Inter-terminal transport on Maasvlakte 1 and 2 in 2030

Towards a multidisciplinary and innovative approach on future inter-terminal transport options

Deliverable 1.1

Analysis for Inter Terminal Transportation demand scenarios for the Maasvlakte I and II in 2030

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Analysis for Inter Terminal Transportation demand scenarios for the Maasvlakte I and II in 2030

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This research is carried out within the framework of the TU Delft, Erasmus University and the Port of Rotterdam Authority joint project "Inter-terminal transport on Maasvlakte 1 and 2 in 2030 - Towards a multidisciplinary and innovative approach on future inter-terminal transport options.”

Delft University of Technology

Subject: **Analysis for Inter Terminal Transportation demand scenarios for the Maasvlakte I and II in 2030**

Due to the expansion of the Port of Rotterdam with the Maasvlakte 2 and the continuing rise in global container transport, there will be an increasing demand for Inter Terminal Transport (ITT) of containers at the Maasvlakte 1 + 2. Until 2020 this demand can be met using 3 TEU trucks that drive on the public road, but after 2020 this option will no longer suffice. One of the possibilities to solve the Inter Terminal Transport problem is by using a Closed Transportation Route. Different types of transportation systems to drive on the Closed Transportation Route could be considered; Terminal Tractors with Terminal Chassis, Multi Trailer Systems, AGVs, Lift AGVs, …

In order to determine what type of transport systems would be most suitable, scenarios regarding how many containers will be available for ITT transport in 2035 will need to be defined. This literature study focuses on that topic. In particular, determination of predictions of expected inter terminal transport demand will be determined; estimates of peak demands and peak durations will be provided; demand scenarios will be defined at a detailed time level, incorporating terminal market shares and developments in the demand estimation; terminal pick-up and drop-off locations and handling capacities will be determined; minimum and maximum demand scenarios will be set up.

Based on the assignment, recommendations will be given for future research opportunities and potential for more ideas and/or applications. The report will be written in English and must comply with the guidelines of the section. Details can be found on the website.

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The supervisors,

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Abstract

Inter Terminal Transportation (ITT) is defined as the exchange of containers between terminals within the same port. This report contains the results of a literature assignment about ITT. The research was carried out in order to create demand scenarios for ITT on the Maasvlakte area in the year 2030.

In order to create demand scenarios, economic projections from the report 'Port Vision 2030' are used as a starting point. In Chapters 3 and 4, these general projections are made more specific and applied to the Maasvlakte area in order generate scenarios for container throughput in 2030. In Chapter 5, the amount of those containers that will need ITT is determined. This yields ITT demand scenarios for the whole year 2030. Chapter 6 provides the equations necessary to compute minimum and maximum ITT demand per month, week and hour. Chapter 7 provides the final steps necessary to create a list of containers that need ITT. This list can be used as input for an ITT computer simulation.

In order to make scenarios, many assumptions have to be made. These are all listed clearly in the report, along with proposed values or possible ranges of values.

The following steps are taken to create a scenario for ITT on the Maasvlakte in 2030:

1. Take one of four economic projections from port Vision 2030 (given in tons per year)
2. Estimate a ton-TEU ratio and calculate a throughput projection in TEUs
3. Choose expectation for import-export ratio
4. Choose expectation for full-empty ratios for import and export
5. Choose a possible modal split for 2030
6. Calculate import and export flows, TEUs per mode and full and empty TEUs.
7. Choose one of the possible layouts for the Maasvlakte in 2030
8. Divide total cargo flow for the port into TEUs per location per year on the Maasvlakte and TEUs for the other terminals (outside of the Maasvlakte area)
9. Convert TEU throughput per year to throughput per month
10. Convert flows per month to throughput patterns per day
11. Convert flows from TEUs to containers
12. Assign an arrival time and origin to each container
13. Assign a due time and destination to each container

This will give a list of containers with origins, destinations, arrival times and due times. This list can be used as an input file for a computer model of an ITT system.

Scenarios are always based on assumptions, estimates and generalisations. They cannot predict the future, only show a range of possible future situations that can be prepared for. There are certain kinds of future developments that cannot be accurately represented using scenarios. Still, scenarios are a useful and powerful tool for decision making. The scenarios generated using this report will provide a detailed overview of the possible developments and foreseeable future situations for an ITT system on the Maasvlakte.

1 Introduction

The future of container shipping offers great opportunities, but also great challenges. One of those challenges is the increasing demand for transportation between terminals and the looming threat of lack of infrastructure capacity when current practices are not changed. Research is carried out by the Delft University of Technology and Erasmus University, in order to come up with a system for transporting containers within the port area that is ready to make the most of future opportunities. This report covers a part of that research, namely the generation of demand scenarios for Inter Terminal Transportation in the year 2030.

1.1 Project description

The Port of Rotterdam Authority, TU Delft and Erasmus University are working on a joint project to develop innovative, non-conventional concepts for ITT for the port of Rotterdam. In order to develop those concepts, creating scenarios that describe possible demand for ITT in 2030 is a necessary first step. To determine how to develop such scenarios, a literature study was carried out, the results of which are presented in this report.

1.2 Role of this research in the larger project

Developing demand scenarios for ITT is the first of a number of tasks defined in a research statement written by the Port Authority and Delft University of Technology [1]. Based on these scenarios the other tasks van be executed. The full list of tasks (taken from the research statement) is given below.

1. **Scenario definition (this report)**
2. Truck and AGV Configuration
3. Asset Light Configuration
4. Cost/Benefit Evaluation
5. Information exchange evaluation
6. Operational evaluation

Using the steps described in this report, one can choose a possible future situation and calculate the demand for ITT on the Maasvlakte should this future become reality. The report will list the steps that should be taken to get from the generic projections from Port Vision 2030 to detailed scenarios for ITT demand.

A scenario will consist of a list of containers in need of ITT with origins, destinations, arrival times and due times.

1.3 Definition of inter terminal transportation

A terminal is defined as a facility where cargo is transhipped from one mode of transportation to another. The cargo then goes either to the sea to reach its final destination via another port, or is transported to a destination in the hinterland. This report will investigate only container terminals, because bulk terminals generally do not need a lot of inter terminal transportation.

While most containers are handled by the terminals on-site, many containers will have to be transported to another terminal. This is called interterminal transportation, or ITT for short. This report focuses on ITT between terminals and facilities in the Maasvlakte area – traffic to and from other parts of the Port of Rotterdam is not considered to be interterminal traffic.

The report ‘Gesloten transport route – ITT op MV1 en 2’ [2] lists various purposes of ITT. They are visualised in Figure 1.

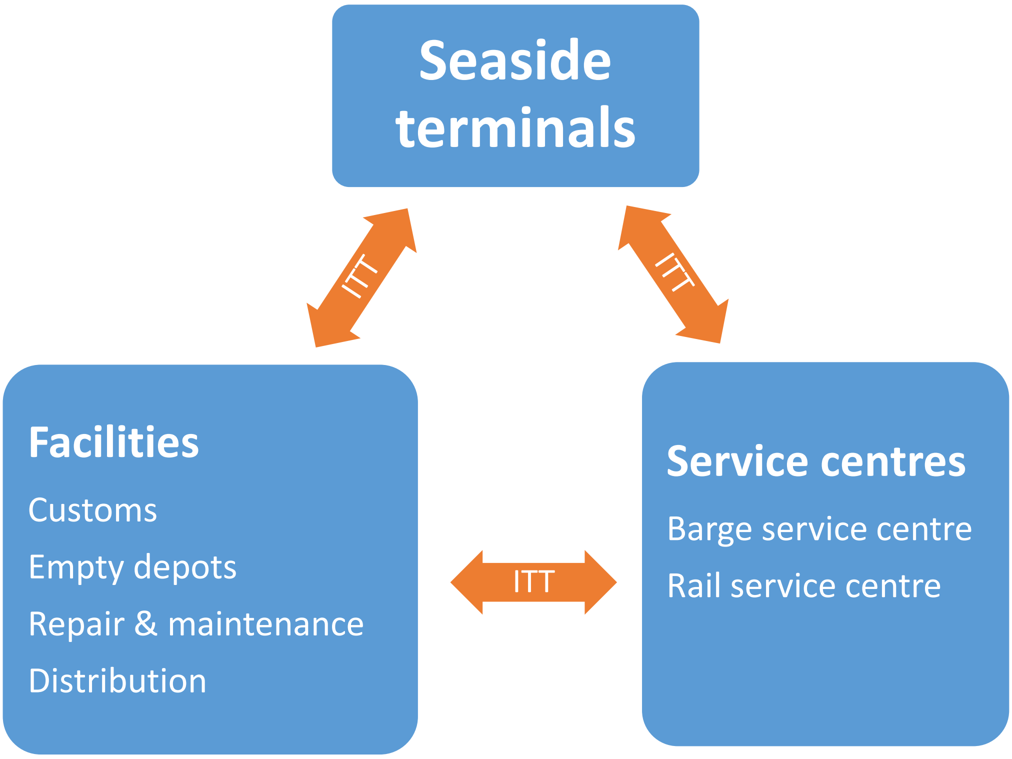

Figure 1 Inter terminal transportation flows. Adapted from [2].

In short, ITT is necessary for traffic between deepsea terminals, service centres, depots and repair centres (which are often on the same site) and the customs facility.

1.4 Research Question

The report will answer the following research question:

What are possible demand scenarios for Inter Terminal Transportation on the Maasvlakte in 2030?

The following sub questions will be answered

- What are possible pick-up and drop-off locations for an ITT system?
- What will be the handling capacities per location?
- What will be the possible effects of establishing common transport links (common barge / rail service centers) vs. terminal-specific solutions
- What are the minimum- and maximum demand scenarios for ITT demand in the MV area?
- What will be the peak demand and peak duration?

1.5 Summary and remarks

This report contains the result of a literature assignment about ITT demand on the Maasvlakte in 2030. It contains guidelines for developing demand scenarios for ITT on the Maasvlakte in 2030. These scenarios are based on cargo throughput projections made in the report 'Port Vision 2030' and the results of the literature study.

A report cannot tell the reader what the future will be like. What it can do is show how to calculate, given a future situation, what the demand for ITT between terminals on the Maasvlakte I and II could be. It lists assumptions and expectations about the future taken from literature, interviews, reports and statistics, and combines these into coherent and plausible scenarios. The reader has to decide which scenario(s) he or she is interested in, and use the scenarios wisely when planning for an uncertain and unpredictable future.

2 Modelling approach

In order to answer the research question, we need to determine the possible demand scenarios for ITT on the Maasvlakte in 2030. As stated in paragraph 1.2, the economic projections for 2030 from Port Vision 2030 will be used as a starting point. They will be combined with assumptions based on literature review to indicate how ITT demand can be calculated from cargo throughput projections in tonnes. Where this is possible, possible values and bandwidths will be given for projected numbers. A model approach is proposed to generate scenarios using the following data as input:

1. **Cargo throughput scenarios for 2030 in tonnes per year**
   These are taken from Port of Rotterdam documents [3] [4] and give predictions for future container flows through the port of Rotterdam based on macro-economic scenarios.
2. **Number of participants in an ITT system in 2030 and their annual throughput capacity**
   Which terminals will be on the Maasvlakte 1 and 2 in 2030, how many containers will they handle, and will all of them need ITT?
3. **Modal split**
   A plausible future modal split for sea- and landside cargo flows through the port of Rotterdam in 2030.
4. **Full-empty ratio**
   How many containers that are handled in Rotterdam in 2030 will be full and how many will be empty?
5. **Import-export ratio**
   How many of the containers mentioned in point 1 will be imported, and how many will be exported?
6. **Causes of ITT**
   What will be the reasons to transport containers between terminals in 2030?

2.1 Scenario creation

Based on these inputs, we can calculate scenarios for the cargo throughput and ITT demand per location. The following paragraphs will explain how this can be done. The reader is strongly advised to look at the complete process diagram in Figure 4, as it explains the sequence of steps needed to calculate ITT demand for a given scenario, shows input data and assumptions needed for each step and outlines the structure of the following chapters.

The following steps are taken to form a complete ITT scenario:

14. Take one of four economic projections from port Vision 2030 (given in tons per year)
15. Estimate a ton-TEU ratio and calculate a throughput projection in TEUs
16. Choose expectation for import-export ratio
17. Choose expectation for full-empty ratios for import and export
18. Choose a possible modal split for 2030
19. Calculate import and export flows, TEUs per mode and full and empty TEUs.
20. Choose one of the possible layouts for the Maasvlakte in 2030
21. Divide total cargo flow for the port into TEUs per location per year on the Maasvlakte and TEUs for the other terminals (outside of the Maasvlakte area)
22. Convert TEU throughput per year to throughput per month
23. Convert flows per month to throughput patterns per day
24. Convert flows from TEUs to containers

25. Assign an arrival time and origin to each container
26. Assign a due time and destination to each container

This will give a list of containers with origins, destinations, arrival times and due times. This list can be used as an input file for a computer model of an ITT system.

2.2 Structure of the report

Below is a short overview of the topics covered in each chapter of the report.

Chapter 3 Calculations describing the conversion of projections from ‘Port Vision 2030’ to cargo flow scenarios for the whole port.

Chapter 4 Making a list of locations and cargo flow scenarios for each location.

Chapter 5 Calculating ITT demand scenarios for the year 2030.

Chapter 6 Calculations concerning ITT demand per year, month and hour.

Chapter 7 Making a list of containers for use with an ITT model.

