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Analysis of the determinants of container throughput of the major ports in the Hamburg Le Havre range

by

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“The battle of life is, in most cases, fought uphill; and to win it without a struggle were perhaps to win it without honour. If there no difficulties there would be no success; if there was nothing to struggle for, there would be nothing to be achieved”
– Samuel Smiles
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Abstract

Port competition in the Hamburg Le Havre range is extremely competitive in the container segment because of the close proximity shared between these ports and overlapping hinterlands among other factors. In order to survive in this highly competitive environment, strategic planning is undertaken. Before strategic planning is undertaken, it is crucial for the ports to understand their unique determinants of their container throughput.

In this study four major container ports, one from each country in the Hamburg Le Havre range has been selected to analyze the determinants of their container throughput. In addition to other studies to port competition determinants, this study uses classical regression model to ascertain the determinants of container throughput of the selected ports and understand its significance and impact on the throughput.

Around 20 variables impacting container throughput were identified for the Port of Antwerp, Port of Hamburg, Port of Rotterdam and Port of Le Havre.

For the Port of Antwerp, 10 variables formed the determinants of its container throughput out of which 6 were found significant comprising of 4 positive determinants and 2 negative determinants. For the Port of Hamburg, 10 variables also formed the determinants of its container throughput out of which again 6 were found to be significant comprising of only 2 positive determinants and 4 negative determinants. The Port of Le Havre returned with only 5 variables that determine its container throughput out which 3 were found to be significant and 2 insignificant. Finally, for the Port of Rotterdam, 8 variables were found to determine its container throughput, 5 out which were significant and 3 insignificant.

Based on the results of the simple regression results and multi regression model of the selected ports, several long term strategies of each port were analyzed to determine to what extent they fit their unique determinants for container throughput.

This study is aimed to be useful for the port authorities of the selected ports and port stakeholders.
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<td>Austria</td>
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<td>BEL</td>
<td>Belgium</td>
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<td>CHE</td>
<td>Switzerland</td>
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<td>CZK Rep</td>
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<td>DEU</td>
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<td>EUR</td>
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<td>FRA</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>MLN</td>
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<td>POL</td>
<td>Poland</td>
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<td>SSS</td>
<td>Short Sea Shipping</td>
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<td>SVK Rep</td>
<td>Slovak Republic</td>
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<tr>
<td>TEU</td>
<td>Twenty Feet Equivalent Unit</td>
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<td>TT</td>
<td>Total Transport</td>
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<td>Ttonne</td>
<td>Thousand tonne</td>
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1. Introduction

1.1 Importance of the Hamburg Le Havre Range

From Le Havre to Hamburg, the Northern Range is one of the main and most competitive port ranges in the world (Joly, 2006). Within a distance of about 850 kilometres, 11 ports are located with more than 1,224,300,000 tons throughput in 2015 (Port of Rotterdam Authority, 2016a).

The below figure 1 shows the Hamburg Le Havre range which helps in visualizing the proximity of the ports to each other.

Further, the figures of container throughput of these 11 ports are as per the below table 1 which show that the Port of Rotterdam is the most dominant container port followed by Port of Antwerp and Port of Hamburg.
The first major factor for the significance of the Hamburg Le Havre port range is that two-thirds of the population and industry on the European continent lives in the hinterland of these ports. (Port of Rotterdam, 2011). That is a significant reason for the large scale of container handling in Northern Europe.

The industries in Europe are concentrated in a zone termed as the European Banana Zone. This zone contains a very high concentration of high value economic activity. It roughly encompasses the region from North-West England to Northern Italy. The zone is a cluster of regions that have a long history of high economic development like London, Manchester, Amsterdam, Brussels, Belgium, Venice, Cologne, Milan and Zurich (Cattoor, 2012). The below figure 2 shows the European Banana Zone.
The second major factor is the geography of the continent. The Alps in particular form a barrier to freight transport (Port of Rotterdam, 2011). At the same time, rivers such as the Rhine open up a large part of the continent for the highly competitive mode of transport; inland shipping (Port of Rotterdam, 2011). The same applies to railways and roads, which are easier to construct in the northern part of Europe (Port of Rotterdam, 2011).

The third factor is the size of the container vessels which transport cargo to/from Europe. In terms of cost per container, it is more cost effective to send large ships from the Far East to Northern Europe than smaller ones to South European ports (Port of Rotterdam, 2011). It is not commercially viable to use very large ships there because of the smaller volumes.

1.2 Motivation and relevance of the study

Summarizing the above, there is a clear rationale for the Hamburg Le Havre range being the most competitive port range in Europe. However, how do each of the ports within this range compare with each other? What are their unique competitive advantages?
As the competition between sea ports is high in the Hamburg Le Havre range it is crucial to understand which are the unique determinants that impact throughput significantly and which do not. Such a study will help the port authorities of the ports and relevant stakeholders of these ports to formulate strategies on the significant determinants and investment in the related projects. Therefore, this study will help ports to have the quantitative rationale for their main competitive advantages in this range.

Furthermore, it is good tradition for ports to publish their long term strategies. The long term port strategies of the selected ports are:

a) Port of Antwerp: Sustainability Report 2015
b) Port of Hamburg: The Port Development Plan to 2025 “Hamburg is staying on Course”
c) Port of Le Havre: Overview of the Strategic Plan 2014-19
d) Port of Rotterdam: Port Vision 2030 - “Port Compass”

These port strategies are capital intensive and their gestation period are long. As such choosing to invest in the most significant areas which would impact its throughput positively is important and stakeholders would like to know these ‘significant determinants’.

Finally, from the literature review it was observed that the regression model was successfully used in analyzing the determinants of container throughput of different ports. In their paper titled, “Empirical analysis of influence factors to container throughput in Korea and China ports” the authors used the regression model to analyze the strongest variables that impact the throughput of the port of Korea and China. They found that the strongest determinants of throughput of Korea container ports were transshipment (positive effect) and port tariff (negative effect) and for Chinese container ports it was hinterland’s GDP (positive effect), hinterland’s import/export volume (positive effect) and investment made by the Government (positive effect) (Park, 2011).

However, based on the literature review, regression model has not been used by any distinguished authors for the Hamburg Le Havre range. As such this study is unique, as regression model is used to analyze the determinants of container throughput of the selected ports and its significance will be analyzed.

1.3 Scope of the research

As mentioned earlier, for the purpose of this study four ports are selected, each being the dominant container port of the particular country. As such the Port of Antwerp is selected from Belgium, Port of Hamburg is selected from Germany, Port of Rotterdam is selected from the Netherlands and Port of Le Havre is selected from France. The port throughput of these ports are depicted in figure 3 to help visualize each port’s cargo segments.
As can be seen from figure 3 above the two dominant cargo segment for all four ports are containers and liquid bulk. For the purpose of this study “container” segment is chosen. The reason for this selection is that it represents a substantial share of the selected ports. As such it becomes important to study the determinants of container throughput of these ports. Further, from the literature review undertaken, it is observed that all the selected ports want to stay competitive in the container segment.

The last motivation for studying solely the container segment is a matter of methodology. This study seeks to find the usefulness of a regression model in testing the determinants of container throughput of the ports. From the literature review undertaken it was observed that a regression model was very useful in understanding the variables that impacted the container throughput of several port/ port regions including China and Korea (Park, 2011).

1.4 Main Research Question and Sub Research Questions

The main question which the study seeks to address is, “What are the significant determinants of container throughput of the major container ports in the Hamburg Le Havre range?”

In order to answer the main research question, the study seeks to answer three sub-research questions which are critical.
First sub-research question: "What are determinants of container throughput?"

It would be imperative to first understand the commonly identified determinants of container throughput. This would be answered by the literature review that is covered by this study. There are general determinants such as GDP of a country, draft of the port, terminal efficiency, labour, etc which are common to all sea ports. Further, there are determinants identified during the literature review that apply to particular ports. In this study one of the unique variables is the hinterland as it differs from port to port. Also, the multi regression model will help identify the determinants of container throughput of the selected ports from the pool of general determinants of throughput.

Second sub-research question: “What is the significance of these determinants on the container throughput of the selected ports?"

After identifying the general determinants of container port throughput it is important to understand its significance per port. i.e. how strong is the linear relationship of the determinant on the specific port’s container throughput and whether it is significant or not. The strength of the linear relationship will be analysed using the simple regression method, while the significance will be determined using the multi regression model.

Third sub-research question: “How do port strategies compare with the results from the regression analysis of this study?"

The selected ports in the Hamburg Le Havre range for this study have plans and vision documents for the next 10-15 years. They have outlined in these documents various areas and avenues they would be investing in. As such based on the analysis and observations from this study, the strategies of these ports will be analysed and conclusions drawn whether they have the right focus in case they want to maximize port throughput.
2. Literature review: the determinants of port throughput

Measuring port performance

To help analyze the determinants of port throughput, its impact on the performance of the port would need to be measured. Port performance can be measured in a number of ways.

The most widely used indicator is the throughput volume of goods (the number of containers in TEU or tons of cargo) (Peter de Langen, 2007). Growth of throughput is regarded as evidence of the performance of ports (Peter de Langen, 2007).

However, throughput does not provide information on the economic impact of the port and the attraction value of the port as a location for port connected industries. As such port-related employment and value added are also used as port performance indicators (Peter de Langen, 2007).

Financial indicators are also used to measure port performance as a port authority should be aware of the costs generated by its operations and the revenue resulting from them (United Nations, 1976). It is opined that port operational indicators such as service time, gang idle time & tons per ship hour at berth are more significant to port managers as through the control of these operational indicators, financial performance of the port could be controlled as well (United Nations, 1976).

As per the PPRISM report of the UNCTAD Ad Hoc Expert Meeting on Assessing Port Performance, port performance indicators include, (a) Socio Economic Indicators: employment & added value, (b) Market Trend indicators: maritime traffic & call size and (c) Logistical Indicators: maritime container connectivity & intermodal container connectivity (Fontanet, 2012)

Other performance indicators include (a) market dynamics & logistics performance indicators: i.e. maritime & intermodal connectivity and quality of customs procedures, (b) environment indicators: carbon footprint recycling measures, (c) governance indicators: autonomous management & corporate social responsibility measures sustainability and governance (Thomas, 2012).

To conclude, as the most common port performance is ‘throughput’, the same is used in this study as the common performance indicator for the four selected ports. It is also noted that in the port strategy reports of the selected ports, throughput in TEU’s is commonly used to measure the performance of the port.

In the regression model, container port throughput measured in TEU’s (Twenty-foot Equivalent Unit) has been used. TEU is an inexact unit of cargo capacity often used to describe the capacity of container ships and container terminals.

Determinants of Port Throughput

There is a lot of academic literature on determinants of port throughput and port choice. Based on the literature review, there appears to be consensus on three main
areas that are of prime importance for the port throughput (1) maritime connections, (2) port efficiency and (3) the ports hinterland.

Based on the literature review, the following have been identified as the determinants of container port throughput.

2.1 Economy of the port’s country

The usage of a sea port arises only when there is existence of export, imports and transshipment activities in a country. As such the sea port depends on these actors for its operationalization or in other words transport is a derived factor of the economy.

Therefore, important macroeconomic components such as a country's GDP, export and import value should be taken into account as a determinant for the port performance. Research has showed that these factors indeed has a significant influence on the port performance (Tongzon, 1994).

In their research the value of imports into a country was found to be the most significant determinant of throughput volumes (William Seabrooke et al, 2003).

It was also found that the economic development of a country has a significant influence on its sea ports performance as it is largely responsible for the ports expansion (Victor R Caldeirinha, 2009).

2.2 Geographical Location

The geographical location plays an important factor in the throughput of a sea port and therefore determines port throughput. This factor is related to the geographical location of the ports in relation to main sailing routes and to main industrial zones (Herrera, 1999). This is logical as if the port is situated close to an industrial complex it would be chosen as the center for exports and imports to the hinterland.

In the case of the ports in the Hamburg Le Havre range, the distance of the ports to important economic centers in Europe would be a crucial determinant of throughput. In this case the proximity or inclusiveness in the European Banana zone would be critical.

2.3 Accessibility

Accessibility of a port includes important factors such as pilots, draft and sea locks which determine the competitiveness of sea port. The deeper the draft of the port, the larger the container vessels would be able to access the port. Average container vessel sizes have increased continually, from 400 to 1000 TEU's in 1960’s to 7000 to 9000 TEUs in 2000 and 18000 to 20000 TEU’s in 2015 (Hook, 2002) (Shen, 2015). There is evidence that the draft of the sea port is critical in attracting the large vessels thereby impacting port performance (Heng, 2005), (Peter W. de Langen, 2012), (Victor R Caldeirinha, 2009). Further, insufficient water depth results in less economical vessels calling and lower efficiency of terminals (Victor R Caldeirinha, 2009). Draft is mainly a constraint on ship maneuverability and speed, and vessels with draught bigger than the lower draft will have to wait in some cases for the tide (Herrera, 1999).
Number of pilots used is an economic and nautical constraint because vessels have to reduce speed despite new techniques when pilots are boarding (Herrera, 1999). In addition, locks are important to take into consideration because they consume considerable maneuvering time. (Herrera, 1999).

2.4 Seaport Charges

Another influential factor is the amount of the port charges which are the charges that port users must pay for the services and facilities in the port. There are several costs which are incurred for a shipping company when its vessel calls at a particular port. Such charges include pilot fees, tug boat charges, gauger, port & quay dues, communication expenses, administration charges, terminal handling expenses, storage and bunkering charges, commission fees, agency fees and waste processing charges (AVV, Transport Research Centre Dutch Ministry of Transport - Public Works and Water Management, 2007).

While this has been historically an important factor, Tongzon in his paper observes that shippers (and more significantly shipping companies) are more concerned with indirect costs associated with delays, loss of markets/market share, loss of customer confidence, and opportunities foregone due to inefficient service (Tongzon, 1994).

Further, the total cost of the supply chain would be important, sea port charges only forming a part of it (Tongzon, 1994). In their paper, (Park, 2011) tested the effect of port tariff on port performance, but found a negative effect in the case of Korean and Chinese ports.

2.5 Port and terminal efficiency

It would be logical to say the port which has more number of container gantry cranes available and dedicated container berth length would be in a situation to load/ unload container vessels more efficiently than its peers. Tongzon and Heng also took in consideration the quay length of the terminal as an independent variable for the total throughput in a container port. The same was found to have a positive effect (Heng, 2005).

Further, Tongzon in his paper published in 1994 mentioned that terminal efficiency is determined by the following factors also:

a) “Container mix: composition of trade in relation to the proportions of 40 foot and 20 foot containers
b) Work practices: Delays in commencing and during stevedoring which result in inefficiency. Delays occur on account of meal breaks, equipment break down, weather etc

   c) Crane efficiency: This depends on the ‘number of cranes’ and ‘crane operations’. 3 cranes per vessel are used by highly productive ports while in others 2 cranes are used. Crane operations implies number of lifts per crane hour”
   (Tongzon, 1994)

Tongzon further observed that terminal efficiency has a significant, positive impact on port performance (Tongzon, 1994).
In other instances, the container throughput in Hong Kong grew at an annual rate of 9.8%, inspite of the adverse impact of the Asian financial crisis on (Hook, 2002). High productivity and operational efficiency of container moves per crane was a reason behind it (Hook, 2002).

Other important aspects in terminal is the capacity, i.e. the maximum number of TEU’s it can handle and the area of the terminal depicted in hectares. The larger the terminal area, the more number of TEU’s it can manage (Carruthers, 2014).

2.6 Labour

The quality and quantity of labour available in a country can be a determinant of the performance of a port. In their paper the authors showed that labour is the most flexible component of transportation in terms of cost, time and risk (Turnbull, 2002). They argued that operating costs consists for 60-70% of labour costs (Turnbull, 2002). Labour demand and labour costs fluctuate daily, because of the variable activities in a port (Turnbull, 2002).

In the past the number of labourers was important as operations were less automated and machine dependent. However, the level of automation and mechanization has reduced the requirement of labour in areas such as loading and unloading (Lloyd's, n.d.).

2.7 Hinterland

2.7.1 Economy of hinterland

While many authors have observed that the economy of the port’s country plays an important role for the port’s performance, the economy of its hinterland is equally important. This is because not all countries have their own sea ports on account of them being landlocked or in case they do not have the required quality of port infrastructure. As such these countries depend on the sea ports of neighboring countries.

The findings of the authors while studying the ports of China and Korea confirm that the economic development of their hinterland had a significant influence on their port performance (Park, 2011).

2.7.2 Hinterland access

Along with the economy of the hinterland, access to the hinterland also plays a crucial role in achieving a high port performance. Several authors have opined that hinterland access is important for the competitiveness of seaports (Notteboom, 1997) and (Wever, 1998).

Ports have become parts of the supply chains. As such it would have to ensure that
it has good capacity and quality of inland transport systems that can handle large volumes of goods quickly.

Hinterland access is important for seaports that have a high throughput volume where a large part of the cargo is transported to the hinterland (Chouly, 2004).

2.8 Container Traffic (choice of shipping companies)

Another important determinant for the throughput of a sea port is the ability to attract maximum container vessel traffic, i.e. container vessels that call at its port.

The choice for a port is increasingly often taken by shipowners (Huybrechts, 2002). When making the choice, competition between logistic chains takes a more important position, than competition between seaports (AVV, Transport Research Centre Dutch Ministry of Transport - Public Works and Water Management, 2007). Other factors such as hinterland connections, partnerships between shipowners and shippers / logistics service providers in hinterland transport, and the geographic and economic position of the ports play a more important role for the shippers than just the seaport's own performance (AVV, Transport Research Centre Dutch Ministry of Transport - Public Works and Water Management, 2007). Hence ports are often in a difficult position in this respect. On the one hand, they are no longer the most powerful partners in logistics chains; that balance has shifted in favour of shipping companies and large forwarders and shippers (Hilde Meersman, 2016).

A port's total traffic volume no longer solely depends on 'local' traffic, but also on the hubbing strategies of container shipping lines (Hilde Meersman, 2016). As such the ability to attract container vessels is a determinant of throughput of sea ports. It may be noted that container vessel traffic also represents the container shipping companies as ultimately the company decides on the choice of port for calling of its vessels.

2.9 Port infrastructure investment

Another important determinant that impacts the throughput of sea ports is the amount of money that is being invested in port infrastructure annually by the respective ports. Logically, investment made in port infrastructure should improve its efficiency and productivity and thereby increasing its throughput. However, it may be noted here that if investments are not being made in right areas or is not at an optimal level it would not impact the port's performance. This is an important aspect as investment in any port infrastructure (eg. sea lock, quay areas, land reclamation) is an expensive affair and if the respective port is not able to manage its budget well, would lose out on several areas to its competitors.

This study analyses the investment decisions of the selected ports based on the results of the regression model read with the strategy documents of the selected ports. It may also be noted that such type of analysis has not yet been done by any other author based on the literature review that was undertaken making this study
unique in this respect.

2.10 Short Sea Shipping

Various inland modes such as road, rail, inland waterways and pipeline are used to access the hinterland (Chouly, 2004). Short sea shipping is also one such mode that is used to access the hinterland region of the concerned port. As such this mode of transport plays an important role in transporting containers from ports to hinterland regions. This segment is particularly important in the Hamburg Le Havre range due to the fact that Europe has a respectable large coastline and as such the ports can access hinterland regions by short sea shipping efficiently.

2.11 Other factors

There are many other factors that would determine the throughput and competitiveness of a port. These include the presence of organized labour forces, i.e. trade unions, customs procedures, port policy, domestic legislations and regulations, enforcement level, political stability and environmental aspects. While these factors are important, a thorough qualitative review would need to be done and quantified to gauge its impact on throughput which is beyond the scope of this thesis. As such only those determinants that are quantified and available from public databases are used in this study.

Hypotheses

Given the literature review, the following hypotheses are presented which are necessary to prove/disprove in order to ascertain the set of determinants of container throughput of the selected ports. It is observed from the literature review above that while each of the below variables were found to be determinants of container throughput of the concerned ports by the relevant authors, the same may/may not be for the selected ports forming part of this study. Further, it would need to be observed if the same set of variables form the determinants of the selected ports or if it differs between each port:

<table>
<thead>
<tr>
<th>No.</th>
<th>Category</th>
<th>Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>Economy</td>
<td>The GDP of the country of a port is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H2</td>
<td>Economy</td>
<td>The exports of the country of a port is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H3</td>
<td>Economy</td>
<td>The imports of the country of a port is a determinant of its</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>----------------------</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td>H4</td>
<td>Hinterland</td>
<td>The exports of the hinterland(s) of a port is/ are a determinant of its container port throughput</td>
</tr>
<tr>
<td>H5</td>
<td>Hinterland</td>
<td>The imports of the hinterland(s) of a port is/ are a determinant of its container port throughput</td>
</tr>
<tr>
<td>H6</td>
<td>Terminals</td>
<td>The total quay length of the container terminals in the port is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H7</td>
<td>Terminals</td>
<td>The total terminal area of the container terminals in the port is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H8</td>
<td>Terminals</td>
<td>The total number of dedicated container cranes in a port is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H9</td>
<td>Terminals</td>
<td>The total container capacity in the port is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H10</td>
<td>Inland Transport</td>
<td>The length of inland motorways of the country where the port is situated is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H11</td>
<td>Inland Transport</td>
<td>The length of inland railways of the country where the port is situated is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H12</td>
<td>Inland Transport</td>
<td>The length of inland rivers of the country where the port is situated is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H13</td>
<td>Inland Transport</td>
<td>The length of inland canals of the country where the port is situated is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H14</td>
<td>Inland Transport</td>
<td>The freight carried by motorways of the country where the port is situated is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H15</td>
<td>Inland Transport</td>
<td>The freight carried by railways of the country where the port is situated is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H16</td>
<td>Inland Transport</td>
<td>The freight carried by inland waterways (rivers &amp; canals) of the country where the port is situated is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H17</td>
<td>Short Sea Shipping</td>
<td>The freight carried through short sea shipping is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H18</td>
<td>Labour</td>
<td>The labour productivity index of the country where the port is situated is a determinant of its container port throughput</td>
</tr>
<tr>
<td>H19</td>
<td>Choice of Shipping Companies</td>
<td>The number of container vessels calling at the port is a determinant of its container port throughput</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>H20</td>
<td>Investment</td>
<td>The amount of investment made in port infrastructure is a determinant of its container port throughput</td>
</tr>
</tbody>
</table>

The hypotheses have been proved/dis-proved in the analysis section of this study
3. Profiles of the ports

On the basis of the literature review it was shown that there are various possible determinants for container throughput. In order to identify the relevant determinants for the specific ports, their profiles and characteristics first needs to be analyzed. Further, it would also be useful to observe how each of the selected ports compare in certain common determinants such as GDP, terminals and inland transport system.

The profiles and characteristics of the selected ports are presented below.

3.1 Port of Antwerp

The Port of Antwerp is an estuary port, connected via the River Scheldt to the North Sea, and is one of the largest ports in the world in terms of area (130 square kilometres), covering more than a third of the city (OECD, 2014(a)). Further, it is one of the fastest growing container ports of the Hamburg - Le Havre range (Port of Antwerp, 2016).

The port map is given below in figure 4 to get a graphical view of its layout:

![Port of Antwerp](image-url)

As can be seen from figure 5 below the main cargo segment of the port of Antwerp
is its container segment which contributes to more than half other total port throughput (tons) and liquid bulk cargo segment which contributes to almost 1/3rd of the port’s throughput. Dry bulk contributes around 7% and such is relatively less significant.

![Figure 5](image)

Port of Antwerp Cargo Segments

(Port Authorities & Port of Rotterdam, 2015)

**Terminals**

The port of Antwerp has 6 dedicated container terminals which are given below in table 3:

**Table 3**

<table>
<thead>
<tr>
<th>Operators Container Terminals</th>
<th>Full Quay Length (meter)</th>
<th>Terminal Area (ha)</th>
<th>No Quayside Cranes</th>
<th>Total Cont. Capacity</th>
<th>Depth Alongside (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Independent Maritime Terminal (IMT)</td>
<td>700</td>
<td>16.7</td>
<td>2</td>
<td>200,000</td>
<td>12</td>
</tr>
<tr>
<td>2 PSA Europa Terminal</td>
<td>1180</td>
<td>72</td>
<td>9</td>
<td>1,800,000</td>
<td>14.5</td>
</tr>
<tr>
<td>3 PSA Noordzee Terminal</td>
<td>1125</td>
<td>79</td>
<td>10</td>
<td>2,100,000</td>
<td>17</td>
</tr>
</tbody>
</table>
The port of Antwerp faces several challenges also. One of the main challenges it faces is with respect to road congestion. The roads and highways in and around Antwerp are heavily used, with considerable congestion costs resulting from. (OECD, 2014(a)).

Hinterland

The main hinterland regions for the Port of Antwerp are Belgium itself, the Netherlands, Germany, Switzerland and France (OECD, 2014(a)).

Inland Transport

In 2014, around 55% of containers was carried by road, 38% by inland waterways and 7% by railways (Port of Antwerp, 2015). The port aims to make the modal split even more sustainable by 2030, with 42% of containers carried by barge, 15% by rail and only 43% by road (Port of Antwerp, 2015).

The Port of Antwerp has access to 1,763 kms (2015 figure) of roadways, around 3,582 kms (2010 figure) of railways, 875 kms of navigable canals (2008 figure) and 641 kms of navigable rivers (2008 figure) (European Commission, 2016). Further, in 2015, roadways carried 20,769 thousand tonnes of containers and 21,655 thousand tonnes of containers in 2014 (European Commission, 2016).

Short sea shipping carried 43,464 thousand tonnes of containers from/to the Port of Antwerp in 2014 (European Commission, 2016).

