perfectly sound model is to combine Equation 1 and 3 by taking the averages of the forecasts.

<sup>11</sup> There is a tradeoff between statistical soundness and theoretical validity of the model. Particularly in applied econometrics the logarithm is often taken to improve the statistical soundness of model. This approach however comes with the risk of producing a model that is theoretically unsound and therefore biased.

## 4.5 Combining forecasting models

Forecasting literature indicates that it is good practice to combine forecast in order to obtain more stable results. This is particularly the case when it is uncertain which method provides the most accurate forecast (Armstrong, 2001, p.417). On the very long run Equation 1 is likely to overestimate the trend as result of trend breaches (that are likely to have a negative impact on throughput volumes). On the contrary Equation 3 is expected to underestimate the very long term trend as a result of the constant negative  $\alpha$  coefficient. Combining both forecasts is therefore expected to reduce bias and improves the forecast. The same holds for the width of the prediction intervals as the variance of Equation 1 is too small (as it contains unit roots) and the variance of Equation 3 will, due to the poor fit and ignorance of common drivers, be larger than the prediction intervals of the real unknown perfect forecast. For this reason the average of the forecasts based on the relations of Equation 1 and 3 is expected to provide a better indication of the order of magnitude and uncertainty related to the future port throughput volumes in the Le-Havre – Hamburg region than the individual forecasts based on the single Equations 1 or 3.

## 5 Probabilistic Population and GDP Forecasts

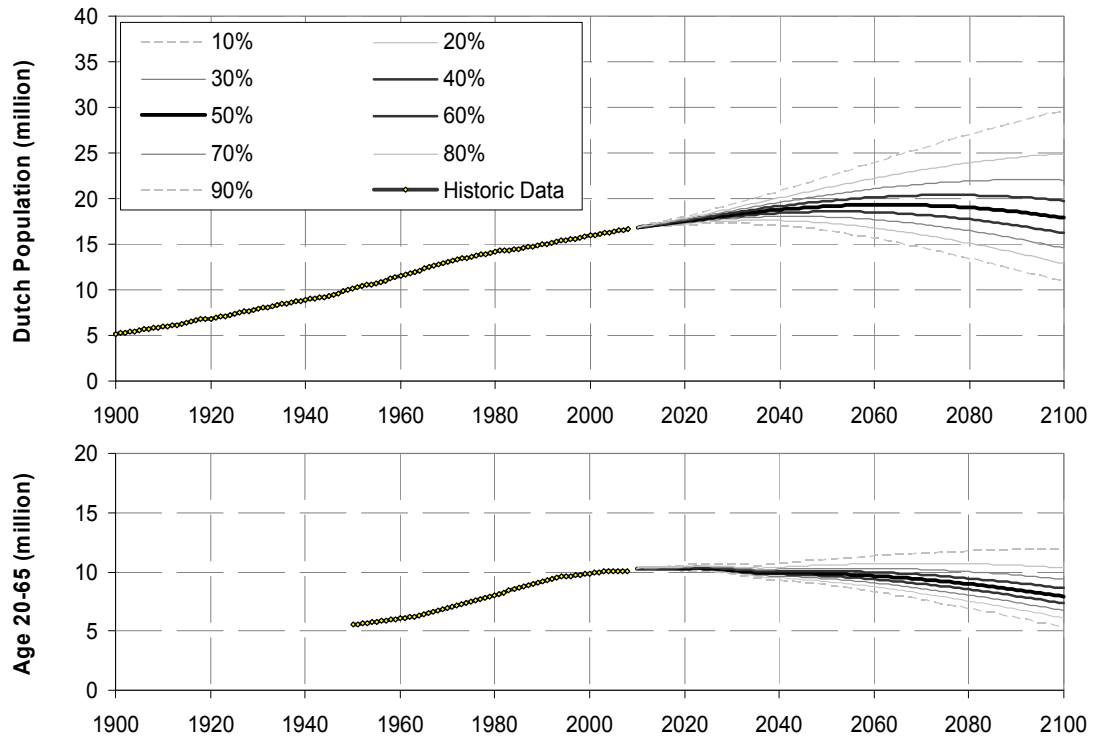
Probabilistic GDP forecasts have, to the best of our knowledge, not been published and are therefore unavailable<sup>12</sup>. For this reason a probabilistic GDP forecast has been developed on the basis of available information and expected trends. In order not to complicate the issue it has been assumed that the very long term development of the Hinterland GDP is similar to the development of the Dutch GDP. This simplification is justified by the fact that the relative development of the GDP moves along quite similar for the *The Netherlands, Belgium, Germany and France* (refer Section 3.1).

### 5.1 Developing a probabilistic population forecast

The development of a probabilistic very long term GDP forecast up to 2100 requires a probabilistic very long term forecast of the population in the working age class of 20-65 years. No such forecast is available for the Netherlands. For this reason a forecast has been compiled from three different sources which include the *probabilistic projections for West-Europe of the World Population Program* (IIASA, 2007 update, [www.iiasa.ac.at](http://www.iiasa.ac.at)), the *probabilistic projections for the Dutch population up to 2050 of the project Uncertain Population of Europe* (Alho and Nikander, 2004), and the *four very long term scenarios for the development of the total population up to 2100* (de Jong, 2008). The discussion of the methodology applied is beyond the scope of this publication. The population forecasts and prediction intervals are indicated in Figure 6. The percentages in the legend refer to the percentiles of the forecast. The 50% percentile represents the mean.