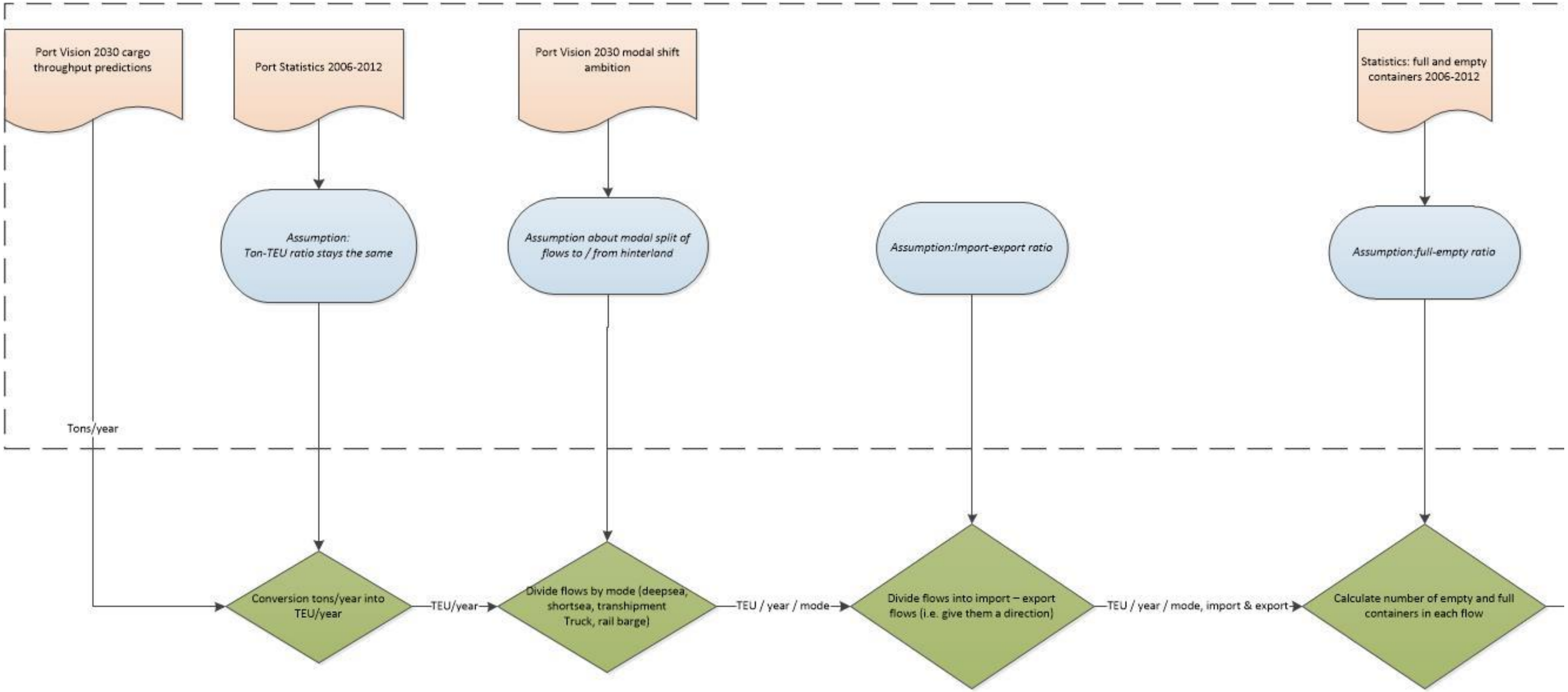

Figure 2 Steps taken in Chapter 3

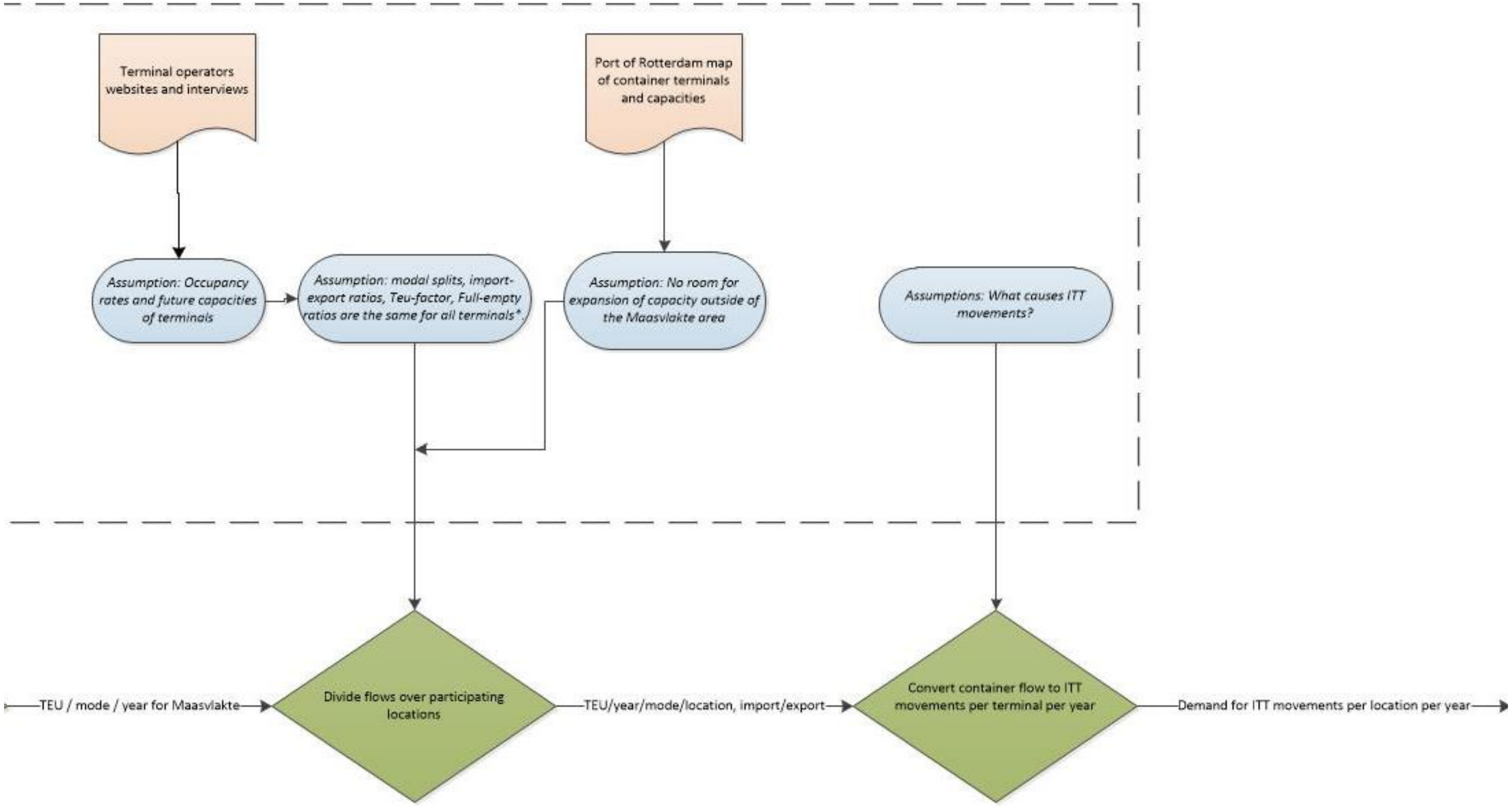

Figure 3 Steps taken in Chapters 4 and 5

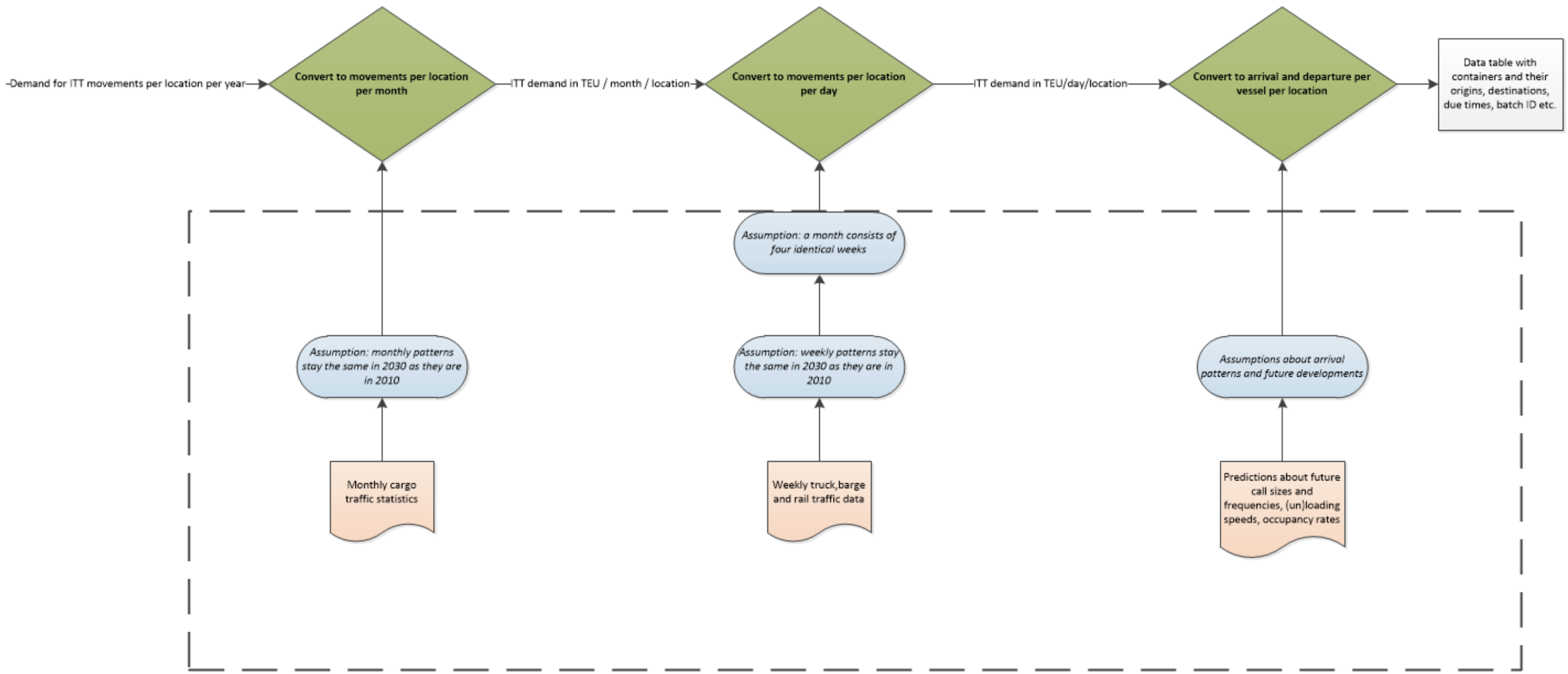

Figure 4 steps taken in Chapters 6 and 7

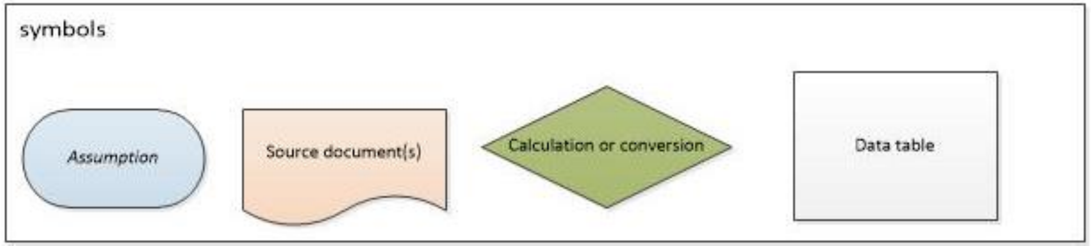

Figure 5 Symbols used in the drawings in previous figures

3 Cargo flow scenarios for the whole port in the year 2030

3.1 Introduction

This chapter describes the way cargo flow scenarios are generated. Starting point are very general projections about container transport in 2030 made by the port of Rotterdam Authority. Following the steps described in this chapter one is able to make an ITT demand scenario conforming to ones expectations about the amount and type of terminals, cargo throughput, types of handled cargo, and many other variables. Proposals for values will be made for each variable.

To arrive at a scenario, one will have to make assumptions about the future and do calculations using data and assumptions. Each step is described in this chapter, starting with the four future projections made by the port of Rotterdam Authority.

3.2 Port Vision 2030 projections

The Rotterdam Port authority outlined four economic projections for 2030 in their document "Port Vision 2030" [4]. In the interest of continuity it is preferable to make more specific scenarios about the future of the port based on these general projections. The four projections are called Low Growth (LG), High Oil Prices (HOP), European Trend (ET) and Global Economy (GE). Each one predicts a certain number of tonnes of throughput for the Port of Rotterdam in 2030. The projections are graphically represented in the figure below.