### 3.2 Port of Hamburg

Located right in the centre of the city, the Port of Hamburg is the main hub for traffic from and to the Baltic Sea and a gateway for cargo to Central Europe (OECD, 2014(a)).

Hamburg is an estuary port, and has a disadvantage that the largest ships can only call at the port if they respect restrictive tidal conditions (OECD, 2014(a)). Another challenge the Port of Hamburg faces is with respect to the relative lack of competition in container terminal operators. The majority of container handling services is conducted by only two terminal operators, both being German companies (OECD,
The following figure 6 gives a graphical view of the port.

Figure 6
Port of Hamburg

As can be seen from figure 7, the container segment is critical for the Port of Hamburg as it determines 2/3rd of the port throughput (tons). Another important segment is the dry bulk throughput followed by the liquid bulk which is comparatively less significant.
Terminals

The port of Hamburg has four terminals which are depicted below in table 4 along with key details:

<table>
<thead>
<tr>
<th>Sl.</th>
<th>Operators Full Container Terminals</th>
<th>Quay Length (meter)</th>
<th>Terminal Area (ha)</th>
<th>No Quayside Cranes</th>
<th>Total Cont. Capacity</th>
<th>Depth Alonside (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HHLA-Container Terminal Burchardkai CTB</td>
<td>2850</td>
<td>160</td>
<td>30</td>
<td>5,200,000</td>
<td>16.5</td>
</tr>
<tr>
<td>2</td>
<td>Tollerort Container Terminal GmbH TCT</td>
<td>1240</td>
<td>34.5</td>
<td>12</td>
<td>950,000</td>
<td>15.2</td>
</tr>
<tr>
<td>3</td>
<td>HHLA-Container Terminal Altenwerder CTA</td>
<td>1400</td>
<td>80</td>
<td>15</td>
<td>3,000,000</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td>Eurogate Terminal CTH</td>
<td>Container Terminal Hamburg</td>
<td>2100</td>
<td>140</td>
<td>23</td>
<td>4,100,000</td>
</tr>
<tr>
<td>---</td>
<td>----------------------</td>
<td>---------------------------</td>
<td>------</td>
<td>----</td>
<td>----</td>
<td>-----------</td>
</tr>
</tbody>
</table>

[ (Port of Hamburg, 2016) and website of terminal operators]

**Hinterland**

As per OECD’s report, “The Competitiveness of Global Port-Cities: The Case of Hamburg – Germany”, it is noted that the German market is Hamburg’s most important hinterland. Further, it is also noted that the Port of Hamburg is the first port for Hungary and Czech Republic. Other important hinterland regions for Port of Hamburg include, Poland, Switzerland, Austria and Slovak Republic (Merk, 2012).

**Inland Transport**

In 2010, around, 63% of containers was carried by roadways, 35% of containers was carried by railways and 2% by inland waterways (Merk, 2012).

Further, the Port of Hamburg has access to 12,949 kms of roadways, 37,775 kms of railway lines, 2,163 kms of navigable canals and 5,565 of navigable rivers in Germany as per 2014 figures (European Commission, 2016).

In 2014, roadways carried 272,822 thousand tonnes of container by roadways, 66,458 thousand tonnes by railways and 20,078 thousand tonnes by inland waterways (European Commission, 2016).

Further, short sea shipping from/ to the Port of Hamburg carried 27,619 thousand tonnes of containers in 2014 (European Commission, 2016).

**3.3 Port of Le Havre**

Le Havre is a small city of approximately 250,000 inhabitants with a large port, serving the greater Paris area and a large part of France (OECD, 2014(a)).

The Port of Le Havre is the largest container port in France. (World Port Source, 2016). It is France’s second busiest port and the fifth biggest port in Northern Europe (World Port Source, 2016). It is a multi-purpose commercial port with a wide range of terminals that can process all types of cargo (World Port Source, 2016).

The following figure 8 gives a graphical view of the port.
As can be seen from the figure 9 below, the main cargo for the Port of Le Havre is Liquid Bulk which constitutes 59% of total throughput (tons) and container which constitutes 37%. The other segments are relatively less significant.
The port faces many challenges as well. Most of the industrial development on the port site is not linked to port activities or Le Havre’s local economic structure (OECD, 2014(a)). Further, hinterland modes other than road traffic remain a problem (OECD, 2014(a)).

**Terminals**

The Port of Le Havre has two container terminals which are given in table 5 below:

**Table 5**

<table>
<thead>
<tr>
<th>Operators Container Terminals</th>
<th>Full Quay Length (meter)</th>
<th>Terminal Area (ha)</th>
<th>No Quayside Cranes</th>
<th>Total Cont. Capacity</th>
<th>Depth Alonside (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Terminal Atlantic (NTB)</td>
<td>1308</td>
<td>115</td>
<td>8</td>
<td>1,645,973</td>
<td>14.3</td>
</tr>
<tr>
<td>2 Terminal Nord – North terminals (GMP)</td>
<td>1076</td>
<td>95</td>
<td>6</td>
<td>1,354,027</td>
<td>14.3</td>
</tr>
</tbody>
</table>

(Authors own work based on information available from website of terminal operators)
Hinterland

The Port of Le Havre has lost most of its natural hinterland to competing ports such as Port of Rotterdam and Port of Antwerp (Merk, 2011). As such this is a weakness that it faces compared to other ports.

Inland Transport

At present around 85% of containers are transported by road, 10% by inland waterways and 5% by railways (Grand Port Maritime Du Havre, 2015). The target of the Port of Le Havre is to have around 75% of containers carried by roadways, 14% by inland waterways and 11% by railways by 2020 (Grand Port Maritime Du Havre, 2015).

The Port of Le Havre has access to 11,469 kms of roads, 29,386 kms of railway lines, 5,607 kms of navigable canals and 2,894 kms of navigable rivers (European Commission, 2016). In 2014, roadways carried 21,219 thousand tonnes, railways carried 13,036 thousand tonnes and inland waterways carried 4,268 thousand tonnes of containers (European Commission, 2016).

The figures for short sea shipping were not available hence the same could not be ascertained and mentioned in this part of the study.

3.4 The Port of Rotterdam

The port of Rotterdam’s annual throughput amounts to over 465 million tonnes (Port of Rotterdam, 2016d). This makes the port of Rotterdam the largest port in Europe. With respect the segment of containers, it is the largest container port in Europe. The port area includes 12,500 ha i.e. land and water (Port of Rotterdam, 2016d). Approximately 30,000 seagoing vessels and 110,000 inland vessels visit the port of Rotterdam every year. (Port of Rotterdam, 2016d). Further, it is a coastal port with the best nautical accessibility profile in north Europe (Merk, 2013).

The Port of Rotterdam, has an advantage over other ports as it has a deep draft of around 23 metres and open access to sea as there are no locks.

The following figure 10 gives a graphical view of the Port of Rotterdam.
Figure 10
Port of Rotterdam

As can be seen from figure 11 below, the two main segments for the Port of Rotterdam are its liquid bulk segment and container segment. Other important businesses for the port of Rotterdam are its petrochemical industry and general cargo transshipment handlings.

Figure 11
Port of Rotterdam Cargo Segments

(Port Authorities & Port of Rotterdam, 2015)
Terminals

Following is the summary of the certain key features of container terminals of the Port of Rotterdam in table 6:

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Container Terminals of Port of Rotterdam</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operators Full Container Terminals</strong></td>
<td><strong>Quay Length (meter)</strong></td>
</tr>
<tr>
<td>1</td>
<td>Rotterdam Short Sea Terminals</td>
</tr>
<tr>
<td>2</td>
<td>ECT Delta Terminal</td>
</tr>
<tr>
<td>3</td>
<td>Uniport Multipurpose Terminals</td>
</tr>
<tr>
<td>4</td>
<td>Barge Center Waalhaven</td>
</tr>
<tr>
<td>5</td>
<td>APM Terminals Rotterdam</td>
</tr>
<tr>
<td>6</td>
<td>Delta Container Services</td>
</tr>
<tr>
<td>7</td>
<td>Container Terminal Twente (CTT)</td>
</tr>
<tr>
<td>8</td>
<td>Rotterdam Container Terminal</td>
</tr>
<tr>
<td>9</td>
<td>ECT Delta Barge Feeder Terminal (barge)</td>
</tr>
<tr>
<td>10</td>
<td>Waalhaven Botlek Terminal (barge)</td>
</tr>
<tr>
<td>11</td>
<td>Euromax Terminal Rotterdam</td>
</tr>
<tr>
<td>12</td>
<td>Rotterdam World Gateway</td>
</tr>
</tbody>
</table>
Hinterland regions

As per the OECD report “The Competitiveness of Global Port-Cities: The Case of Rotterdam/Amsterdam – the Netherlands” it is observed that Germany is the most important foreign hinterland for Rotterdam. Further, Rotterdam is the largest port for Switzerland and the second largest for Austria. Other important hinterland regions include Slovak Republic, Hungary and the Czech Republic.

Inland Transport

One of the reasons for its high competitiveness in Europe is because of its hinterland connections. The port of Rotterdam has an extensive intermodal network of rail, road and inland waterways that ensures that the cargo is efficiently transported from and to the rest of Europe. The main industrial and economic centres of Western Europe can be reached from Rotterdam within as less as 24 hours (Port of Rotterdam, 2016e).

The Port of Rotterdam has access to around 2600 kms of Dutch road network, 3000 kms of Dutch railways, 4700 kms of navigable canals and around 1400 kms of navigable rivers (European Commission, 2016).

In 2014, the above transport network carried 44,390 thousand tonnes of containers by road, 14,857 thousand tonnes by railway and 43,161 thousand tonnes by inland waterways (European Commission, 2016). Further, 33,943 thousand tonnes of containers was transported by short sea shipping to/ from the Port of Rotterdam (European Commission, 2016).

The modal split of inland transportation of containers of the Port of Rotterdam in 2009 was around 47% by road, 40% by inland waterways and 13% by railways. The plan is to have a shift in these modes whereby in 2035 road would carry around 35% of containers, inland waterways around 45% and railways 20%
4. Methodology

4.1 Reviewing different models

Several authors have used different models to analyse determinants of port throughput. From a literature review on the methodologies used by such authors few important ones are presented below.

4.1.1 TRANS-TOOLS model

In the paper “Combining Models and Commodity Chain Research for Making Long-Term Projections of Port Throughput: an Application to the Hamburg- Le Havre Range” the authors used the TRANS-TOOLS model to predict the port throughput of the ports in the Hamburg Le-Havre Range. The 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 (Peter W. de Langen, 2012). The main input of the TRANS-TOOLS model consists of socio-economic data which includes economic structure and population on a regional level and transport data on network level (Peter W. de Langen, 2012). The model translates the macro-economic scenarios into developments of freight flows in terms of projected annual growth rates for different commodities (Peter W. de Langen, 2012). For the projections of the throughput in the Hamburg – Le Havre range, the sub-model dealing with regional freight generation and interregional distribution of flows was applied since the projections focus on maritime transport flows (Peter W. de Langen, 2012).

While this model is very useful in comparing the port throughput between the ports in the Hamburg Le Havre range, it is not commonly used as it requires expert knowledge to use the same (European Commission, 2008). Further the focus of this thesis is to under the determinants of the competitiveness of the selected ports in the Hamburg Le Havre range. As such a model that gives the correlation between each variable and port throughput and significance of the determinant was required.

4.1.2 Time series and trend extrapolation

Another commonly used method for comparing the competitiveness of ports are the time series and trend extrapolation techniques that rely on historic data (Jansen, 2014). The forecasted port throughput figures of the selected ports are compared with each other to understand its competitiveness. However, the time series and trend extrapolation model does not give any correlation or insight into the variables that determine cargo throughput in ports. As such this method is not useful in understand the determinants of competitiveness.

4.1.3 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is another method that has been used to analyze port competitiveness. Data envelopment analysis (DEA) is a linear programming methodology that measures the efficiency of multiple decision-making variables where the process presents a structure of multiple inputs and outputs. The technique
is useful in resolving the measurement of port efficiency because the calculations are nonparametric and do not require specification or knowledge of a priori weights for the inputs or outputs, as is required for estimation of efficiency using production functions (Geoffrey Poitras, 1996). The concept of DEA is developed around the basic idea that the efficiency of a Decision Making Unit (DMU) is determined by its ability to transform inputs into desired outputs (Geoffrey Poitras, 1996). In addition to providing relative efficiency rankings, DEA also provides results on the sources of input and output inefficiency, as well as the ports which were used for the efficiency comparison (Geoffrey Poitras, 1996). The ability to identify the sources of inefficiency would be useful to port authority managers in inefficient ports, acting as a guide to focusing efforts at improving port performance (Geoffrey Poitras, 1996).

The model was used in determining the efficiency of ports and impact on competitiveness of short sea shipping versus road transport in Europe (Tovar, 2007), determining the impact of improving port infrastructure on cargo volumes in two Spanish ports (Martin-Bofarull, 2007; H.W.H. Welters, 2002), determining the efficiency of six West African ports competing for regional hub status (van Dyck, 2015), identifying factors influencing routing decisions through Rotterdam compared to other ports in Western Europe (Bückmann, 2003).

4.1.4 Classical Regression Model

The classical regression model is another model used in practice. Regression analysis is not only used widely for prediction and forecasting, but also used to understand which independent variables are related to the dependent variable and to explore the forms of these relationships (Park, 2011). By measuring the co-movement of variables, this model detects causal relationships (Jansen, 2014). A regression analysis helps to describe data, estimate parameters and verify relations that arise from economic logic (Jansen, 2014).

It is important to mention here that regression proves if there is a linear relationship between the dependent and independent variables. It does not prove ‘causation’ of the relationship. As such ‘causation’ is proved using qualitative literature review which has been duly followed in the study.

In their paper, “Empirical Analysis of Influence Factors to Container Throughput in Korea and China Ports, the authors used the regression model to examine the relationship among container throughputs of China and Korea ports, and identify factors which determine container throughputs for China and Korea ports based on empirical data collected from 2001-2007 (Park, 2011). The authors also compared differences of port industry between China and Korea. The following variables were selected by them for their analysis:
Figure 12

Regression Model: Empirical Analysis of Influence Factors to Container Throughput in Korea and China Ports

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Independent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Throughput (Y)</td>
<td>Terminal storage capability (X_1)</td>
</tr>
<tr>
<td></td>
<td>: Berth length (X_2)</td>
</tr>
<tr>
<td></td>
<td>Geographical Position (B) : Direct-call liner (X_3)</td>
</tr>
<tr>
<td></td>
<td>: Transshipment (X_4)</td>
</tr>
<tr>
<td></td>
<td>Hinterland’s Economy Level (C) : Hinterland’s GDP (X_5)</td>
</tr>
<tr>
<td></td>
<td>: Hinterland’s import-export volume (X_6)</td>
</tr>
<tr>
<td></td>
<td>Port’s Service Level (D) : Port’s tariff (X_7)</td>
</tr>
<tr>
<td></td>
<td>Government Attitude (E) : FTZ area (X_8)</td>
</tr>
<tr>
<td></td>
<td>: Investment of government (X_9)</td>
</tr>
</tbody>
</table>

Regression equation:

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_8 X_8 + \beta_9 X_9 + \ldots \]

(Park, 2011)

The regression model is relatively simple to use with the help of statistical packages such as Minitab, Data Analysis Tool in Microsoft Excel and others. As such this method has been adopted to test the strength of linear relationship between the independent variables that determine container port throughput to the container port throughput measure in TEU (Twenty Foot Equivalent Unit).
4.2 Selection of variables in the regression model

Based on the literature review the following variables have been selected/ excluded from the regression model:

4.2.1 Economy of the port’s country

Macroeconomic components such as the country’s GDP where the selected port is situated, its exports and imports value has been used as a variable in the regression model to test if it results as a determinant of the particular port.

4.2.2 Geographical Location

This determinant has been excluded for the regression analysis. There are two reasons for this. The first reason is that all four sea ports are located in the same zone, i.e the Hamburg Le Havre range. As such this factor, though an important one would not show any useful results in the analysis of this thesis. Secondly the distance of the selected ports to the economic centers in the Blue Banana Zone is constant and as such cannot be used in the regression model. The regression model can be used only if there is more than one value of the variable.

4.2.3 Accessibility

As there was no increase in depth of the draft for any of the ports during the period of the data that has been used in the study, the same has been excluded from the regression model.

4.2.4 Seaport Charges

This factor has been excluded from the regression model and analysis of this thesis as based on the literature review that was done, it was observed that the total cost of supply chain was more important and not seaport charges alone. Total cost of supply chain is beyond the scope of this study.

4.2.5 Port and terminal efficiency

For the study, the total berth length of container terminals, the number of dedicated container cranes, the capacity of the terminal and the area of the terminal will be tested in the regression model. Other components such as berth productivity and crane moves per hour is being excluded as the same are not available in public databases and further to access them from private databases is extremely expensive.
For the regression model the Labour Productivity growth of the country of the port has been used to test the productivity of labour on the container throughput. The Labour Productivity growth is being used in this model as firstly, a port has varied operations and utilizes different types of skills from it labour force. As such a general labour index is being used viz. the labour productivity growth rate of the country where the port is situated. Secondly, availing port specific labour productivity related data is not available in public domain and would be a cumbersome exercise to calculate the same. Thirdly, even the if the data of each port is availed it would not be standardized between ports and hence meaningful comparison would not be easily possible. As such a standardized benchmark, i.e. the Labour Productivity growth is being used which is extracted from the OECD database and hence is credible.

**4.2.7 Hinterland**

**4.2.7.1 Economy of hinterland**

For the regression model used in this paper the hinterlands export and import value has been used for each of the hinterland region of the selected ports.

**4.2.7.2 Hinterland access**

The length of motorways, railway tracks and rivers & canal of the country where the port is situated is selected for the regression analysis.

Further, the volume of goods (tonnes) carried in containers over the road, railway and inland waterways has also been included in the regression model. The tonnage of goods in container will give an indication on the capacity and importance of the particular mode of transport to the port.

**4.2.8 Container Traffic (choice of shipping companies)**

The regression model uses container vessel traffic that calls at the selected seas port as the variable that will be tested against the container throughput. It may be noted that container vessel traffic also represents the container shipping companies as ultimately the company decides on the choice of port for calling of its vessels.

**4.2.9 Port infrastructure investment**

In the regression model investment in port infrastructure by the country has been used to test its impact on the throughput of the container port except the Port of Rotterdam whose previous years annual reports were referred to and investment amounts recorded. This was done as the details of investment made by Dutch stakeholders in port infrastructure projects was not available from the OECD database.
4.2.10 Short Sea Shipping

Short sea shipping volumes has been included in the regression model to test its relationship with container throughput.

4.2.11 Other factors

Other factors that determine throughput include the presence of organized labour forces, i.e. trade unions, customs procedures, port policy, domestic legislations and regulations, enforcement level, political stability and environmental aspects. As a thorough qualitative review would need to be done and quantified first, which is beyond the scope of the thesis these variables are being excluded from the regression model.

4.3 Data

For the purposes of the study the data sets were prepared using the following data sources as mentioned in table 7:

<table>
<thead>
<tr>
<th>Category</th>
<th>Data</th>
<th>Unit</th>
<th>Time period</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economy</td>
<td>GDP</td>
<td>Million Euros</td>
<td>Port of Antwerp: 1999-2015</td>
<td>OECD Data (OECD, 2016a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Port of Rotterdam: 1997-2015</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Port of Le Havre: 1995-2014</td>
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<td></td>
<td>Port of Rotterdam: 1997-2015</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Port of Le Havre: 1995-2014</td>
<td></td>
</tr>
<tr>
<td>Imports</td>
<td></td>
<td>Million Euros</td>
<td>Port of Antwerp: 1999-2015</td>
<td>UN Comtrade</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Port of Rotterdam: 1997-2015</td>
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<td>Port of Le Havre: 1995-2014</td>
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<td>Port of Le Havre: 1995-2014</td>
<td></td>
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</tr>
<tr>
<td>Hinterland</td>
<td>Exports</td>
<td>Million Euros</td>
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<td>Port of Rotterdam: 1997-2015</td>
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<tr>
<td></td>
<td></td>
<td>Port of Le Havre: 1995-2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminals</td>
<td>Quay length</td>
<td>Meters</td>
<td>Website of the selected ports</td>
<td></td>
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<td></td>
<td></td>
<td>Port of Antwerp: 1999-2015</td>
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<td>Port of Rotterdam: 1997-2015</td>
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<tr>
<td></td>
<td></td>
<td>Port of Le Havre: 1995-2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total terminal area</td>
<td>Hectare s</td>
<td>Port of Antwerp: 1999-2015</td>
<td>Website of the selected ports</td>
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<td>Port of Rotterdam: 1997-2015</td>
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<tr>
<td></td>
<td></td>
<td>Port of Le Havre: 1995-2014</td>
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</tr>
<tr>
<td>Total number of dedicated container cranes</td>
<td>Number</td>
<td>Port of Antwerp: 1999-2015</td>
<td>Website of the selected ports</td>
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<td>Port of Rotterdam: 1997-2015</td>
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<td>(European Commission, 2016)</td>
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<td>(European Commission, 2016)</td>
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<td>Eurostat – 'Transport'</td>
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<td>(European Commission, 2016)</td>
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</tbody>
</table>

From the above table 7, it is observed that the data for inland transport are for fewer years (2006 onwards) when compared to the other variables (1995 onwards). As such the multi regression model is being run twice to determine throughput, i.e. once for all the variables except inland transport & short sea shipping and the second time where only inland transport & short sea shipping variables will be used.
5. Results

Based on the regression model performed using Minitab statistical tool, the following results for each port are presented. The results include the significance of the determinants of container throughput for each of the selected ports.

5.1 Port of Antwerp

Analysis of the simple regression results and multi regression model

The simple regression results of the Port of Antwerp are as follows:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Model</th>
<th>Co-Efficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRA Exports (MLN EUR)</td>
<td>Hinterland</td>
<td>397900</td>
<td>96.14</td>
</tr>
<tr>
<td>FRA Imports (MLN EUR)</td>
<td>Hinterland</td>
<td>442094</td>
<td>95.23</td>
</tr>
<tr>
<td>DEU Rep Export (MLN EUR)</td>
<td>Hinterland</td>
<td>447663</td>
<td>95.11</td>
</tr>
<tr>
<td>NLD Export (MLN EUR)</td>
<td>Hinterland</td>
<td>538971</td>
<td>92.92</td>
</tr>
<tr>
<td>DEU Rep Import (MLN EUR)</td>
<td>Hinterland</td>
<td>542831</td>
<td>92.81</td>
</tr>
<tr>
<td>NLD Import (MLN EUR)</td>
<td>Hinterland</td>
<td>580149</td>
<td>91.79</td>
</tr>
<tr>
<td>BEL GDP (MLN EUR)</td>
<td>Economy</td>
<td>611008</td>
<td>90.90</td>
</tr>
<tr>
<td>BEL Export (MLN EUR)</td>
<td>Economy</td>
<td>618626</td>
<td>90.67</td>
</tr>
<tr>
<td>BEL Import (MLN EUR)</td>
<td>Economy</td>
<td>659965</td>
<td>89.38</td>
</tr>
<tr>
<td>Container Capacity (TEU)</td>
<td>Terminal</td>
<td>852916</td>
<td>82.26</td>
</tr>
<tr>
<td>Quay Side Cranes (Nos)</td>
<td>Terminal</td>
<td>853719</td>
<td>82.23</td>
</tr>
<tr>
<td>Terminal Area (Hectares)</td>
<td>Terminal</td>
<td>854325</td>
<td>82.20</td>
</tr>
<tr>
<td>Quay length (meters)</td>
<td>Terminal</td>
<td>868185</td>
<td>81.62</td>
</tr>
<tr>
<td>CHE Exports (MLN EUR)</td>
<td>Hinterland</td>
<td>996314</td>
<td>75.79</td>
</tr>
</tbody>
</table>
As can be observed from the results of the simple regression above in Table 8, the variables that have a strong linear relationship with the throughput of the Port of Antwerp are its hinterland, local economy i.e. Belgium GDP, exports and imports and its terminals.

In its hinterland the exports and imports of France, Germany, The Netherlands and Switzerland exports are strongly linearly related to container throughput.

Further, Swiss imports, container shipping companies, and short sea shipping to/from the Port of Antwerp have a medium linear relationship to its throughput.

However, motor and inland waterways transport, labour productivity and investment in sea infrastructure did not show a linear relationship to its container throughput.
Multi Regression Model

From the below table 9 it is observed that the multi regression model of the Port of Antwerp comprises of quay length & total area of terminals, labour productivity index of Belgium, Belgium GDP, Switzerland and France exports & imports, container vessels called at the Port of Antwerp and investment made in port infrastructure.

Table 9

Multi Regression Model of Port of Antwerp

\[
\text{TEU} = -6972662 - 399.2 \text{ Quay length (meter)} + 6569 \text{ Terminal Area (ha)} + 112344 \text{ Labour Productivity Index} + 20.204 \text{ BEL GDP (MLN EUR)} - 16.288 \text{ CHE Export (MLN EUR)} + 11.919 \text{ CHE Import (MLN EUR)} + 33.455 \text{ FRA Export (MLN EUR)} - 18.884 \text{ FRA Import (MLN EUR)} + 614.7 \text{ Container Traffic (calling)} + 0.001572 \text{ Sea Infra Invest (EUR)}
\]

As can be observed from table 10 below the multi regression model of the Port of Antwerp is valid with a high R square of 99.90%.