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<sup>12</sup>No attempt has been made to verify if probabilistic forecasts are available in the private sector. It is not unlikely that for example insurance companies have developed similar forecasts themselves.

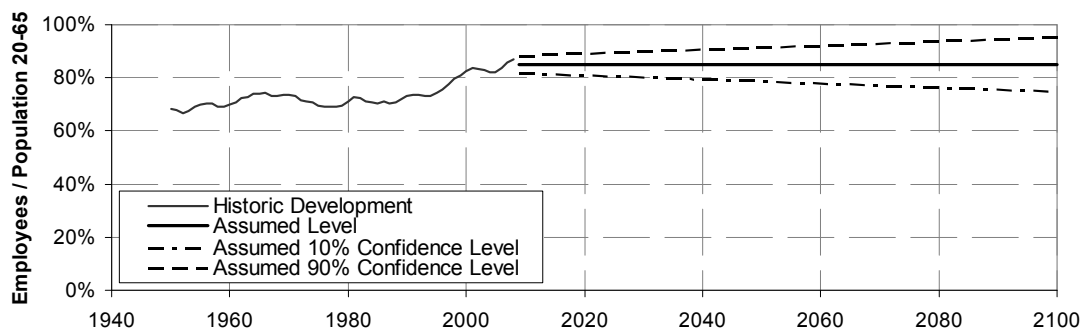


Source: Historic Data obtained from Maddison (2010) and CBS (2010)

Figure 6: Probabilistic Forecast of the development of the Dutch Population

### 5.2 Developing a probabilistic GDP forecast

The probabilistic GDP forecast has been developed on the basis of the available population forecasts and probabilistic modelling techniques. For this purpose use has been made of the Excel Add-on @Risk, a simulation program designed for stochastic calculations. For each of the variables *labour participation (working class 20-65)*, *working hours per employee per year*, and *GDP contribution per working hour* a distribution function (type, mean, and variance) has been defined for the period up to 2100. The assumptions on labour participation are indicated in Figure 7.

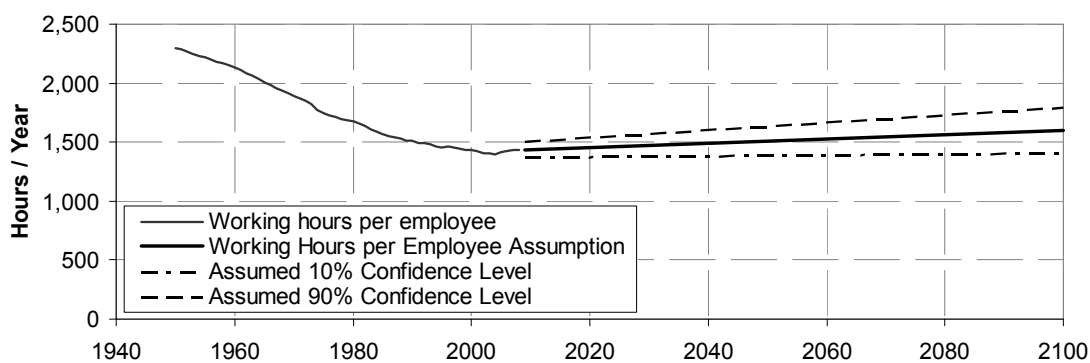


Source: Historic Data on population and size of labour force has been obtained from the Bureau of Statistics ([www.cbs.nl](http://www.cbs.nl)) and The Conference Board ([www.conference-board.org](http://www.conference-board.org))

Figure 7: Assumed development of the Labour Participation in the Netherlands

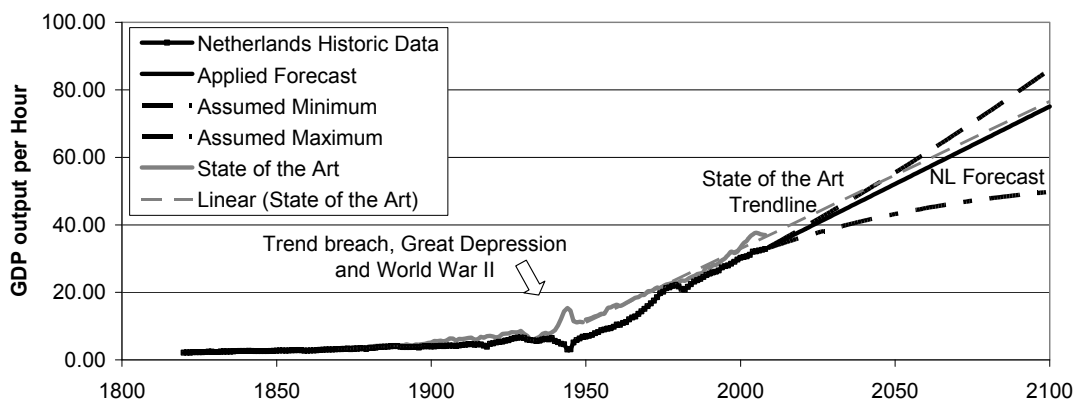
The figure indicates that labour participation has increased considerable over the past decades. The high current value of about 85% leaves little room for further increase. On the other hand the expected reduction in working age population leaves little room for a reduction either. It has therefore been assumed that the labour participation rate will remain more or less constant at a level of 85%. The variance has been assumed to be reflected by a normal distribution with a standard deviation of 3% in 2009 increasing to 8% in 2100.