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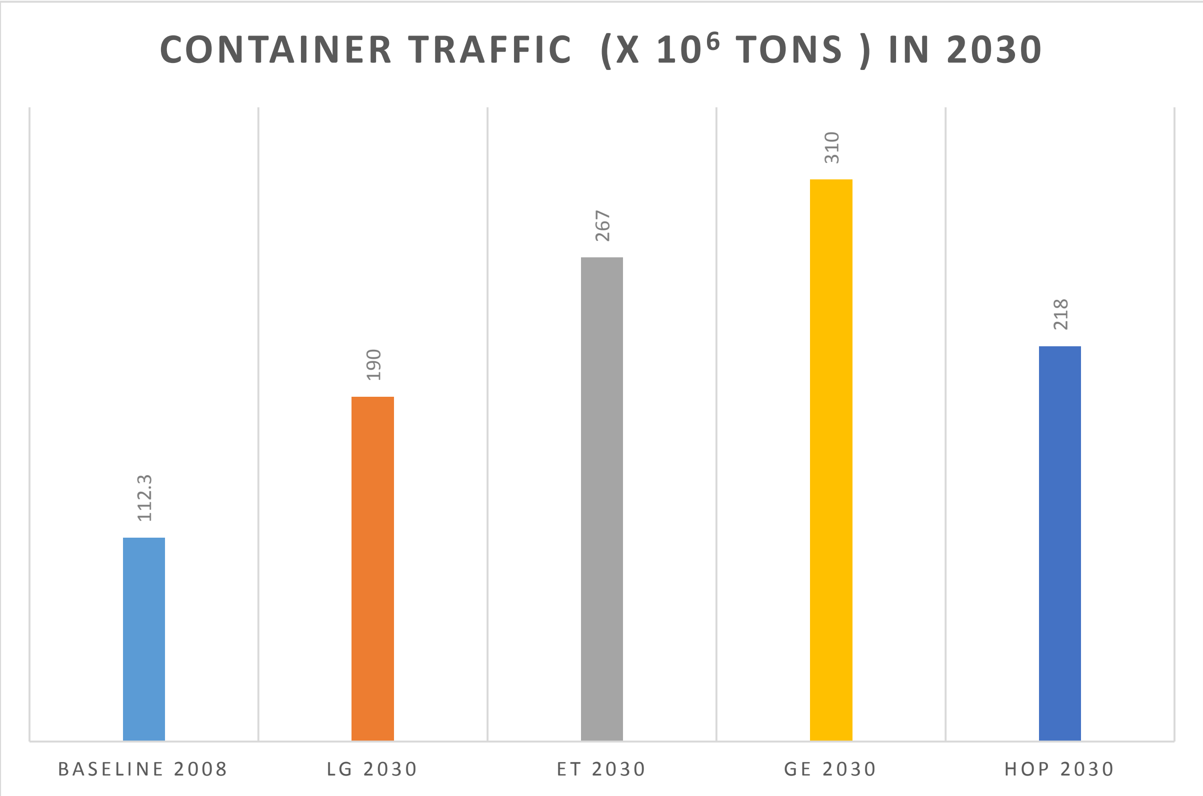

Figure 6 Predicted container traffic in millions of tons per year – Source: Port Vision 2030 [4]

3.3 From tonnes to TEU per year

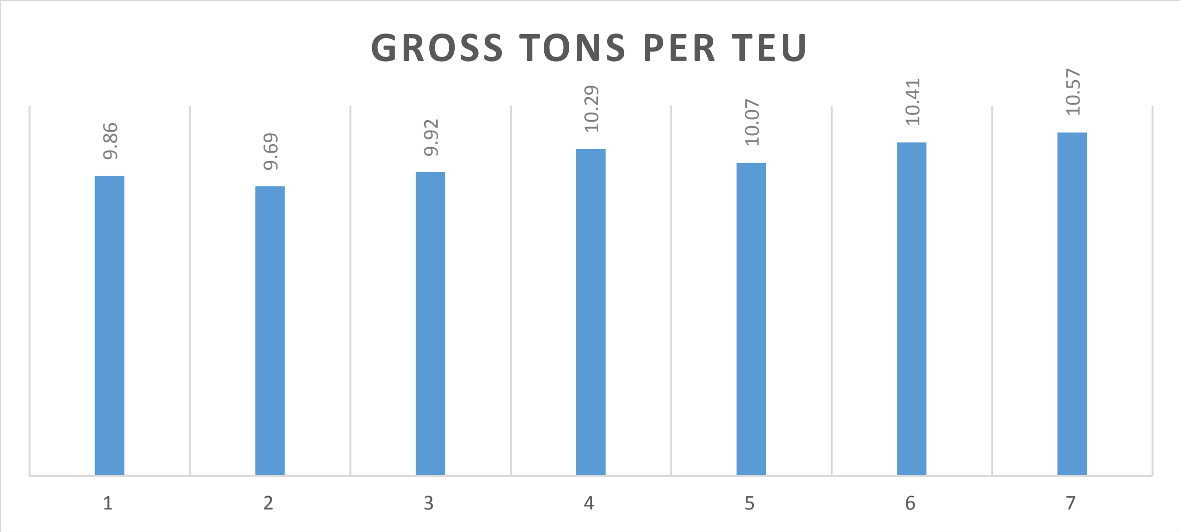

Figure 7 Average weight of a TEU. Source: Port of Rotterdam Authority

The growth scenarios presented by the Port of Rotterdam Authority (PoR) are calculated in gross tonnes of cargo. When studying ITT it is more useful to do calculations in TEUs (Twenty-foot Equivalent Units), because capacities of terminals, depots and vessels are often given in TEUs.

Each year, the Port of Rotterdam Authority publishes a document called 'Port Statistics <year>' where it lists both the number of tonnes handled by container and the number of TEUs handled. These historical data help us determine the amount of tonnes in a TEU and whether or not this number is constant.

Analysing the Port Statistics from 2006 to 2012 [5] [6] [7] [8], it is clear that 1 TEU was approximately equal to 10 tonnes of cargo during this period (see

Figure 7). No information was found in literature to indicate any foreseeable change in the ton-TEU ratio. Therefore, the ton-TEU ratio is assumed to be approximately 0.10 in 2030.

Assumption: The amount of tons per TEU will be the same in 2030 as it was in 2012, so $c_{tt} = 0.10$

$$V_y = V_{y,ton} * c_{tt} \tag{1}$$

c_{tt} = Number of tons per TEU

$V_{y,ton}$ = annual cargo throughput in tons

V_y = annual cargo throughput in TEU

Using the data provided by the Port Authority and the assumption, it is possible to calculate estimates for cargo throughput in TEUs for each of the four projections. The results of this calculation are shown in Figure 8.

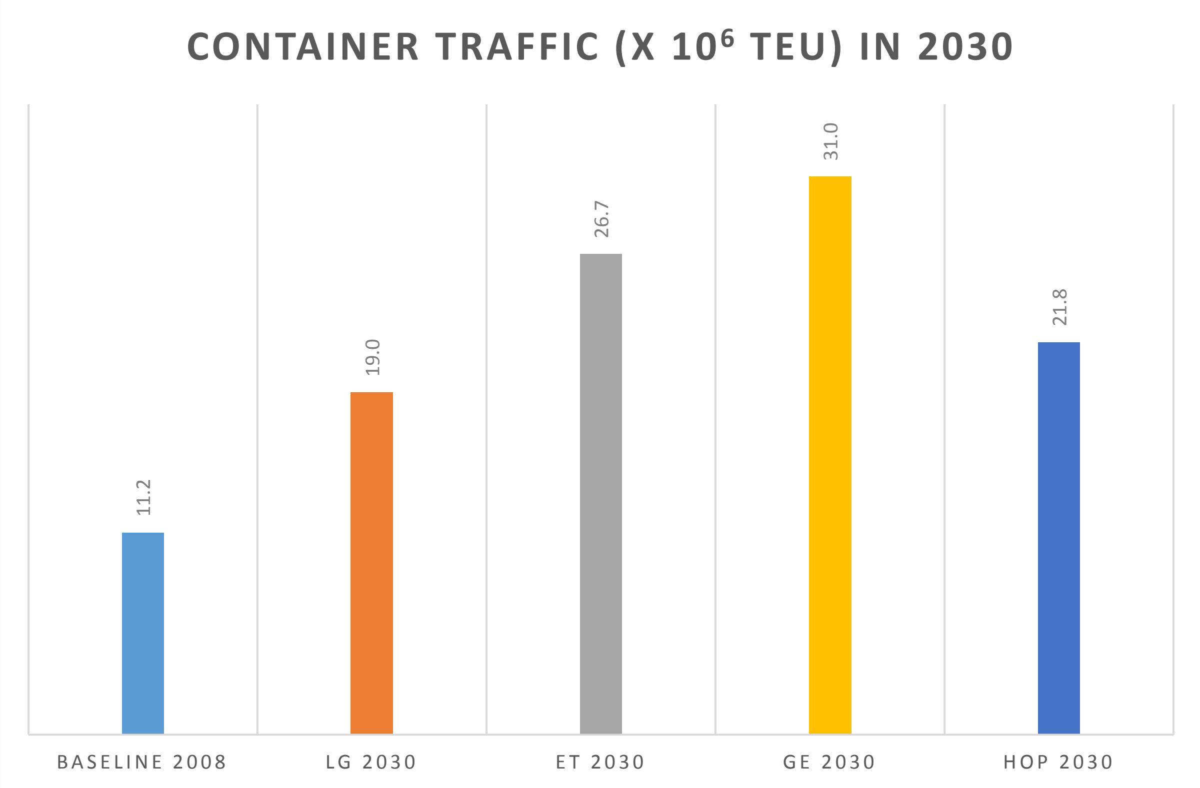

Figure 8 Container traffic in millions of TEU per year.

3.4 TEU-factor – from TEUs to containers

The TEU-factor is the average amount of TEUs (Twenty-foot Equivalent Units) per container. Since almost all containers are either 1 or 2 TEU (meaning a 20 or 40 feet container), in most cases

$$1 < C_{TEU} < 2 \qquad (2)$$

Where

The amount of TEUs arriving can be calculated as follows:

$$V_{x,container} = \frac{V_x}{C_{teu}} \qquad (3)$$

Where

V_x = Volume per unit of time, in TEUs

$V_{x,container}$ = Volume per unit of time, in containers

C_{TEU} = TEU-factor

Figure 9 shows the TEU-factor from 2007 to 2012. In those years the TEU-factor did not change much, but was always roughly 1.66 (see Figure 9). This means one container is equal to 1.66 TEU, and that roughly 62 % of all containers are 40 foot (2 TEU) containers[1]. This is assumed to stay the same,

[1] 45 foot containers are also often classified as 2 TEU, instead of 2.25 TEU.

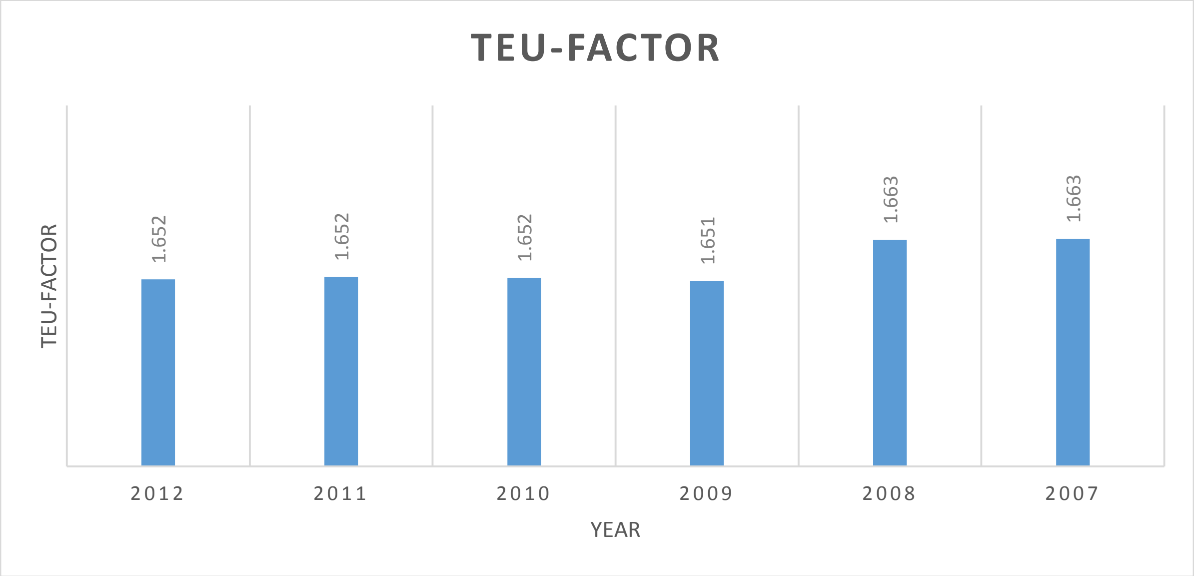

Figure 9 TEU-factor from 2007 to 2012 for the port of Rotterdam

because there are no reasons to assume that the use of 20 foot containers will be reduced even further. Experiments with larger containers have proven unsuccessful in the past [9].

3.5 Modal split

Seaside and landside traffic are both split across several modes of transportation. For the landside movements these are rail, truck and barge. The port of Rotterdam wants to change the current modal split significantly, shifting cargo from trucks to barge or rail (see Figure 10).

3.5.1 Landside modal split

The Port of Rotterdam Authority has made legally binding agreements with terminal operators [10] forcing them to reduce the percentage of trucks used from 48% in 2010 to 35% in 2035. If terminal

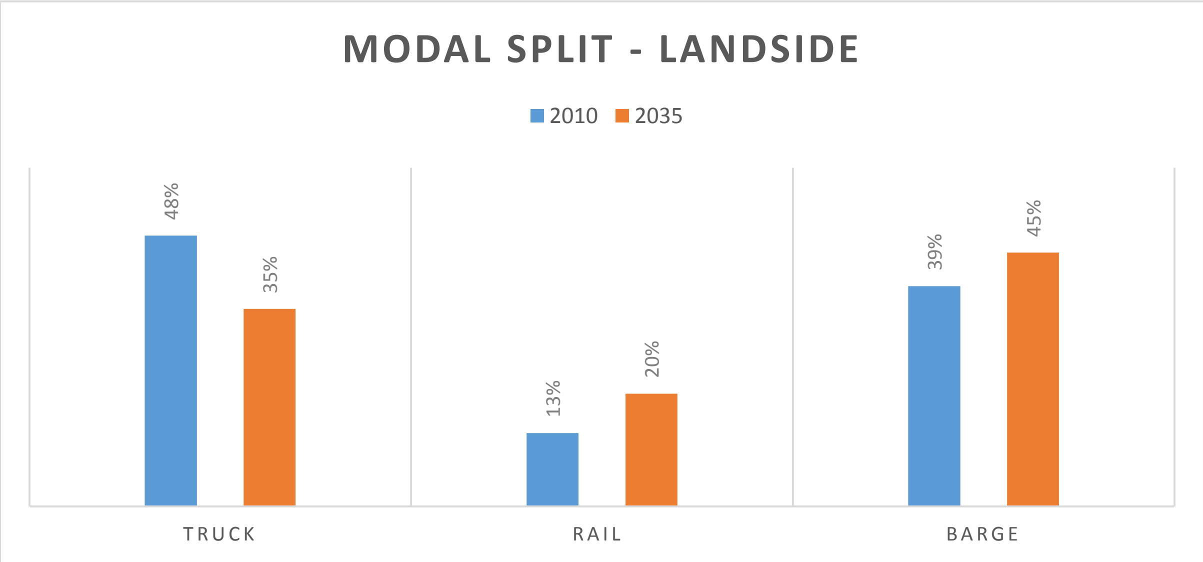

Figure 10 Current modal split (blue, left) and the ambition of the Port of Rotterdam Authority (orange, right). Source: [4]

operators will not reduce their truck use, they will be penalized by the port authority [10]. It is therefore safe to assume a 37% truck share when developing scenarios. The barge and rail percentages are not fixed or penalized and should be treated as guidelines.

