



# **Inter-terminal transport on Maasvlakte 1 and 2 in 2030**

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

## **Deliverable 1.2**

### **Generator for future inter terminal container transport demand scenarios on the Maasvlakte 1 and 2**

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**Subject: Generator for future inter-terminal container transport demand scenarios on the Maasvlakte 1 and 2**

Freight transport has been growing rapidly over the last decades. Transport has so far been a major contributor to economic growth, terminals of the Port of Rotterdam wish to increase their capacity to be able to go along with this growth. The Port of Rotterdam has create the Maasvlakte 2 to enable terminals to expand, however the future of the Maasvlakte 2 depends on terminals wanting to expand here. The Port of Rotterdam is therefore looking into ways to attract companies. Making the Maasvlakte 2 accessible for future cargo ships, creating Rail and Barge Service Centers, creating possibilities for Inter-terminal Transportation, etc.

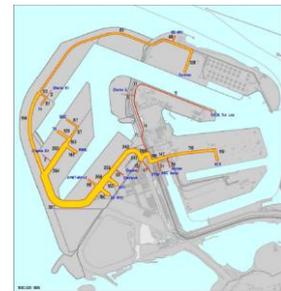


Fig. 1: Inter-terminal transportation flows on the Maasvlakte I & II.

In this research assignment you will create a generator implemented with all possible scenarios that will influence the flows of the Inter-terminal transportation on the port area and display these flows in a clear way. The research question and relevant steps are:

- How will the future inter-terminal transportation flows on the Maasvlakte 1 and 2 be influenced by certain scenarios and can these flows be predicted?
- Use the decision tree from the literature study for the creation of the generator. Display the decision tree used for the generator in the report.
- Every variable should be adjustable, however the known variables should be implemented and recommended by the model.
- The generator must be able to predict inter-terminal transportation flows for future scenarios.
- The results of the model should be a list of containers with their important attributes which represent the inter-terminal transportation flows on the Maasvlakte 1 and 2.

Based on your research assignment, it is expected that you present a digital generator which has the ability to generate the inter-terminal transportation flows for future scenarios on the Maasvlakte 1 and 2. These flows should be presented in a clear way so that they may be used in future research.

The report must 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 supervisor,  
Dr. R.R. Negenborn



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# Preface

This research is carried out within the framework of the TUDelft, 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”.



# **Generator for future inter-terminal container transport demand scenarios on the Maasvlakte 1 and 2**

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March 31, 2014



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# Abstract

The Technical University of Delft and the Erasmus University Rotterdam have a joint project for the Port of Rotterdam. The purpose of this project is the development of innovative, non-conventional concepts for Inter-Terminal Transport (ITT) for the port of Rotterdam. The joint project has three phases the *Definition of ITT Scenarios*, *Configuration of ITT Technology* and *Evaluation of ITT configurations*. A literature study on the ITT scenarios has been done by Gerritse [1]. The output of this study are general flows for ITT and the needed estimations and assumptions, unfortunately this study has calculated only one output. The input for the different configurations of ITT technologies of the second step in the joint project needs a list of containers instead of general flows. Therefore the gap between the general flows and the list of containers should be closed by a computer generator. One of the benefits of creating a computer model for this problem is that adjustable variables can be used for the calculations, this means that multiple scenarios can be generated by changing the input variables of the generator.

The generator will be created to be able to predict how future inter-terminal transportation flows on the Maasvlakte 1 and 2 be influenced by certain scenarios. With the possibility to generate multiple scenarios by changing variables. The output of the generator should be a list of containers which can be used in the second stop of the joint project.

The generator has been structured into four phases, *The Model Approach*, *The Processes of the Generators*, *The verification* and *The validation of the Generator*. In the *Model Approach* the research assignment will discuss what objects and parameters the computer generator needs to create a model which can be compared to the real situation on the port. The *Processes of the Generator* will discuss the processes of these objects and the overall process of the computer generator itself. In the *Verification* the output of the computer generator will be verified and discussed after which the validation can be done in the *Validation* using the results of the report of Gerritse [1].

The output of the research assignment will be a list of ITT moves of containers that can be used for further research into the ITT project of the MV1 and MV2.



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## Abstract (in Dutch)

De Technische Universiteit Delft en de Erasmus Universiteit Rotterdam hebben een gezamenlijk project voor het Rotterdamse havenbedrijf. Het doel van dit project is de ontwikkeling van innovatieve, niet-conventionele concepten voor ITT voor de haven van Rotterdam. Het gezamenlijke project kent drie fases de *Definitie van ITT Scenario's*, *Configuratie van ITT Technologie* en *Evaluatie van ITT configuraties*. Een literatuurstudie over de ITT scenario's is gedaan door Gerritse [1]. De output van deze studie zijn de algemene stromen voor ITT en de nodige schattingen en veronderstellingen, helaas is in deze studie slechts een output berekend. De input van de verschillende configuraties van ITT technologieën van de tweede stap in het gezamenlijke project heeft een lijst van containers in plaats van algemene stromen nodig. Daarom zal het gat tussen de algemene stromen en de lijst van containers gesloten moeten worden door een computer generator. Een van de voordelen van het creëren van een computermodel voor dit probleem is dat instelbare variabelen kunnen worden gebruikt voor de berekeningen, dit betekent dat meerdere scenario's gegenereerd kunnen worden door het veranderen van de invoervariabelen van de generator.

De generator wordt gecreëerd voor het kunnen voorspellen hoe toekomstige inter-terminal transportstromen op Maasvlakte 1 en 2 worden beïnvloed door bepaalde scenario's. Met de mogelijkheid om meerdere scenario's te genereren door het veranderen van variabelen. De output van de generator zou een lijst van containers moeten zijn die kunnen worden gebruikt in de tweede fase van het gezamenlijke project.