The historical data and assumptions related to the average annual working hours per worker per year are indicated in Figure 8. It has been assumed that the average worked hours per year slightly increase from 1435 hours in 2009 to 1600 hours in 2100 due to a relative decrease in working age population (refer Figure 8). The variance has been defined by a normal distribution with a standard deviation of 50 hours per year in 2009 increasing to 150 hours per year in 2100.



**Figure 8: Assumed development of the Annual Working Hours per Employee**

Finally an assumption has been made on the development of the GDP output per hour worked (or labour productivity). For this purpose data series dating back to 1820 have been studied. Data from 1950 onwards has been obtained from The Conference Board (2009). Earlier data has been estimated on the basis of per capita GDP data obtained from Maddison (2010) and the assumption that the labour participation and number of hours worked remained constant over the period 1820 to 1950 (using 1950 data). Figure 9 shows the historical data and assumed forecast (measured in 1990 GK\$).

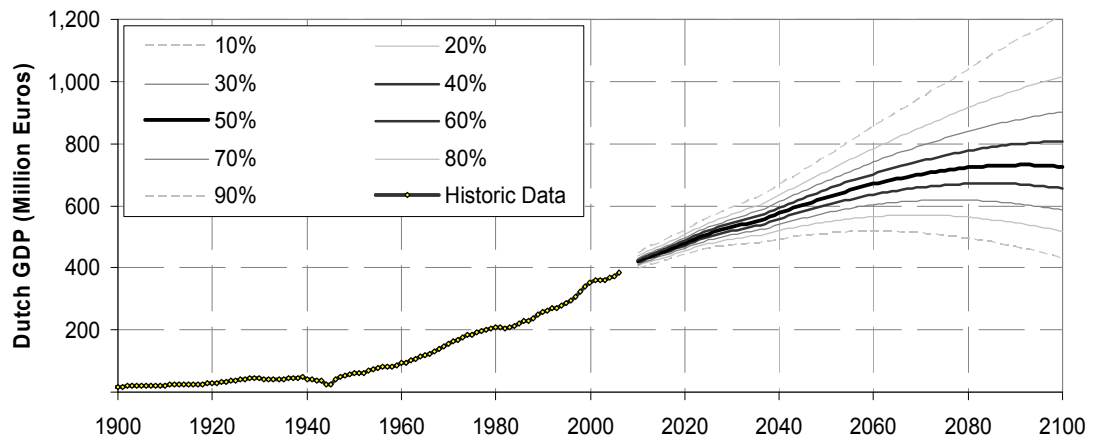


Source: Historic Data from Maddison (2010) and The Conference Board (2009).