The variables S_t, S_r and S_b represent the fractions of hinterland cargo handled by truck, rail and barge respectively. Because all hinterland transportation is done by these three modes, the following rule must hold:

$$S_t + S_r + S_b = 1 \tag{4}$$

where

S_t = fraction of cargo handled by trucks

S_r = fraction of cargo handled by rail

S_b = fraction of cargo handled by barge

Assumption: As stated above we can assume $s_t = 0.37$, $s_r \approx 0.19$ and $s_b \approx 0.44$ in 2030. Sensitivity analysis is needed to determine whether it is useful to use different values of S_r and S_b when generating scenarios.

3.5.2 Seaside modal split

For seaside operations, the container flows are split into three categories: deepsea, shortsea and transhipment. Deepsea traffic is intercontinental traffic. Shortsea traffic typically involves smaller vessels and flows to and from other ports in Europe. Transhipment means the transfer of cargo from one ship to another taking place on a single terminal.

While transhipment is not strictly a mode of transport (it is defined as movement from seagoing vessels to other seagoing vessels) it is useful to distinguish these movements from 'regular' container operations which involve movement between sea and hinterland. The predicted modal split for seaside operations is taken from the Port Vision 2030 document [4] and is slightly different for each of the four cases (LG, ET, GE and HOP). The difference is visualised in Figure 11.

For the seaside modal split, the variables $S_{deepsea}, S_{shortsea}\ and\ S_{trans}$ are used to denote the fraction of deepsea, shortsea and transhipment containers respectively. As for the hinterland, these must add up to 1.

$$S_{deepsea} + S_{shortsea} + S_{trans} = 1 \tag{5}$$

$S_{deepsea}$ = fraction of cargo handled by deepsea

$S_{shortsea}$ = fraction of cargo handled by shortsea

S_{trans} = fraction of cargo being transhipped

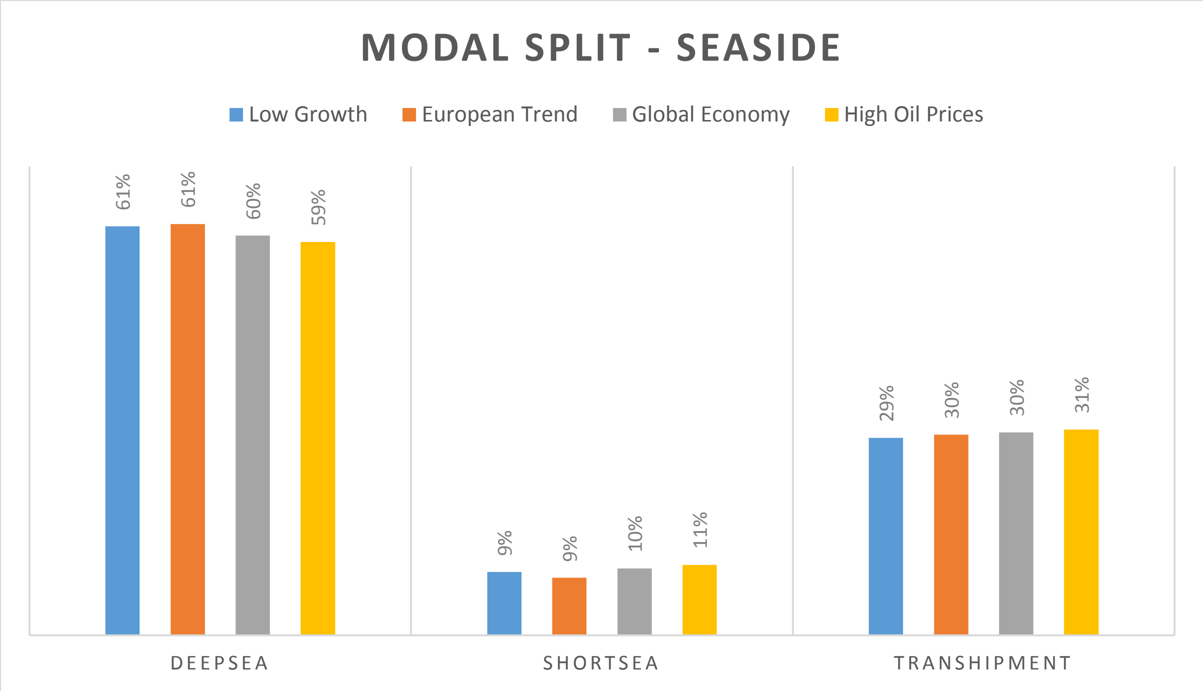

Figure 11 Seaside modal split in 2030 for the four situations.

3.6 Import and export

The scenarios from Port vision 2030 contain only data for the total amount of containers handled divided in three categories. To make scenarios for ITT demand we will need more detail, so we need to split total cargo amounts into import and export flows.

Again, the data available in the Port Statistics documents gives us some guidelines. Each year the Port Authority publishes the number of containers coming in and going out by sea. The import-export ratio has been steady from 2007 onwards at 51% import and 49% export. This means that almost all containers that are imported are also exported again, with a small amount staying somewhere in the hinterland. It seems likely this situation will remain unchanged in the coming years; the Port of Rotterdam Authority, at least, expects this to be the case [3].

The following formula must hold:

$$r_e + r_i = 1 \quad (6)$$

Where

r_e = fraction of containers exported

r_i = fraction of containers imported

Assumption: In 2030 r_e and r_i are assumed to stay the same as they currently are, so

$$r_e = 0.49 \quad (7)$$

$$r_i = 0.51 \quad (8)$$

Note that this means only that the amount of containers imported and exported remains the same: it says nothing about the cargo flows. Rotterdam is an import location [11] when it comes to cargo flows but the amount of containers imported and exported is almost the same. This leads naturally to the next subject to consider: Differentiating between full and empty containers.

3.7 Full and empty containers

Looking at port statistics documents from 2007 onwards it is clear that the amount of full an empty containers varies slightly each year (this can be seen in Figure 12). These numbers are consistent with estimates found in literature [11]. However, the percentage of empty containers for export is always larger than for import. This is understandable because, as mentioned earlier, Rotterdam is an import location. Many containers come in filled with cargo for the Western European market and return empty to other parts of Europe or to East Asia [12].

When modelling the full-empty ratio should be taken into account. The number of empty containers in the export flow is expected to rise because of growing trade volumes with Asia [13]. This suggests that the percentage of imported empties will decrease.

The percentages in Figure 12 only say something about the total amount of containers being handled by sea – perhaps most empty containers enter by feeder and leave by deepsea ship and vice versa. For simplicity, the full-empty ratios are assumed to be the same for all modes.

Assumption: full-empty ratios are identical for all modes

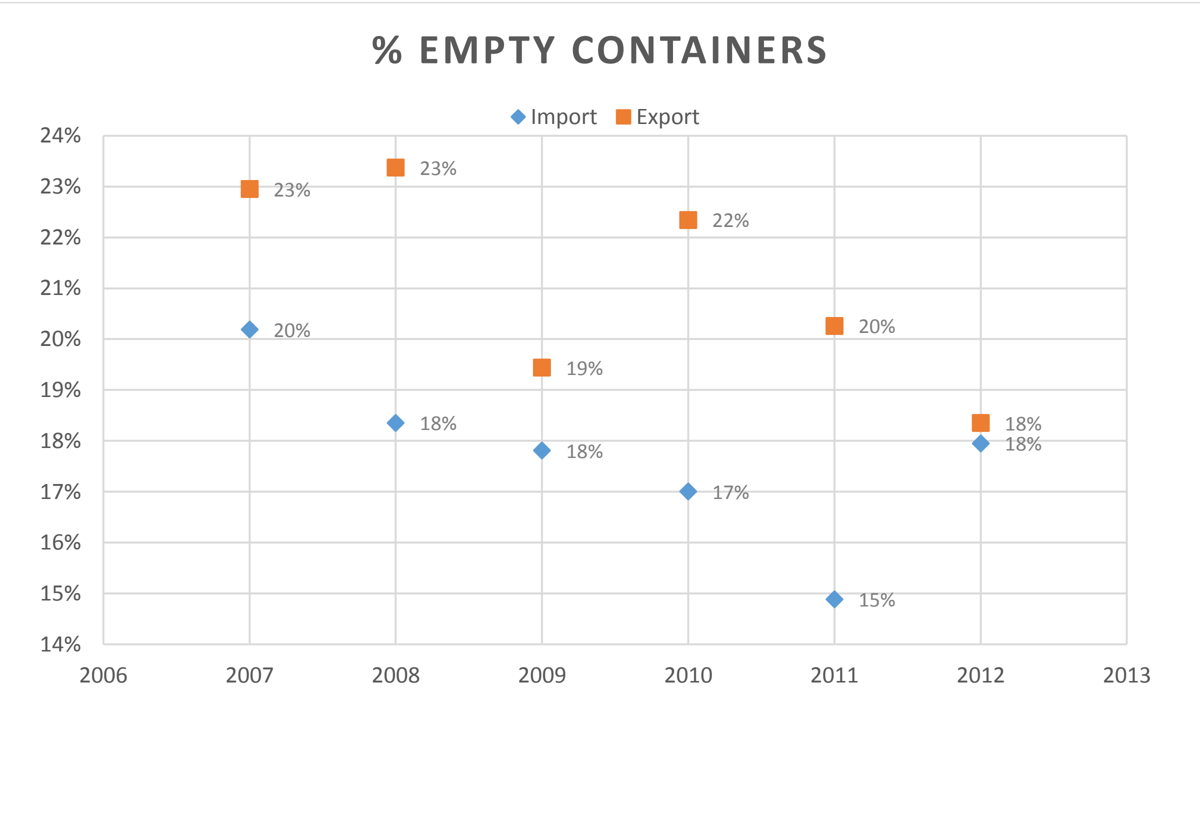

Figure 12 percentage of empty containers entering or leaving the port by sea from 2007 to 2012

Four variables, $r_{e,full}$, $r_{i,full}$, $r_{e,empty}$ and $r_{i,empty}$, are defined as respectively the fraction of full and empty containers in the import and export streams. Since they are parts of the same container flow, the following rules must apply:

$$r_{e,full} + r_{e,empty} = 1 \tag{9}$$

$$r_{i,full} + r_{i,empty} = 1 \tag{10}$$

Where

$r_{e,full}$	=	fraction of export containers that are full
$r_{e,empty}$	=	fraction of export containers that are empty
$r_{i,full}$	=	fraction of import containers that are empty
$r_{i,empty}$	=	fraction of import containers that are empty

Values of r are different each year. This should be taken into account when generating scenarios, because the number of empty containers is quite important when calculating ITT demand as we will see in chapter 5. No fundamental changes are expected in 2030 as the causes of the empty container imbalance will probably still be present. As mentioned above, $r_{e,empty}$ is expected to rise and $r_{i,empty}$ is expected to fall because of growing trade volumes with Asia. It is impossible to quantify this expectation into a meaningful estimate for empty percentages in 2030. We can assume they will probably not be very different from the ones we have seen in Figure 12, with $r_{e,empty}$ being perhaps slightly higher and $r_{i,empty}$ slightly lower. Therefore the following assumption is made:

Assumption: In 2030, $r_{e,empty} = 0.21$ and $r_{i,empty} = 0.18$

3.8 Calculating cargo flows for the whole port

When values for the parameters described above are chosen, it is possible to turn the growth scenarios from Port Vision 2030 into container flows to and from the hinterland. An example is presented below and illustrated in Figure 13.

For the low growth scenario, the port of Rotterdam Authority predicts a yearly throughput of 190 million tons. This is about 19 million TEUs. Of those 19 million TEUs, 5.6 million are transhipment containers. 11.6 Million of those are arriving or leaving by deepsea ship and 1.8 million by shortsea vessels.

Choosing the most optimistic scenario the hinterland modal split will be:

$s_b = 0.44$

$s_r = 0.19$

$S_t = 0.37$

To calculate the amount of TEUs imported by barge in the year 2030, formula 9 should be used.

$$V_{y,b,i} = S_b * r_i * \left(V_{y,deepsea} + V_{y,shortsea}\right) \tag{11}$$

Where

$V_{y,b,i}$ = Amount of TEUs imported by barge in 2030

$V_{y,t,i}$ = Amount of TEUs imported by truck in 2030

$V_{y,r,e}$ = Amount of TEUs exported by rail in 2030

S_b = Fraction of cargo handled by barge

r_i = Fraction of cargo imported

Similar calculations can be done for the other import and export flows, so that the amount imported by truck is:

$$V_{y,t,i} = S_t * r_i * (V_{y,deepsea} + V_{y,shortsea}) \quad (12)$$

The amount exported by rail

$$V_{y,r,e} = S_r * r_e * (V_{y,deepsea} + V_{y,shortsea}) \quad (13)$$

etcetera. Together, the calculations give a scenario for cargo flows into and out of the port, an example of which is depicted in Figure 13.