Table 10

Model Summary of Port of Antwerp

<table>
<thead>
<tr>
<th>R Square</th>
<th>F-Value</th>
<th>F-Test</th>
<th>P-Value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.90%</td>
<td>625.02</td>
<td>4.06</td>
<td>&lt;0.0001</td>
<td>Valid</td>
</tr>
</tbody>
</table>

From the below table 11 it is observed that the total terminal area, labour productivity index, the Belgium GDP, Swiss imports, French exports, container vessels called at the Port of Antwerp and investment made in port infrastructure have a positive impact on the throughput of the Port of Antwerp. The most significant variables among these are the Belgium labour productivity index, Belgium GDP, French Exports and container traffic called at the Port of Antwerp.

On the other hand, total quay length of terminals, Swiss exports and French imports have a negative impact on the throughput of the Port of Antwerp. Amongst these, Swiss exports and French imports are the most significant variables.
### Table 11

Significance of the Determinants of Port of Antwerp

<table>
<thead>
<tr>
<th>Determinant</th>
<th>T Value</th>
<th>P Value</th>
<th>Relationship</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>France Exports</td>
<td>7.83</td>
<td>0.0002</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>Belgium GDP</td>
<td>7.16</td>
<td>0.0004</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>France Imports</td>
<td>-5.15</td>
<td>0.0021</td>
<td>Negative</td>
<td>Significant</td>
</tr>
<tr>
<td>Container Traffic Calling</td>
<td>3.62</td>
<td>0.0111</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>Labour Productivity Index</td>
<td>3.28</td>
<td>0.0167</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>CHE Exports</td>
<td>-2.01</td>
<td>0.0911</td>
<td>Negative</td>
<td>Significant</td>
</tr>
<tr>
<td>Terminal Area</td>
<td>1.63</td>
<td>0.1534</td>
<td>Positive</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Quay Length</td>
<td>-1.55</td>
<td>0.1725</td>
<td>Negative</td>
<td>Insignificant</td>
</tr>
<tr>
<td>CHE Imports</td>
<td>1.54</td>
<td>0.1749</td>
<td>Positive</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Port Infrastructure Investment</td>
<td>1.48</td>
<td>0.1898</td>
<td>Positive</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

Using the data recorded in 2015 of the variables in the multi regression model, the throughput is calculated:

### Table 12

Calculation of container throughput of Port of Antwerp using the multi regression model

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-6972662</td>
<td></td>
<td>-6972662</td>
</tr>
<tr>
<td>Quay length (meter)</td>
<td>-399</td>
<td>10375</td>
<td>-4141700</td>
</tr>
<tr>
<td>Terminal Area (ha)</td>
<td>6569</td>
<td>639</td>
<td>4195620</td>
</tr>
<tr>
<td>Labour productivity index</td>
<td>112344</td>
<td>0.82</td>
<td>92432</td>
</tr>
<tr>
<td>BEL GDP (MLN EUR)</td>
<td>20</td>
<td>446830</td>
<td>9027747</td>
</tr>
<tr>
<td>CHE Export (MLN EUR)</td>
<td>-16</td>
<td>262763</td>
<td>-4279888</td>
</tr>
<tr>
<td>CHE Import (MLN EUR)</td>
<td>12</td>
<td>227837</td>
<td>2715592</td>
</tr>
<tr>
<td>FRA Export (MLN EUR)</td>
<td>33</td>
<td>515750</td>
<td>17254416</td>
</tr>
<tr>
<td>FRA Import (MLN EUR)</td>
<td>-19</td>
<td>586346</td>
<td>-11072559</td>
</tr>
</tbody>
</table>
As can be observed from the above table 12 the multi regression model for the Port of Antwerp fits well and its independent variables can be used to determine and its container port throughput.

The multi regression model for inland transport for the Port of Antwerp is given below in table 13 below.

As can be observed from table 14 the multi regression model (Inland Transport and Short Sea Shipping) of the Port of Antwerp is valid with a relatively high R square of 87.91%.

The above below table 15 shows that the short sea shipping and road transport segment is significant and has a positive impact on the throughput of the Port of Antwerp. However, inland waterways though having a positive impact is insignificant.
Table 15
Significance of the Determinants of Port of Antwerp
(Inland Transport & Short Sea Shipping)

<table>
<thead>
<tr>
<th>Determinant</th>
<th>T Value</th>
<th>P Value</th>
<th>Relationship</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port of Antwerp Short Sea Shipping (Tonne)</td>
<td>4.05</td>
<td>0.0098</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>BEL Road Transport (Tonne)</td>
<td>3.36</td>
<td>0.0201</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>BEL Inland Waterways (Tonne)</td>
<td>0.52</td>
<td>0.6271</td>
<td>Positive</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

The below table 16 is helpful in visualizing the impact of increase of the significant determinants on the container throughput of the Port of Antwerp. It is observed that an increase of one million euro of Belgium GDP increases throughput by 20 TEU’s. Further, French exports are important also as an increase of 1 million euro of it, increases throughput by 33 TEU’s. Swiss exports and French imports on the other hand show a decrease of 16 and 19 TEU’s respectively for every increase of 1 million euro amount.

It is observed that labour is a significant determinant, where a single percent increase in labour productivity index results in healthy increase of 112,344 TEU’s.

Further for every 1 vessel that calls at the Port of Antwerp, the throughput increases by 615 TEU’s.

From the inland transport & short sea shipping category it is observed that an increase of one thousand tonne volume of containers carried by short sea shipping and road transport, increases the throughput by 79 and 253 TEU’s respectively.
<table>
<thead>
<tr>
<th>Labour Productivity Index</th>
<th>Labour</th>
<th>1 Percent</th>
<th>112,344</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container vessels calling at port</td>
<td>Shipping Companies</td>
<td>1 vessel</td>
<td>615</td>
</tr>
<tr>
<td>Port of Antwerp Short Sea Shipping</td>
<td>Short Sea Shipping</td>
<td>Thousand Tonne</td>
<td>79</td>
</tr>
<tr>
<td>BEL Road Transport</td>
<td>Inland Transport</td>
<td>Thousand Tonne</td>
<td>253</td>
</tr>
</tbody>
</table>

Analysis of simple regression results and multi regression model with port strategy of the Port of Antwerp

In the review of the literature used in this thesis, the Sustainability Report 2015 of the Port of Antwerp was referred to, as this document contains latest information and exhaustive measures with respect to the planning and development of the port for future years.

Economy

The results of the simple and multiple regression model confirm the analysis of various authors such as that GDP of the home country plays a significant role in the port throughput of its ports (Tongzon, 1994) (Victor R Caldeirinha, 2009). Table 8 shows a strong linear relationship between GDP and the container port throughput of the Port of Antwerp. Further, as per table 16 it is observed that an increase in the GDP of Belgium by 1 million euro increases the TEU by 20 units.

Shipping Companies (Container vessels calling at port)

The Port of Antwerp, being a leading port in Europe and world, attracts well established container shipping companies. The combination of efficient, high-quality freight handling with an extensive logistics network and a strong supply of cargoes from manufacturing industry makes the port very attractive to shipping companies (Port of Antwerp, 2015). As such a large number of shipping companies, prefer to call their ships at the Port of Antwerp. The results of the simple and multi regression model also bears testament to this. Simple regression results shows a correlation of 73% between the container traffic calling at the port of Antwerp and its container port throughput. Further, the multi regression model shows that for every vessel that calls at the Port of Antwerp, the throughput increase by 615 TEU's.

Hinterland

From the literature review it was observed that the most significant hinterlands of the Port of Antwerp are the countries of the Netherlands, Germany, Switzerland and France. In this context while the simple regression results showed a strong correlation between each of the hinterland regions and the container port throughput of the Port of Antwerp, the multi regression model identified French exports & imports and Swiss
exports as the most significant determinants.

These results would imply that the Port of Antwerp is an important port for French exports along with the Port of Le Havre.

Further, French imports and Swiss exports reduce the throughput of the Port of Antwerp. A reason for this could be that these two cargos seem to be attracted by another port in Europe thereby adversely impacting the throughput of Port of Antwerp. An analysis of the competing ports would help the Port of Antwerp to formulate strategies to gain a share of this cargo thereby improving its throughput.

It is also interesting to observe from the simple regression results that the linear relationship between the container throughput of the Port of Antwerp and exports & imports of France, Germany and the Netherlands are equally strong when compared to the linear relationship between the exports & imports of its home country, i.e. Belgium and the container port throughput of the Port of Antwerp.

One of the reasons why these three countries show such strong linear relationship to the throughput of the Port of Antwerp could be that they share their territorial borders with Belgium and hence the exports and imports of these countries can be routed through the Port of Antwerp. Further, this also indicates the high competition that exists in the Hamburg Le Havre range. All ports being relatively close to one another, exporters/ importers can route their exports/ imports through any of the ports in the Hamburg Le Havre range, without being obliged to choose the port of the home country.

**Labour**

Labour is a significant determinant of the container port throughput of the Port of Antwerp as depicted by the multi regression model. As per the model, a one percent increase in labour productivity amounts to an increase of 112,344 TEU's.

It may however be noted that the simple linear regression model did not show a correlation between container port throughput and labour productivity. A reason for this could be that, this variable gains significance in the multi regression model when it is used together with other variables to determine the container port throughput of the Port of Antwerp.

The Port of Antwerp acknowledges that it benefits from the high labour productivity that is characteristic of Belgium and also found in the port of Antwerp (Port of Antwerp, 2015). As such the result of the multi regression model is in coherence with the statement of the Port of Antwerp.

**Port infrastructure investment**

The 'investment in port infrastructure' is part of the multi regression model though not a significant variable. Its p-value (0.19) was marginally outside the significance limit (i.e. 0.10). Two conclusions can be drawn from this. The first one is that investment in port infrastructure is a necessary determinant and hence this forms a part of the multi regression model that determines port throughput. Secondly and more importantly, it appears that the level of investment in port infrastructure has not been 'optimal' due to which its significance in the multi regression model is not being
established. This argument is supported by the statement made by the Port Authority of Port of Antwerp where it has declared that there has been a fall in the level of investments especially in the maritime cluster in recent years (Port of Antwerp, 2015).

Based on these analysis it would be advisable for the Port of Antwerp to follow a consistent port infrastructure investment policy and invest in such areas of the determinants of its container throughput which are positive and significant.

Inland transport

As per the sustainability report of the Port of Antwerp, in 2014 the proportion of containers carried by road was at 55%, 38% by barge and 7% by rail (Port of Antwerp, 2015).

Road transport:

The sustainability report 2015 of the Port of Antwerp realizes the importance of road transport in hinterland transport and strives to improve the technology of the vehicle fleet and load factor of it (Port of Antwerp, 2015). It may be noted from the multi regression model that road transport (load factor) is a significant variable.

Another strategy of the Port of Antwerp is to set up an extensive information system that will permit intercommunication between road operators, road users and the port community (Port of Antwerp, 2015). The aim of this system is to optimise freight handling, trip planning and use of the road network, and so reduce the amount of time lost (Port of Antwerp, 2015). It would be interesting to note the impact of this strategy. However, intuitively, with a more efficient inland transport system, the port throughput would have a positive impact.

Inland waterways:

Further, as per the sustainability report, in 2014, 38% of freight transport was by inland waterways transport (Port of Antwerp, 2015). It may be noted that Inland waterways (load factor) is not a significant variable as per the multi regression model and neither is it correlated to container port throughput as per simple regression results. As such while the percentage of freight carried by it is appreciable, its significance for container port throughput is negligible according to the modelling results for the period.

Inland railways:

It may be noted that rail transport (load factor) could not be used in the model due to unavailability of data.

Inland transport modal split:

As per the sustainability strategy of the Port of Antwerp, the port aims to make the modal split even more sustainable by 2030, with 42% of containers carried by barge, 15% by rail and only 43% by road (Port of Antwerp, 2015). Based on the results of the regression model, it appears that this strategy would adversely impact the throughput of the Port of Antwerp. This is because shifting the load from roadways which is a significant variable to inland waterways which is an insignificant variable would reduce the container port throughput of the Port of Antwerp.
A reduction of 4% of load factor from road transport which is added to inland waterways reduces container throughput by 234,348 TEU's i.e. around 3% as per the below table 17.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-456490</td>
<td>1</td>
<td>(456,490)</td>
</tr>
<tr>
<td>BEL Road Tonne</td>
<td>252.95</td>
<td>22957</td>
<td>5,807,084</td>
</tr>
<tr>
<td>BEL Inland Watwerways Tonne</td>
<td>7.96</td>
<td>22612</td>
<td>179,988</td>
</tr>
<tr>
<td>P.o.A Short Sea Shipping</td>
<td>78.62</td>
<td>43464</td>
<td>3,417,140</td>
</tr>
<tr>
<td>Throughput as per Multi regression model adjusted with new intermodal split</td>
<td></td>
<td></td>
<td>8,947,722</td>
</tr>
<tr>
<td>Throughput as per initial Multi regression model</td>
<td></td>
<td></td>
<td>9,182,070</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
<td>(234,348)</td>
</tr>
</tbody>
</table>

As such while there may be environmental benefits by the suggested modal split, it would adversely impact container throughput.

**Short sea shipping**

It is also noticed from the simple and multiple regression model that short sea shipping is significant for the competitiveness of the Port of Antwerp. In this regard, its sustainability strategy does not include plans to strengthen this mode of transport. It would be advisable for the port authorities to investigate further opportunities in short sea shipping to/from the Port of Antwerp to maintain and improve its container throughput.

**Conclusion**

Based on the analysis of the simple regression results and multi regression model of container throughput of the Port of Antwerp it is observed that the GDP of Belgium, exports & imports of France, exports of Switzerland, container vessels that call at its port and labour are its significant determinants. On the other hand, terminal area, quay length, Switzerland imports and investments in port infrastructure, though determinants are not significant for its throughput.

It was interesting to see that the exports and imports of Belgium did not appear in the multi regression model. Instead its hinterland exports & imports (i.e. of France & Switzerland) form part of the determinants of its container throughput.

Further, it is not advisable to implement the new modal split by reducing the percentage of freight carried by roadways and increasing the percentage of freight.
carried by inland waterways as this negatively impacts container throughput.

### 5.2 Port of Hamburg

**Analysis of the simple regression results and multi regression model**

The simple regression results of the Port of Hamburg are as follows:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Standard Error</th>
<th>R square</th>
<th>F Value</th>
<th>F Test</th>
<th>P Value</th>
<th>T Value</th>
<th>P Value</th>
<th>Strength of Linear Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUT Export (MLN EUR)</td>
<td>Hinterland</td>
<td>554199</td>
<td>91.29</td>
<td>146.65</td>
<td>4.6</td>
<td>0.0001</td>
<td>12.11</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>HUN Import (MLN EUR)</td>
<td>Hinterland</td>
<td>585248</td>
<td>90.28</td>
<td>130.05</td>
<td>4.6</td>
<td>0.0001</td>
<td>11.4</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>DEU Export (MLN EUR)</td>
<td>Economy</td>
<td>634838</td>
<td>88.56</td>
<td>108.43</td>
<td>4.6</td>
<td>0.0001</td>
<td>10.41</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>AUT Import (MLN EUR)</td>
<td>Hinterland</td>
<td>676123</td>
<td>87.03</td>
<td>93.93</td>
<td>4.6</td>
<td>0.0001</td>
<td>9.69</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>Port of Hamburg Short Sea Shipping TT Tonnes</td>
<td>Short Sea Shipping</td>
<td>374949</td>
<td>86.13</td>
<td>43.47</td>
<td>5.59</td>
<td>0.0003</td>
<td>6.59</td>
<td>0.0003</td>
<td>Strong</td>
</tr>
<tr>
<td>HUN Export (MLN EUR)</td>
<td>Hinterland</td>
<td>749124</td>
<td>84.08</td>
<td>73.92</td>
<td>4.6</td>
<td>0.0001</td>
<td>8.6</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>DEU Import (MLN EUR)</td>
<td>Economy</td>
<td>749939</td>
<td>84.04</td>
<td>73.73</td>
<td>4.6</td>
<td>0.0001</td>
<td>8.59</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>CZK Import (MLN EUR)</td>
<td>Hinterland</td>
<td>808927</td>
<td>81.43</td>
<td>61.4</td>
<td>4.6</td>
<td>0.0001</td>
<td>7.84</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>CZK Export (MLN EUR)</td>
<td>Hinterland</td>
<td>830806</td>
<td>80.41</td>
<td>57.48</td>
<td>4.6</td>
<td>0.0001</td>
<td>7.58</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>POL Import (MLN EUR)</td>
<td>Hinterland</td>
<td>858510</td>
<td>79.09</td>
<td>52.94</td>
<td>4.6</td>
<td>0.0001</td>
<td>7.28</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>SVK Rep Import (MLN EUR)</td>
<td>Hinterland</td>
<td>903648</td>
<td>76.83</td>
<td>46.42</td>
<td>4.6</td>
<td>0.0001</td>
<td>6.81</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>POL Export (MLN EUR)</td>
<td>Hinterland</td>
<td>934516</td>
<td>75.22</td>
<td>42.5</td>
<td>4.6</td>
<td>0.0001</td>
<td>6.52</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>SVK Rep Export (MLN EUR)</td>
<td>Hinterland</td>
<td>967269</td>
<td>73.45</td>
<td>38.74</td>
<td>4.6</td>
<td>0.0001</td>
<td>6.22</td>
<td>0.0001</td>
<td>Medium</td>
</tr>
<tr>
<td>DEU GDP (MLN EUR)</td>
<td>Economy</td>
<td>1082635</td>
<td>66.74</td>
<td>28.1</td>
<td>4.6</td>
<td>0.0001</td>
<td>5.3</td>
<td>0.0001</td>
<td>Medium</td>
</tr>
<tr>
<td>CHE Exports (MLN EUR)</td>
<td>Hinterland</td>
<td>1250507</td>
<td>55.83</td>
<td>17.55</td>
<td>4.6</td>
<td>0.0009</td>
<td>4.19</td>
<td>0.0009</td>
<td>Medium</td>
</tr>
</tbody>
</table>
From the results of the simple regression model (table 18 above), it is observed that the variables which impact the throughput of the Port of Hamburg are the German GDP, exports and imports. Further, each of the hinterland regions exports and imports are linearly related to throughput of the Port of Hamburg. Austrian exports and Hungarian imports had the highest linear relationship (R square of over 90%) while Swiss exports and imports, though linearly related to the throughput was relatively less strong (R square of 55%). The other hinterland regions were strongly positively linearly related where the R square was between 73-87%.

The variables pertaining to container terminals were encouraging with a R square between 40-45%, but however cannot be considered to be strongly linearly related to port throughput.

There were surprising results as well observed from the simple regression model. Container traffic and investment in sea infrastructure returned with R square of less than 45%.
than 3%. This differs from the port of Antwerp where container traffic calling at the port was found to be strongly linearly related to port throughput.

Further, inland transportation also did not seem to have a linear relationship with the port throughput. There was no linear relationship established between the volume of container freight carried through inland waterways, motorways & railways and container port throughput. Further, there was no linear relationship established between length of motorways, railways, & navigable canals/ rivers and container port throughput.

On the positive side, short sea shipping returned with a R square of 86% thereby proclaiming its importance to the Port of Hamburg’s container throughput.

**Multi regression model**

From the multi regression model given below in table 19 it is observed that quay length, terminal area, labour productivity index, German GDP, German exports & imports, container vessels that call at Port of Hamburg, investments in port infrastructure, Slovak Republic Exports and Czech imports determine the container port throughput of the Port of Hamburg.

| TEU = -156426 - 4321 Quay Length (meter) + 71138 Terminal Area (ha) - 55196 Labour Productivity Index + 0.8318 DEU GDP (MLN EUR) + 33.168 DEU Export (MLN EUR) - 6.943 DEU Import (MLN EUR) - 463.4 Container Traffic (calling) + 0.0005157 Investment in Sea Infrastructure - 179.19 SVK Rep Export (MLN EUR) - 90.37 CZK Import (MLN EUR) |

As can be observed from table 20 below, the multi regression model of the Port of Hamburg is valid with a high R square of 99.74%.

<table>
<thead>
<tr>
<th>R Square</th>
<th>F-Value</th>
<th>F-Test</th>
<th>P-Value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.74%</td>
<td>190.91</td>
<td>4.74</td>
<td>&lt;0.0001</td>
<td>Valid</td>
</tr>
</tbody>
</table>

The terminal area, German GDP, German Export and investment in port infrastructure
have a positive impact on the container port throughput as per table 21 given below. Amongst these determinants, terminal area and German exports are significant.

Further, quay length of terminals, Labour Productivity Index, German Imports, container vessels that call at the Port of Hamburg, Slovak Republic exports and Czech imports have a negative impact on the container port throughput of the Port of Hamburg. Amongst these variables quay length of terminals, container vessels that call at Port of Hamburg, Slovak Republic exports and Czech imports are significant.

<table>
<thead>
<tr>
<th>Determinant</th>
<th>T Value</th>
<th>P Value</th>
<th>Relationship</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEU Export</td>
<td>8.16</td>
<td>0.0004</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>SVK Rep Export</td>
<td>-5.50</td>
<td>0.0027</td>
<td>Negative</td>
<td>Significant</td>
</tr>
<tr>
<td>Container Traffic</td>
<td>-4.27</td>
<td>0.0079</td>
<td>Negative</td>
<td>Significant</td>
</tr>
<tr>
<td>CZK Import</td>
<td>-2.76</td>
<td>0.0400</td>
<td>Negative</td>
<td>Significant</td>
</tr>
<tr>
<td>Terminal Area</td>
<td>2.58</td>
<td>0.0492</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>Quay Length</td>
<td>-2.43</td>
<td>0.0594</td>
<td>Negative</td>
<td>Significant</td>
</tr>
<tr>
<td>DEU Import</td>
<td>-1.61</td>
<td>0.1680</td>
<td>Negative</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Investment in Port Infrastructure</td>
<td>1.15</td>
<td>0.3018</td>
<td>Positive</td>
<td>Insignificant</td>
</tr>
<tr>
<td>DEU GDP</td>
<td>0.86</td>
<td>0.4278</td>
<td>Positive</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Labour Productivity Index</td>
<td>-0.81</td>
<td>0.4522</td>
<td>Negative</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

Using the data recorded in 2015 of the variables in the multi regression model, the throughput is calculated as per table 22 given below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-156426</td>
<td>1</td>
<td>-156426</td>
</tr>
<tr>
<td>Quay length (meter)</td>
<td>-4321</td>
<td>7590</td>
<td>-32796390</td>
</tr>
<tr>
<td>Terminal Area (ha)</td>
<td>71138</td>
<td>415</td>
<td>29486701</td>
</tr>
<tr>
<td>Labour productivity index</td>
<td>-55196</td>
<td>0.57</td>
<td>-31319</td>
</tr>
<tr>
<td>DEU GDP (MLN EUR)</td>
<td>0.83</td>
<td>3463443</td>
<td>2880892</td>
</tr>
<tr>
<td>DEU Export (MLN EUR)</td>
<td>33</td>
<td>1198074</td>
<td>39737729</td>
</tr>
</tbody>
</table>
The multi regression model for inland transport for the Port of Hamburg is given below in table 23 below.

<table>
<thead>
<tr>
<th>DEU Import (MLN EUR)</th>
<th>Container Traffic (calling)</th>
<th>Sea Infra Invest (EUR)</th>
<th>SVK Rep Export (MLN EUR)</th>
<th>Czech Import (MLN EUR)</th>
<th>Total as per Multi Regression Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>-7</td>
<td>-463</td>
<td>0.0005</td>
<td>-179</td>
<td>-90</td>
<td>8,859,833</td>
</tr>
<tr>
<td>950706</td>
<td>4111</td>
<td>671533333</td>
<td>67731</td>
<td>110270</td>
<td>8,800,000</td>
</tr>
<tr>
<td>-6600755</td>
<td>-1905037</td>
<td>346310</td>
<td>-12136748</td>
<td>-9965122</td>
<td>59,833</td>
</tr>
</tbody>
</table>

The multi regression model for inland transport for the Port of Hamburg is given below in table 23 below.

### Table 23

Multi Regression Model for Inland Transport & Short Sea Shipping of Port of Hamburg

\[
TEU = 5774914 - 1.275 \text{DEU MW TT T tonnes} + 65.61 \text{DEU RLY TT T tonnes} - 229.85 \text{DEU IW TT T tonnes} + 157.58 \text{PoHmbg SSS TT T tonnes}
\]

As can be observed from table 24 below, the multi regression model of Inland Transport & Short Sea Shipping of the Port of Hamburg is valid with a high R square of 97.05%.

### Table 24

Model Summary
Inland Transport & Short Sea Shipping Port of Hamburg

<table>
<thead>
<tr>
<th>R Square</th>
<th>F-Value</th>
<th>F-Test</th>
<th>P-Value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>97.05%</td>
<td>32.88</td>
<td>6.39</td>
<td>0.0026</td>
<td>Valid</td>
</tr>
</tbody>
</table>

As can be observed from the below table 25, the significant determinants for the Port of Hamburg are its short sea shipping (load volume), German inland waterways (load volume) and German railways (load volume) out of which short sea shipping and German railways have positive relationship to container throughput while German inland waterways has a negative relationship.
German motorways (load volume) on the other hand has a negative relationship to container throughput and is an insignificant determinant.

<table>
<thead>
<tr>
<th>Determinant</th>
<th>T Value</th>
<th>P Value</th>
<th>Relationship</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port of Hamburg Short</td>
<td>4.52</td>
<td>0.0107</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>Sea Shipping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEU Inland Waterways</td>
<td>-2.56</td>
<td>0.0624</td>
<td>Negative</td>
<td>Significant</td>
</tr>
<tr>
<td>DEU Railways</td>
<td>2.54</td>
<td>0.0640</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>DEU Motorways</td>
<td>-0.59</td>
<td>0.5892</td>
<td>Negative</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

The below given table 26 is helpful in visualizing the impact of increase of the significant determinants on the container throughput of the Port of Hamburg.