**Figure 9: Assumed development of the Labour Productivity**

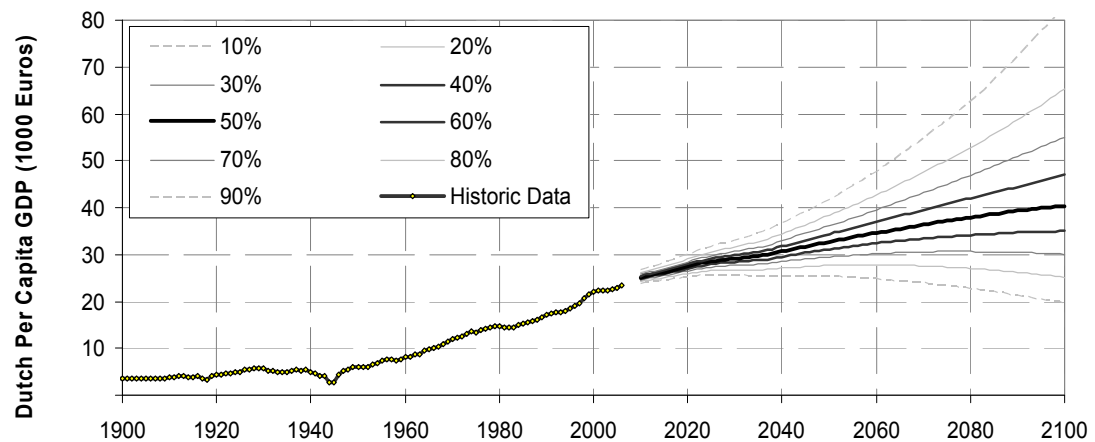


The gray line indicates the hourly labour productivity for the most productive country in the world. This line is referred to as the *State of the Art*. The black line indicates developments for the Netherlands. Both lines indicate a trend breach at the instance of the Great Depression and the Second World War. It appears that the *State of the Art* line follows a strong linear trend since the early 1950's but shows a small jump over the last decade (2000-2010). This small jump is related to a temporary increase in oil prices that shifted the Norwegian GDP beyond the long term equilibrium state of the state of the art line. Therefore this small jump does not mark a potential breach of the linear trend. The black line indicates the development of the labour productivity in the Netherlands. Ever since the Second World War the Netherlands is performing well and slowly creeping towards the state of the art trend line. The forecast of the Dutch GDP per hour worked has been defined as a triangular distribution function of which the mean follows a linear extrapolation of the post war trend; the maximum is defined as a 15% increase imposed on trend causing an upward shift of the state of the art line; and the minimum is defined as a 30% fall compared to the trend. On the basis of the above assumptions a probabilistic forecast of the Dutch GDP and GDP per capita is derived. The results are indicated in Figure 10 and 11.



Source: Historic Data obtained from Maddison (2010)

**Figure 10: Probabilistic forecast of the Dutch GDP**



Source: Historic Data obtained from Maddison (2010)

**Figure 11: Probabilistic forecast of the Dutch GDP per Capita**

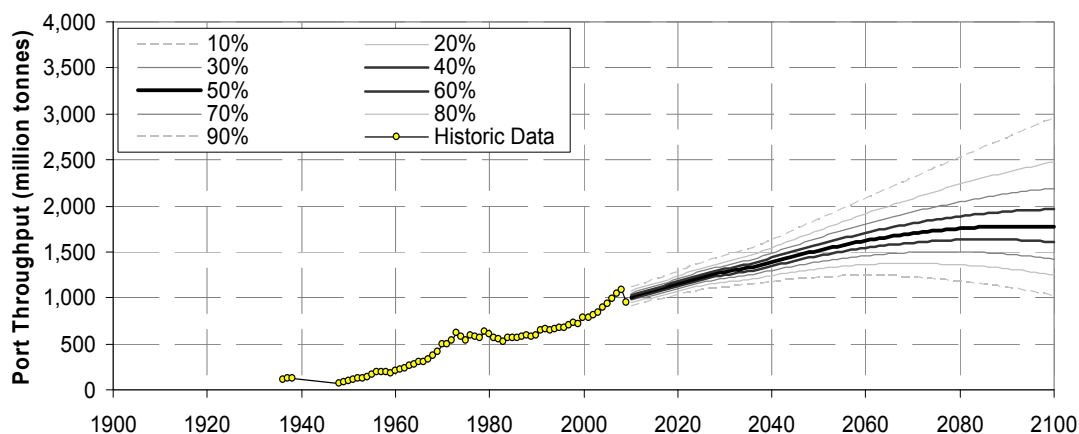
The figures indicate that the GDP (and GDP per capita) growth will reduce over the next two decades as a result of the retirement of the baby boom generation. This effect cannot be fully compensated by the increase in labour productivity. After stabilisation of the labour outflow the GDP will further increase until the working population inflow starts to decrease.

## 6 Very Long Term Forecast for Le-Havre – Hamburg Range

Unfortunately it has not been possible to derive a forecast relation that is both theoretically and statistically sound. For those who believe forecasts are misleading and by definition wrong: here is your argument! For those who seek a pragmatic solution in order to try to develop an as good as it gets order of magnitude indication of the future port throughput: the best way forward is probably to take the averages of the outcomes of Equation 1 and 3. We prefer to be pragmatic, but at the same time we realize that it is essential to address the issue of reliability carefully. This section therefore starts with a discussion on the development of the forecast results followed by an equally important discussion on the reliability of the forecast.

### 6.1 Preparation of forecast based on levels approach

The forecast based on the (spurious) relation of Equation 1 compares the levels of the GDP directly to the levels of the Port Throughput. In order to obtain the probabilistic forecast for each year 10.000 simulations have been made in the Excel Add-on @Risk. For each simulation the GDP value has been drawn from the distribution function of the year under consideration. This value has been used in the stochastic relation between GDP and Port Throughput to obtain an estimate of the throughput volume of the ports. Finally the outcome statistics have been summarized in order to derive the prediction intervals. The results are indicated in Figure 12.