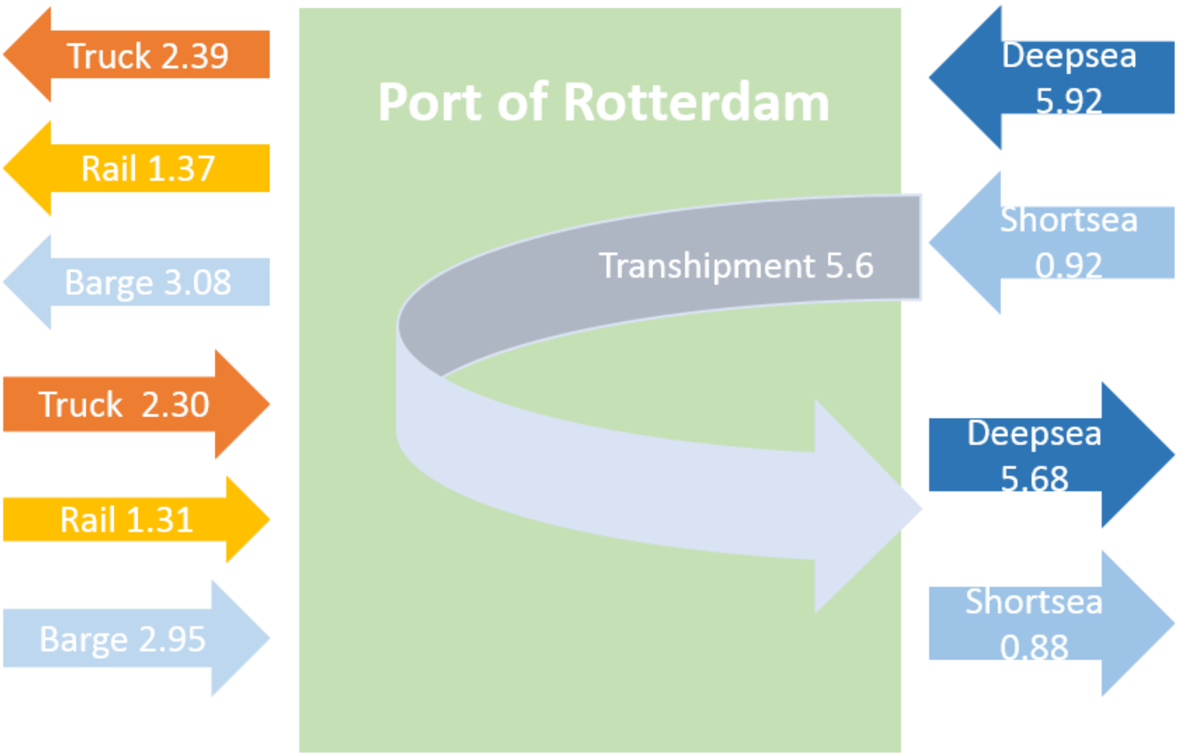

Figure 13 Container flows (x 1,000,000 TEU/year) for the Low Growth situation.

3.9 Summary

Using one of the four scenarios from 'Port Vision 2030' as input, and applying the formulas presented in this chapter, it is possible to calculate the cargo flows for the year 2030 for the port of Rotterdam. This requires making assumptions about the modal split, average TEU-factor, average number of tons per TEU, full-empty ratio and import-export ratio.

4 Calculating cargo flows per location

In the previous section the scenarios from the Port Vision 2030 were applied to the port and expressed as specific cargo flows per modality. In order to make useful scenarios we need to know exactly where these cargo flows are going.

4.1 Locations

There are many container handling facilities and companies on the Maasvlakte area. This model uses the locations in Table 1 as possible customers for an ITT system.

The rows marked with * are locations that have not yet been developed but might become part of the port in the future. For each scenario a selection of participants has to be chosen. Obviously, this selection will have a large impact on the volume and direction of ITT flows. A more detailed table can be found in appendix 1.

4.2 Applying scenarios for the whole port area to the Maasvlakte I and II

Looking at a map of all container terminals [14] provided by the Port of Rotterdam Authority, we note that most, but not all container terminals are located on the Maasvlakte. There are four large (< 100,000 TEU) container terminals in other parts of the port: their names and current capacities are listed in Table 2.

Table 1 A list of participants in the ITT model of the Maasvlakte. Source: [15] [16] [17] [18] [19] [20]

	Terminal name	Function
1	ECT Delta	Deepsea
2	EuroMax	Deepsea
3	APM MV1	Deepsea
4	RWG	Deepsea
5	APM MV 2	Deepsea
6	T3 *	Deepsea
7	T4 *	Deepsea
8	ECT Delta barge feeder	Barge / feeder
9	Delta Container Services	Barge / feeder
10	Common rail terminal *	Rail
11	Rail Terminal West	Rail
12	RCT	Barge / feeder
13	Common Barge Service Centre *	Terminal
14	Kramer Delta Depot	Depot
15	Van Doorn Container Depot	Depot
16	Emty Depot spotterstrand *	Depot
17	Empty Depot MV1 *	Depot
18	Douane	Customs
19	Distripark	Distribution
20	Rhenus *	Deepsea

Table 2 Large container facilities outside the Maasvlakte area in the Port of Rotterdam. (source: [20])

Terminal name	Capacity (TEU/year)
ECT City Terminal	1,150,000
Rotterdam Shortsea	1,450,000
Uniport Multipurpose	1,200,000
Barge Center Waalhaven	200,000
Total	**4,000,000**

In 2010, more than 30% of container handling capacity was not located on the Maasvlakte. However, the construction of the second Maasvlakte (MVII) and the opening of new container terminals means most -if not all- of the growth of capacity for container handling operations will occur there. The growth in container traffic to and from the Port of Rotterdam is expected to be driven mainly by the arrival of vessels larger than 13000 TEU [3]. These vessels cannot enter the terminals located further inland.

To calculate numbers for the MV area, starting from scenarios for the whole port, it is assumed that the container handling capacity of terminals outside the MV will not increase and that no new terminals will be constructed outside of the Maasvlakte. All increases in container traffic are assumed to be accommodated on MVI and MVII. At most 4 million TEU can be handled outside of the MV.

Assumption: At most 4,000,000 TEU per year can be handled outside the Maasvlakte area. This capacity will not increase between now and 2030.

How many TEUs are actually handled outside the MV depends on the amount of participants and occupancy rates for the terminals on the Maasvlakte.

4.2.1 Example

In the low growth scenario the port will handle a total of 19 million TEUs in 2030. 11.6 million TEU will arrive or depart by deepsea vessel and 1.8 million TEU by shortsea ships. The remaining 5.6 million TEU are transhipment containers.

These flows can be handled with the terminals and occupancy rates shown in Table 3.

Table 3 Possible selection of participants for the LG scenario.

Location	**Capacity (x 10^6 TEU)**	**Utilization rate**	**handled cargo (x 10^6 TEU)**	**% deepsea cargo**	**% shortsea cargo**
ECT	5.10	85%	4.34	26.5%	
Euromax	2.75	85%	2.34	14.3%	
APMTR1	2.40	85%	2.04	12.5%	
RWG	4.50	85%	3.83	23.4%	
APMTR2	4.50	85%	3.83	23.4%	
T3	0.00	0%	0.00	0.0%	
T4	0.00	0%	0.00	0.0%	
ECT Delta barge feeder	0.33	85%	0.28		33.7%
Delta container Services	0.15	85%	0.13		15.3%
RCT	0.50	85%	0.43		51.0%
Common BSC	0.00	0%	0.00		0.0%
Rhenus	0.00	0%	0.00	0.0%	
Total	**20.23**	**85%**	**17.20**	**100.0%**	**100%**

Note that the total amount of cargo handled is only 17.20 million TEU. The remaining 1.8 million TEU will be handled on the other container terminals outside the Maasvlakte, giving them an average occupancy rate of roughly 45%. This is a lower rate than the Maasvlakte terminals, explained by the fact that the city terminals are further from the sea and smaller and thus less capable of taking advantage of economies of scale. This difference between the Maasvlakte and other parts of the port is predicted by terminal operators as well [15].

In another possible scenario there would be a new terminal (T3) with a capacity of 2.4 million TEU per year. This selection of participants is shown in Table 4.

Table 4 Another possible selection of participants for the LG scenario

Location	**Capacity (x 10^6 TEU)**	**Utilization rate**	**handled cargo (x 10^6 TEU)**	**% deepsea cargo**	**% shortsea cargo**
ECT	5.10	85%	4.34	26.5%	
Euromax	2.75	85%	2.34	14.3%	
APMTR1	2.40	85%	2.04	12.5%	
RWG	3.00	85%	2.55	15.6%	
APMTR2	3.00	85%	2.55	15.6%	
T3	3.00	85%	2.55	15.6%	
T4	0.00	0%	0.00	0.0%	
ECT Delta barge feeder	0.33	85%	0.28		33.7%
Delta container Services	0.15	85%	0.13		15.3%
RCT	0.50	85%	0.43		51.0%
Common BSC	0.00	0%	0.00		0.0%
Rhenus	0.00	0%	0.00	0.0%	
Total	**20.23**	**85%**	**17.20**	**100.0%**	**100%**

The differences between Table 3 and Table 4 clearly show that even when using the same situations from Port Vision 2030 as a starting point, one can construct different future scenarios.

4.3 Calculating cargo flows to and from individual locations

After deciding which facilities to include in the scenario it is possible to model container flows to and from these locations. To calculate the cargo flow for each terminal, a number of assumptions and simplifications is necessary. Below, these will be discussed for each mode (deepsea, shortsea and transhipment) separately.

Remember that the list of participants and occupancy rates has already been made by this point in the construction of the model, so total handling amounts for each terminal have been determined. We will now divide the total cargo flows (an example of which can be seen in Figure 8) across the participants.

4.3.1 Deepsea cargo

Deepsea flows can only be handled by deepsea terminals. It is assumed all deepsea terminals have the same seaside modal split. This means that the amount of deep sea containers handled by a deepsea terminal can be determined by computing its share of the total deepsea handling capacity and multiplying the total amount of deepsea containers by this percentage, as done in the formula below.

The share of the deepsea market per terminal is calculated as follows:

$$M_{deepsea,n} = V_{y,n}/V_{total,deepsea} \tag{14}$$

The total amount of deepsea cargo handled by a location in a year is calculated with the following formula:

$$V_{y,deepsea,n} = M_{deepsea,n} * V_{y,deepsea} \tag{15}$$

here

$V_{y,deepsea,n}$	=	Amount of deepsea TEUs handled at location *n* per year
$V_{y,n}$	=	Total amount of TEUs handled at location *n* per year
$V_{total,deepsea}$	=	Sum of handled cargo amounts of all deepsea terminals
$M_{deepsea,n}$	=	Fraction of deepsea cargo handled by location *n*

Assumption: Deepsea cargo is handled by deepsea terminals and divided across them pro rata, meaning according to their percentage of total capacity.

4.3.1.1 Example

ECT Delta terminal has an annual capacity of 5.1 million TEU. This is 26.5% of the total capacity of all deepsea terminals combined. ECT Delta terminal is therefore assumed to handle 26.5% of all containers coming from or going to deepsea vessels.

4.3.2 Shortsea

The shortsea flows will be handled at the deepsea and barge / feeder terminals. It is assumed that the total amount of shortsea containers is divided across them according to their share of the total handling capacity, similar to the way deepsea cargo is divided across deepsea terminals.

Assumption: Shortsea cargo is handled by deepsea and barge / feeder terminals and divided across them pro rata, meaning according to their percentage of total capacity.

Each terminal's share of the shortsea market can be computed with the following formula:

$$M_{shortsea,n} = (V_{y,n} - V_{y,deepsea,n})/(V_{y,total} - V_{y,deepsea}) \quad (16)$$

The amount of shortsea traffic handled per terminal per year can be computed with the following formula:

$$V_{y,shortsea,n} = M_{shortsea,n} * V_{y,shortsea} \quad (17)$$

Here

$V_{y,trans,n}$	=	Amount of transhipment TEUs handled at location *n* per year
$V_{y,shortsea,n}$	=	Amount of shortsea TEUs handled at location *n* per year
$V_{y,n}$	=	Total amount of TEUs handled at location *n* per year
$V_{y,total}$	=	Total handled cargo for all deepsea and barge / feeder terminals
$M_{shortsea,n}$	=	Fraction of shortsea cargo handled by location *n*

4.3.3 Transhipment

We assume that transhipment takes place at all deepsea and barge / feeder terminals. Deepsea terminals will handle most or all of their transhipment containers on-site, but barge / feeder terminals obviously cannot do so since deepsea vessels cannot reach their quays.

Note that a transhipment container counts as two moves because it is handled twice – once during loading and once during unloading.

The amount of transhipment containers for terminals can be computed with formula 17.

$$V_{y,trans,n} = V_{y,n} - (V_{y,shortsea,n} + V_{y,deepsea,n}) \quad (18)$$

$V_{y,trans,n}$	=	Amount of transhipment TEUs handled at location number *n* per year
$V_{y,shortsea,n}$	=	Amount of shortsea TEUs handled at location number *n* per year
$V_{y,deepsea,n}$	=	Amount of deepsea TEUs handled at location number *n* per year
$V_{y,n}$	=	Total amount of TEUs handled at location number *n* per year

4.3.4 Traffic to and from the hinterland

When making a scenario, every terminal is assumed to have the same model split regarding hinterland traffic. This assumption is made because there is no reasonable way of predicting modal splits for individual locations. Currently the modal split is not uniform, as can be seen from Port of Rotterdam documents [21] [22].

Assumption: All terminals can handle all hinterland modalities. The only exception to this rule is DCS which does not have its own rail facilities. However, DCS has a backdoor connection to the Rail Terminal West and is assumed to use that to handle rail cargo without the need for ITT.

4.4 Summary

Using the total cargo flow numbers computed in Chapter 3, assumptions about the future layout of the Maasvlakte area and the equations in this chapter the cargo flows per terminal can be computed. The process leading to the creation of a list of terminals (as discussed in section 4.1) answers the first two research questions discussed in Chapter 1. Calculating the cargo flows to and from each individual location answers the third research question. Those questions are:

- What are possible pick-up and drop-off locations for an ITT system?
- What will be the handling capacities per location?
- What will be the possible effects of establishing common transport links (common barge / rail service centers) vs. terminal-specific solutions

5 From cargo flows to ITT demand

In the previous chapters a method was proposed to calculate cargo flows for individual terminals in 2030, based on possible future situations and predictions from the Port of Rotterdam Authority.

As we have already seen in Figure 1, ITT is necessary for:

- flows between terminals and empty depots
- flows to and from common service centres
- a percentage of transhipment flows
- flow to and from customs

(Source: [2], [23], [24])

This chapter will detail each driver for ITT demand and propose methods for generating actual ITT demand scenarios.

5.1 Flow between terminals and empty depots

Empty containers arriving via sea in the port can go either directly to a customer or to a depot [12]. We assume the transhipment containers will stay on the terminals (except for the percentage determined earlier). The empties from the deepsea and shortsea flows will go either to the hinterland or to a depot. Same goes for exported empties – they can come from the hinterland or from a depot. A large number of empties are taken out of the port to be used elsewhere – see [25].