It is interesting to note that from the economy category only the exports of Germany is a significant determinant. An increase of 1 million euro of German exports results in an increase of 33 TEU's of the container throughput of the Port of Hamburg.

Terminals variables also are significant for the Port of Hamburg. While terminal area has positive relationship where an increase of a hectare results in 71,138 TEU's increase in container throughput, quay length returns a negative relationship where an increase of 1 meter of quay length reduces container throughput by 4,321 TEU's.

From the hinterland category, Slovak Republic Exports and Czech imports are significant though both have a negative relationship to the container throughput. In increase in 1 million euro Slovak Republic exports and Czech imports results in a decrease of 179 and 90 TEU's of container throughput.

It is observed that the container shipping companies though a significant determinant for the Port of Hamburg has a negative relationship with its container throughput. For every container vessel that calls at the Port of Hamburg, it reduces the container throughput by 463 TEU's.

However, short sea shipping has a positive relationship and is a significant determinant. An increase of 1 thousand tonne transported through short sea shipping mode increases the throughput by 158 TEU's.

From the inland transport category, inland waterways and railways resulted as significant variables. Inland waterways has a negative relationship to throughput where an increase of 1 thousand tonne transported by it reduces throughput by 230 TEU's. On the other hand railways has a positive relationship where an increase of 1 thousand tonnes transported by it increase throughput by 66 TEU's.
Table 26
Significant Coefficients of the Multi Regression Model for the Port of Hamburg

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Category</th>
<th>Unit Increase</th>
<th>TEU increases/ (decreases) by</th>
</tr>
</thead>
<tbody>
<tr>
<td>German Exports</td>
<td>Economy</td>
<td>1 Million Euro</td>
<td>33</td>
</tr>
<tr>
<td>Quay length</td>
<td>Terminal</td>
<td>1 Meter</td>
<td>(4321)</td>
</tr>
<tr>
<td>Terminal Area</td>
<td>Terminal</td>
<td>1 Hectare</td>
<td>71138</td>
</tr>
<tr>
<td>Slovak Republic Exports</td>
<td>Hinterland</td>
<td>1 Million Euro</td>
<td>(179)</td>
</tr>
<tr>
<td>Czech Imports</td>
<td>Hinterland</td>
<td>1 Million Euro</td>
<td>(90)</td>
</tr>
<tr>
<td>Container vessels calling at port</td>
<td>Shipping Companies</td>
<td>1 vessel</td>
<td>(463)</td>
</tr>
<tr>
<td>Port of Hamburg Short Sea Shipping</td>
<td>Short Sea Shipping</td>
<td>1 Thousand Tonne</td>
<td>158</td>
</tr>
<tr>
<td>DEU Inland Waterways</td>
<td>Inland Transport</td>
<td>1 Thousand Tonne</td>
<td>(230)</td>
</tr>
<tr>
<td>DEU Railways</td>
<td>Inland Transport</td>
<td>1 Thousand Tonne</td>
<td>66</td>
</tr>
</tbody>
</table>

Analysis of simple regression results and multi regression model with port strategy of the Port of Hamburg

The strategy report for the Port of Hamburg upto 2025 is “Hamburg is staying on Course The Port Development Plan to 2025” (Hamburg Port Authority, 2012).

The strategies mentioned in this report was referred and is discussed in this section along with results from the regression model.

Inland Transport

Inland waterways for the Port of Hamburg:

The most frequently used route to approach the Port of Hamburg by sea is the 130km-long passage from the North Sea on the River Elbe (Hamburg Port Authority, 2012). Other relevant waterways are the Kiel Canal for feeder transports, the Mid Elbe/Upper Elbe and the Elbe Lateral Canal that link the port to the European inland waterway network (Hamburg Port Authority, 2012). The River Elbe is one of the most significant and most frequented waterways in Europe (Hamburg Port Authority, 2012). It is the basis of the economic success of the Port of Hamburg (Hamburg Port Authority, 2012).
The Sustainability Report 2015 mentions that the share of transports by inland waterway vessels as a part of the Port of Hamburg’s container hinterland traffic is still rather low. The following strategies are being used by it to improve inland waterways transport.

a) Expansion of Kiel Canal

There is a planned expansion of the Kiel canal to accommodate larger ship sizes to further increase the cost-effectiveness on this route (Hamburg Port Authority, 2012). However, from the results of the simple regression results it is observed that inland waterways load and the length of navigable canals & rivers does not linearly impact the container throughput of the Port of Hamburg. In fact, the multi regression model of Inland Transport shows that, though a significant variable, inland waterways negatively impacts the container port throughput of the Port of Hamburg.

In view of the aforementioned, it is opined that the expansion of the Kiel Canal will not have a positive impact on the container throughput of the Port of Hamburg. However, this does not imply there are no benefits from this expansion. It would intuitively seem that there would be benefits, but not impacting container port throughput. In fact the literature about this expansion mentions that it would be necessary to expand the Kiel Canal, because if it is not expanded, there is a risk that cargo bound for the Baltic Sea area will shift from Hamburg (Hamburg Port Authority, 2012). Keeping this necessity in mind, it would be advisable for the Port Authority to pursue the project but not fund it. It would hence be advisable to allow other public authorities or private players to develop this project. The Port Authority’s financial resources could be better utilized on projects that have a positive linear relationship with the container port throughput of the Port of Hamburg.

b) Enhancing navigability of Mid Elbe and Upper Elbe

The Hamburg Port Development Plan upto 2025 mentions that if the navigability of the Mid Elbe and Upper Elbe is ensured, cross-border transports towards the Czech Republic are likely to increase (Hamburg Port Authority, 2012). However, as per the multi regression model it is observed that Czech exports is not a determinant of the container port throughput of the Port of Hamburg. Further, Czech imports though a significant variable has a negative impact on the container port throughput of the Port of Hamburg. As such this particular project should be cautiously pursued as there would not be any benefit for the container port throughput.

c) Fairway adjustment of the Lower Elbe and Outer Elbe River Channels

Another strategy of the Port of Hamburg is deepening the Lower Elbe and Outer Elbe River Channel by one metre for both tidal and non-tidal passages. This it predicts will bring effective short-term economic benefits and also enhance the attractiveness of Hamburg as a port site (Hamburg Port Authority, 2012). This measure should increase the throughput of the port of Hamburg. This is because large container ships which have deep draughts would be able to access the Port of Hamburg through the Lower Elbe and Outer Elbe river channels. The intended channel deepening will allow ships to carry approximately 1,000 TEU in addition to its load (Hamburg Port Authority, 2012).

d) Promotion of inland waterway transport services
The Port Development Plan 2015 mentions that in order to realise inland waterway potential, a marketing campaign to promote inland waterway vessels needs to be launched that emphasizes the ecological potential and helps to acquire potential large-volume shippers and new providers of inland waterway transport services (Hamburg Port Authority, 2012). This strategy would not yield much benefit on the container port throughput as per the results of the simple regression results and multi regression model but can be pursued as it is not capital intensive.

Road transport:

The Port Development Plan up to 2025 also mentions that the most significant mode of transport in the metropolitan region and the surrounding countries of Germany is the road (Hamburg Port Authority, 2012). The results of the simple regression results differ from this as it did not validate a linear relationship between motorways load factor and container port throughput. Further, the multi regression model showed that it was non-significant variable that had a negative relationship to the container port throughput of the Port of Hamburg. As such, while roadways may be important on account of carrying the highest container volume traffic in the inland transportation network in Germany, its impact could not be interpreted by the multi regression model.

Other plans as part of its Port Development strategy upto 2025 to ensure the long-term competitiveness of the port of Hamburg are:

1) Extending links to the main routes towards Berlin and Hanover to improve access to central and eastern Europe
2) Relieving congestion in the Elbtunnel and on Köhlbrand- brücke by building the new A 26 autobahn which connects the A 7 to the A 1
3) Expanding and extending the trunk road network
   (Hamburg Port Authority, 2012)

Based on the multi regression model, the impact of the above three plans on the container port throughput of the Port of Hamburg cannot be determined.

Shift in inter modal split:

The Hamburg Port Development Plan 2025 strives to increase the share of containers transported by rail and inland waterway vessels as these have a lower carbon footprint compared to road transport (Hamburg Port Authority, 2012). As per the results of the multi regression model, rail transport holds most promise as it is the only one which is a significant variable that has a positive impact on the container port throughput. As such it would be advisable to increase the share of containers transported by railways.

To summarise, we can observe that the Port of Hamburg is developing several strategies for improving hinterland transport. While this might be necessary, it would be advisable to look at ways of getting the funding from private players and avoid utilizing the Port Authorities budget.
Terminals

During the 2009 financial crisis, container port throughput of the Port of Hamburg dropped significantly (Hamburg Port Authority, 2012). The throughput fell from 9,737,000 TEU's in 2008 to 7,008,000 TEU's in 2009 (Port Authorities & Port of Rotterdam, 2015). It took almost 5 years to recover wherein in 2014 recorded throughput was 9,729,000 (Port Authorities & Port of Rotterdam, 2015). One of the reason why a significant drop was witnessed was low share of dedicated terminals in Hamburg compared to competing ports (Hamburg Port Authority, 2012). The simple regression results also indicates this weakness, as container terminal determinants such as quay length and number of container cranes does not show strong linear relationship to throughput. The R square was between 40-45% only. Further, the multi regression model presents terminal area as a positive significant determinant. Quay length, though part of the model shows to have a negative relationship.

One of the reasons for the different variables under terminals to have a low impact on container port throughput could be that the planning and development of the terminals, though, have taken place are not ‘optimal’. Better planning would help to have a stronger impact on the container throughput of the Port of Hamburg.

Efficient utilization of space:

To enable the Port of Hamburg to actually achieve the forecasted handling potential, the Hamburg Port Development Plan 2025 prescribes sufficient capacities to be available. Due to spatial restrictions the Senate of Hamburg and the port industry has assigned priority to the subsequent areas of action:

a) Upgrading existing infrastructure and suprastructure
b) Increasing productivity at the terminals
c) Restructuring areas in the port (port expansion to the inside)
d) Developing further site potentials

(Hamburg Port Authority, 2012)

These measures should improve the container throughput. Using the multi regression model, the impact of restructuring and developing further terminal area sites on container port throughput is predicted. An increase in total terminal area from the present 415 hectares to 425 hectares increases throughput from around 8.8 million TEU to around 9.6 million (table 27) TEU while an increase to 450 hectares improves TEU to around 11.4 million TEU (table 28)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-156426</td>
<td>1</td>
<td>-156426</td>
</tr>
<tr>
<td>Quay length (meter)</td>
<td>-4321</td>
<td>7590</td>
<td>-32796390</td>
</tr>
</tbody>
</table>

Table 27
Impact on throughput by increase in terminal area to 425 hectares
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-156426</td>
<td>1</td>
<td>-156426</td>
</tr>
<tr>
<td>Quay length (meter)</td>
<td>-4321</td>
<td>7590</td>
<td>-32796390</td>
</tr>
<tr>
<td>Terminal Area (ha)</td>
<td>71138</td>
<td>450</td>
<td>32012100</td>
</tr>
<tr>
<td>Labour productivity index</td>
<td>-55196</td>
<td>0.57</td>
<td>-31319</td>
</tr>
<tr>
<td>DEU GDP (MLN EUR)</td>
<td>0.83</td>
<td>3463443</td>
<td>2880892</td>
</tr>
<tr>
<td>DEU Export (MLN EUR)</td>
<td>33</td>
<td>1198074</td>
<td>39737729</td>
</tr>
<tr>
<td>DEU Import (MLN EUR)</td>
<td>-7</td>
<td>950706</td>
<td>-6600755</td>
</tr>
<tr>
<td>Container Traffic (calling)</td>
<td>-463</td>
<td>4111</td>
<td>-1905037</td>
</tr>
<tr>
<td>Sea Infra Invest (EUR)</td>
<td>0.0005</td>
<td>671533333</td>
<td>346310</td>
</tr>
<tr>
<td>SVK Rep Export (MLN EUR)</td>
<td>-179</td>
<td>67731</td>
<td>-12136748</td>
</tr>
<tr>
<td>Czech Import (MLN EUR)</td>
<td>-90</td>
<td>110270</td>
<td>-9965122</td>
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<td><strong>Total as per Multi Regression Model</strong></td>
<td></td>
<td></td>
<td>9,606,782</td>
</tr>
<tr>
<td><strong>Total as per Recorded throughput 2015</strong></td>
<td></td>
<td></td>
<td>8,800,000</td>
</tr>
<tr>
<td><strong>Increase in TEU</strong></td>
<td></td>
<td></td>
<td>806,782</td>
</tr>
</tbody>
</table>

### Terminal Capacities:

The port of Hamburg realizes the potential of upgrading container terminal facilities. It includes in its port development strategy the further optimisation and expansion of terminal sites both in Altenwerder and Tollerort that would create a further 2m to 3m TEU handling capacity annually and ensure that Hamburg will stays in the growth lane.
The Association of Hamburg Port Operators [Unternehmensverband Hafen Hamburg] reckons with the following future container handling capacities:

1) Container Terminal Altenwerder – 4mln TEU
2) Container Terminal Burchardkai - 6mln TEU
3) Container Terminal Hamburg (Waltershof) – 6mln TEU
4) Container Terminal Tollerort - 4mln TEU

(Hamburg Port Authority, 2012)

From the results of the simple regression it is observed that increase in terminal capacity has a weak linear relationship with port throughput (R square 44.89%) while the multi regression model does not include terminal capacity in the model. As such the above expansion would not have a strong impact on the container port throughput of the Port of Hamburg.

Quay Length:

As part of its Land Strategy, the Port of Hamburg has aimed to optimize, make compact and intensify land including quay facilities (Hamburg Port Authority, 2012).

It is noted from the multi regression model that quay length of terminals shows a negative relationship to the container port throughput. This gives an indication that the quay length of its terminals are not being utilized efficiently. Given this scenario, the aforementioned strategy appears to be in the right direction.

Short Sea Shipping

Short-sea shipping and feeder services to and from northern, central and eastern Europe and Hamburg moved a significant 1.6m TEU in 2010 and about 2.4m TEU in 2011 (Hamburg Port Authority, 2012). This validates the results of the regression where short sea shipping showed a strong 86.13% R square linear relationship with the container port throughput. Further the multi regression model also shows that short sea shipping is a significant variable and has a positive relationship to container port throughput.

There were no strategies found in the Port Development Plan upto 2025 of the Port of Hamburg regarding measures to develop this segment. It would be advisable to invest in short sea shipping projects as this definitely has positive impact on the container throughput of the Port of Hamburg.

Hinterland

The Port of Hamburg recognizes that it faces competition with other ports for its hinterland. It is observed that the hinterland is crucial for the competitiveness of the Port of Hamburg as validated by several authors and also from the results of the simple regression and multi regression model. In this regard, as part of its development plans, the Port of Hamburg has improvement of hinterland connections as an important target (Hamburg Port Authority, 2012).
Based on the analysis of the hinterland transport of the Port of Hamburg made earlier, it would be advisable to use railways and short sea shipping to pursue this strategy as both forms of transport have a positive impact on container port throughput.

**Investment in port infrastructure**

The Hamburg Port Development Plan upto 2025 mentions that new production and consumption centres as well as larger overall production, trade and transport volumes will require considerable investment in all areas of infrastructure. (Hamburg Port Authority, 2012). Further, new funding models involving private partners will be leaned on to provide infrastructure facilities in accordance with demand (Hamburg Port Authority, 2012). New funding models by involving private players is a very good decision by the Port of Hamburg.

The simple regression results show that sea infrastructure investments do not have a linear relationship with port throughput. Further, the multi regression model show that while investment in port infrastructure is a determinant, it is not significant. These results indicate that investment in port infrastructure is not optimal.

As such it would be advisable to invest only in those areas of port infrastructure which have a positive and significant impact on container port throughput and involve private players for the funding of other port projects allowing the budget of the Port Authority of Hamburg to be used effectively.

**Shipping Companies**

All over the world shipping companies hold interests in terminals to use them exclusively. Such terminals are known as dedicated terminals. From a port-strategic point of view dedicated terminals offer advantages as well as disadvantages. Dedicated terminals help in stabilizing handling of cargo in economically weak periods and generate additional volume during an upswing. A possible disadvantage of dedicated terminals may lie in the fact that a port becomes economically dependent on specific shipping companies.

From the results of the simple regression it is observed that the number of container vessels calling at the Port of Hamburg does not have a linear relationship to its container throughput. Further, as per the multi regression model also, the number of vessels that call at the Port of Hamburg, though a significant variable has a negative relationship to the container port throughput.

As such in light of the aforementioned results, the plan to have dedicated terminals can thus be analysed from two views. First, the ratio of dedicated terminals should be on the lower side to allow more number of vessels of different shipping companies to call at the Port of Hamburg. This strategy is used taking the Port of Antwerp as an example for whom the number of shipping companies represented by the number of container vessels calling at its port has a strong linear relationship to its throughput.

Another strategy would be to have a higher ratio of dedicated terminals provided though that the agreement allows minimum committed cargo handling loads. This will allow the terminal area to be used effectively contributing to high port throughput.

It may be noted here that the within the scope of the future allocations of the Port of
Hamburg, the option to establish dedicated terminals has not been excluded outright by it (Hamburg Port Authority, 2012).

Land constraints

“Hamburg faces stiff competition from other ports in North-Western Europe most of which unlike Hamburg are able to offer large sites when it comes to attracting businesses that benefit economically from being close to a waterway and look for a site. The only sites available in Hamburg suitable to house modern port facilities are located in the area of the Southern Elbe. The northern banks of the River Elbe mark the state boundary and in Harburg, the Elbbrücken and the densely populated Wilhelmsburg area restrict development”. (Hamburg Port Authority, 2012)

The zone I expansion area (Moorburg) offers the last large cohesive site with excellent infrastructure connections to the navigation channel, the railway network and the autobahns and thus represents the only option to develop another section of the port (Hamburg Port Authority, 2012).

As such land constraints will in the long run compromise the competitiveness of the Port of Hamburg. This is a weakness of the Port of Hamburg.

Conclusion

From the analysis of the Port of Hamburg it is observed that the significant determinants of its container throughput are German exports and terminal area which have a positive relationship to it. The other significant determinants include, Slovak Republic exports, container vessels that call at the Port of Hamburg, Czech imports and quay length, all of which have a negative relationship to its throughput.

While comparing the strategies of the port of Hamburg to the simple regression results and multi regression model, it is observed that the plans with regard to inland transport i.e. expansion of Kiel Canal, enhancing navigability of Mid Elbe and Upper Elbe, fairway adjustment of the Lower Elbe and Outer Elbe River Channels and promotion of inland waterways transport services would not have a positive linear relationship to container throughput. As such it is advisable for the Port of Hamburg to involve private players and other institutions to invest in these projects.

Further, roadways resulted as an insignificant determinant and as such the impact other road strategies of the Port of Hamburg cannot be determined. As such the Port of Hamburg is cautioned on their road strategies and should thoroughly analyze with other statistical and econometric models to gauge the impact on container throughput.

With regard to inter modal split of transport, it is advisable to implement strategies to increase the load of freight in favour of rail transport as it is a positive significant determinant and will thereby increase the container throughput of Port of Hamburg.

Moving onto terminals it is observed that apart from terminal area, the other variables do not have a positive relationship to container throughput. The Port of Hamburg is aware of the shortcomings of its terminals and has formulated strategies with respect too upgrading infrastructure and increasing productivity at the terminals which intuitively should show positive results in the future. Further, as it faces sever space
constraints its strategies pertaining to restructuring areas in the port and developing further site potentials are a welcome move and will have a positive impact on container throughput.

On the other hand, strategies pertaining to increase of terminal capacities should be purused with caution as it did not appear as a determinant in the multi regression model. Strategies with regard to optimisation of quay length is in the right direction.

Short sea shipping holds a lot of promise, though there does not seem to be any strategies for its development by the Port of Hamburg. The port should promote this mode of transport for higher container throughput levels.

Investment in port infrastructure should be done carefully because even though it was a determinant of container throughput as per the multi regression model, it was found not be significant and hence its impact cannot be gauged. It would be advisable to use different statistical and econometric models to aid in future investment strategies.

Lastly, with regard to the attraction value of shipping companies to the Port of Hamburg, it was observed that container vessels calling at the port is a significant determinant, but negative. As such formulation of strategies relating to dedicated terminals can be made in either direction, i.e. in favour of it or against it.

5.3 Port of Le Havre

The simple regression results of the Port of Le Havre are as follows in table 29 below:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Categories</th>
<th>Standard Error</th>
<th>R Squares</th>
<th>F Value</th>
<th>F Test</th>
<th>P Value</th>
<th>T Value</th>
<th>P Value</th>
<th>Strength of Linear Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRA GDP (MLN EUR)</td>
<td>Economy</td>
<td>195126</td>
<td>87.48</td>
<td>125.78</td>
<td>4.41</td>
<td>0.0001</td>
<td>11.22</td>
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</tr>
<tr>
<td>FRA Export (MLN EUR)</td>
<td>Economy</td>
<td>219955</td>
<td>84.09</td>
<td>95.15</td>
<td>4.41</td>
<td>0.0001</td>
<td>9.75</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>FRA Import (MLN EUR)</td>
<td>Economy</td>
<td>233034</td>
<td>82.14</td>
<td>82.81</td>
<td>4.41</td>
<td>0.0001</td>
<td>9.1</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>Investment in Sea Infrastructure (Euro)</td>
<td>Investment</td>
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<td>42.84</td>
<td>13.49</td>
<td>4.41</td>
<td>0.0170</td>
<td>3.67</td>
<td>0.0170</td>
<td>Weak</td>
</tr>
<tr>
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<td>Labour</td>
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<td>32</td>
<td>8.47</td>
<td>4.41</td>
<td>0.0093</td>
<td>-2.91</td>
<td>0.0093</td>
<td>Weak</td>
</tr>
<tr>
<td>Container Traffic (Nos)</td>
<td>Shipping Companies</td>
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<td>18.45</td>
<td>1.58</td>
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</tr>
<tr>
<td>FRA Railway lines (TT Tonnes)</td>
<td>Inland Transport</td>
<td>169465</td>
<td>10.16</td>
<td>0.79</td>
<td>5.59</td>
<td>0.4032</td>
<td>0.89</td>
<td>0.4032</td>
<td>NIL</td>
</tr>
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<td>-------------------------------</td>
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</tr>
<tr>
<td>FRA Motorways (TT Tonnes)</td>
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<td>4.02</td>
<td>0.29</td>
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<tr>
<td>FRA Motorways (Kms)</td>
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<td>FRA Railway lines (Kms)</td>
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<td>5.59</td>
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<tr>
<td>FRA Inland Waterways (TT Tonnes)</td>
<td>Inland Transport</td>
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<td>*Quay length (meters)</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>*Terminal Area (Hectares)</td>
<td>Terminal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>*Quay Side Cranes (Nos)</td>
<td>Terminal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>*Container Capacity (TEU)</td>
<td>Terminal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>*FRA Navigable canals (Kms)</td>
<td>Inland Transport</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>*FRA Navigable rivers (Kms)</td>
<td>Inland Transport</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
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<td>Short Sea Shipping</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</table>

* Data unavailable or is constant

### Analysis of the results of simple regression

The most significant variable were the French GDP, exports and imports. The linear relationship was established for all 3 variables with a R square of 87% for French GDP, 84% for French exports and 82% for French imports.

French labour productivity index returned with a valid model, though the linear relationship was weak with R square of 32%. However, it is interesting to note that the Port of Le Havre is the only port amongst all four ports analyzed in this thesis to have a linear relationship of the labour productivity index of its country (France) to its container port throughput. As such it is advisable for the Port Authorities to find out opportunities to improve the quality of labour. This in future holds potential to increase the strength of the linear relationship which would have a positive impact on the container port throughput.

Investment in sea infrastructure (including ports) returned with R square of 43% for sea infrastructure investment. As such the linear relationship though was found to be present is ‘weak’. Again it was interesting to note that, the Port of Le Havre was the
only port amongst all four analyzed to have linear relationship between the investments made in sea infrastructure and its container port throughput. This finding is a welcome observation which would give a lot of confidence to the Port Authorities and other investors to invest in sea infrastructure projects such as sea locks and other port infrastructure projects.

The model was found to be invalid for the test with respect to inland transportation means which included motorways (length and load factor), railway lines (length and load factor) and inland waterways (load factor). Data was not available for the length of navigable rivers & canals and hence the model could not be tested for these variables.

The model could also not be tested for short sea shipping due to unavailability of data.

The model was found to be invalid for container vessel calling at the Port of Le Havre.

Terminal variables such as quay length, cranes and terminal areas have been constant during the previous years. Hence the simple regression results for these variables could not be produced.

Multi regression model

The determinants of the container port throughput of the Port of Le Havre are the GDP of France, French exports & imports, French labour productivity index and investment in port infrastructure.

The multi regression model for the Port of Le Havre containing the determinants of its container port throughput is as follows in table 30.

<table>
<thead>
<tr>
<th>Table 30 Multi Regression Model for Port of Le Havre</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEU = -1778291 - 29253 Labour Productivity Index + 1.3850 FRA GDP (MLN EUR) + 18.743 FRA Export (MLN EUR) - 13.874 FRA Import (MLN EUR) + 0.0000376 Investment in Port Infrastructure</td>
</tr>
</tbody>
</table>

As can be seen from the table 31 below the multi regression model for the Port of Le Havre is valid and has a R square of 95.15%

<table>
<thead>
<tr>
<th>Table 31 Model Summary of Multi regression model Port of Le Havre</th>
</tr>
</thead>
<tbody>
<tr>
<td>R Square</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>95.15%</td>
</tr>
</tbody>
</table>
The significance of determinants of the Port of Le Havre are presented in table 32 below.