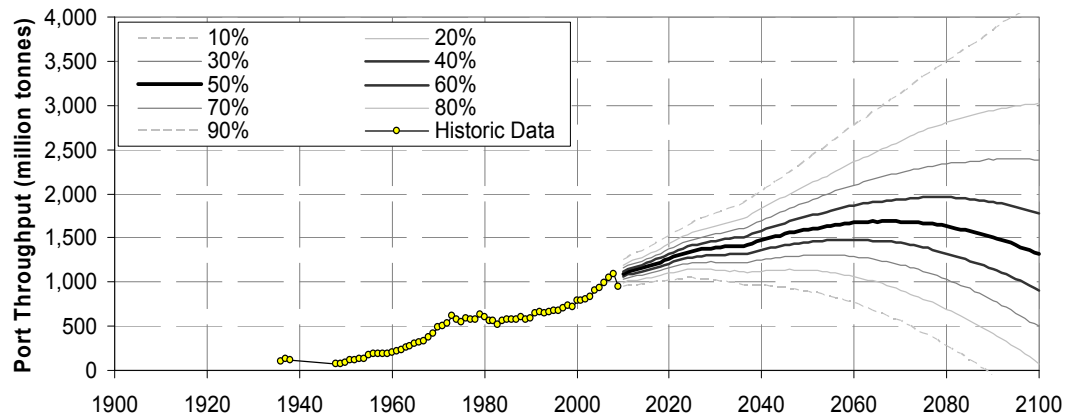
Source: Historic Data from Port Authority of Antwerp (1936-2007) and Rotterdam (2008, 2009)

Figure 12: Single Forecast based on Levels Approach of Equation 1

Please note that the model is **statistically unsound**, is likely to be misspecified in the sense that it is vulnerable to trend breaches, and has a prediction interval that is too small (due to spurious regression caused by common drivers). There was also a problem with the fact that the error term was not normal distributed, but this problem has been solved by using more advanced techniques for the calculation of the prediction intervals.

## 6.2 Preparation of forecast based on differences approach

The forecast based on the differences approach of Equation 3 has been derived using a similar methodology as discussed for the levels approach of Equation 1. The results are indicated in Figure 13.



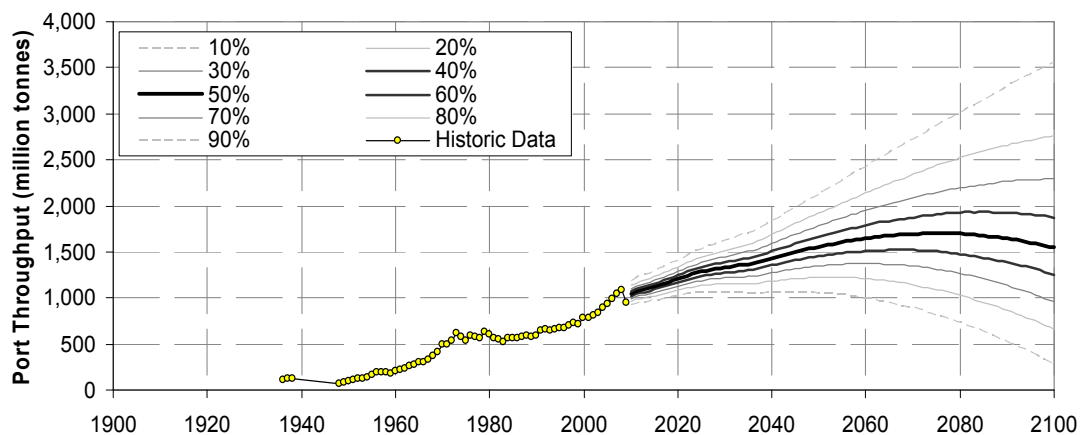
Source: Historic Data from Port Authority of Antwerp (1936-2007) and Rotterdam (2008, 2009)

**Figure 13: Single Forecast based on Differences Approach of Equation 3**

The differences approach is statistically sound and therefore much more robust than the levels approach but also **theoretically unsound** as the negative  $\alpha$  coefficient forces the model downwards to a zero throughput on the very long run. Therefore the forecast can be expected to be increasingly downward biased as time passes. In addition to this the forecast ignores the fact that there will remain some common drivers (the ones that cause the risk for trend breaches in the levels approach) and therefore the variance estimate can be expected to be too conservative (compared to the real unknown perfect forecast).

## 6.3 Final forecast based on a combined approach

Combining both forecasts is expected to reduce the bias in the mean and prediction intervals. The final forecast has been derived by taking the average percentiles of both forecasts (refer Figure 14).



Source: Historic Data from Port Authority of Antwerp (1936-2007) and Rotterdam (2008, 2009)

**Figure 14: Combined Forecast based on Levels and Differences Approach**

The combined forecast indicates that an overall increase in cargo volumes by a factor 1½ to 2 up to 2080 can be expected (based on the 40 to 60 percent confidence intervals). A possible decline thereafter is not unlikely. The reduced pace of growth between 2010 and 2030 is caused by the mass retirement of the baby boom population<sup>13</sup>. After 2030 the labour outflow stabilizes and both GDP and Port Throughput are expected to grow as a result of increased labour productivity. Finally from 2080 onwards the overall population decrease is expected to result in a stabilisation and decline of GDP and Port Throughput volumes.

#### **6.4 On the subject of reliability**

Throughout this paper we have discussed many issues related to the reliability of the forecast. Some issues such as the absence of a valid forecast relation are so important that it had to be concluded that it is not possible to develop a completely sound forecast. However, the question remains whether the results are reliable enough to provide an acceptable order of magnitude estimate instead. This section will discuss the issues related to the reliability of the forecast as well as our interpretation of the perceived levels of uncertainty.