It is assumed that empty containers for export come from the empty depots, where they have been delivered from the hinterland [11]. For transport between the depots and terminals ITT is required. In reality, not all empty containers visit a depot but many do. This is modelled by assuming that none of the transhipment containers will go to a depot and all of the im- and export empties will.

Assumption: each terminal exchanges containers with a single empty depot. All empty import and export containers visit an empty depot – transhipment containers do not.

The amount of containers going from terminal *n* to a depot is computed with formula 16.

$$V_{todepot,n} = \left(V_{y,deepsea,n} + V_{y,shortsea,n}\right) * r_i * r_{i,empty} * r_{depot} \tag{19}$$

A similar formula can be used to compute the cargo flow from a depot to a terminal.

$$V_{fromdepot,n} = \left(V_{y,deepsea,n} + V_{y,shortsea,n}\right) * r_e * r_{e,empty} * r_{depot} \tag{20}$$

Here

r_{depot} = fraction of empty containers stored in empty depots instead of in the terminal stack.

For the sake of simplicity it is assumed r_{depot} = 1. That means all empty containers will go to an empty depot instead of being stored in the stack of a terminal.

Assumption: All empty containers entering a terminal go to an empty depot; all empty containers leaving via a terminal come from an empty depot. This means $r_{depot} = 1$.

When generating scenarios it is assumed that all empty containers for a given terminal come from one and the same empty depot. A proposed list of terminals and their corresponding depots is presented in Table 5, but this can be changed when developing scenarios.

Table 5 A list of terminals and their empty depots.

	Location	Empty Depot
1	ECT Delta	Kramer Delta Depot
2	Euromax	Empty Depot MV1
3	APM TR 1	Kramer Delta Depot
4	Rwg	Empty Depot MV2
5	APM TR 2	Empty Depot MV2
6	T3	Empty Depot MV2
7	T4	Empty Depot MV1
8	Delta Barge Feeder	Kramer Delta Depot
9	Delta Container Services	Kramer Delta Depot
10	Common Rail Terminal	Van Doorn container depot
11	Rail Terminal West	Van Doorn container depot
12	Rotterdam Container Terminal	Van Doorn container depot
13	Common Barge terminal	Empty Depot MV2
19	Distripark	Van Doorn container depot
20	Rhenus	Van Doorn Container Depot

5.2 Common service centres

The flows to and from common service centres depends on their handling capacity and customers. Some or all of the deepsea terminals can be customers. Currently there are two common service centres planned for the Maasvlakte, one for rail cargo near APM TR2 and one for barges at the end of the Prinses Alexiahaven. To estimate maximum capacities we use a rough heuristic, putting the maximal throughput of a terminal at 27,000 TEU per hectare per year. This number was obtained from the Port of Rotterdam Authority [26].

The barge service centre plot (location number 13) is 14,2 hectares, giving it a theoretical maximum capacity of 380,000 TEU per year.

The area reserved for the rail terminal (location number 13) has an approximate surface of 12 ha, giving it a theoretical maximum capacity of 324,000 TEU per year. However, capacity is constrained by the fact that trains will still have to enter and leave the Maasvlakte via rail infrastructure. If the capacity of that bottleneck is not expanded the real capacity of a future RSC may be much less than the theoretical maximum.

Assuming an occupancy rate and thus real handled capacity for both service centres in 2030, it is possible to compute the cargo flows to and from each centre. It is assumed im- and export ratios r_i and r_e apply to the service centres as well. The container flows $V_{y,i,n}$ and $V_{y,e,n}$ can then be calculated with the following formulas:

$$V_{y,i,n} = r_i * V_{y,n} \tag{21}$$

$$V_{y,e,n} = r_e * V_{y,n} \tag{22}$$

Where

$V_{y,i,n}$ = Number of TEUs imported to location number *n* in 2030

$V_{y,e,n}$ = Number of TEUs exported from location number *n* in 2030

5.2.1 Cargo flows to and from common service centres

All service centre cargo flows come from or go to terminals. All containers will arrive by barge or rail (depending on the type of service centre) and leave by ITT, or vice versa. Obviously, a dedicated service centre will serve only one modality, so the flows to and from the hinterland do not have a modal split.

Common centres are mainly for the bundling of 'thin streams' [24] [23], container shipments to and from locations that are too small or infrequent customers for a single terminal to fill a barge or train. All seaside terminals are assumed to be customers of common service centres. The cargo flows to and from these centres are divided across them pro rata. Containers handled at a service centre still count as containers for a seaside terminal – thus the flows to and from service centres should be subtracted from the total amount of moves a terminal makes per year. This is because service centres do not handle cargo independently but instead facilitate cargo handling by terminals.

The amount of containers handled by a service centre is decided by its capacity and occupancy rate. Flows between a terminal and a service centre are computed with the following formulas.

$$V_{n\rightarrow ss} = V_{y,ss} * (V_{y,n}/V_y\ ) * r_i \quad (23)$$

$$V_{ss\rightarrow n} = V_{y,ss}\ \ * (V_{y,n}/V_y\ ) * r_e \quad (24)$$

Where

$V_{n\rightarrow ss}$	=	Flow from terminal *n* to service centre
$V_{n\rightarrow ss}$	=	Flow from service centre to terminal *n*
$V_{y,ss}$	=	Total amount of TEUs handled at the service centre
$(V_{y,n}/V_y\ )$	=	Share of all containers handled by terminal *n*

For example, in a European trend scenario ECT Delta terminal handles 5,500,000 TEU per year. It also sends 50,646 TEU to the common barge service centre. These containers are coming from ECT and going to the hinterland by barge, and should thus be subtracted from the total amount of containers ECT is expected to send to the hinterland by barge.

Assumption: The common BSC has a maximum capacity of 380,000 TEU per year, the common RSC has a maximum capacity of 324,000 TEU per year. Cargo to and from each service centre is divided across deepsea and shortsea terminals pro rata.

5.2.2 Distripark

The distripark is a facility in the middle of the Maasvlakte area where containers are unpacked and their contents transferred to trucks. Full containers go from the seaside to a terminal, from a terminal to the distripark, are unpacked and afterwards stored in an empty depot. The moves from the terminal to the distripark and from the distripark to the depot can be done by ITT.

There is no data available on how much cargo is handled at the distripark. It is assumed that a percentage of cargo that goes from the seaside to the hinterland by truck is unpacked at the distripark. The distripark has a surface area of 125 hectares, giving it a theoretical maximum capacity of 3,375,000 TEU per year when using the heuristic for terminal capacity from paragraph 5.2. It is likely that the actual capacity is quite a bit lower, given the fact that packing and unpacking of individual containers will take more space and time than just loading and unloading them.

The amount of cargo going to the distripark is calculated with the following formula.

$$V_{y,19} = V_{y,t,i} * r_{distripark} \tag{25}$$

Where

$V_{y,19}$ = The total amount of TEUs going to the distripark per year

$V_{y,t,i}$ = the total amount of TEUs going to the hinterland by truck per year

$r_{distripark}$ = fraction of TEUs going to the hinterland by truck that will visit the distripark

Assumption: $r_{distripark}$ = 0.10. This means one in ten containers going to the hinterland by truck is unpacked at the distripark. The others are unpacked somewhere else.

5.3 Transhipment flows

Most transhipment is done on one terminal. However, some exchange of transhipment containers between marine terminals is perfectly possible. In the report by Koeman and Diekman, the authors disagree about whether or not marine terminals will exchange containers ([2], p.39). When creating scenarios it is suggested to assume that the exchange will either be 1% of transhipment containers or that it is non-existent ($r_{exchange}$ = 0.01 or 0.00).

Assumptions: Exchange of transhipment containers between marine terminals is either 1% or 0% of transhipment volume. Transhipment flows from each shortsea terminal are divided over the deepsea terminals pro rata. Transhipment from deepsea terminals is divided across deepsea and shortsea terminals pro rata.

$$V_{exchangedtranshipment,n} = V_{transhipment,n} * r_{exchange} \tag{26}$$

Example – in a low growth scenario RWG will handle 600,000 TEU worth of transhipment moves a year. This means 300,000 TEU, handled twice. 1% will go to other deepsea terminals, meaning RWG will transport 3,000 TEU to other deepsea and shortsea terminals. It will also receive transhipment containers from the other seaside terminals.

5.3.1 Shortsea terminals and transhipment

Shortsea terminals receive transhipment containers but cannot handle transhipment on-site, because deepsea vessels cannot access their quays. These containers will have to enter or leave the terminal via ITT. They will also receive transhipment containers from deepsea terminals.

To calculate transhipment flows per shortsea terminals, first calculate the total amount each terminal receives from deepsea terminals. Detract this number of TEUs from the total number of transhipment TEUs by the shortsea terminal. The remaining TEUs must go to deepsea terminals and are divided across them pro rata.

The following formulas apply only to shortsea terminals:

$$V_{transhipmentsent,n} = V_{transhipment,n} - V_{transhipmentreceived,n} \tag{27}$$

$$V_{transhipmentsent,n \to m} = V_{transhipmentsent,n} * (V_{y,n}/V_{y,deepsea}) \tag{28}$$

Where

$V_{transhipmentsent,n}$ = Amount of transhipment TEUs sent to deepsea terminals by terminal *n*

$V_{transhipmentreceived,n}$ = Amount of transhipment TEUs received by terminal *n*

$V_{transhipment,n}$ = Amount of transhipment TEUs handled per year by terminal *n*

$V_{transhipmentsent,n \to m}$ = Transhipment sent from terminal number *n* to *m*

$(V_{y,n}/V_{y,deepsea})$ = Fraction of deepsea terminal capacity possessed by a single deepsea terminal

5.4 Flow to and from customs

Most large terminals are expected to handle customs on-site. Thus, only a small flow to and from the central customs location near the distripark is expected. In the future most scanning activities will probably be undertaken at the terminal itself. Only a very small percentage will be handled at the central scanning facility on the bosporusweg.

Koeman and Diekman [2] assume 0.25% of all container will make this trip. This means deepsea terminals will transport one in every four hundred containers to a central customs facility. This is still a significant amount of containers, considering terminals handle millions of TEUs a year.

The following formula can be used to calculate the amount of cargo going to the central customs facility:

$$V_{y,customs} = r_{customs} * V_y \tag{29}$$

Where

$r_{customs}$ = Fraction of handled TEUs visiting the central customs facility

$V_{y,customs}$ = Amount of TEUs handled by the customs facility each year

V_y = Amount of TEUs handled in the port each year

Each visit is assumed to require two ITT moves – one from the terminal to the customs site and another one back to the terminal of origin.

Assumption: 0.25% of all containers visit the central customs facility. A visit to the central customs facility always requires two ITT moves.

5.5 Backdoor connections

Backdoor connections are direct connections between different terminals that are not part of the public road network. They allow terminals to transfer containers using vehicles that are not allowed on public roads, such as AGVs, multi-trailer vehicles or reach stackers.

Using backdoor connections, terminals can exchange containers directly without using an ITT system. Whether or not they will do this is impossible to predict, but it is definitely a possibility.

Backdoor connections exist between:
ECT Delta: RCT, Rail Terminal West, Van Doorn, Kramer, Distripark, DCS
APMMV2: Rail Terminal West, Empty Depot MV2
EuroMax : Empty Depot MV1, T4
DCS: ECT Delta, AMPT1, Rail terminal West, Distripark, Customs
RCT: ECT Delta, Rail Terminal West, APMTR1, Customs, Distripark
Sources: [27] [28]

5.6 Summary

Inter Terminal Transportation is necessary for transportation:

- between empty depots and terminals

- between common service centres and terminals

- between deepsea and barge / feeder terminals (transhipment containers)

- between terminals and the central customs facility

- between deepsea terminals (this will be a very small or negligible amount of containers)

Some ITT moves can also be accomplished using backdoor connections between terminals and equipment belonging to terminal operators, i.e. not part of an ITT system.

6 Variation in cargo flows and ITT demand

In the previous chapters, we have seen how to arrive at scenarios describing yearly container flows in the Maasvlakte area. However, these flows are not constant: they change, increasing or decreasing in volume with the arrival of ships, barges, trains and trucks, the change of the seasons and the days of the week.

6.1 Cargo flow variation per month, week and day

In order to design an ITT system it is necessary to know not just the average amount of cargo it will have to transport, but also the maximum and minimum demand. This means the maximum amount of new requests for transport entering the system at any given time and the duration of the period of large demand. Demand variations will be examined on a monthly, weekly and daily level.

6.1.1 Cargo flow variation per month

To determine whether there is a variation in container transport throughout the year, we take a look at statistics.

6.1.1.1 Quarterly variation

The European bureau of statistics Eurostat [29] keeps track of container volumes to and from the Netherlands per quarter. We assume those numbers are relevant for modelling the Port of Rotterdam. Looking at data from 1996 to 2002, we notice very small quarterly variations – all quarters contain between 23 and 26 % of yearly cargo volumes. This would mean that on average, a quiet month would contain 7.6 % of yearly cargo throughput while a busy month would contain 8.6%. Both values are very close to the yearly average of 8.3% per month.

6.1.1.2 Monthly variation

Eurostat does not contain monthly data for cargo shipping. Neither does the Dutch Central Bureau of Statistics (CBS). Research from the University of Antwerp [30] shows that there are seasonal variations in the amount of containers handled in ports. These variations are roughly the same every year.

From 1996 until 2002, the CBS did collect monthly data on inland shipping container volumes. These data, visualised in in Figure 14, show that during the busiest months of the period barges carried ten percent of yearly cargo volumes. The chart also clearly shows the volatility of the inland shipping sector. During the least busy month, barges carried a mere one percent of the yearly volume!

The data from the CBS contains a large negative outlier. This is understandable, as shipping volumes are constrained by the amount of available ships but demand shrinkage is not. In other words, cargo shipping volumes can fall, but not rise, sharply. We can therefore expect months with very low volumes in the future but not months with very high volumes.