The French GDP, French exports and investment have a positive impact on the throughput, among which French GDP and French exports are significant.

French imports and French labour productivity index have a negative impact on the throughput among which French imports is significant.

<table>
<thead>
<tr>
<th>Determinant</th>
<th>T Value</th>
<th>P Value</th>
<th>Relationship</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRA Export</td>
<td>4.29</td>
<td>0.0007</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>FRA GDP</td>
<td>4.1</td>
<td>0.0011</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>FRA Import</td>
<td>-4.01</td>
<td>0.0013</td>
<td>Negative</td>
<td>Significant</td>
</tr>
<tr>
<td>Labour Productivity Index</td>
<td>-0.83</td>
<td>0.4219</td>
<td>Negative</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Investment in Port Infrastructure</td>
<td>0.08</td>
<td>0.9359</td>
<td>Positive</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

Using the data recorded in 2014 of the variables in the multi regression model, the throughput is calculated as per below table 33:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1778291</td>
<td>1</td>
<td>-1778291</td>
</tr>
<tr>
<td>FRA GDP (MLN EUR)</td>
<td>1.39</td>
<td>2352033</td>
<td>3257566</td>
</tr>
<tr>
<td>FRA Export (MLN EUR)</td>
<td>19</td>
<td>509991</td>
<td>9558753</td>
</tr>
<tr>
<td>FRA Import (MLN EUR)</td>
<td>-14</td>
<td>593885</td>
<td>-8239559</td>
</tr>
<tr>
<td>Investment in Port Infrastructure</td>
<td>0.000038</td>
<td>460000000</td>
<td>17296</td>
</tr>
<tr>
<td>Labour Productivity</td>
<td>-29253</td>
<td>0</td>
<td>1747</td>
</tr>
<tr>
<td><strong>Total as per Multi Regression Model</strong></td>
<td><strong>2,817,512</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total as per recorded throughput (2014)</td>
<td>2,551,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td><strong>266,512</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Multi regression model for inland transport

The multi regression model for inland transport of the Port of Le Havre did not present a valid model. The following table 34 gives the details of its invalidity.

<table>
<thead>
<tr>
<th>R Square</th>
<th>F-Value</th>
<th>F-Test</th>
<th>P-Value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.99%</td>
<td>0.25</td>
<td>5.41</td>
<td>0.8592</td>
<td>Invalid</td>
</tr>
</tbody>
</table>

The significant coefficients of the multi regression model of the Port of Le Havre are presented in the below table 35.

As can be seen observed from the table, an increase of 1 million euro of French GDP and exports increase the container throughput of the Port of Le Havre by 1 TEU and 19 TEU respectively. As such French exports is extremely crucial for the container throughput of the Port of Le Havre.

On the other hand an increase of 1 million euro in the French imports reduces the container throughput by 14 TEU’s.

Analysis of the simple regression results and multi regression model with port strategy of the Port of Le Havre

The 2014-19 Strategic Plan of the Port of Le Havre was referred to understand its long term objectives and strategies that would be adopted to increase its competitiveness. The 2014 - 2019 Strategic Plan was approved by the Supervisory Board on 26 June 2015 (Grand Port Maritime Du Havre, 2015).

As per the 2014-19 Strategic Plan containers has been identified as the activity that has the greatest potential for development and is a major stake for the institution, the port community and the Seine corridor as a whole. (Grand Port Maritime Du Havre, 2015)"
Container Traffic

The 2014-19 plan outlines for the berthing of larger vessels (Grand Port Maritime Du Havre, 2015). While this strategy is appreciable, the maximum draft of Port of Le Havre currently is at 15.50 meters. Vessels such as the Emma Maersk have a draught of around 16 meters (Maersk, n.d.). As such the depth of port would need to be sufficiently increased to allow the larger vessels to call. Deepening of the depth, was not an identified strategy in the 2014-19 plan.

Hinterland

The 2014-19 Plan provides for the establishment of the Multimodal Terminal, improving rail connections (in particular the Serqueux-Gisors line), and the development of combined maritime and inland waterway transport that would help improve the performance of multimodal solutions and the port’s capacity to expand its hinterland and increase traffic (Grand Port Maritime Du Havre, 2015).

It would be challenge to implement this strategy as the hinterland of Port of Le Havre has been captured by other ports. As such it would need to compete with ports who would already have established themselves in the hinterland regions. Secondly, based on the results of simple regression it was observed that there was no linear relationship found between TEU throughput of Port of Le Havre and any of the inland transport variables. Further, the multi regression model for France inland transport on container port throughput was found to be invalid.

Investment in Port Infrastructure

From the simple regression results it is observed that investment in port infrastructure has a weak linear relationship with container throughput of the Port of Le Havre. Also, the multi regression model does not include investment in port infrastructure as a determinant of throughput.

The Port 2014-19 Plan mentions that European funding can be solicited to develop ports, railways, inland waterways and multimodal systems, such as the facilities needed to increase capacity on the Paris-Le Havre rail link via the traditional route, or through Gisors-Serqueux in particular (Grand Port Maritime Du Havre, 2015).

It is observed from the simple regression results that inland transport load factor does not have a linear relationship to container throughput and neither do railways or motorways. As such investing in these systems from the budget of the Port Authority would not have a positive impact on the container port throughput. However, if the funding is available from other sources, such as the financial institutions or authorities of Europe, the same could be pursued.

Further the following Major investment plans have been outlined in its 2014-19 Plan (Grand Port Maritime Du Havre, 2015):

1. Terminals, including container terminals - 87 Mln Euro

While the regression model could not be run for the container terminals as the same
was found constant for the past several years, intuitively any investment in container terminals should have a positive impact on the port throughput.

2. **Creation of logistics park – 40 Mln Euro**

This strategy should be carefully analysed. Any logistics park would depend on the internal transport system for it to be successful. However, based on the results of the simple regression and multi regression model for inland transport, none of the internal transport means are linearly related to container port throughput. As such the funding of this project should be better left to private players or other authorities.

3. **Port railway network and rail access to container terminals - 13 Mln Eur and studies for river access to Port 2000 (through a passage in the breakwater)- 2 Mln Eur**

Again, as mentioned in point 3, railways transport and inland waterways do not have a linear relationship to container port throughput. More importantly the multi regression model did not show any inland transport mode as a determinant of throughput. As such this project should not be funded by the Port Authority of the Port of Le Havre

4. **Modernization of locks – 27 M euro**

From the results of the regression model it is observed that investment in sea infrastructure has a linear relationship on container port throughput. However, this relationship currently is weak. As such it would be advisable to thoroughly analyze the project and then make the investment. However, it holds promise and the potential exists. With careful planning and execution, the linear relationship could become stronger in the future.

**Labour**

It is observed from the simple regression results that labour productivity index has a weak negative linear relationship with container throughput of the Port of Le Havre. The Port of Le Havre should initiate plans to improve the quality of labour. As port of its Port 2014-19 plan it includes adapting skills and manpower to the port’s new assignments and new business lines in accordance with its strategic objectives (Grand Port Maritime Du Havre, 2015). This measure appears to be in right direction.

**Conclusion**

Based on the analysis of the Port of Le Havre it is observed that significant determinants of its container throughput are the French GDP, exports and imports.
While French GDP and exports have a positive relationship to container throughput, French import was found to have a negative relationship.

With respect to the port strategies of the Port of Le Havre, it was observed that the plan to develop its inland transport system and reach out to its hinterland to attract cargo would be a challenging one as its hinterland is already captured by rival ports and further its inland transport system is not a determinant of its container throughput. It would be advisable to carefully implement the same.

Further, the strategies to create the logistics park and port rail network to access terminals should be carefully assessed. The simple regression results did not show any linear relationship between any inland transport mode and throughput. More importantly, the multi-regression model did not show any inland transport mode as a determinant of throughput. As such, it is advisable to allow private players to fund these projects leaving the funds of the Port Authority of the Port of Le Havre available to invest in projects that have a positive impact on container throughput.

Strategy with respect to modernization of sea locks should be carefully assessed again. It may be noted that investment in port infrastructure shows a weak linear relationship to throughput as per the simple regression results and was not found as a determinant of throughput in the multi-regression model. As such, it is better to have private players invited to fund this project.

The 2014-19 plan outlines for the berthing of larger vessels. This would help increase the traffic of container vessels that call at Port of Le Havre. However, there were no plans regarding the deepening of the draft to accommodate larger vessels in the 2014-19 plan which would be necessary for the success of this objective.

There are several strategies pertaining to terminals which could not be analyzed by the regression model as all container variables were a constant during the time period which was used to run the regression tests and model.

When compared to the other three ports, Port of Le Havre showed a linear relationship between the investment it makes in port infrastructure and container throughput. Even though the relationship is weak, it is a promising sign and shows that the investments are being made in the right direction. By focusing on making investment in projects that have a strong positive impact on throughput, the relationship will grow stronger.

Lastly, with regard to labour, it was noted that it had a negative linear relationship with throughput. In this regard, the Port of Le Havre has adopted a strategy to adapt skills and manpower with its strategic objectives. This strategy appears to be in the right direction.
## 5.4 Port of Rotterdam

The simple regression results of the Port of Rotterdam are as follows in table 36:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Standard Error</th>
<th>R square</th>
<th>F Value</th>
<th>F Test</th>
<th>P Value</th>
<th>T Value</th>
<th>P Value</th>
<th>Strength of Linear Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>CZK Export (MLN EUR)</td>
<td>Hinterland</td>
<td>351651</td>
<td>98.1</td>
<td>876.89</td>
<td>4.45</td>
<td>0.0001</td>
<td>29.61</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>CZK Import (MLN EUR)</td>
<td>Hinterland</td>
<td>390481</td>
<td>97.65</td>
<td>707.95</td>
<td>4.45</td>
<td>0.0001</td>
<td>26.61</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>HUN Export (MLN EUR)</td>
<td>Hinterland</td>
<td>432002</td>
<td>97.13</td>
<td>575.29</td>
<td>4.45</td>
<td>0.0001</td>
<td>23.99</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>DEU Exports (MLN EUR)</td>
<td>Hinterland</td>
<td>466018</td>
<td>96.66</td>
<td>491.98</td>
<td>4.45</td>
<td>0.0001</td>
<td>22.18</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>SVK Import (MLN EUR)</td>
<td>Hinterland</td>
<td>510186</td>
<td>96.00</td>
<td>407.67</td>
<td>4.45</td>
<td>0.0001</td>
<td>20.19</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>DEU Imports (MLN EUR)</td>
<td>Hinterland</td>
<td>533938</td>
<td>95.62</td>
<td>370.73</td>
<td>4.45</td>
<td>0.0001</td>
<td>19.25</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>SVK Export (MLN EUR)</td>
<td>Hinterland</td>
<td>550287</td>
<td>95.34</td>
<td>348.03</td>
<td>4.45</td>
<td>0.0001</td>
<td>18.66</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>NLD Export (MLN EUR)</td>
<td>Economy</td>
<td>568242</td>
<td>95.03</td>
<td>325.33</td>
<td>4.45</td>
<td>0.0001</td>
<td>18.04</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>NLD GDP (MLN EUR)</td>
<td>Economy</td>
<td>569982</td>
<td>95.00</td>
<td>323.24</td>
<td>4.45</td>
<td>0.0001</td>
<td>17.98</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>NLD Import (MLN EUR)</td>
<td>Economy</td>
<td>575229</td>
<td>94.91</td>
<td>317.06</td>
<td>4.45</td>
<td>0.0001</td>
<td>17.81</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>AUT Import (MLN EUR)</td>
<td>Hinterland</td>
<td>586595</td>
<td>94.71</td>
<td>304.24</td>
<td>4.45</td>
<td>0.0001</td>
<td>17.44</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>HUN Import (MLN EUR)</td>
<td>Hinterland</td>
<td>591292</td>
<td>94.62</td>
<td>299.16</td>
<td>4.45</td>
<td>0.0001</td>
<td>17.3</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>AUT Export (MLN EUR)</td>
<td>Hinterland</td>
<td>599435</td>
<td>94.47</td>
<td>290.63</td>
<td>4.45</td>
<td>0.0001</td>
<td>17.05</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>NLD Inland Waterways (TT Tonnes)</td>
<td>Inland Transport</td>
<td>233523</td>
<td>93.05</td>
<td>80.39</td>
<td>5.99</td>
<td>0.0001</td>
<td>8.97</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>CHE Exports (MLN EUR)</td>
<td>Hinterland</td>
<td>1065965</td>
<td>82.52</td>
<td>80.28</td>
<td>4.45</td>
<td>0.0001</td>
<td>8.96</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>CHE Imports (MLN EUR)</td>
<td>Hinterland</td>
<td>1105459</td>
<td>81.21</td>
<td>73.45</td>
<td>4.45</td>
<td>0.0001</td>
<td>8.57</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>Port of Rotterdam Short Sea Shipping TT Tonnes</td>
<td>Terminal</td>
<td>441979</td>
<td>80.52</td>
<td>28.93</td>
<td>5.59</td>
<td>0.001</td>
<td>5.38</td>
<td>0.001</td>
<td>Strong</td>
</tr>
<tr>
<td>Quay length (meters)</td>
<td>Terminal</td>
<td>1138221</td>
<td>80.08</td>
<td>68.32</td>
<td>4.45</td>
<td>0.0001</td>
<td>8.27</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>Container Capacity (TEU)</td>
<td>Terminal</td>
<td>1246575</td>
<td>76.1</td>
<td>54.13</td>
<td>4.45</td>
<td>0.0001</td>
<td>7.36</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
<tr>
<td>Quay Side Cranes (Nos)</td>
<td>Terminal</td>
<td>1259935</td>
<td>75.59</td>
<td>52.63</td>
<td>4.45</td>
<td>0.0001</td>
<td>7.25</td>
<td>0.0001</td>
<td>Strong</td>
</tr>
</tbody>
</table>
### Terminal Area (Hectares)

<table>
<thead>
<tr>
<th>Terminal Area (Hectares)</th>
<th>Terminal</th>
<th>1418048</th>
<th>69.07</th>
<th>37.97</th>
<th>4.45</th>
<th>0.0001</th>
<th>6.16</th>
<th>0.0001</th>
<th>Medium</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NLD Railway lines (Kms)</th>
<th>Inland Transport</th>
<th>575695</th>
<th>66.95</th>
<th>14.18</th>
<th>5.59</th>
<th>0.007</th>
<th>3.77</th>
<th>0.007</th>
<th>Medium</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NLD Railway lines (TT Tonnees)</th>
<th>Inland Transport</th>
<th>676524</th>
<th>54.36</th>
<th>8.34</th>
<th>5.59</th>
<th>0.0234</th>
<th>2.89</th>
<th>0.0234</th>
<th>Medium</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NLD Motorways (Kms)</th>
<th>Inland Transport</th>
<th>733712</th>
<th>46.32</th>
<th>6.04</th>
<th>5.59</th>
<th>0.0436</th>
<th>2.46</th>
<th>0.0436</th>
<th>Weak</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Container Traffic (Nos)</th>
<th>Shipping Companies</th>
<th>1917088</th>
<th>43.48</th>
<th>13.08</th>
<th>4.45</th>
<th>0.0021</th>
<th>3.62</th>
<th>0.0021</th>
<th>Weak</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Investment in Port of Rotterdam Infrastructure (Euro)</th>
<th>Investment</th>
<th>1676851</th>
<th>26.12</th>
<th>4.24</th>
<th>4.75</th>
<th>0.0618</th>
<th>2.06</th>
<th>0.0618</th>
<th>NIL</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NLD Motorways (TT Tonnees)</th>
<th>Inland Transport</th>
<th>875340</th>
<th>23.59</th>
<th>2.16</th>
<th>5.59</th>
<th>0.185</th>
<th>-1.47</th>
<th>0.185</th>
<th>NIL</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Labour Productivity Index</th>
<th>Labour</th>
<th>2273899</th>
<th>20.48</th>
<th>4.38</th>
<th>4.45</th>
<th>0.0517</th>
<th>-2.09</th>
<th>0.0517</th>
<th>NIL</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NLD Navigable canals (Kms)</th>
<th>Inland Transport</th>
<th>904023</th>
<th>18.50%</th>
<th>1.59</th>
<th>5.59</th>
<th>0.2479</th>
<th>1.26</th>
<th>0.2479</th>
<th>NIL</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NLD Navigable rivers (Kms)</th>
<th>Inland Transport</th>
<th>990249</th>
<th>2.21%</th>
<th>0.16</th>
<th>5.59</th>
<th>0.7026</th>
<th>-0.4</th>
<th>0.7026</th>
<th>NIL</th>
</tr>
</thead>
</table>

---

Analysis of the simple regression results and multi regression model with port strategy of the Port of Rotterdam

The results of the simple regression for the Port of Rotterdam show that almost all the variables are linearly related to its container port throughput.

The results show that the container port throughput is strongly related to the Dutch GDP, exports and imports where the R square for all three components are around 95%.

Further, its hinterland plays a crucial part in its throughput too. All its hinterland regions produced a R square of over 90% except for Switzerland which produced a R square of 83% for Swiss exports and 81% for Swiss imports.

With respect to the results of terminal related components it was observed that quay length of terminal area was most linear related with a R square of 80%. Quay side cranes and container capacity produced strong results too, both producing around 76% R square results. Terminal area was also linearly related with a relatively strong R square of 69%.

The modes of transport that were strongly linearly related to container port throughput were railways and inland waterways. Railways track length produced R square of 67% while the goods load factor through railways produced result of R square of 54%.
Inland waterways showed a very strong linear relationship of 93%.

Further, short sea shipping result showed a linear relationship of 81% R square with respect to the container throughput of the Port of Rotterdam.

Motorways showed a weak liner relationship to container throughput in both categories, motorway length (46%) and load factor (24%).

It was observed that container traffic calling at the Port of Rotterdam also showed a weak liner relationship of 43%.

Investment in port infrastructure showed a weak liner relationship of 26%. It may be noted that while for the Port of Antwerp, Hamburg and Le Havre, the data with respect to investment was pertaining to “sea infrastructure including ports” extracted from the Eurostat database, the data for the Port of Rotterdam pertains exclusively to investment in the port infrastructure of the Port of Rotterdam taken from the annual reports of the Port of Rotterdam. The results though, as observed produce a weak relationship.

Across the remaining three ports, analyzed in this thesis, the same results were observed. Once could assume the reason for a weak linear relationship, is that infrastructure investment takes time to have an impact on port throughput, its benefit felt only in successive years. Further, it is difficult to segregate port infrastructure for each segment, ie. container, dry-bulk, liquid bulk etc. Lastly, infrastructure investment could also include in areas that are necessary, but not impacting port throughput (eg. administrative buildings, safety equipment etc)

Multi regression model

The multi regression model of the Port of Rotterdam is presented below in table 37 below. From the multi regression model it is observed that the Dutch GDP, Dutch exports & imports, all four components of terminals viz. quay length, quay cranes, terminal area & terminal capacity and container vessels that call at the Port of Rotterdam determine the container port throughput of the Port of Rotterdam.

<table>
<thead>
<tr>
<th>Table 37 Multi Regression Model for Port of Rotterdam</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEU = 24384971 + 3469 Quay Length (meter) Cumulative + 177099 Terminal Area Cumulative (ha) – 2616561 No of Quayside Cranes cumulativ + 4.528 Cumulative Capacity Increase + 24.218 NLD GDP (MLN EUR) – 14.94 NLD Export (MLN EUR) + 20.86 NLD Import (MLN EUR) + 543.6 Container Traffic (calling)</td>
</tr>
</tbody>
</table>

As can be observed from table 38 the multi regression model of the Port of Rotterdam is valid with a high R square of 99.05%.
Table 38
Model Summary for Port of Rotterdam

<table>
<thead>
<tr>
<th>R Square</th>
<th>F-Value</th>
<th>F-Test</th>
<th>P-Value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.05%</td>
<td>65.15</td>
<td>4.82</td>
<td>0.0001</td>
<td>Valid</td>
</tr>
</tbody>
</table>

From the below table 39 it is observed that the determinants in the multi regression model which have a positive relationship to the container port throughput are quay length, terminal area, terminal capacity, Dutch GDP & imports and container vessels that call at the Port of Rotterdam. Out of these, terminal area & capacity, Dutch GDP and container traffic are significant.

Further, the determinants which have a negative impact on the container port throughput are quayside cranes and Dutch exports. Out of these two only quayside cranes are significant.

Table 39
Significance of determinants of the Port of Rotterdam

<table>
<thead>
<tr>
<th>Determinant</th>
<th>T Value</th>
<th>P Value</th>
<th>Relationship</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal Area</td>
<td>3.33</td>
<td>0.0208</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>Terminal Capacity</td>
<td>2.95</td>
<td>0.0320</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>Quayside Cranes</td>
<td>-2.87</td>
<td>0.0349</td>
<td>Negative</td>
<td>Significant</td>
</tr>
<tr>
<td>NLD GDP</td>
<td>2.7</td>
<td>0.0429</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>Container Traffic</td>
<td>2.46</td>
<td>0.0570</td>
<td>Positive</td>
<td>Significant</td>
</tr>
<tr>
<td>Quay Length</td>
<td>1.9</td>
<td>0.1152</td>
<td>Positive</td>
<td>Insignificant</td>
</tr>
<tr>
<td>NLD Import</td>
<td>1.17</td>
<td>0.2947</td>
<td>Positive</td>
<td>Insignificant</td>
</tr>
<tr>
<td>NLD Export</td>
<td>-0.81</td>
<td>0.4539</td>
<td>Negative</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

Using the data recorded in 2015 of the variables in the multi regression model, the throughput is calculated as per below table 40:

Table 40
Calculation of container throughput of Port of Rotterdam using the multi regression model

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>24384971</td>
<td>1</td>
<td>24384971</td>
</tr>
</tbody>
</table>
The multi regression model for the inland transport for the Port of Rotterdam is given below in table 41. As can be observed from the table the inland transport variables that are the determinants of the container throughput of the Port of Rotterdam are motorways (load factor), railways (load factor) and inland waterways (load factor). Short sea shipping (load factor) is included also as a determinant.

### Table 41

**Multi Regression Model for Inland Transport**

\[
\text{TEU} = 8035009 + 8.506 \times \text{Motorways Total Transport} - \text{Tho} + 27.78 \times \text{Railway Total Transport} - \text{Thous} + 143.80 \times \text{Inland Waterways Total Transport} - 81.3 \times \text{PoR Short Sea Shipping Total Tr}
\]

From the below table 42 it is observed that the multi regression model for the Port of Rotterdam comprising of inland transport determinants and short sea shipping is valid with a high r square of 95.34%.

### Table 42

**Model Summary Port of Rotterdam**

<table>
<thead>
<tr>
<th>R Square</th>
<th>F-Value</th>
<th>F-Test</th>
<th>P-Value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>95.34%</td>
<td>15.33</td>
<td>9.12</td>
<td>0.0245</td>
<td>Valid</td>
</tr>
</tbody>
</table>

From the below table 43 it is observed that the while inland waterways (load factor), motorways (load factor) and railways (load factor) have a positive relationship to container throughput, only inland waterways (load factor) is significant.

Short sea shipping has a negative relationship but is insignificant.
The following table 44 shows the significant co-efficient which helps in visualizing the impact on the container throughput of the Port of Rotterdam. It is observed that an increase of 1 million euro in the Dutch GDP increases throughput by 24 TEU. Further, terminal area has as strong impact as well, as an increase of 1 hectare increases the throughput by 177,099 TEU. Further an increase of 1 container vessel that calls at the Port of Rotterdam increases the throughput by 544 TEU's. Further, inland waterways transport also has a strong impact as an increase of 1 thousand tonnes carried by it increases throughput by 144 TEU. On the other hand an increase of 1 quayside terminal reduces throughput by around 2.6 million which gives an indication that quayside crane planning and development is not at an optimal level.

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Category</th>
<th>Unit Increase</th>
<th>TEU increases/ (decreases) by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dutch GDP</td>
<td>Economy</td>
<td>1 Million Euro</td>
<td>24</td>
</tr>
<tr>
<td>Terminal Area</td>
<td>Terminal</td>
<td>1 Hectare</td>
<td>177,099</td>
</tr>
<tr>
<td>Quayside Cranes</td>
<td>Terminal</td>
<td>1 Nos</td>
<td>(2,616,561)</td>
</tr>
<tr>
<td>Terminal Capacity</td>
<td>Terminal</td>
<td>1 TEU</td>
<td>5</td>
</tr>
<tr>
<td>Container vessels calling at port</td>
<td>Shipping Companies</td>
<td>1 vessel</td>
<td>544</td>
</tr>
<tr>
<td>Inland Waterways</td>
<td>Inland Transport</td>
<td>1 Thousand Tonnes</td>
<td>144</td>
</tr>
</tbody>
</table>
Analysis of simple regression results and multi regression model with port strategy of the Port of Rotterdam

The literature that has been referred to extensively in this section is the “Port Vision 2030 – Port Compass” of the Port of Rotterdam Authority.

Inland Transport

Under its Vision 2030 Plan, the Port of Rotterdam Authority has expansion of the European network of inland hubs as well as rail and inland shipping infrastructure (Port of Rotterdam, 2011) as one of the main areas for attention. From the simple regression results it is noted that both inland waterways (R square 93.05%) and rail transport (R square of 54.36%) show a positive linear relationship to container port throughput. As per the multi regression model for inland transport (table 41) also both these modes have a positive relationship though only inland waterways is significant. In view of the overall observations, this strategy should be pursued as it would have positive impact on the container port throughput.