The first issue relates to the description of the Hinterland. Due to interaction with other port regions and over land trade connections it is not possible to sharply define the Hinterland of the port region. Therefore, instead of defining a distinct area it was assumed that the port throughput is related to the relative economic development of the main Hinterland area defined as the Netherlands, Germany, Belgium and France. The economic development has been defined as an index of the combined GDP output of these countries with an arbitrary base year 2000. This simplification of the Hinterland is expected to have almost no impact on the reliability of the forecast.

The second issue refers to the non-availability of a probabilistic GDP forecast for the Hinterland area. In order to deal with this issue it was assumed that the GDP development of the main Hinterland countries moves similar to the GDP development of the Netherlands. Historical evidence has been provided in Figure 1 for a period of 110 years, but the future may develop in a different direction. We expect that this simplification is sufficient for the development of an order of magnitude estimate of the port throughput. However, new forecasts may point out strong differences in the development of the Dutch, German, Belgium, and French GDP.

The third issue is related to the non-availability of a probabilistic GDP forecasts for the Netherlands. For this reason a GDP forecast has been developed on the basis of a probabilistic forecast of the working age population, and probabilistic assumptions on the development of the labour participation, worked hours per employee, and labour productivity. We expect that the assumptions on which this forecast is based are reasonable and sufficient to provide an acceptable order of magnitude estimate. However, our views may be different from the views of demographic and socio-economic experts as this has not been verified.

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<sup>13</sup> It should be noticed that the slowdown of the economic growth and Port Throughput matches the downswing of the 5<sup>th</sup> Kondratieff wave. This is however a coincident as economic cycles are not forecasted in the model.

The fourth issue is related to the non-availability of a very long term probabilistic forecast of the overall population and the working age population up to 2100 in the Netherlands. Since no probabilistic forecast was available it has been compiled from a probabilistic forecast for the Netherlands up to 2050, a probabilistic forecast for Western Europe up to 2100, and a set of very long term scenarios for the development of the Dutch population up to 2100. The population forecasts have been carefully compiled from the above sources but may differ from a new forecasts developed by a renowned demographic institute. We nevertheless expect the forecast to provide a reasonable order of magnitude estimate.

The fifth issue is related to the theoretical and statistical validity of the evaluated causal forecast relations of Equation 1 and 3. The statistical unsoundness of Equation 1 results in a long term trend with a virtual high fit that is very sensitive to trend breaches. Likely the high fit is caused by common drivers such as globalisation which have shifted both GDP and port throughput upward causing the illusion of causality. As a result the calculated bandwidth based on Equation 1 will be too small – and the long term mean is likely to be too high in case of trend breaches (assuming that it is more likely that a trend breach will have a negative effect than a positive effect).

The theoretical unsoundness of Equation 3 leads to a fundamental problem on the very long term as it forces the port throughput towards zero after stabilisation of the GDP. The calculated bandwidth of Equation 3 is relatively high due to the low explanatory value of the regression formula. Common drivers that cause the risk of trend breaches in Equation 1 are no longer implicitly included in the forecast relation. However they may remain influential drivers for at least some time. This makes the bandwidth of the forecast based on Equation 3 larger than necessary.

Based on the above considerations it can be expected that Equation 1 and 3 alone are not suitable to provide reasonable very long term forecast. However it can be argued that a combination of both forecasts (taking the averages) may well provide a suitable order of magnitude estimate of the port throughput in the Le-Havre – Hamburg range. The argumentation is based on the following considerations. First: the forecasts are likely to be counter biased with respect to their mean and variance. Second: both forecasts performed remarkably well in the long term ex-post evaluation. On the basis of these two arguments we expect the combined approach to be suitable for the development of a reasonable order of magnitude estimate of the port throughput.

The sixth issue is related to trend breaches. Even though no trend breach has occurred to the causal forecast relationship over the past 73+ years it is not possible to rule out the possibility of a future trend breach. As discussed Equation 1 is very sensitive to trend breaches but also Equation 3 will be subject to changes. Drastic policies related to climate change may severely restrict mobility in an attempt to create fully self sustainable communities. Shortage of fossil fuels may lead to substitution of energy systems from conventional oil, gas, and coal to mega solar plants in desert countries connected by global energy grids not requiring any marine transportation at all. Global food shortage may lead to an export ban in food exporting countries. Political conflicts between the “old world” and the new industrial powers of China, India, Russia, and Brazil may result in a trade war that effectively bans all transport towards Europe and the United States. Since we cannot rule out the possibility of a trend breach we have to consider their likely effects.

Now first consider two types of trend breaches. The first type reflects disasters. Their impact is considerable and they will probably lead to a reduction of 50% to 100% of the total throughput. The second type is related to major changes in the world not being a disaster. Most likely these changes will have a downward effect, but an upward shift is also possible. Quite likely such a trend breach will affect only one of the “commodity” classes such as containers, dry bulk, liquid bulk, and break-bulk. Taking this into account it can be expected that the total impact of a large trend breach on the total throughput volume will not be larger than say twenty to thirty percent. Such an effect is reasonably covered by the bandwidth of the forecast. Therefore, despite the possibility of trend breaches the forecast is still expected to provide a reasonable order of magnitude estimate of the port throughput volumes.