6.1.2 Calculating cargo flows per month

The Eurostat data show that on a quarterly basis, container cargo does not exhibit much volatility. In other words, average quarterly values are not very different from the yearly average. A look at monthly data for the inland shipping sector suggests the volatility of the handled volume is larger than suggested by quarterly data. Monthly data for the whole container sector is not available for free use, so the data for the inland shipping sector are used as reference values. If modal split does not change during the year, patterns for one modality should match those for all containers.

There are no foreseeable ways the seasonal patterns will change, so we assume they will be roughly the same in 2030 as in 2002.

Based on the CBS and Eurostat data, and the assumption that they are relevant tot container handling in the port of Rotterdam, it is proposed to assume that during a busy month, 10 % of the yearly container volume will be handled by the port of Rotterdam in 2030. A very quiet month will mean handling 1% of yearly volumes. A proposed ITT system should be able to handle both situations and everything in between.

$$V_{busymonth} = V_y * 0.10 \tag{30}$$

$$V_{quietmonth} = V_y * 0.01 \tag{31}$$

Where

$V_{busymonth}$	=	Amount of TEUs handled during a very busy month
$V_{quietmonth}$	=	Amount of TEUs handled during a very quiet month
V_y	=	Amount of TEUs handled per year

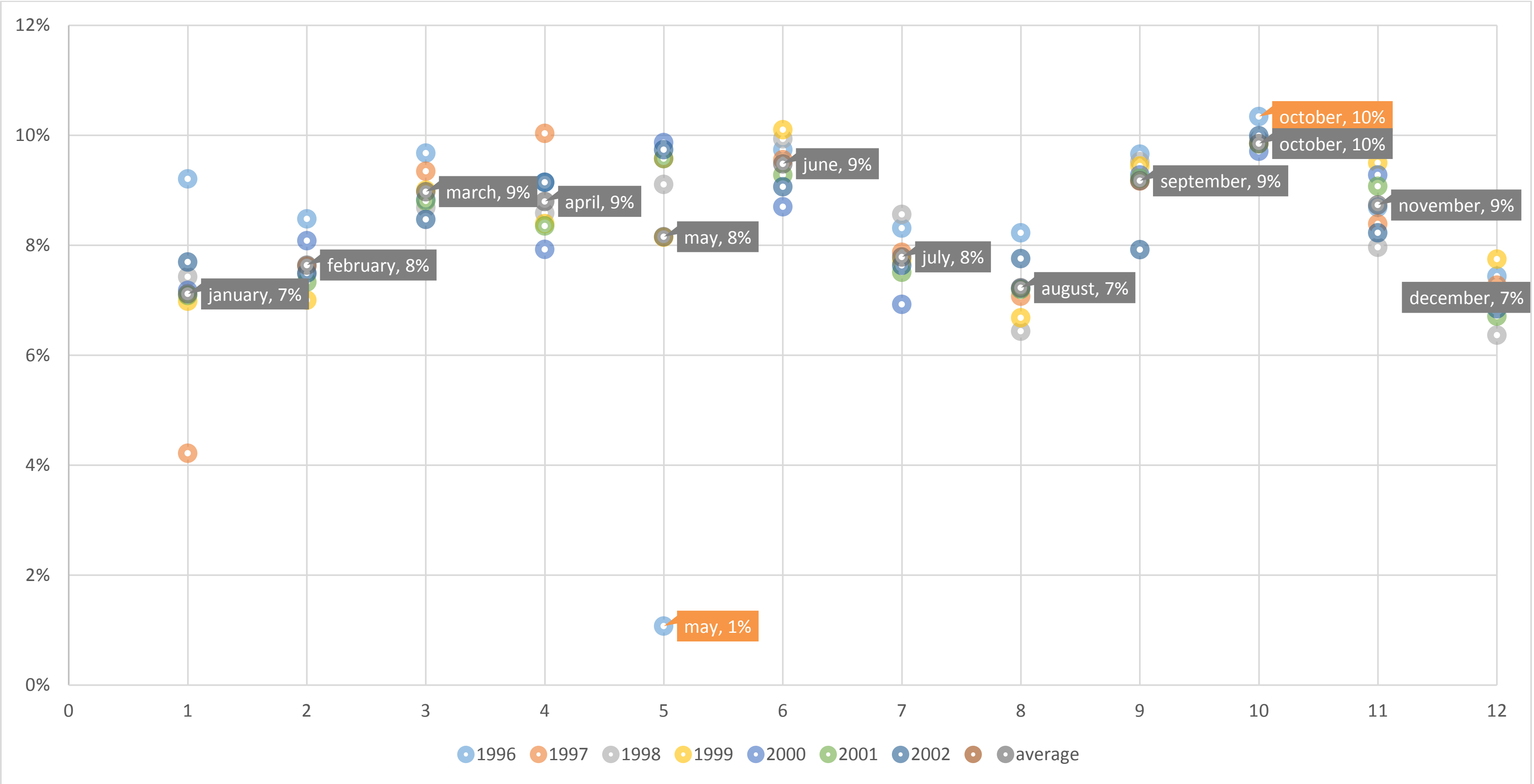

Figure 14 Monthly inland shipping cargo volume as percentage of yearly volume from 1996 to 2002. Grey labels contain average values for that month, orange labels contain extreme values. Source: CBS

6.1.3 Cargo flow variation per week

Cargo does not arrive in a steady stream during the week, but different days have different amounts of containers arriving in and leaving the port of Rotterdam. Rick Jansen analysed traffic flows to and from the hinterland for his thesis [27]. These give an indication of the variations in the amount of handled cargo during the week. Data for the arrival of barges at APM MV1 and ECT, arrival of trucks at the Maasvlakte and arrival of trains at rail terminal west are included in his report. While they are all different, each set shows that on a busy day about 20% of cargo is handled. On quiet days about 5% of all weekly cargo is handled, although it must be noted that barge visits are more evenly spread out than truck or train visits.

In 2030, hinterland transportation will probably still be done with a large number of smaller vehicles. Trains are expected to be longer than they currently are and to depart more often, but trucks and barges are expected to stay roughly the same. This means arrival and departure patterns for the recent past are the best indication of future patterns.

Assumption: on the busiest weekday 22% of all weekly cargo will be handled. On a quiet day only 5% will be handled. A month consists of four identical weeks.

The formulas used to compute daily cargo amounts are presented below.

$$V_{busyday} = \frac{V_{month}}{4} * 0.22 \quad (32)$$

$$V_{quietday} = \frac{V_{month}}{4} * 0.05 \quad (33)$$

Where

$V_{busyday}$ = Amount of cargo handled during a busy day

$V_{quietday}$ = Amount of cargo handled during a quiet day

6.1.4 Cargo flow variation per hour

Input of containers into the ITT system on a daily scale is not uniform, but depends on where, when and what kind of vessels are arriving and departing. Important factors for ITT demand are not just the amount of TEUs arriving each day, but also the origin and destination of each container destined for ITT, the time between the arrival of the container and its required delivery time, and the amount of containers being released into the ITT system at once.

6.2 Relationship between variations in cargo flows and variations in ITT demand

Using the methods described in Chapters 3, 4 and 5, ITT demand per year can be calculated. The ITT demand is a constant fraction of the total cargo flow. This means that a change in the cargo volume flowing through the port will produce an equivalent change in ITT demand.

6.3 Due time and arrival time

When containers destined for ITT arrive, there is a certain period of time until the moment they need to be at their destination. This is the period during which the container can be transported by an ITT system. A long time window means transporters have more flexibility regarding the exact pickup and delivery times.

To get a proper understanding of the arrival patterns and ITT demand during a day, simulation is a more useful tool than literature research. This research cannot give an accurate impression of the arrival and departure patterns in 2030. It is possible to comment on the current state of affairs and suggest trends in future developments.

'Entering the ITT system' is defined as the moment a request for transportation is made to the operator of the ITT system. This is not to be confused with the moment the container is physically transferred from the terminal to an ITT vehicle.

6.3.1 Number of calls

Obviously, the amount of containers entering and leaving the port plays a large part in the demand for ITT. Most of this report has dealt with determining yearly, monthly and daily values for this number.

Containers are delivered and picked up by vessels and vehicles. Each time a vessel or vehicle stops at the port of Rotterdam to load or unload is termed a call.

6.3.2 Vessel size and call size

The amount of containers loaded or unloaded, or 'call size', determines the time during which containers are entered into the port. A part of those containers will need ITT. Thus, call size determines the duration the period in which containers from that vessel enter the ITT system.

Of particular interest here are very large container ships, because of their massive sizes and expected increase in ITT demand during loading and unloading. Currently, the largest container ships carry about 18,000 TEU. This number is expected to grow to 20,000 or even 22,000 TEU in the near future [4] [31] [32]. Employing ever larger vessels is only economical if they are filled [33], suggesting a trend towards larger call sizes and fewer calls. This change is already starting to happen, as exemplified by the reduction in calls made by ships owned by the P3 alliance [34] [35].

As can be seen in Figure 15 most new orders are for very large container ships. The numbers for the outstanding orders suggest that in 2030 many (and perhaps most) containers will be arriving in very large vessels. Orders for ships larger than 18,500 TEU are not included as they have not been placed yet. To get a glimpse of the future of the container fleet, two scenarios (visualised in Figure 16) are proposed.

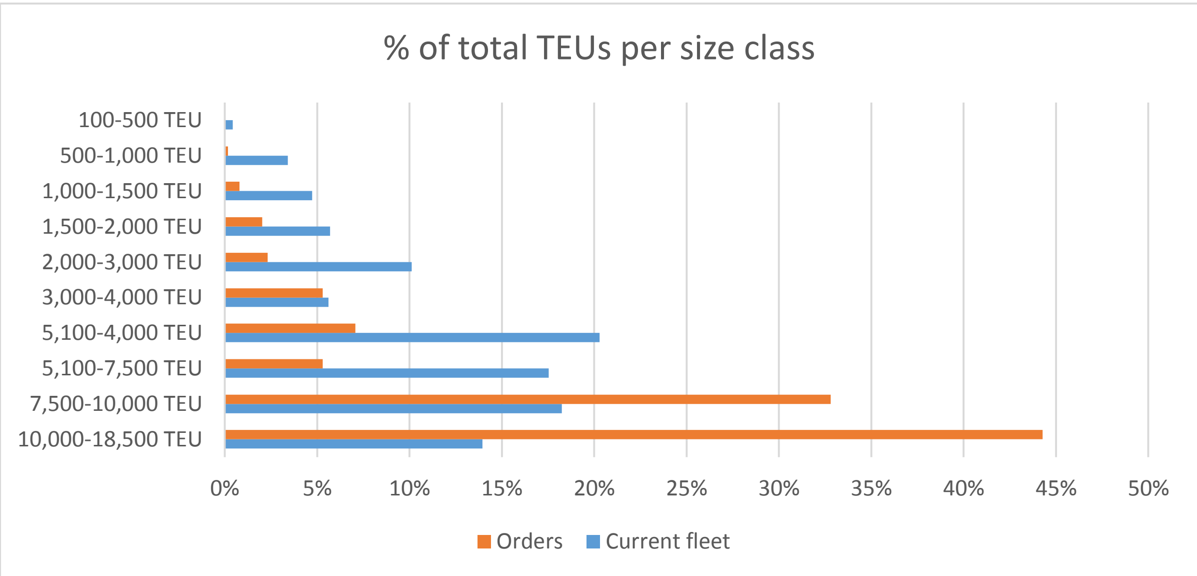

Figure 15 % of total TEUs per size class of the current container fleet and outstanding orders, july 2013. Source:

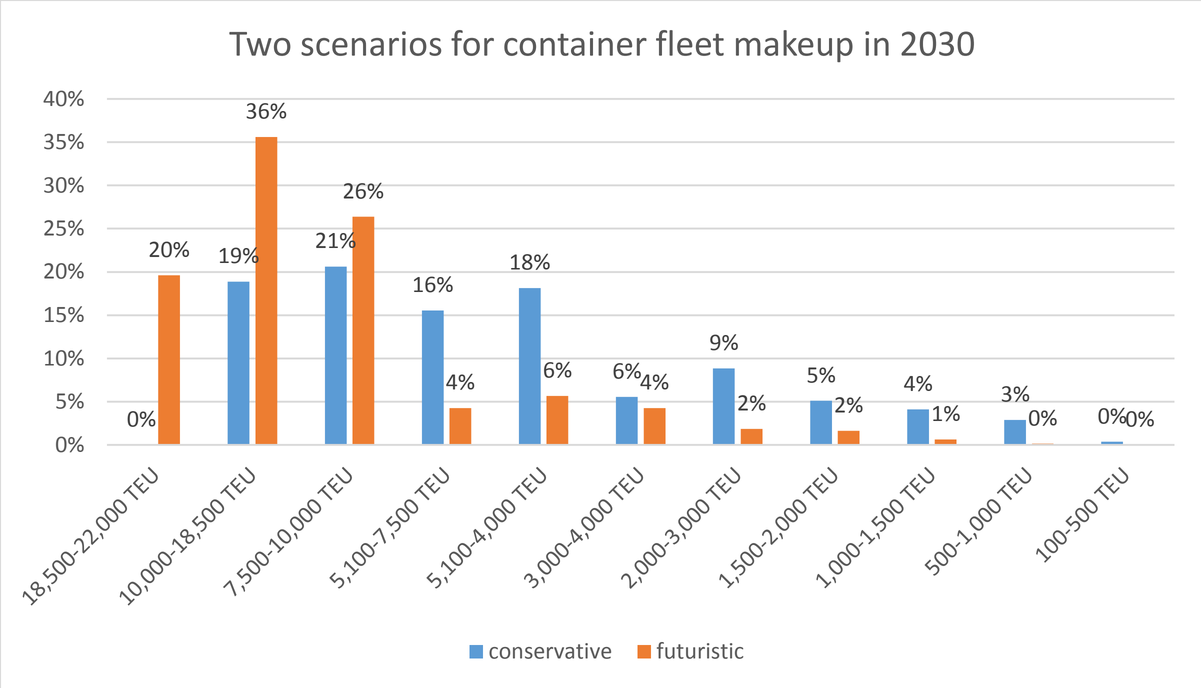

Figure 16 Scenarios for the makeup of the container fleet in 2030

The first, or 'conservative' scenario is based on the current fleet and outstanding orders as recorded in July 2013. Adding the outstanding orders to the existing fleet gives a fleet makeup that is consistent with current information about the future.