Roadways:

Another objective of the Vision Plan 2030 is the energetic expansion of the national road network, including the Blankenburg tunnel and A4 South motorway (Port of Rotterdam, 2011). This plan should not be funded by Port Authority of Port of Rotterdam as from the simple regression results, the linear relationship of motorway length and load factor is weak to container throughput (R square 23.59%). Also, as per the multi regression model for Inland Transport road transport though shows a positive relationship is not significant.

Regarding motorways, there are several objectives as well in the Port Vision 2030 Plan. It mentions that on the north-eastern edge of Rotterdam, the A13-A16 must be constructed before 2020, and following that, the capacity of the Van Brieneenoord corridor must be increased: if the east side of the ring route deadlocks, the accessibility of the port via the A15 and in a north-easterly direction will be impacted negatively (Port of Rotterdam, 2011).

Further it also mentions that the A4 South must be constructed between 2020 and 2030, to relieve the ring road and secure a robust north-south connection (Port of Rotterdam, 2011). This route is the last missing link in the direct Rotterdam-Antwerp connection (Port of Rotterdam, 2011). The A4 South Rotterdam Antwerp Connection would increase the reach of the Netherlands to Belgium which though not its dominant hinterland region, could allow it to increase its presence there.

It may be noted here that though motorways is not linearly related to container port throughput, it may be a necessity to invest in these projects. As such it is advisable to include private players to invest in these projects allowing the budget of the Port of Rotterdam to be utilized in areas that improve its competitiveness of its port throughput.

Inland waterways:
Another plan is the construction of the Seine-Nord Europe Canal that will bring Northern France within reach as a new inland shipping market in about 2020 (Port of Rotterdam, 2011). This is a welcome plan as from the simple regression results it was observed that inland transport has a strong linear relationship to container port throughput (R square 93%). Also as per the multi regression model, inland waterways has a positive relationship and is significant. Further, the construction of the Canal provides the opportunity for the Port of Rotterdam to extend its hinterland to France.

Next, the development of inland shipping terminals at Alphen aan den Rijn and Alblasserdam (transfer hub) is also a measure under the Port Vision 2030 plan (Port of Rotterdam, 2011). These measures should be actively pursued by the Port of Rotterdam based on the favourable results of the simple and multiple regression model which produced a strong linear relationship between container throughput and inland waterways load factor.

Other measures under the Port Vision 2030 plan includes the operationalization of the Blankenburg tunnel that will have to go into service before 2020 (Port of Rotterdam, 2011). This tunnel is closer to the Benelux tunnel and will therefore provide a considerably better traffic flow on the ring road than the alternative Oranje tunnel (Port of Rotterdam, 2011). The Port of Rotterdam Authority feels that the Oranje tunnel would be particularly useful in connecting the port and the Greenport and for the spatial-economic development of the coastal area. Construction of the Oranje tunnel around 2030 would be opportune for the port. Based on the simple regression results and multi regression model both these strategies would be ideal for the competitiveness of the Port of Rotterdam as inland waterways in strongly linearly related to container port throughput of the Port of Rotterdam. As such either or both could be selected. (Port of Rotterdam, 2011)

The Port Vision 2030 also mentions that the Volkerak and Kreekrak lock capacity on the inland shipping route between Rotterdam and Antwerp would require increasing, because of the growth in cargo shipped between the two ports and the construction of the Seine-Nord link (Port of Rotterdam, 2011). This will open up the Paris region for inland shipping, significantly increasing the potential of the sector (Port of Rotterdam, 2011). This measure should be actively pursued by the Port of Rotterdam. The regression results show that inland waterways is strongly related to container throughput. Further, the inland shipping route would also allow the Netherlands to extend its hinterland region to Belgium.

Railways:

The port Vision plan also mentions that in order to facilitate further growth in rail transport, the government’s High-Frequency Rail Programme must be implemented on schedule (Port of Rotterdam, 2011). This will secure the freight capacity on the rail corridors to the North of the Netherlands, Germany, Belgium and France (Port of Rotterdam, 2011). This strategy should be actively pursued as railways is positively linearly related to container port throughput of the Port of Rotterdam (R square 54.36%)

Also mentioned in the Vision 2030 Plan is the plan for the connection of the Betuweroute to the German railway system, improvement of East-west connections to realise good connections to Central Europe and attention to the rail corridors to Switzerland and Italy (Port of Rotterdam, 2011). These should be actively pursued as
it would strengthen the access of the Port of Rotterdam to its current dominant hinterland regions of Germany and Switzerland.

Realizing a modal shift:

The Port Vision 2030 has advised to change the modal split of inland transport. It prefers more transport by water and rail, less by road. The aim for 2030 is a maximum 35% of containers transported to and from the Maasvlakte by road (Port of Rotterdam, 2011). Currently, it stands at 47% (Port of Rotterdam, 2011). This modal split change calls for a substantial improvement in the quality of transport by rail and inland waterway. It would require the use of high-frequency permanent shuttles between maritime and inland terminals.. (Port of Rotterdam, 2011).

The results of the simple regression and multi regression model are favourable to implement this change and will bear positive results on container port throughput of the Port of Rotterdam. The following table 45 shows that if containers are reduced from roadways and absorbed by railways and inland waterways the container throughput would increase by 876,752 TEU's, i.e. an increase of 6.65%

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>8,035,009</td>
<td>1</td>
<td>8,035,009</td>
</tr>
<tr>
<td>Motorways (Ttonnes)</td>
<td>8.506</td>
<td>35,843</td>
<td>304,879</td>
</tr>
<tr>
<td>Railways (Ttonnes)</td>
<td>27.78</td>
<td>17,046</td>
<td>473,530</td>
</tr>
<tr>
<td>Inland Waterways (Ttonnes)</td>
<td>143.8</td>
<td>49,519</td>
<td>7,120,900</td>
</tr>
<tr>
<td>Short Sea Shipping (Ttonnes)</td>
<td>-81.3</td>
<td>33,943</td>
<td>(2,759,566)</td>
</tr>
<tr>
<td>Throughput as per multi regression model</td>
<td></td>
<td></td>
<td>13,174,752</td>
</tr>
<tr>
<td>Recorded throughput in 2014</td>
<td></td>
<td></td>
<td>12,298,000</td>
</tr>
<tr>
<td>Increase in TEU</td>
<td></td>
<td></td>
<td>876,752</td>
</tr>
</tbody>
</table>

**Table 45**

Impact of inland transport modal split on container throughput as per Port of Rotterdam Vision 2030

Investment in Port Infrastructure

From the Port Vision 2030 plan it was noticed that the (central) government and the Port Authority will be investing heavily upto 2030. Private investments is also being made which would be around € 25 to € 35 billion for the same period and the central government will invest € 5 to € 6 billion (Port of Rotterdam, 2011). This money will be invested mainly in infrastructure to maintain accessibility, which is not only important for the port (Port of Rotterdam, 2011).
In concrete terms, the projects that would be included are the widening of the A15 motorway between Maasvlakte and Vaanplein, the construction of a tunnel beneath the Nieuwe Waterweg, the construction of the A4 South, solving the Caland rail bridge bottleneck, increasing the capacity of the Volkerak and Kreekrak locks, solving other inland waterway bottlenecks in the Netherlands, and implementation of the High-Frequency Rail Programme. (Port of Rotterdam, 2011)

In the period up to 2030, the Port Authority will invest €5 to €6 billion where around €2 billion of this is earmarked for completing and developing Maasvlakte 2, and €3 to €4 billion for investment in the existing ports of Rotterdam, Dordrecht and Moerdijk (Port of Rotterdam, 2011). This involves public infrastructure such as roads, docks and berths, and more customer-specific infrastructure such as quays, jetties, pipelines and site restructuring (Port of Rotterdam, 2011). Investments to boost the hinterland network also form part of this. (Port of Rotterdam, 2011).

As observed from the regression model, investment in inland waterways and railways would be fruitful while for motorways it would not.

The Port Authority will also be investing in public space, safety (including a car park with facilities for truckers) and ground decontamination in Waalhaven East, Waalhaven South and on Sluisjesdijk (Port of Rotterdam, 2011).

The amount of money that is being invested in these projects is appreciable, though as per the results of the regression model, it is observed that they would not have a positive linear relationship with container port throughout. One of the reasons would be that investment amount includes areas that would not contribute to port throughput directly such as car parking facilities, facilities for truckers, ground decontamination facility etc. It would be advisable for private players to invest in these projects.

Labour

The Port Vision 2030 also mentions strategies relating to labour. These include long-term work-study programmes focusing on technical and logistics skills, policies geared towards enthusing and recruiting special target groups, facilitating state of the art educational facilities for technical and port related schools. (Port of Rotterdam, 2011)

Investments are being made in academic chairs for port studies at the universities of Rotterdam and Delft and lectureships at the Rotterdam colleges of higher professional education (Port of Rotterdam, 2011). Further partnerships between universities and technical colleges are reinforced (Port of Rotterdam, 2011).

The results of the simple regression model do not show a positive linear relationship between productivity of labour and container port throughput. Further, labour is not included as a determinant in the multi regression model. As such it is advisable for the Port Authority to pursue only those labour strategies that are not financial intensive.

Hinterland

The Port Vision 2030 plan includes the strategy of integration of the Antwerp and the Rotterdam industrial clusters that offers advantages to businesses in Antwerp and
Rotterdam, as they can produce more efficiently (Port of Rotterdam, 2011). If further mentions that without this integration, efficiency-related advantages will not be as great, making it harder for both ports to attract investments. (Port of Rotterdam, 2011). It may noted here that one of the dominant hinterland regions for the Port of Antwerp is the Netherlands, while Belgium is not a dominant hinterland region for the Port of Rotterdam. As such while this strategy would pose several opportunities for the Port of Rotterdam to extend its hinterland region to Belgium, it could also allow the Port of Antwerp to compete more intensively in the Netherlands, thereby adversely impacting the Port of Rotterdam’s container throughput.

Another plan under the Vision 2030 is the development of more extended gates in the hinterland, enabling administrations to take place at multiple locations (Port of Rotterdam, 2011). This strategy should increase the operational efficiency in the hinterland regions and as such will have a positive impact on the container throughput. As such it should be pursued.

**Container vessel Traffic**

As per the literature review it was found that Rotterdam is one of the most central and accessible turntables in the global container liner service network. As per the multi regression model, container vessel traffic has a positive impact and is significant, though simple linear regression showed weak correlation (R square 43.48%) to container port throughput.

The Port Vision 2030 includes measures to stimulate the use of terrain, quays and jetties by multiple companies (Port of Rotterdam, 2011). It further has plans to optimise the calling of sea going vessels in Rotterdam, by directing sailing speeds at sea (from Gibraltar) (Port of Rotterdam, 2011). As such the aforementioned measures should make the linear relationship stronger and this would have a better positive impact on the Port of Rotterdam’s container throughput.

**Conclusion**

Based on the analysis of the Port of Rotterdam it is observed that the significant determinants of its container throughput are its terminal area, terminal capacity, Dutch GDP and container vessels that call at its port. All of these determinants have a positive impact. On the other hand, quayside cranes is a significant determinant, though having a negative impact.

Other variables which are the determinants of the Port of Rotterdam are quay length & Dutch imports which have a positive relationship and Dutch exports which has a negative relationship to container throughput.

With respect to the port strategies of the Port of Rotterdam, it is observed from the simple regression results and multi regression model that the strategy with respect to expansion of the European network of inland hubs as well as rail and inland shipping infrastructure should be pursued as it would have positive impact on the container port throughput.

With respect to inland waterways, the strategy of construction of the Seine-Nord Europe Canal should be pursued (and funded by the port authority of Port of Rotterdam it needed be) as inland transport is a significant determinant of the
container throughput of the Port of Rotterdam which has as positive impact on the throughput. Other inland waterways projects such as (a) development of inland shipping terminals at Alphen aan den Rijn and Alblasserdam, (b) operationalization of the Blankenburg tunnel or Oranje tunnel and (c) increasing Volkerak and Kreekrak lock capacity should be actively pursued by the Port of Rotterdam as it will have a positive impact on its container throughput.

With respect to railways the projects are implemented by the Government. The simple regression results show that railways (load actor) has a medium correlation to container throughput. Based on this result the projects should have a positive impact on throughput. However, the multi regression model, though found railways (load factor) as determinant did not find it significant and as such its impact cannot be determined.

Further, the strategy with respect to its roadways such as (a) expansion of national road network, the Blankenburg tunnel & A4 South motorway, (b) construction of A4 South & A13-A16 and (c) increase in capacity of Van Brienenoord corridor should not be funded by Port Authority of Port of Rotterdam as it would not impact the throughput positively.

The modal shift plan to decrease the load carried by roadways from the current 47% to proposed 35% is a favourable strategy as per the multi regression model (inland transport and short sea shipping) as the same would increase throughput by 6.65%.

Investment in port infrastructure had disappointing results. The simple regression result did not show a linear relationship between investment in port infrastructure and throughput. Further the multi regression model did not include investment in port infrastructure as a determinant. These results give an insight into port infrastructure investment planning and shows that it has not been ‘optimal’.

With respect to labour, the results of the simple regression model do not show a positive linear relationship between productivity of labour and container port throughput. Further, labour is not included as a determinant in the multi regression model. As such it is advisable for the Port Authority to pursue only those labour strategies that are not financial intensive.

Based on the simple regression results, strategies with respect to development of more extended gates in the hinterland should have a positive impact on throughput. The integration of the Antwerp and the Rotterdam industrial clusters should be implement carefully as this might benefit the Port of Antwerp at cost of Port of Rotterdam’s container throughput interests.

Finally strategies to invite more container shipping companies such as (a) stimulating the use of terrain, quays and jetties by multiple companies and (b) optimize the calling of sea going vessels in Rotterdam, by directing sailing speeds at sea (from Gibraltar) will have a positive impact on container throughput as simple regression result show a positive linear relationship and multi regression model shows container vessels that call at the Port of Rotterdam are a positive significant determinant.
6. Conclusion

6.1 Answering the research questions

Based on the literature review and results of the regression model, it is observed that the determinants of container port throughput of the Port of Antwerp, Port of Hamburg, Port of Le Havre and Port of Rotterdam are unique and varied.

For the Port of Antwerp, 10 variables formed the determinants of its container throughput out of which 6 were found significant comprising of 4 positive determinants and 2 negative determinants. It was interesting to observe that the hinterland regions of France and Switzerland are important for the container throughput of Port of Antwerp. It was surprising to see that none of the terminal variables formed part of the variable set that determine throughput. It was also observed that investment in port infrastructure was a determinant for throughput but was found to be insignificant. Among inland transport variables short sea shipping and road transport were found to be significant.

For the Port of Hamburg, 10 variables also formed the determinants of its container throughput out of which again 6 were found to be significant comprising however of only 2 positive determinants and 4 negative determinants. It was interesting to observe that Slovak Republic exports and Czech imports were found to be important hinterland regions for the Port of Hamburg thought however both being significant has a negative impact on throughput. It was further interesting to observe that unlike the Port of Antwerp, Port of Hamburg had two variables from the terminal category that determine its container throughput. Container terminal area was found to have a positive impact while quay length of terminals was found to have a negative impact. Further, the container vessels that call at the Port of Hamburg, though a significant determinant was found to have a negative impact. This differs from the Port of Antwerp, for whom it has a positive impact. However, investment in port infrastructure, though a determinant was found to be insignificant similar to the Port of Antwerp. Among inland transport variables inland waterways, railways and short sea shipping were found to be significant though inland waterways showed a negative impact. Roadways was found to be an insignificant variable which differs from Port of Antwerp where it was a significant determinant.

The Port of Le Havre returned with only 5 variables that determine its container throughput out which 3 were found to be significant and 2 insignificant. The results showed that all variables of the economy, i.e. French GDP, exports and imports are significant determinants though French imports has a negative impact. Similar to Port of Antwerp and Port of Hamburg, investment in port infrastructure was found to be an insignificant determinant. It was surprising to see that the multi regression model for inland transport resulted as invalid. This was not the case for any of the other three ports.

Finally, for the Port of Rotterdam, 8 variables were found to determine its container throughput, 5 out which were significant and 3 insignificant. It was interesting to note that all four terminal variables determine the throughput, though only 3 are significant, i.e. terminal area and terminal capacity both having a positive impact while quayside cranes has a negative impact. Also, as compared to Port of Antwerp container vessels
that call at the Port of Rotterdam has a positive impact and is significant. It was surprising to note that unlike the other three ports, investment in port infrastructure was not found to be a determinant of the container throughput of the Port of Rotterdam. Among the inland transport variables and short sea shipping, all were determinants though only inland waterways showed a positive significant relationship.

There were common observations also. The GDP for all four ports was a positive determinant though for the Port of Hamburg it was found to be insignificant.

Another observation was that imports and exports of the home country of the port were found to be determinants for all ports except Port of Antwerp which would imply for the later that its hinterland region then becomes very important for its throughput.

The study also showed that there is a good potential to further develop short sea shipping as it has a positive impact on the container port throughput for two of the three leading container ports i.e. Port of Antwerp and Port of Hamburg.

While the results for the Port of Le Havre were less impressive compared to its rivals there is a potential for it to be modeled as a transshipment port. The reason for this are two. Firstly, its natural hinterland has been captured by rival ports. Further, most of the industrial development on the port site is not linked to port activities or Le Havre’s local economic structure. Secondly, its position as the first port of arrival and the last port of departure in the North-European range makes it a convenient port for transshipment.

The most interesting observation from this study was that investment in port infrastructure was found to be an insignificant determinant (positive though) for three ports, i.e. Port of Antwerp, Port of Hamburg and Port of Le Havre. For the Port of Rotterdam it did not show as a determinant. The reasons for this could be several. Investment in port infrastructure takes many years to reap benefits and as such this time distorts the linear relationship between port and investment. Hence, it appears that investment in ports are not optimal or not in areas that would positively impact the container port throughput of the port. It would be advisable for ports to understand their main determinants of container throughput and only invest in them. For other areas of the port infrastructure, private players should be invited thereby saving scarce financial resources of the port.

With regard to the regression model it was found that it is useful tool in ascertaining the determinants of container throughput and analyzing the strategies of ports along with the results.

6.2 Limitations of the study

There have been several limitations of this study. Firstly, there would be many more determinants which impact the container port throughput which has not been tested here. For example, berth productivity and crane productivity are extremely important which could not be tested due to unavailability of date in public sources.

Other factors include the presence of organized labour forces, i.e. trade unions, customs procedures, port policy, domestic legislations and regulations, enforcement level, political stability and environmental aspects. A thorough qualitative review would need to be done and quantified and tested using the regression model.
Secondly, it would be important to test the determinants using different econometric models and compare the results for greater accuracy and usefulness. However, the regression model proves that it is useful in testing the existence of linear relationship between determinants of container port throughput.

Lastly studies should be made regarding future determinants of container port throughput and have them quantified. The regression model could then be tested to see its impact on container port throughput.

6.3 Suggestion for future studies

Future studies is suggested to be made in the field of determinants of information technology and automation on container port throughput. This is because as information technology is replacing labour and several other systems which would impact the ports. Further, port community systems seeks to integrate the port complex and stakeholders into one large business family. All these factors would impact port throughput. It would be important to conduct a qualitative research on these factors and quantify its future impact to enable better decision making and planning today.
Bibliography


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Hilde Meersman, E. V. d. V. T. V., 2016. Port competitiveness now and in the future: What are the issues and challenges?, Belgium: s.n.

Huybrechts, M. V. V. H. V. a. W., 2002. Port Competitiveness, an economic and legal analysis of the factors determining the competitiveness of seaports, s.l.: s.n.


Joly, P. T. a. O., 2006. Port Competition in the Northern Range from Le Havre to Hamburg, Le Havre: s.n.


Appendix:

Port of Antwerp – Minitab Results
Simple Regression: TEU versus Quay length (meter)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
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Model Summary

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td></td>
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Coefficients

<table>
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<td>Quay length (meter)</td>
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Regression Equation

\[ TEU = 2814198 + 518.43 \text{ Quay length (meter)} \]

Fits and Diagnostics for Unusual Observations

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<tr>
<th>Obs</th>
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*R Large residual*
Simple Regression: TEU versus Terminal Area (ha)

Analysis of Variance

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Model Summary

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Coefficients

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Regression Equation

TEU = 3017222 + 8128.9 Terminal Area (ha)

Fits and Diagnostics for Unusual Observations

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R Large residual
Simple Regression: TEU versus Number of cranes

Analysis of Variance

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Model Summary

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Coefficients

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Regression Equation

TEU = 2742756 + 78140 Number of cranes

Fits and Diagnostics for Unusual Observations

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R Large residual
Simple Regression: TEU versus Container Capacity (TEU)

Analysis of Variance

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Model Summary

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Coefficients

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Regression Equation

TEU = 2903819 + 0.36122 Container Capacity (TEU)

Fits and Diagnostics for Unusual Observations

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R Large residual
Simple Regression: TEU versus Labour Productivity Index

Analysis of Variance

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Model Summary

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<th>S</th>
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Coefficients

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</table>

Regression Equation

TEU = 7558857 − 641418 Labour Productivity Index
Simple Regression: TEU versus BEL GDP (MLN EUR)

Analysis of Variance

<table>
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Model Summary

<table>
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<tbody>
<tr>
<td>611008</td>
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Coefficients

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<td>12.24</td>
<td>&lt;0.0001</td>
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Regression Equation

TEU = -2651622 + 27.777 BEL GDP (MLN EUR)
Simple Regression: TEU versus BEL Export (MLN EUR)

Analysis of Variance

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<td>6.15125E+13</td>
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Model Summary

\[
S = 818626 \quad R^2 = 90.67\% \quad R^2 \text{adj} = 90.03\%
\]

Coefficients

<table>
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<tr>
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Regression Equation

\[\text{TEU} = 1126710 + 18.382 \times \text{BEL Export (MLN EUR)}\]

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
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<th>Resid</th>
<th>Std Resid</th>
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<td>1947191</td>
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*R Large residual*
Simple Regression: TEU versus BEL Import (MLN EUR)

Analysis of Variance

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<th>Adj MS</th>
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Model Summary

- S: 859965
- R-sq: 69.38%
- R-sq(adj): 68.87%

Coefficients

<table>
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Regression Equation

TEU = 1425215 + 18.268 BEL Import (MLN EUR)

Fits and Diagnostics for Unusual Observations

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R Large residual
Simple Regression: TEU versus Container Traffic (calling)

Analysis of Variance

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Model Summary

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Coefficients

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Regression Equation

TEU = -4310657 + 2973.5 Container Traffic (calling)
Simple Regression: TEU versus Sea Infra Invest (EUR)

Analysis of Variance

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</table>

Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1921919</td>
<td>9.93%</td>
<td>3.92%</td>
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Coefficients

<table>
<thead>
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<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
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<tbody>
<tr>
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<td>2889620</td>
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<td>0.2681</td>
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<td>Sea Infra Invest (EUR)</td>
<td>0.01849</td>
<td>0.01437</td>
<td>1.29</td>
<td>0.2180</td>
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Regression Equation

TEU = 3322359 + 0.01849 Sea Infra Invest (EUR)
Simple Regression: TEU versus NLD Export (MLN EUR)

Analysis of Variance

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<tr>
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<th>P-Value</th>
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<tbody>
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<tr>
<td>Total</td>
<td>16</td>
<td>6.15125E+13</td>
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Model Summary

<table>
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<td>92.44%</td>
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Coefficients

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<td>NLD Export (MLN EUR)</td>
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Regression Equation

TEU = 1668057 + 14.781 NLD Export (MLN EUR)

Fits and Diagnostics for Unusual Observations

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<th>TEU</th>
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<tr>
<td>17</td>
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<td>7946582</td>
<td>1707418</td>
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R Large residual
Simple Regression: TEU versus NLD Import (MLN EUR)

Analysis of Variance

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Model Summary

<table>
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<td>580149</td>
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Coefficients

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<td>NLD Import (MLN EUR)</td>
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</table>

Regression Equation

TEU = 1639112 + 16.544 NLD Import (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
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R Large residual
Simple Regression: TEU versus DEU Export (MLN EUR)

Analysis of Variance

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<tr>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<tbody>
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<td>447663</td>
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Coefficients

<table>
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<tr>
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<tbody>
<tr>
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<td>352377</td>
<td>3.58</td>
<td>0.0027</td>
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<tr>
<td>DEU Export (MLN EUR)</td>
<td>5.8783</td>
<td>0.3440</td>
<td>17.09</td>
<td>&lt;0.0001</td>
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Regression Equation

TEU = 1261953 + 5.8783 DEU Export (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
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<tr>
<th>Obs</th>
<th>TEU</th>
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<td>1349442</td>
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R Large residual
Simple Regression: TEU versus DEU Import (MLN EUR)

Analysis of Variance

<table>
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Model Summary

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<td>92.84%</td>
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Coefficients

<table>
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<th>P-Value</th>
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<td>0.0118</td>
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Regression Equation

TEU = 1241159 + 7.1809 DEU Import (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
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* R Large residual
Simple Regression: TEU versus CHE Export (MLN EUR)

Analysis of Variance

<table>
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Model Summary

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>985314</td>
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<td>74.18%</td>
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Coefficients

<table>
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<tbody>
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</table>

Regression Equation

TEU = 3574210 + 20.873 CHE Export (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
<th>R Large residual</th>
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</thead>
<tbody>
<tr>
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</table>

R Large residual
Simple Regression: TEU versus CHE Import (MLN EUR)