Taking these issues into consideration we expect that the presented forecast provides a reasonable order of magnitude indication of the overall future port throughput volumes in the Le-Havre – Hamburg range up to 2100. However, we realize that there are issues with the reliability that may be interpreted differently.

## 7 Conclusions

The research questions have been defined in section 1.3. This section concludes with the discussion of the findings related to the questions.

Question 1: There is not much literature available on the subject of port throughput forecasting and most likely no handbook on the subject has been written. Port throughput forecasting is generally applied by port authorities and specialised consultants. In practice forecasts are usually based on causal relationships between port throughput volumes and demographic, economic or industrial developments.

Question 2: The review of very long term forecast methodology indicated that little has been written on the subject. To move beyond the classical forecast horizon set by mere trend extrapolation the use of scenarios was suggested. However, it was also indicated that scenarios are not predictions. An alternative approach is the development of a probabilistic forecast. Probabilistic techniques have already been successfully applied to develop probabilistic very long term population forecasts. The probabilistic forecasting methodology has been adopted in this paper.

Question 3: A sensible approach for the development of a very long term forecast is to start with the evaluation of the long term relationship between port throughput and hinterland GDP. The next step is to develop a very long term probabilistic forecast of the economic development in the hinterland (measured by GDP). Finally, on the basis of the above, a probabilistic very long term forecast of the port throughput in the Le-Havre – Hamburg range can be developed.

Question 4: Reasonable long term historical data series (from 1936 onwards) on the development of the Port Throughput are available at the Antwerp Port Authority. Long historical data ranges on the development of the Hinterland GDP are available from Maddison. The length of both data series is sufficient to define a very long term forecast relation for the port throughput in the Le-Havre – Hamburg range.

Question 5: There are too many issues related to the development of this forecast to be able to speak of a valid forecast. Nevertheless, the forecast can be expected to provide a reasonable order of magnitude estimate of the future development of the port throughput volumes in the Le-Havre – Hamburg range up to 2100.

Question 6: The development of a probabilistic forecast for the port throughput volumes in the Le-Havre – Hamburg range requires a probabilistic forecast of the Hinterland GDP. Such a forecast was not available and had to be developed. Since the GDP of the various countries located in the Hinterland follows a similar trend the forecast has been based on a probabilistic forecast of the Dutch GDP only. The probabilistic forecast of the Dutch GDP was developed on the basis of a probabilistic forecast of the working age population and some probabilistic assumptions on the overall development of the labour productivity.

Question 7: The combined forecast indicates that an overall increase in cargo volumes by a factor 1½ to 2 up to 2080 can be expected (based on the 40 to 60 percent confidence intervals). A possible decline thereafter is not unlikely.

## Acknowledgements

This paper has been previously presented at the “*Port Infrastructure Seminar 2010*” which was held on the 22 and 23 of June 2010 at the Delft University of Technology. The original paper and presentation are available at <http://www.citg.tudelft.nl/live/pagina.jsp?id=5083b014-a321-4a75-a7a9-8201a9624b7f&lang=en>. Minor changes have been made to the headers to fit the TRAIL format. Further changes have been made in particular to section 5.2 and 6.4. Section 5.2 now includes a description of the assumptions made for the development of the Dutch GDP forecast. Section 6.4 has been expanded to provide a discussion of the reliability of the forecast and the possible effects of trend breaches. Section 7 has been reduced in content to increase the readability of the paper. The paper is considered (but not yet accepted) for publication in a special issue on Port Planning of the European Journal of Transport and Infrastructure Research (EJTIR).

## References

- Alho, J.M. and Nikander, T. (2004) ‘Uncertain Population of Europe Summary Results from a Stochastic Forecast’. Deliverable 12 belonging to *Work Package 6 of an EU 5th frame work funded research project Uncertain Population of Europe (UPE)*, HPSE-CT-2001-00095.
- Armstrong, J.S. ed. (2001) *PRINCIPLES OF FORECASTING, A Handbook for Reaserachers and Practioners*, Kluwer Academic Publishers, Boston / Dordrecht / London.
- Bails, D.G. and Peppers L.C. (1993) *Business Fluctuations: Forecasting Techniques and Applications*, Prentice Hall, Englewood Cliffs, New Jersey.
- Bowerman, B.L., O’Connell, R.T. and Koehler, A.B. (2005) *Forecasting, Time Series and Regression: An Applied Approach*, Thomson Brooks/Cole.