Adding an imaginary order for 40 20,000 TEU vessels and using only the data from outstanding orders (not those for the current fleet) results in the 'futuristic' scenario where very large container ships make up the majority of the fleet in 2030.

Larger vessels will mean peaks in ITT demand that last longer. It will also mean that quiet periods will be quieter, as less vessels are arriving.

The fact that the stacking yard is between the ITT system and the seaside quay will mean it acts as a buffer, because not all containers entering the stack will need ITT immediately (most will not need it at all). However, the amount of requests filed will be higher when many containers are arriving at the same time then when the arrival is evenly spread out.

6.3.3 Loading / unloading productivity

The amount of containers being taken from or loaded unto ships, trucks and/or trains per hour determines the amount of containers entering the ITT system. Thus, the loading and unloading speed is important to determine the height of peaks in ITT demand. These speeds are expected to rise [4], meaning peak heights are expected to increase.

Currently 215 moves per hour is about the maximum quayside productivity for any one terminal in the Port of Rotterdam [36] when unloading a single ship. This number is expected to increase because of rising crane productivity and new technologies, for example the use of floating cranes [37] which could realise a capacity of 25 or more moves per hour. This would mean berth productivity could go as high as 300 moves per hour. When a terminal is handling 2 very large (12,000+ TEU) container ships at the same time, this could mean that as much as 600 containers enter the yard every hour. The number of ITT moves this would generate depends on the scenario and the exact way of generating scenarios. More on this in chapter 7.

6.4 Summary

For a year, we know the cargo volume when we pick one of four scenarios from the Port Vision 2030 document (see Figure 8).

For a month, the amount of cargo handled can be calculated with the following formula:

$$V_m = V_y * C_m \tag{34}$$

The volume for a day can be calculated as follows:

$$V_d = V_y * C_m / 4 * C_d \tag{35}$$

Where

V_d = Amount of cargo handled per day in TEUs

V_y = Amount of cargo handled per year in TEUs

C_m = Fraction of cargo handled during the chosen month

C_d = Fraction of weekly cargo handled during the chosen day

The amount of containers arriving per hour depends on the number of vessels arriving and their size.

Landside operations are not expected to change in a significant way. Seaside operations will change due to a higher number of quayside moves per hour, larger call sizes and fewer calls. This will lead to more containers being entered into the ITT once for a longer period of time, i.e. fewer peaks but they will be higher and last longer. Due to increased terminal handling volumes, dwell times of containers are expected to shorten. This means ITT has to be accomplished in a shorter time window, leading to higher peaks.

7 Constructing a list of containers for use in an ITT model

The goal of this report, as stated in chapter 2, is to outline steps to creating list of containers that can serve as input for an ITT model. Each entry represents a container and has an origin, a destination, an arrival time (the moment it becomes available for ITT) and a due time (moment it needs to be delivered).

7.1 Amount of TEUs and containers arriving

As seen in chapter 6, containers do not arrive in a continuous flow but in batches. When making a list of containers one should look at the amount of containers expected to arrive per year and calculate the percentage of those expected to arrive during the period one is interested in. For the amount of TEUs per year, use the projections given in section 3.2. Formula 31 and 32 can be used to calculate the amount of cargo during a month or week. Using the heuristic from section 3.4, the amount of TEUs can be converted to a number of containers.

7.2 Assigning origins and destinations to containers

The origin of a container that has to be transported by ITT is the location where it has to be picked up. The destination of a container is the place it needs to be transported to. Each container on the list will need an origin and a destination. The origin and destination cannot be the same location.

Not all TEUs that arrive during a given period of time need ITT. Chapter 5 describes the calculations necessary to determine how many containers will need ITT, and from where to where they need to be transported.

7.3 Assigning arrival times and due times to containers

The arrival times have been discussed in Chapter 6. Obviously, all containers in a scenario will arrive in 2030. However, as we have seen in Chapter 6, containers do not arrive in a steady stream. Arrival rates vary with seasons, days of the week and the arrival of the vessels carrying the containers.

ITT demand is generated by containers entering or leaving the port. Each container entering the ITT system has an arrival time and a due time. The amount of time between these two moments is called the time window and indicates how much flexibility the ITT system operator has in deciding when to move the container. Can the operator leave it in the yard for a few days, or does it have to be on the other side of the port in an hour to be loaded onto a vessel bound for departure?

Because terminals will have to handle more containers per year in 2030 than they do now, dwell times are expected to shorten. The FAMAS study conducted in 2002 expects them to shorten by around 20 percent [38].

A report by the Incomaas-project ITT from 1996 [39] estimated containers have due times of 2, 4, 8, 12, 24, or 72 hours from their arrival time. These time windows are expected to shorten as dwell times are expected to shorten. It is proposed to assume time windows will shorten by approximately 20% (just like dwell times) so that due times will be the arrival time of the container + 2, 4, 8, 10, 20 or 60 hours.

In absence of a useful way of predicting due times for individual containers, it is proposed to pick one of these options randomly for each ITT container in a scenario. Alternatively, each container could have an arrival and departure vehicle assigned to it in the model, in which case arrival and due times would be dependent on the vehicle.

7.4 Summary

Using the scenario created following the steps described in Chapters 3 – 6, one should know that a certain number of TEUs or containers need to be handled during a chosen timeframe. Assigning origins and destinations to each container is done either stochastically or by simulating the arrival and departure of vessels delivering and picking up the container in question. The same goes for the departure and arrival times, which are either inherited from a vessel or assigned stochastically.

8 Conclusion

When generating a list of containers, four parameters need to be included for each container: an arrival time, a due time, an origin and a destination. The total amount of containers that need ITT during the chosen time period is determined by choosing a scenario from Chapter 3 and using calculation methods from Chapter 5. This yields the yearly amount of containers, their origins and their destinations.

Using the calculations and tables from Chapter 6 and the results obtained, the amount of ITT containers per month, week and day can be calculated for each terminal. This will yield a scenario for a given time period with an amount of ITT moves per day, with origins and destinations.

The arrival time and due time depend on the departure and arrival time of vehicles and vessels. To simulate this it is possible to simulate actual arrival and departure of vessels, or to pick arrival and departure times randomly. In order to simulate the arrival of vessels accurately, fleet makeup scenarios are presented in section 6.3.2. The assignment of arrival and departure times is describes in section 7.3.

Following all the steps above will result in a list of containers with an origin, destination, arrival time and due time for each container. This is all the information necessary for using the list as input for an ITT model.

9 Suggestions for further research

Creating plausible scenarios for a situation more than fifteen years in the future is easy. Since many aspects of the future situation are still unknown, the author has considerable freedom when describing scenarios. Scenarios are not predictions – just a vision of what the future could be like.

The situation becomes more complex when decisions need to be made. Because most information about the future is still unknown, scenarios offer only an incomplete picture of the future possibilities. [40] This means one should be cautious when using them as a basis for decision making.

Also, scenarios cannot include so-called ‘black swan’ events. These are, by definition, unpredictable and unforeseeable but can have very large impact [41]. This means there is a significant amount of possible futures that cannot at this moment in time be accurately represented by scenarios.

Collecting additional data would give more insight into specific processes but the biggest source of uncertainty is our limited ability to predict the future. Using more data or modelling processes in more detail will not do anything to address this problem.

That being said, gaining a better understanding of the interactions between terminals and empty depots, terminals and the distripark and a more accurate way of predicting dwell times of individual containers would surely make the scenarios presented in the previous chapters more realistic.

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Appendix 1 – List of participants

Table 6 A List of all locations used in modelling ITT on the Maasvlakte.

		Function	Current capacity - TEU/year	Possible capacity - TEU/year	Area (ha)
1	ECT Delta	Deepsea terminal	5,100,000	6,912,000	256
2	EuroMax	Deepsea terminal	2,500,000	4,544,100	168.3
3	APM MV1	Deepsea terminal	2,400,000	2,700,000	100
4	RWG	Deepsea terminal	2,400,000	4,214,700	156
5	APM MV 2	Deepsea terminal	2,700,000	4,860,000	180
6	T3	Deepsea terminal	0	4,222,800	156.4
7	T4	Deepsea terminal	0	793,800	29.4
8	ECT Delta barge feeder	Shortsea terminal	330,000	770,000	8
9	Delta Container Services	Shortsea terminal	150,000	67,500	2.5
10	Common rail terminal	Rail service centre	0		
11	Rail Terminal West	Rail terminal			
12	Rotterdam Container Terminal	Shortsea terminal	500,000	500,000	17
13	Common Barge Service Centre	Barge service centre	0	383,400	14.2
14	Kramer Delta Depot	Depot			10
15	Van Doorn Container Depot	Depot			9.5
16	Empty Depot MV1	Depot			
17	Empty Depot MV2	Depot			
18	Douane	Customs			
19	Distripark	Distribution	0		
20	Rhenus	Deepsea terminal	0	540,000	20

The numbers in Table 6 are taken a variety of sources. For current capacities, the websites of each company was consulted along with an overview of terminals and depots provided by the port of Rotterdam Authority [42] and a report by the Policy Research Corporation [15]. The maximal capacities are calculated by assuming a maximum capacity of 27,000 TEU/year for each hectare of available land. The information about hectares comes from another map, also made by the port of Rotterdam Authority [43].

Appendix 2 – Map of locations

1 ECT Delta terminal
2 EuroMax terminal
3 APM MV1 terminal
4 Rotterdam World Gateway (RWG)
5 APM MV2 terminal
6 ? (T3)
7 ? (T4)
8 ECT Delta Barge Feeder terminal
9 Delta Container Services
10 Common rail terminal
11 Rail terminal west
12 Barge service center Hartelhaven
13 Common barge service center
14 Kramer Delta depot
15 Van Doorn container depot
16 Empty depot MV1
17 Empty depot MV2
18 Douane
19 Distripark
20 Rhenus

Appendix 3 – Data tables corresponding to selected figures

Figures 6 and 8 – predicted container traffic in millions of tons and millions of TEUs per year

Table 7 Forecast for cargo throughput in the port of Rotterdam in 2030

Scenario	million tons per year	million TEU per year
baseline 2008	112.3	11.23
LG 2030	190.0	19.00
ET 2030	267.0	26.70
GE 2030	310.0	31.00
HOP 2030	218.0	21.80

Table 8 - Tons, TEUs and containers. Source: Port Statistics 2007-2012

Figure 7 – Tons per TEU

Year	Containers handled	TEUs handled	Cargo handled (x 10^6 ton)	TEU-factor	ton/teu	ton/container
2012	7,183,675	11,865,916	125.4	1.652	10.6	17.46
2011	7,187,243	11,876,900	123.6	1.652	10.4	17.20
2010	6,746,802	11,147,572	112.3	1.652	10.1	16.64
2009	5,900,114	9,743,290	100.3	1.651	10.3	17.00
2008	6,485,464	10,783,825	107.0	1.663	9.9	16.50
2007	6,488,646	10,790,829	104.6	1.663	9.7	16.12

Modal split for the seaside in each of the four future scenarios in Port Vision 2030 and for the hinterland, depicted in figures 10 and 11.

Table 9 Modal split in 2010 and ambition for 2035

year	truck	rail	barge
2010	48%	13%	39%
2035	35%	20%	45%

Table 10 Modal split for each of the four scenarios from Port Vision 2030

Scenario	deepsea	shortsea	transhipment
Low Growth	61%	9%	29%
European Trend	61%	9%	30%
Global Economy	60%	10%	30%
High Oil Prices	59%	11%	31%

Percentages of empty containers, as depicted in figure 12.

Table 11 Empty containers as a percentage of all containers handled

year	% emtpy in	% empty out
2012	18%	18%
2011	15%	20%
2010	17%	22%
2009	18%	19%
2008	18%	23%
2007	20%	23%
Average	18%	21%

Table 12 A typical week for truck cargo flows with percentage of weekly cargo per day

Day	**Percentage of weekly cargo**
Monday	17%
Tuesday	22%
Wednesday	21%
Thursday	21%
Friday	20%
Saturday	5%
Sunday	6%

Container fleet makeup and outstanding orders – figure 15

Table 13 - container fleet and outstanding orders (2013)

	ships existing	**TEU existing**	**Current**	**ships ordered**	**TEU ordered**	**Ordered**
10,000-18,500 TEU	183	2,357,532	14%	103	1,451,508	44%
7,500-10,000 TEU	355	3,082,735	18%	119	1,075,437	33%
5,100-7,500 TEU	482	2,964,138	18%	27	173,629	5%
5,100-4,000 TEU	758	3,428,711	20%	49	231,423	7%
3,000-4,000 TEU	275	946,502	6%	47	173,396	5%
2,000-3,000 TEU	671	1,708,860	10%	31	75,848	2%
1,500-2,000 TEU	565	962,650	6%	38	66,061	2%
1,000-1,500 TEU	683	799,639	5%	24	25,664	1%
500-1,000 TEU	774	576,324	3%	7	5,580	0%
100-500 TEU	222	71,134	0%	0	0	0%

Fleet makeup scenarios – figure 16

Table 14 two scenarios for the container fleet makeup in 2030

Size	TEU conservative	TEU futuristic	% conservative	% futuristic
18,500-22,000 TEU	0	800,000	0%	20%
10,000-18,500 TEU	3,809,040	1451,508	19%	36%
7,500-10,000 TEU	4,158,172	1075,437	21%	26%
5,100-7,500 TEU	3,137,767	173,629	16%	4%
5,100-4,000 TEU	3,660,134	231,423	18%	6%
3,000-4,000 TEU	1,119,898	173,396	6%	4%
2,000-3,000 TEU	1,784,708	75,848	9%	2%
1,500-2,000 TEU	1,028,711	66,061	5%	2%
1,000-1,500 TEU	825,303	25,664	4%	1%
500-1,000 TEU	581,904	5,580	3%	0%
100-500 TEU	71,134	0	0%	0%