Analysis of Variance

<table>
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<tr>
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<th>P-Value</th>
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<td>6.15125E+13</td>
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Model Summary

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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1038566</td>
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Coefficients

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<tbody>
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<tr>
<td>CHE Import (MLN EUR)</td>
<td>23.808</td>
<td>3.672</td>
<td>6.48</td>
<td>&lt;0.0001</td>
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</table>

Regression Equation

TEU = 3401076 + 23.808 CHE Import (MLN EUR)
Simple Regression: TEU versus FRA Export (MLN EUR)

Analysis of Variance

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<tr>
<th>Source</th>
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Model Summary

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<th></th>
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<tr>
<td></td>
<td>397900</td>
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Coefficients

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Regression Equation

TEU = -759320 + 18.6869 FRA Export (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
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<tr>
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<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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R Large residual
Simple Regression: TEU versus FRA Import (MLN EUR)

Analysis of Variance

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<th>Adj MS</th>
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Model Summary

<table>
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<tbody>
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<td>94.92%</td>
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Coefficients

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<th>P-Value</th>
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</tbody>
</table>

Regression Equation

TEU = 707115 + 13.4864 FRA Import (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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<tr>
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</table>

R Large residual
Simple Regression: BEL TEU versus BEL Road TT – Tonne

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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Model Summary

- R-sq: 24.70%
- R-sq(adj): 13.95%

Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
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<th>P-Value</th>
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<tr>
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<td>3552081</td>
<td>0.82</td>
<td>0.4407</td>
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<td>BEL Road TT - Tonne</td>
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<td>158.6</td>
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Regression Equation

BEL TEU = 2902866 + 240.4 BEL Road TT - Tonne

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>BEL TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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</table>

R Large residual
Simple Regression: BEL TEU versus BEL IW TT - Tonne

### Analysis of Variance

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<tr>
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<th>DF</th>
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<th>Adj MS</th>
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<tr>
<td>Total</td>
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<td>3.57306E+12</td>
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### Model Summary

- $S$: 827135
- R-sq: 22.95%
- R-sq(adj): 11.94%

### Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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<td>BEL IW TT - Tonne</td>
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</table>

### Regression Equation

BEL TEU = 7390853 + 40.27 BEL IW TT - Tonne
Simple Regression: BEL TEU versus PoAtwp SSS TT-Tonne

Analysis of Variance

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Model Summary

- $S = 452385$
- $R^2 = 59.91\%$
- $R^2(adj) = 54.18\%$

Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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<tbody>
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Regression Equation

BEL TEU = 5244818 + 82.08 PoAtwp SSS TT-Tonne

Fits and Diagnostics for Unusual Observations

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<thead>
<tr>
<th>Obs</th>
<th>BEL TEU</th>
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<th>Resid</th>
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R Large residual
Port of Hamburg Minitab results
Simple Regression: TEU versus Quay Length (meter)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
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<th>Adj MS</th>
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Model Summary

<table>
<thead>
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<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1413437</td>
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<td>39.26%</td>
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Coefficients

<table>
<thead>
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<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1711705</td>
<td>1897684</td>
<td>0.90</td>
<td>0.3823</td>
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<td>Quay Length (meter)</td>
<td>1044.2</td>
<td>319.3</td>
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Regression Equation

TEU = 1711705 + 1044.2 Quay Length (meter)
Simple Regression: TEU versus Terminal Area (ha)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
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<th>Adj MS</th>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1445058</td>
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<td>36.52%</td>
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Coefficients

<table>
<thead>
<tr>
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<th>P-Value</th>
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</thead>
<tbody>
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<td>1563353</td>
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<tr>
<td>Terminal Area (ha)</td>
<td>15735</td>
<td>5071</td>
<td>3.10</td>
<td>0.0078</td>
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Regression Equation

TEU = 3089191 + 15735 Terminal Area (ha)
Simple Regression: TEU versus No of Quayside Cranes

Analysis of Variance

<table>
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<tr>
<th>Source</th>
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Model Summary

<table>
<thead>
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<th>S</th>
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<th>R-sq(adj)</th>
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Coefficients

<table>
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<tbody>
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<td>95447</td>
<td>29404</td>
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<td>0.0059</td>
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Regression Equation

TEU = 1999456 + 95447 No of Quayside Cranes
Simple Regression: TEU versus Container Capacity (TEU)

Analysis of Variance

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<tr>
<th>Source</th>
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<th>Adj MS</th>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
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<tbody>
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Coefficients

<table>
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<td>1.65</td>
<td>0.1218</td>
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Regression Equation

TEU = 2603631 + 0.5312 Container Capacity (TEU)
Simple Regression: TEU versus Labour Productivity Index

Analysis of Variance

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</table>

Model Summary

S: 1819943  R-sq: 6.02%  R-sq(adj): 0.00%

Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
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<th>P-Value</th>
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<td>Labour Productivity Index</td>
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<td>-0.95</td>
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</table>

Regression Equation

TEU = 8193601 - 351093 Labour Productivity Index

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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X: Unusual X
Simple Regression: TEU versus DEU GDP (MLN EUR)

Analysis of Variance

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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1082635</td>
<td>66.74%</td>
<td>64.37%</td>
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Coefficients

<table>
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<th>P-Value</th>
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<tbody>
<tr>
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<td>0.8604</td>
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<td>DEU GDP (MLN EUR)</td>
<td>2.9992</td>
<td>0.5658</td>
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</table>

Regression Equation

\[\text{TEU} = -277575 + 2.9992 \times \text{DEU GDP (MLN EUR)}\]
Simple Regression: TEU versus DEU Export (MLN EUR)

Analysis of Variance

<table>
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Model Summary

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<tr>
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<td>S</td>
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Coefficients

<table>
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<tbody>
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<td>554337</td>
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<td>0.0011</td>
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<td>DEU Export (MLN EUR)</td>
<td>5.5042</td>
<td>0.5286</td>
<td>10.41</td>
<td>&lt;0.0001</td>
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</table>

Regression Equation

TEU = 2279256 + 5.5042 DEU Export (MLN EUR)
### Simple Regression: TEU versus DEU Import (MLN EUR)

#### Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
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<th>Adj MS</th>
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<th>P-Value</th>
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#### Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<tbody>
<tr>
<td>749939</td>
<td>94.04%</td>
<td>92.90%</td>
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#### Coefficients

<table>
<thead>
<tr>
<th>Term</th>
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<th>P-Value</th>
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<td>DEU Import (MLN EUR)</td>
<td>6.5783</td>
<td>0.7661</td>
<td>8.59</td>
<td>&lt;0.0001</td>
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</table>

#### Regression Equation

\[
\text{TEU} = 2389629 + 6.5783 \times \text{DEU Import (MLN EUR)}
\]
Simple Regression: TEU versus Container Traffic (calling)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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<td>4.93401E+13</td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1856789</td>
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<td>0.00%</td>
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Coefficients

<table>
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<tr>
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<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.0014</td>
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<td>0.5859</td>
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</tbody>
</table>

Regression Equation

TEU = 9050269 – 208.3 Container Traffic (calling)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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<tbody>
<tr>
<td>1</td>
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<td>7851792</td>
<td>-3603792</td>
<td>-2.01 R</td>
</tr>
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<td>5</td>
<td>7003000</td>
<td>7189616</td>
<td>-186816</td>
<td>-0.13 X</td>
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R Large residual
X Unusual X
Simple Regression: TEU versus Investment in Sea Infrastructure

Analysis of Variance

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<tr>
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<th>Adj SS</th>
<th>Adj MS</th>
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<tbody>
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<tr>
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<td>3.48085E+12</td>
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<tr>
<td>Total</td>
<td>15</td>
<td>4.93401E+13</td>
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Model Summary

<table>
<thead>
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<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1865705</td>
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<td>0.00%</td>
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Coefficients

<table>
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<th>T-Value</th>
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<tbody>
<tr>
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<td>1747730</td>
<td>4.07</td>
<td>0.0012</td>
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<td>Investment in Sea Infrastructure</td>
<td>0.001048</td>
<td>0.002508</td>
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</table>

Regression Equation

TEU = 7105810 + 0.001048 Investment in Sea Infrastructure
Simple Regression: TEU versus CHE Export (MLN EUR)

Analysis of Variance

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Model Summary

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<td></td>
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Coefficients

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<td>744794</td>
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<td>CHE Export (MLN EUR)</td>
<td>16.724</td>
<td>3.992</td>
<td>4.19</td>
<td>0.0009</td>
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</table>

Regression Equation

TEU = 4977682 + 16.724 CHE Export (MLN EUR)
Simple Regression: TEU versus CHE Import (MLN EUR)

Analysis of Variance

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<td>4.93401E+13</td>
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</table>

Model Summary

- $S$: 1255630
- $R^2$: 55.28%
- $R^2_{adj}$: 52.07%

Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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</thead>
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<td>19.278</td>
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<td>4.16</td>
<td>0.0010</td>
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Regression Equation

$TEU = 4808792 + 19.278 \text{ CHE Import (MLN EUR)}$
Simple Regression: TEU versus AUT Export (MLN EUR)

Analysis of Variance

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<tr>
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Model Summary

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<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>554199</td>
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<td>90.66%</td>
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Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
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<td>501906</td>
<td>3.92</td>
<td>0.0015</td>
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<tr>
<td>AUT Export (MLN EUR)</td>
<td>50,172</td>
<td>4,143</td>
<td>12.11</td>
<td>&lt;0.0001</td>
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Regression Equation

TEU = 1968031 + 50.172 AUT Export (MLN EUR)
### Simple Regression: TEU versus AUT Import (MLN EUR)

#### Analysis of Variance

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#### Model Summary

<table>
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<tr>
<th></th>
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<td>86.10%</td>
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#### Coefficients

<table>
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<tbody>
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<td>607284</td>
<td>3.55</td>
<td>0.0032</td>
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<tr>
<td>AUT Import (MLN EUR)</td>
<td>47.124</td>
<td>4.892</td>
<td>9.69</td>
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**Regression Equation**

\[ TEU = 2156703 + 47.124 \text{ AUT Import (MLN EUR)} \]
Simple Regression: TEU versus SVK Rep Export (MLN EUR)

Analysis of Variance

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Model Summary

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<td>71.56%</td>
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Coefficients

<table>
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<td>SVK Rep Export (MLN EUR)</td>
<td>62.80</td>
<td>10.09</td>
<td>6.22</td>
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</table>

Regression Equation

\[ TEU = 4931523 + 62.80 \times \text{SVK Rep Export (MLN EUR)} \]
Simple Regression: TEU versus SVK Rep Import (MLN EUR)

Analysis of Variance

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<thead>
<tr>
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<th>Adj MS</th>
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<th>P-Value</th>
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Model Summary

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<tbody>
<tr>
<td>905648</td>
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Coefficients

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<th>P-Value</th>
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<tbody>
<tr>
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<td>514567</td>
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<td>SVK Rep Import (MLN EUR)</td>
<td>68.63</td>
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<td>6.81</td>
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Regression Equation

TEU = 4659876 + 68.63 SVK Rep Import (MLN EUR)
Simple Regression: TEU versus HUN Export (MLN EUR)

Analysis of Variance

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Model Summary

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<td>749124</td>
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Coefficients

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<tr>
<td>HUN Export (MLN EUR)</td>
<td>59.617</td>
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<td>8.60</td>
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Regression Equation

TEU = 3644290 + 59.617 HUN Export (MLN EUR)
Simple Regression: TEU versus HUN Import (MLN EUR)

Analysis of Variance

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Model Summary

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Coefficients

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<td>HUN Import (MLN EUR)</td>
<td>72.956</td>
<td>6.397</td>
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Regression Equation

TEU = 2843721 + 72.956 HUN Import (MLN EUR)
Simple Regression: TEU versus CZK Export (MLN EUR)

Analysis of Variance

<table>
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<tr>
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Model Summary

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Coefficients

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<th>P-Value</th>
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<td>472266</td>
<td>9.73</td>
<td>&lt;0.0001</td>
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<tr>
<td>CZK Export (MLN EUR)</td>
<td>39.389</td>
<td>5.195</td>
<td>7.58</td>
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</table>

Regression Equation

\[ \text{TEU} = 4594095 + 39.389 \text{ CZK Export (MLN EUR)} \]
Simple Regression: TEU versus CZK Import (MLN EUR)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
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<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>800927</td>
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<td>80.11%</td>
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Coefficients

<table>
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<th>Term</th>
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<th>SE Coef</th>
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<th>P-Value</th>
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<td>CZK Import (MLN EUR)</td>
<td>44.450</td>
<td>5.673</td>
<td>7.84</td>
<td>&lt;0.0001</td>
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</table>

Regression Equation

\[
\text{TEU} = 4231494 + 44.450 \times \text{CZK Import (MLN EUR)}
\]
Simple Regression: TEU versus POL Export (MLN EUR)

Analysis of Variance

<table>
<thead>
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<tr>
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<td>1.22265E+13</td>
<td>8.73320E+11</td>
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<td></td>
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<tr>
<td>Total</td>
<td>15</td>
<td>4.93401E+13</td>
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Model Summary

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<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>934516</td>
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Coefficients

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<td>9.06</td>
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<tr>
<td>POL Export (MLN EUR)</td>
<td>26.978</td>
<td>4.138</td>
<td>6.52</td>
<td>&lt;0.0001</td>
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Regression Equation

TEU = 4749075 + 26.978 POL Export (MLN EUR)
**Simple Regression: TEU versus POL Import (MLN EUR)**

### Analysis of Variance

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<tr>
<th>Source</th>
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<th>Adj MS</th>
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<tr>
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<td>7.37940E+11</td>
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<td>Total</td>
<td>15</td>
<td>4.93381E+13</td>
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### Model Summary

<table>
<thead>
<tr>
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<th>R-sq</th>
<th>R-sq(adj)</th>
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<tr>
<td></td>
<td>859510</td>
<td>79.09%</td>
<td>77.59%</td>
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### Coefficients

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<tbody>
<tr>
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<td>534520</td>
<td>7.95</td>
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<tr>
<td>POL Import (MLN EUR)</td>
<td>28.203</td>
<td>3.876</td>
<td>7.28</td>
<td>&lt;0.0001</td>
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### Regression Equation

\[ \text{TEU} = 4247829 + 28.203 \times \text{POL Import (MLN EUR)} \]
Simple Regression: TEU versus DEU Motorways (Kms)

Analysis of Variance

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<th>P-Value</th>
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<td>983033815457</td>
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<tr>
<td>Total</td>
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<td>7.09664E+12</td>
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Model Summary

<table>
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<tr>
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<th></th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>S</td>
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<td>3.03%</td>
<td>0.00%</td>
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Coefficients

<table>
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<th>Term</th>
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<th>T-Value</th>
<th>P-Value</th>
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<tbody>
<tr>
<td>Constant</td>
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<td>29969010</td>
<td>0.75</td>
<td>0.4693</td>
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<tr>
<td>DEU Motorways (Km)</td>
<td>-1096</td>
<td>2345</td>
<td>-0.47</td>
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</table>

Regression Equation

TEU = 22925518 – 1096 DEU Motorways (Kms)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>7008000</td>
<td>8877854</td>
<td>-1869854</td>
<td>-2.01 R</td>
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</tbody>
</table>

R Large residual
## Simple Regression: TEU versus PoHmbg SSS TT T Tonnes

### Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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<tbody>
<tr>
<td>Regression</td>
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<td>6.11E+12</td>
<td>6.11E+12</td>
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<td>0.0003</td>
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<td>Error</td>
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<td>9.84E+11</td>
<td>1.40E+11</td>
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<tr>
<td>Total</td>
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<td>7.06E+12</td>
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</tbody>
</table>

### Model Summary

- **S**: 374949
- **R-sq**: 66.13%
- **R-sq(adj)**: 84.15%

### Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3116295</td>
<td>888660</td>
<td>3.51</td>
<td>0.0099</td>
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<tr>
<td>PoHmbg SSS TT T Tonnes</td>
<td>242.23</td>
<td>36.74</td>
<td>6.59</td>
<td>0.0003</td>
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</tbody>
</table>

### Regression Equation

\[
\text{TEU} = 3116295 + 242.23 \times \text{PoHmbg SSS TT T Tonnes}
\]
Simple Regression: TEU versus DEU Railway Lines (Kms)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
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<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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<tbody>
<tr>
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<td>1.01136E+12</td>
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<td>Total</td>
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<td>7.09604E+12</td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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</thead>
<tbody>
<tr>
<td>1005666</td>
<td>0.23%</td>
<td>0.00%</td>
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Coefficients

<table>
<thead>
<tr>
<th>Term</th>
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<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
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<tbody>
<tr>
<td>Constant</td>
<td>-2997875</td>
<td>93317795</td>
<td>-0.03</td>
<td>0.9753</td>
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<tr>
<td>DEU Railway Lines (Kms)</td>
<td>314</td>
<td>2463</td>
<td>0.13</td>
<td>0.9020</td>
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Regression Equation

TEU = -2997875 + 314 DEU Railway Lines (Kms)

Fits and Diagnostics for Unusual Observations

<table>
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<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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</thead>
<tbody>
<tr>
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<td>7008000</td>
<td>8931876</td>
<td>-1923876</td>
<td>-2.04 R</td>
</tr>
</tbody>
</table>

* R Large residual
Simple Regression: TEU versus DEU RLY TT T Tonnes

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
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<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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<tbody>
<tr>
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<td>7.0960E+12</td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>888957</td>
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<td>14.87%</td>
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Coefficients

<table>
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<th>P-Value</th>
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<td>3197806</td>
<td>1.25</td>
<td>0.2527</td>
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<td>DEU RLY TT T Tonnes</td>
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<td>50.98</td>
<td>1.55</td>
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Regression Equation

TEU = 3986197 + 78.94 DEU RLY TT T Tonnes
Simple Regression: TEU versus DEU Navigable Canals (Kms)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
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<td>1.01232E+12</td>
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<td>7.09604E+12</td>
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<td></td>
<td></td>
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</tbody>
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Model Summary

- \( S \) = 1006142
- \( R^2 \) = 0.14%
- \( R^2(\text{adj}) \) = 0.00%

Coefficients

<table>
<thead>
<tr>
<th>Term</th>
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<tbody>
<tr>
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<td>1.16</td>
<td>0.2823</td>
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<td>DEU Navigable Canals (Kms)</td>
<td>334</td>
<td>3400</td>
<td>0.10</td>
<td>0.9244</td>
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Regression Equation

\[
\text{TEU} = 8223869 + 334 \times \text{DEU Navigable Canals (Kms)}
\]

Fits and Diagnostics for Unusual Observations

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<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
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<tr>
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</table>

R Large residual
Simple Regression: TEU versus DEU Navigable rivers (Kms)

Analysis of Variance

<table>
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<td>895012960469</td>
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Model Summary

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Coefficients

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<th>P-Value</th>
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<td>0.0614</td>
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Regression Equation

TEU = 15713013 – 1195 DEU Navigable rivers (Kms)

Fits and Diagnostics for Unusual Observations

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<th>Std Resid</th>
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<td>1386196</td>
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<td>8350804</td>
<td>-1342804</td>
<td>-2.00 R</td>
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R Large residual
Simple Regression: TEU versus DEU IW TT TToones

Analysis of Variance

<table>
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<tr>
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<td>2.80615E+12</td>
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<td>Total</td>
<td>8</td>
<td>7.09604E+12</td>
<td></td>
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Model Summary

<table>
<thead>
<tr>
<th></th>
<th>S</th>
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</tr>
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<tbody>
<tr>
<td></td>
<td>7.82541</td>
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<td>0.931%</td>
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Coefficients

<table>
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<th>P-Value</th>
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<tbody>
<tr>
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</table>

Regression Equation

TEU = 18252355 – 481.2 DEU IW TT TToones
Simple Regression: TEU versus DEU MW TT TTonnes

Analysis of Variance

<table>
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<tr>
<th>Source</th>
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<th>Adj MS</th>
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<th>P-Value</th>
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<tbody>
<tr>
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<td>6.27360E+10</td>
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<td>Error</td>
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<tr>
<td>Total</td>
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<td>7.09660E+12</td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1002376</td>
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<td>0.00%</td>
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</table>

Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
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<td>1094956</td>
<td>8.38</td>
<td>&lt;0.0001</td>
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<tr>
<td>DEU MW TT TTonnes</td>
<td>-1.225</td>
<td>4.904</td>
<td>-0.25</td>
<td>0.8099</td>
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</table>

Regression Equation

TEU = 9178000 – 1.225 DEU MW TT TTonnes

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>7008000</td>
<td>8899400</td>
<td>-1891400</td>
<td>-2.01 R</td>
</tr>
</tbody>
</table>

R Large residual
Port of Rotterdam Minitab results
Simple Regression: TEU versus Quay Length (meter) Cumulative

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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<tr>
<td>Total</td>
<td>18</td>
<td>1.10537E+14</td>
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</tbody>
</table>

Model Summary

- $S = 1138221$
- $R^2 = 80.08\%$
- $R_{adj}^2 = 78.90\%$

Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
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<tbody>
<tr>
<td>Constant</td>
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<td>0.1768</td>
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<tr>
<td>Quay Length (meter) Cumulative</td>
<td>1002.6</td>
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</table>

Regression Equation

$TEU = -1919974 + 1002.6 \text{ Quay Length (meter) Cumulative}$

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
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<tbody>
<tr>
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<td>12234535</td>
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R Large residual
X Unusual X
Simple Regression: TEU versus Terminal Area Cumulative (ha)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
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<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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Model Summary

<table>
<thead>
<tr>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1418048</td>
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Coefficients

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<th>Coef</th>
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<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
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<td>-0.81</td>
<td>0.4263</td>
</tr>
<tr>
<td>Terminal Area Cumulative (ha)</td>
<td>20298</td>
<td>3294</td>
<td>6.16</td>
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Regression Equation

TEU = -1420586 + 20298 Terminal Area Cumulative (ha)

Fits and Diagnostics for Unusual Observations

<table>
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<th>Obs</th>
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R Large residual
X Unusual X
Simple Regression: TEU versus No of Quayside Cranes cumulativ

Analysis of Variance

<table>
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<tr>
<th>Source</th>
<th>DF</th>
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<th>P-Value</th>
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<tbody>
<tr>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-se(aj)</th>
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</thead>
<tbody>
<tr>
<td>1259835</td>
<td>75.99%</td>
<td>74.15%</td>
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Coefficients

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<thead>
<tr>
<th>Term</th>
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<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
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<td>1511925</td>
<td>-1.08</td>
<td>0.2946</td>
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<tr>
<td>No of Quayside Cranes cumulativ</td>
<td>124961</td>
<td>17225</td>
<td>7.25</td>
<td>&lt;0.0001</td>
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</table>

Regression Equation

TEU = -1635007 + 124961 No of Quayside Cranes cumulativ

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
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R Large residual
X Unusual X
Simple Regression: TEU versus Cumulative Capacity Increase

Analysis of Variance

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Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1246575</td>
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<td>74.70%</td>
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Coefficients

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<tbody>
<tr>
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<td>0.0285</td>
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<td>Cumulative Capacity Increase</td>
<td>0.50709</td>
<td>0.00892</td>
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Regression Equation

TEU = 2319551 + 0.50709 Cumulative Capacity Increase

Fits and Diagnostics for Unusual Observations

<table>
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<th>Obs</th>
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X: Unusual
Simple Regression: TEU versus Labour Productivity Index

Analysis of Variance

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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
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<td>15.80%</td>
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Coefficients

<table>
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<th>T-Value</th>
<th>P-Value</th>
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<tbody>
<tr>
<td>Constant</td>
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<td>718385</td>
<td>14.15</td>
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<td>Labour Productivity Index</td>
<td>-890888</td>
<td>425777</td>
<td>-2.09</td>
<td>0.0517</td>
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Regression Equation

TEU = 10164803 − 890888 Labour Productivity Index

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
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<tbody>
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X Unusual X
Simple Regression: TEU versus NLD GDP (MLN EUR)

Analysis of Variance

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<tr>
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<tbody>
<tr>
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<td>Total</td>
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<td>1.10537E+14</td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
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<td>589982</td>
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<td>94.71%</td>
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Coefficients

<table>
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<tr>
<th>Term</th>
<th>Coef</th>
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<tbody>
<tr>
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<td>627115</td>
<td>-3.02</td>
<td>0.0077</td>
</tr>
<tr>
<td>NLD GDP (MLN EUR)</td>
<td>19.068</td>
<td>1.061</td>
<td>17.98</td>
<td>&lt;0.0001</td>
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Regression Equation

TEU = -1895588 + 19.068 NLD GDP (MLN EUR)
Simple Regression: TEU versus NLD Export (MLN EUR)

Analysis of Variance

<table>
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<th>Source</th>
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<th>P-Value</th>
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<tbody>
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Model Summary

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<tr>
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Coefficients

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<td>NLD Export (MLN EUR)</td>
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Regression Equation

TEU = 3126799 + 17.7224 NLD Export (MLN EUR)

Fits and Diagnostics for Unusual Observations

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<th>TEU</th>
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<th>Resid</th>
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R Large residual
Simple Regression: TEU versus NLD Import (MLN EUR)

Analysis of Variance

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Model Summary

<table>
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<td>575229</td>
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<td>94.81%</td>
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Coefficients

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<th>P-Value</th>
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<tr>
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Regression Equation

TEU = 3063480 + 19.927 NLD Import (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
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<th>Resid</th>
<th>Std Resid</th>
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<tbody>
<tr>
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R Large residual
Simple Regression: TEU versus DEU Export (MLN EUR)

Analysis of Variance

<table>
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<tr>
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<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
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<th>P-Value</th>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
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Coefficients