- Chen, S. and Chen, J. (2010) 'Forecast container throughputs at ports using genetic programming', *Expert Systems with Applications*, Vol. 37, no. 3, pp. 2054-2058.
- De la Fuente Layos, L. (2007) 'Inland Waterways Freight Transport in Europe in 2006, EU transport static'. *Eurostat, Statistics in focus*, 132/2007.
- De la Fuente Layos, L. (2009) 'Inland Waterways Freight Transport in Europe in 2007 remains stable'. *Eurostat, Statistics in focus*, 27/2009.
- DeLurgio, S.A. (1997) *Forecasting Principles and Applications*, McGraw-Hill College.
- Diebold, F.X. (2004) *Elements of Forecasting*, Tomson South-Western, Canada.
- Fildes, R. (1986) 'Editorial: Long-Term Forecasting and the Experts', *International Journal of Forecasting*, Vol. 2, no. 1, pp. 3-4.
- Fildes, R. (2006) 'The forecasting journals and their contribution to forecasting research: Citation analysis and expert opinion', *International Journal of Forecasting*, Vol. 22, no. 3, pp. 415-432.
- Fung, K. (2001) 'Competition between the ports of Hong Kong and Singapore: a structural vector error correction model to forecast the demand for container handling services', *Maritime Policy & Management*, Vol. 28, no. 1, pp. 3-22.
- Granger, C.W.J. and Newbold, P. (1974) 'Spurious Regressions in Econometrics', *Journal of Econometrics*, Vol. 2, no. 2, pp. 111-120.
- Guo, Z., Xiangqun, S. and Jian Y. (2005) 'A verhulst model on time series error corrected for port throughput forecasting', *Journal of the Eastern Asian Society for Transportation Studies*, Vol. 6, pp. 881-891.
- Hanke, J.E. and Wichern, D.W. (2008) *Business Forecasting*, Pearson/Prentice Hall, Upper Saddle River, New York.
- Huggins, D. (2009) *Panorama of Transport*, Eurostat, ISSN 1831-3280, <http://epp.eurostat.ec.europa.eu>.
- 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.
- Heijer, F. den, Wolters, M.A., Dorsser, J.C.M. van, Berger, H.E.J. and Hijdra, A.C.L. (2010) 'Developing a substitution strategy for hydraulic structures to meet the challenges of a new century'. Paper presented at the 32<sup>nd</sup> PIANC Congress, May 2010, Liverpool, UK.
- Jong, A. de (2008) 'Vier scenario's voor de zeer lange termijn', *Bevolkingstrends*, Quarter 4, Centraal Bureau voor de Statistiek.
- Klein, A. (1996) 'Forecasting the Antwerp Maritime Traffic Flows Using Transformations and Intervention Models', *Journal of Forecasting*, Vol. 15, no. 5, pp. 395-412.
- Levenbach, H. and Cleary, J.P. (2005) *Forecasting: Practice and Process for Demand Management*, Thomson Brooks/Cole, Belmont, CA.
- Li, J., Chen, Y. and Cui, X. (2008) 'Port Throughput Forecast Based on Nonlinear Combination Method'. Paper presented at the 7<sup>th</sup> WSEAS International Conference on



*APPLIED COMPUTER & APPLIED COMPUTATIONAL SCIENCE (ACACOS '08)*, April 2008, Hangzhou, China.

Maddison, A. (2010) 'Statistics on World Population, GDP and Per Capita GDP, 1-2008 AD', *horizontal-file\_02-2010.xls*, <http://www.ggdc.net/maddison/>.

Makridakis, S., Wheelwright, S.C. and Hyndman, R.J. (1998) *FORECASTING, Methods and Applications*, John Wiley & Sons, Inc., USA.

Meersman, H. and Van de Voorde, E. (2008) 'The Relationship between Economic Activity and Freight Transport', in Ben-Akiva, M., Meersman, H. and Van de Voorde, E. (ed) *Recent Developments in Transport Modelling, Lessons for the Freight Sector*, Emerald, UK.

Mentzer, J. and Bienstock, C. (1998) *Sales Forecasting Management*, Sage Pub, Thousand Oaks, CA.

Pindyck, R.S. and Rubinfeld, D.L. (1998) *Econometric Models and Economic Forecasts*, Irwin McGraw-Hill, Boston.

Port of Antwerp (2009) *Yearbook of statistics 2008*, Gemeentelijk Havenbedrijf Antwerpen, Havenhuis, Entrepotkaai 1, 2000 Antwerpen, België.

Schwartz, P. (1996) *The Art of the Long View*, Currency and Doubleday, New York.

The Conference Board (2009) *Total Economy Database.xls*, <http://www.conference-board.org/economics/database.cfm>.

Veenstra, A.W. and Haralambides, H.E. (2001), 'Multivariate autoregressive models for forecasting seaborne trade flows', *Transportation Research Part E*, Vol. 37, no. 4, pp. 311-319.

Weiqun C. and Nuo, W. (2003) 'Container throughput forecast model for a district port based on bp neural network', *Proceedings of the Eastern Asia Society for Transportation Studies*, Vol. 4, pp.254-258. [Note: title contained errors in words throughput and distinct].

West, M., and Harrison, J. (1999) *Bayesian Forecasting and Dynamic Models*, Springer, New York.

Wilson, J.H., Keating, B. and John Galt Solutions Inc. (2009) *Business Forecasting with ForecastX*, McGraw-Hill/Irwin, Boston.