<table>
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<tr>
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<th>SE Coef</th>
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<th>P-Value</th>
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<tbody>
<tr>
<td>Constant</td>
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<td>312559</td>
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<td>&lt;0.0001</td>
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<tr>
<td>DEU Export (MLN EUR)</td>
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</table>

Regression Equation

TEU = 2616828 + 7.0667 DEU Export (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
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<th>Std Resid</th>
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</thead>
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A Large residual
Simple Regression: TEU versus DEU Import (MLN EUR)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
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Model Summary

<p>| | | |</p>
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<tbody>
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<td>533338</td>
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<tr>
<td>R-sq</td>
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</tr>
<tr>
<td>R-sq(adj)</td>
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Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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<tbody>
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<td>&lt;0.0001</td>
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<td>8.7613</td>
<td>0.4550</td>
<td>19.25</td>
<td>&lt;0.0001</td>
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Regression Equation

\[ \text{TEU} = 2475350 + 8.7613 \times \text{DEU Import (MLN EUR)} \]

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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<tbody>
<tr>
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<td>R</td>
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<td>1429747</td>
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R Large residual
Simple Regression: TEU versus CHE Export (MLN EUR)

Analysis of Variance

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<tr>
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<th>P-Value</th>
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<td>Total</td>
<td>18</td>
<td>1.10537E+14</td>
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</tbody>
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Model Summary

<table>
<thead>
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<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>1065965</td>
<td>82.92%</td>
<td>81.50%</td>
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Coefficients

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<tbody>
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<td>CHE Export (MLN EUR)</td>
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Regression Equation

TEU = 4940527 + 27.257 CHE Export (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
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<th>Std Resid</th>
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<tr>
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R Large residual
Simple Regression: TEU versus CHE Import (MLN EUR)

### Analysis of Variance

<table>
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<tr>
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<tr>
<td>Total</td>
<td>18</td>
<td>1.10537E+14</td>
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### Model Summary

<table>
<thead>
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<th>S</th>
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<th>R-sq(adj)</th>
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<td>1105459</td>
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<td>80.10%</td>
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### Coefficients

<table>
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<tbody>
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<td>CHE Import (MLN EUR)</td>
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</table>

### Regression Equation

\[
\text{TEU} = 4677907 + 31.305 \text{ CHE Import (MLN EUR)}
\]

### Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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</thead>
<tbody>
<tr>
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Simple Regression: TEU versus AUT Export (MLN EUR)

Analysis of Variance

<table>
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<tr>
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<tbody>
<tr>
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<td>1.10537E+14</td>
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<td></td>
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</tbody>
</table>

Model Summary

- \( S \) = 599435
- R-sq = 94.47%
- R-sq(adj) = 94.15%

Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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<tbody>
<tr>
<td>Constant</td>
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<tr>
<td>AUT Export (MLN EUR)</td>
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<td>17.05</td>
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</table>

Regression Equation

\[ \text{TEU} = 2637510 + 61.018 \times \text{AUT Export (MLN EUR)} \]

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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</thead>
<tbody>
<tr>
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<td>1618976</td>
<td>2.81</td>
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* R Large residual
Simple Regression: TEU versus AUT Import (MLN EUR)

Analysis of Variance

<table>
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<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
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<th>P-Value</th>
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<tbody>
<tr>
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Model Summary

<table>
<thead>
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<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
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Coefficients

<table>
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<th>P-Value</th>
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<tbody>
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<td>404913</td>
<td>6.10</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>AUT Import (MLN EUR)</td>
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</table>

Regression Equation

TEU = 2470188 + 60.370 AUT Import (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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<tbody>
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<td>-2.19 R</td>
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<td>10507934</td>
<td>1726501</td>
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R Large residual
Simple Regression: TEU versus SVK Rep Export (MLN EUR)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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<tbody>
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<td>1.05389E+14</td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
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Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
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<th>P-Value</th>
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<tbody>
<tr>
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<td>SVK Rep Export (MLN EUR)</td>
<td>91.469</td>
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</table>

Regression Equation

TEU = 5469053 + 91.469 SVK Rep Export (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
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<th>Std Resid</th>
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R Large residual
Simple Regression: TEU versus SVK Rep Import (MLN EUR)

Analysis of Variance

<table>
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<tr>
<th>Source</th>
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<th>Adj SS</th>
<th>Adj MS</th>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<tbody>
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Coefficients

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</table>

Regression Equation

TEU = 5197642 + 97.489 SVK Rep Import (MLN EUR)

Fits and Diagnostics for Unusual Observations

| Obs | TEU  | Fit  | Resid | Std Resid | |
|-----|------|------|-------|-----------| |
| 9   | 9288000 | 8200901 | 1087399 | 2.20 | R |

*R Large residual*
Simple Regression: TEU versus HUN Export (MLN EUR)

Analysis of Variance

<table>
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<tr>
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<th>Adj MS</th>
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<th>P-Value</th>
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Model Summary

<table>
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<th></th>
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<td>98.99%</td>
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Coefficients

<table>
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Regression Equation

TEU = 4333078 + 77.369 HUN Export (MLN EUR)

Fits and Diagnostics for Unusual Observations

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<th>Resid</th>
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R Large residual
Simple Regression: TEU versus HUN Import (MLN EUR)

Analysis of Variance

<table>
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<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
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<th>P-Value</th>
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<td>18</td>
<td>1.10537E+14</td>
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</tr>
</tbody>
</table>

Model Summary

\[ S \quad R^{\text{sq}} \quad R^{\text{sq(adj)}} \]
591282  94.62%  94.31%

Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>11.29</td>
<td>&lt;0.0001</td>
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<tr>
<td>HUN Import (MLN EUR)</td>
<td>67.574</td>
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</table>

Regression Equation

\[ \text{TEU} = 3800564 + 67.574 \times \text{HUN Import (MLN EUR)} \]

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
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<td>-2.92 R</td>
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<td>12234535</td>
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<td>2.32 R</td>
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</table>

*R Large residual*
Simple Regression: TEU versus CZK Export (MLN EUR)

Analysis of Variance

<table>
<thead>
<tr>
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<th>P-Value</th>
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<td>1.23658E+11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>1.10537E+14</td>
<td></td>
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</table>

Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>351651</td>
<td>98.10%</td>
<td>97.99%</td>
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Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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<tbody>
<tr>
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<td>154079</td>
<td>34.04</td>
<td>&lt;0.0001</td>
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<tr>
<td>CZK Export (MLN EUR)</td>
<td>54.538</td>
<td>1.842</td>
<td>29.61</td>
<td>&lt;0.0001</td>
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Regression Equation

TEU = 5244164 + 54.538 CZK Export (MLN EUR)
Simple Regression: TEU versus CZK Import (MLN EUR)

Analysis of Variance

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<tr>
<th>Source</th>
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<th>Adj MS</th>
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<th>P-Value</th>
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<tbody>
<tr>
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<td>1.07945E+14</td>
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Model Summary

<table>
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<th>R-sq(adj)</th>
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<tbody>
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<td>390481</td>
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<td>97.52%</td>
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Coefficients

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<tbody>
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<td>26.21</td>
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<tr>
<td>CZK Import (MLN EUR)</td>
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<td>26.61</td>
<td>&lt;0.0001</td>
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Regression Equation

TEU = 4837666 + 60.484 CZK Import (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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<tr>
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<td>-885248</td>
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R Large residual
Simple Regression: TEU versus Container Traffic (calling)

Analysis of Variance

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<th>Adj MS</th>
<th>F-Value</th>
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</thead>
<tbody>
<tr>
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<td>4.80578E+13</td>
<td>13.08</td>
<td>0.0021</td>
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<td>3.67523E+12</td>
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<td>Total</td>
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<td>1.10537E+14</td>
<td></td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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</thead>
<tbody>
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<td>1917088</td>
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<td>40.15%</td>
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Coefficients

<table>
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<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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</thead>
<tbody>
<tr>
<td>Constant</td>
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<td>0.2965</td>
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<td>Container Traffic (calling)</td>
<td>2169.0</td>
<td>599.8</td>
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<td>0.0021</td>
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Regression Equation

TEU = -3914968 + 2169.0 Container Traffic (calling)
Simple Regression: TEU versus Motorways (Kms)

Analysis of Variance

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<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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</thead>
<tbody>
<tr>
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<td>3.25104E+12</td>
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<td>Error</td>
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<td>3.76833E+12</td>
<td>5.38333E+11</td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>7.01937E+12</td>
<td></td>
<td></td>
<td></td>
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</table>

Model Summary

<table>
<thead>
<tr>
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<th>R-sq</th>
<th>R-sq(adj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>733712</td>
<td>46.32%</td>
<td>38.95%</td>
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Coefficients

<table>
<thead>
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<th>Term</th>
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<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
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<td>19096168</td>
<td>-1.88</td>
<td>0.1027</td>
</tr>
<tr>
<td>Motorways (Kms)</td>
<td>17821</td>
<td>7252</td>
<td>2.46</td>
<td>0.0436</td>
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</table>

Regression Equation

TEU = -35837704 + 17821 Motorways (Kms)
Simple Regression: TEU versus Motorways Total Transport - Tho

Analysis of Variance

<table>
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<tr>
<th>Source</th>
<th>DF</th>
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<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.655583E+12</td>
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<tr>
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<td>Total</td>
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Model Summary

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<tr>
<td>S</td>
<td>875340</td>
<td>23.59%</td>
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<td></td>
<td></td>
<td>12.87%</td>
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Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
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<th>P-Value</th>
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</thead>
<tbody>
<tr>
<td>Constant</td>
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<td>914674</td>
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<td>&lt;0.0001</td>
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<tr>
<td>Motorways Total Transport - Tho</td>
<td>-29.61</td>
<td>20.14</td>
<td>-1.47</td>
<td>0.1850</td>
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</table>

Regression Equation

\[ TEU = 12360809 - 29.61 \cdot \text{Motorways Total Transport - Tho} \]

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
<th>X</th>
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</thead>
<tbody>
<tr>
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<td>12149916</td>
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<td>X</td>
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</table>

X: Unusual X
Simple Regression: TEU versus Railway Lines (Kms)

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
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<th>P-Value</th>
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<td>8</td>
<td>7.01937E+12</td>
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Model Summary

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td></td>
<td>575695</td>
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<td>62.23%</td>
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Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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<tbody>
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<td>Railway Lines (Kms)</td>
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<td>0.0070</td>
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Regression Equation

TEU = -12289437 + 7949 Railway Lines (Kms)
Simple Regression: TEU versus Railway Total Transport - Thous

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
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<th>Adj MS</th>
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<th>P-Value</th>
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<tr>
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<td>8.34</td>
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<td>3.20379E+12</td>
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<td>7.01937E+12</td>
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Model Summary

<p>| | | | |</p>
<table>
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<tr>
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<tbody>
<tr>
<td>S</td>
<td>R-sq</td>
<td>R-sq(adj)</td>
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<td>695524</td>
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<td>47.84%</td>
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Coefficients

<table>
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<tr>
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<tbody>
<tr>
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<td>6.59</td>
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<td>2.89</td>
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Regression Equation

TEU = 7752748 + 294.3 Railway Total Transport - Thous

Fits and Diagnostics for Unusual Observations

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<th>Obs</th>
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<td>10605270</td>
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R Large residual
### Simple Regression: TEU versus Navigable Canals (Kms)

#### Analysis of Variance

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<th>Adj MS</th>
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<td>7.01937E+12</td>
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#### Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>90423</td>
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#### Coefficients

<table>
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<tr>
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<td>53946</td>
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<td>0.2479</td>
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#### Regression Equation

TEU = -242758125 + 53946 Navigable Canals (Kms)

#### Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
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<tr>
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<td>597657</td>
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<td>X</td>
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</tbody>
</table>

*Unusual X*
Simple Regression: TEU versus Navigable rivers (Kms)

Analysis of Variance

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<th>Adj MS</th>
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<th>P-Value</th>
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<td>9809374559</td>
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Model Summary

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<tbody>
<tr>
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Coefficients

<table>
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<th>P-Value</th>
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<tbody>
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<td>26893110</td>
<td>0.81</td>
<td>0.4446</td>
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<tr>
<td>Navigable rivers (Kms)</td>
<td>-7707</td>
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<td>0.7028</td>
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</table>

Regression Equation

TEU = 21785100 – 7707 Navigable rivers (Kms)

Fits and Diagnostics for Unusual Observations

<table>
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<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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</thead>
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<tr>
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<td>11449546</td>
<td>171454</td>
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X: Unusual X

168
**Simple Regression: TEU versus Inland Waterways Total Transport**

**Method**

Rows unused: 1

**Analysis of Variance**

<table>
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<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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</thead>
<tbody>
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<td>4.38379E+12</td>
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**Model Summary**

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>233523</td>
<td>0.9305%</td>
<td>0.9190%</td>
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**Coefficients**

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>7462435</td>
<td>432130</td>
<td>17.27</td>
<td>&lt;0.0001</td>
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<tr>
<td>Inland Waterways Total Transport</td>
<td>107.23</td>
<td>11.96</td>
<td>8.97</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

**Regression Equation**

\[ \text{TEU} = 7462435 + 107.23 \times \text{Inland Waterways Total Transport} \]
Simple Regression: TEU versus PoR Short Sea Shipping Total Tr

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
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<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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</thead>
<tbody>
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<td>7.01937E+12</td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>441979</td>
<td>80.52%</td>
<td>77.74%</td>
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Coefficients

<table>
<thead>
<tr>
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<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
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<tbody>
<tr>
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<td>1.01</td>
<td>0.3443</td>
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<tr>
<td>PoR Short Sea Shipping Total Tr</td>
<td>299.71</td>
<td>55.72</td>
<td>5.38</td>
<td>0.0010</td>
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</table>

Regression Equation

TEU = 1764056 + 299.71 PoR Short Sea Shipping Total Tr
Simple Regression: TEU versus Investment in Port Infrastructure

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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<tbody>
<tr>
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Model Summary

- S: 167851
- R-sq: 26.12%
- R-sq(adj): 19.97%

Coefficients

<table>
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<tr>
<th>Term</th>
<th>Coef</th>
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<th>T-Value</th>
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<tbody>
<tr>
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Regression Equation

TEU = 8629663 + 0.006089 Investment in Port Infrastructure

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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<tr>
<td>11</td>
<td>11862000</td>
<td>12439799</td>
<td>-577739</td>
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X Unusual X
Port of Le Havre Minitab results
Simple Regression: TEU versus Labour Productivity Index

Analysis of Variance

<table>
<thead>
<tr>
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<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Total</td>
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Model Summary

<table>
<thead>
<tr>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>454743</td>
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<td>28.23%</td>
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Coefficients

<table>
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<th>T-Value</th>
<th>P-Value</th>
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<tbody>
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<td>Labour Productivity Index</td>
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Regression Equation

TEU = 2228003 – 239041 Labour Productivity Index

Fits and Diagnostics for Unusual Observations

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R Large residual
Simple Regression: TEU versus FRA GDP (MLN EUR)

Analysis of Variance

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<tr>
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<tbody>
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<td>Total</td>
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<td>5.47427E+12</td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>195126</td>
<td>87.48%</td>
<td>86.79%</td>
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Coefficients

<table>
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<tbody>
<tr>
<td>Constant</td>
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<td>194405</td>
<td>-1.12</td>
<td>0.2786</td>
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<tr>
<td>FRA GDP (MLN EUR)</td>
<td>1.2297</td>
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<td>11.22</td>
<td>&lt;0.0001</td>
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</table>

Regression Equation

TEU = -217203 + 1.2297 FRA GDP (MLN EUR)

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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</thead>
<tbody>
<tr>
<td>13</td>
<td>2638000</td>
<td>2194024</td>
<td>443976</td>
<td>2.36</td>
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</table>

R Large residual
**Simple Regression: TEU versus FRA Export (MLN EUR)**

### Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
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### Model Summary

<table>
<thead>
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<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
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<td>219955</td>
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<td>83.21%</td>
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### Coefficients

<table>
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<tr>
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<td>180476</td>
<td>1.18</td>
<td>0.2519</td>
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<td>FRA Export (MLN EUR)</td>
<td>4.4747</td>
<td>0.4587</td>
<td>9.73</td>
<td>&lt;0.0001</td>
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</table>

### Regression Equation

\[
TEU = 213634 + 4.4747 \times \text{FRA Export (MLN EUR)}
\]
Simple Regression: TEU versus FRA Import (MLN EUR)

Analysis of Variance

<table>
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<tr>
<th>Source</th>
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<th>Adj MS</th>
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<tbody>
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<td>5.47427E+12</td>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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<tbody>
<tr>
<td>233034</td>
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<td>81.15%</td>
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Coefficients

<table>
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Regression Equation

TEU = 589970 + 3.1655 FRA Import (MLN EUR)
Simple Regression: TEU versus Investment in Sea Infrastructure

Analysis of Variance

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</table>

Model Summary

- S: 415957
- R-sq: 42.84%
- R-sq(adj): 39.69%

Coefficients

<table>
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<tbody>
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<td>0.0008626</td>
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</table>

Regression Equation

TEU = 920946 + 0.0031680 \times \text{Investment in Sea Infrastructure}

Fits and Diagnostics for Unusual Observations

<table>
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<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
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R Large residual
Simple Regression: TEU versus FRA Motorways (Kms)

Analysis of Variance

<table>
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<td>0.7236</td>
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Model Summary

<table>
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<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
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Coefficients

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<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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<tbody>
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Regression Equation

TEU = 1347635 + 91.4 FRA Motorways (Kms)
Simple Regression: TEU versus FRA Motorways Total Transport -

Analysis of Variance

<table>
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<tr>
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<th>P-Value</th>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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Coefficients

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<th>SE Coef</th>
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<th>P-Value</th>
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</table>

Regression Equation

TEU = 2579912 - 6.99 FRA Motorways Total Transport -

Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>TEU</th>
<th>Fit</th>
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<th>Std Resid</th>
<th></th>
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<tr>
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R Large residual
Simple Regression: TEU versus FRA Railway Lines (Kms)

Analysis of Variance

<table>
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<th>Adj SS</th>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
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<th>R-sq(adj)</th>
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<tbody>
<tr>
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Coefficients

<table>
<thead>
<tr>
<th>Term</th>
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<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
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<tr>
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<td>0.4553</td>
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<td>FRA Railway Lines (Kms)</td>
<td>21.64</td>
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<td>0.7740</td>
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</table>

Regression Equation

TEU = 1724477 + 21.64 FRA Railway Lines (Kms)
Simple Regression: TEU versus FRA Railways Total Transport

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
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<th>Adj MS</th>
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<th>P-Value</th>
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Model Summary

<table>
<thead>
<tr>
<th>S</th>
<th>R-sq</th>
<th>R-sq(adj)</th>
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</thead>
<tbody>
<tr>
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Coefficients

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Regression Equation

TEU = 2061991 + 26.59 FRA Railways Total Transport -
Simple Regression: TEU versus FRA Inland Watwerways Total Tr

Analysis of Variance

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Regression Equation

TEU = 2414441 - 10.4 FRA Inland Watwerways Total Tr
Simple Regression: TEU versus Container Traffic Calling

Analysis of Variance

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Regression Equation

TEU = -2895582 + 969.7 Container Traffic Calling
Multiple Regression: TEU versus Quay length (meter), Terminal Area (ha), Labour Productivity Index, BEL GDP (MLN EUR), CHE Export (MLN EUR), CHE Import (MLN EUR), FRA Export (MLN EUR), FRA Import (MLN EUR), Container Traffic (calling), Sea Infra Invest (EUR)

Regression Equation
\[
\text{TEU} = -6972662 - 399.2 \text{ Quay length (meter)} + 6569 \text{ Terminal Area (ha)}
+ 112344 \text{ Labour Productivity Index} + 20.204 \text{ BEL GDP (MLN EUR)}
- 16.288 \text{ CHE Export (MLN EUR)} + 11.919 \text{ CHE Import (MLN EUR)}
+ 33.455 \text{ FRA Export (MLN EUR)} - 18.884 \text{ FRA Import (MLN EUR)}
+ 614.7 \text{ Container Traffic (calling)} + 0.00572 \text{ Sea Infra Invest (EUR)}
\]

Analysis of Variance

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Model Summary

\[
\begin{array}{ccc}
S & R-sq & R-sq(adj) \\
99157.9 & 99.90\% & 99.74\%
\end{array}
\]

Coefficients

<table>
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<td>34200</td>
<td>(28660, 196028)</td>
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<td>BEL GDP (MLN EUR)</td>
<td>20.204</td>
<td>2.821</td>
<td>(13.301, 27.107)</td>
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<td>CHE Export (MLN EUR)</td>
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<td>CHE Import (MLN EUR)</td>
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<td>(-0.001030, 0.004175)</td>
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Multiple Regression: BEL TEU versus BEL Road TT - Ttonne, BEL IW TT - Ttonne, PoAtwp SSS TT-Ttonne

Regression Equation
BEL TEU = -456490 + 252.95 BEL Road TT - Ttonne + 7.96 BEL IW TT - Ttonne + 78.62 PoAtwp SSS TT-Ttonne

Analysis of Variance

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Model Summary

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<td>R-sq(adj)</td>
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Coefficients

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Appendix 6

Port of Hamburg Minitab multi regression model results

Multiple Regression: TEU versus Quay Length (meter), Terminal Area (ha), Labour Productivity Index, DEU GDP (MLN EUR), DEU Export (MLN EUR), DEU Import (MLN EUR), Container Traffic (calling), Investment in Sea Infrastructure, SVK Rep Export (MLN EUR), CZK Import (MLN EUR)

Regression Equation
\[
\text{TEU} = -156426 - 4321 \text{Quay Length (meter)} + 71136 \text{Terminal Area (ha)}
- 53196 \text{Labour Productivity Index} + 0.8318 \text{DEU GDP (MLN EUR)}
+ 33.168 \text{DEU Export (MLN EUR)} - 6.943 \text{DEU Import (MLN EUR)}
- 463.4 \text{Container Traffic (calling)} + 0.0006157 \text{Investment in Sea Infrastructure}
- 179.19 \text{SVK Rep Export (MLN EUR)} - 90.37 \text{CZK Import (MLN EUR)}
\]

Analysis of Variance

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<tr>
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Model Summary

\[
S = 160551, \quad R^2 = 99.74\%, \quad R^2(adj) = 99.22\%
\]

Coefficients

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Multiple Regression: TEU versus DEU MW TT TTonnes, DEU RLY TT TTonnes, DEU IW TT TTonnes, PoHmbg SSS TT TTonnes

Regression Equation

\[
TEU = 5774914 - 1.275 \text{ DEU MW TT TTonnes} + 65.61 \text{ DEU RLY TT TTonnes} - 229.85 \text{ DEU IW TT TTonnes} + 157.58 \text{ PoHmbg SSS TT TTonnes}
\]

Analysis of Variance

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Model Summary

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Coefficients

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<td>DEU RLY TT TTonnes</td>
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<td>PoHmbg SSS TT TTonnes</td>
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<td>(60.73, 254.43)</td>
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Appendix 7

Port of Le Havre Minitab multi regression model results

Multiple Regression: TEU versus Labour Productivity Index, FRA GDP (MLN EUR), FRA Export (MLN EUR), FRA Import (MLN EUR), Investment in Sea Infrastructure

Regression Equation
\[
TEU = -1778291 - 29253 \text{ Labour Productivity Index} + 1.3850 \text{ FRA GDP (MLN EUR)} \\
+ 18.743 \text{ FRA Export (MLN EUR)} - 13.674 \text{ FRA Import (MLN EUR)} \\
+ 0.0000376 \text{ Investment in Sea Infrastructure}
\]

Analysis of Variance

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Model Summary

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Coefficients

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Fits and Diagnostics for Unusual Observations

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R: Large residual
Multiple Regression: TEU versus FRA Motorways Total Transport -, FRA Railways Total Transport -, FRA Inland Waterways Total Tr

Regression Equation

\[
\text{TEU} = 2586252 - 9.11 \text{ FRA Motorways Total Transport} - + 18.73 \text{ FRA Railways Total Transport} - - 70.4 \text{ FRA Inland Waterways Total Tr}
\]

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Appendix 8

Port of Rotterdam Minitab multi regression model results

Multiple Regression: TEU versus Quay Length (meter) Cumulative, Terminal Area Cumulative (ha), No of Quayside Cranes cumulative, Cumulative Capacity Increase, NLD GDP (MLN EUR), NLD Export (MLN EUR), NLD Import (MLN EUR), Container Traffic (calling)

Regression Equations

\[ \text{TEU} = 24384971 + 3469 \times \text{Quay Length (meter) Cumulative} + 1770999 \times \text{Terminal Area Cumulative (ha)} \]
\[ - 26195561 \times \text{No of Quayside Cranes cumulative} + 4.528 \times \text{Cumulative Capacity Increase} \]
\[ + 24.218 \times \text{NLD GDP (MLN EUR)} - 14.94 \times \text{NLD Export (MLN EUR)} \]
\[ + 20.89 \times \text{NLD Import (MLN EUR)} + 543.6 \times \text{Container Traffic (calling)} \]

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Model Summary

\[ S = 294610 \]
\[ R-sq = 99.05\% \]
\[ R-sq(adj) = 97.53\% \]

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 Fits and Diagnostics for Unusual Observations

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X Unusual X

190
Multiple Regression: TEU versus Motorways Total Transport - Tho, Railway Total Transport - Thous, Inland Waterways Total Transport, PoR Short Sea Shipping Total Tr

Method
Rows unused 1

Regression Equation
TEU = 8035009 + 8.506 Motorways Total Transport - Tho + 27.78 Railway Total Transport - Thous + 143.86 Inland Waterways Total Transport - 81.3 PoR Short Sea Shipping Total Tr

Analysis of Variance

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Coefficients

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Appendix 9

Port related data

Port of Antwerp

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