De generator is gestructureerd in vier hoofdstukken, *De Modelling Aanpak*, *de Processen van de Generatoren*, *De verificatie* en *De validatie van de Generator*. In de *Modelling Aanpak* zal de onderzoeksopdracht bespreken welke objecten en parameters de computer generator moet gebruiken om een model te maken dat kan worden vergeleken met de werkelijke situatie op de haven. De *Processen van de generator* zal ingaan op de werkwijzen van deze objecten en het totale proces van de computer generator zelf. In de *Verificatie* zal de output van de computer generator worden geverifieerd en besproken worden waarna de validatie kan worden gedaan in de *Validatie* met behulp van de resultaten van het rapport van Gerritse [1].

De output van de onderzoeksopdracht zal een lijst van ITT bewegingen van containers zijn die kunnen worden gebruikt voor verder onderzoek van het ITT project op de MV1 en MV2.



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# Glossary

## List of Acronyms

<b>MV1</b>	Maasvlakte 1
<b>MV2</b>	Maasvlakte 2
<b>ITT</b>	Inter-Terminal Transport
<b>TEU</b>	Twenty-foot Equivalent Unit
<b>BSC</b>	Binnenvaart Service Center (Inland waterway Service Center)
<b>RSC</b>	Rail Service Center
<b>BOS</b>	Back Order System
<b>PDL</b>	Program Design Language



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# Chapter 1

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## Introduction

### 1-1 General Introduction of the project

For the port authority of the Maasvlakte 1 (MV1) and Maasvlakte 2 (MV2) predictions of future Inter-Terminal Transport (ITT) demand scenarios are needed to determine what kind of ITT facilities the port might implement for its customers. The harbor of Rotterdam is important for the Dutch industry as it provides possibilities for large companies within Europe to trade with the rest of the world. The port authority of the harbor will try to create an environment where large trading companies have easy access to the facilities they need. Not only does this mean creating more acres for the trading companies to grow, but also installing or implementing systems that make the daily routine of the trading companies easier. The MV2 was created so that the port could keep growing and facilities for the handling of the growing sea vessels were installed. The Port of Rotterdam is currently researching even more possibilities for supporting the companies on the port. One of these projects is the Erasmus University Rotterdam and Technical University Delft project for future research of an ITT network. This would provide the companies on the MV1 and MV2 to combine their hinterland flows. This would mean that trains or barge could depart more frequently and thus creating shorter dwell times for containers on the port.

Research into the future demand scenarios for ITT has been done in the literature survey of Gerritse [1]. This research will be used as guideline to create a computer generator of the future demand scenarios for ITT on the Maasvlakte I & II.

In this research assignment the functioning, decisions and assumptions of the generator will be discussed and recommendations for future research will be given.

### 1-2 Problem statement of the research assignment

The ITT project of the port authority requires the development of innovative, non-conventional concepts for ITT for the port of Rotterdam. To develop these concepts the future demand scenarios for ITT are needed. The research of Gerritse [1] has been performed to indicate

possible future scenarios. However the possible scenarios are limited and the calculations are based on averages. This will give a good indication of the future demand flows for ITT on the port, but not a specific scenario with visible peaks and peak durations. The FAMAS study [2] elaborates on this element linking the container arrival to the arrival of carriers, unfortunately it misses the opportunity to link the departure of carriers to the container departure. Instead of linking the departure of the carriers to the containers a static time window is used. In this research assignment the possibilities of linking the arrival and the departure of carriers to the containers will be discussed to create a dynamic and more realistic time window for the future ITT demand scenarios. The output of the computer generator will be a list of containers with a container name, origin, destination, start time, delivery time, TEU amount, empty, start batch identification and end batch identification. Where the batch identification numbers are used to link the container to the carriers. An example of such a list is given in Appendix A in Figure B-11

The assumptions needed for this research assignment are itemized in the Appendix A. The assumptions are either made by Gerritse [1] or have been added within this research assignment.

### 1-3 Research question and relevant steps

The research question this research assignment will try to answer and the relevant steps that are needed will be the following:

- How will the future inter-terminal transportation flows on the Maasvlakte 1 and 2 be influenced by certain scenarios and can these flows be predicted?

The relevant steps for creating a computer generator for answering the research question will be:

- Use the decision tree from Gerritse [1] literature study to create the computer generator and show the functioning, decisions and assumptions made in the generator.
- Use adjustable variables to create specific scenarios for future ITT demand.
- Use all the predictions and variables to create a list of containers for ITT for a determined runtime of the generator.

### 1-4 Structure of the research assignment

Answering the research question of the assignment will require the design, verification and validation of the computer generator. The structure of the report will be to clarify the computer generator first, split into two chapters. Chapter 2 will discuss what objects and parameters the computer generator needs to create a model which can be compared to the real situation on the port. Chapter 3 will discuss the processes of these objects and the overall process of the computer generator itself. In Chapter 4 the output of the computer generator will be verified and discussed after which the validation can be done in Chapter 5 using the results of the report of Gerritse [1]. In the last Chapter 6 the conclusions and recommendations of the research assignment will be given.

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## Chapter 2

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# Modeling approach

Linking the computer generator to the current situation on the MV1 and MV2 objects and parameters of the model will be identified and explained in the following chapter. First the identification of objects for the computer generator will be done, hereafter the parameters that are needed for the objects to function within the computer generators process will be discussed. These parameters will be taken from the report of Gerritse [1].

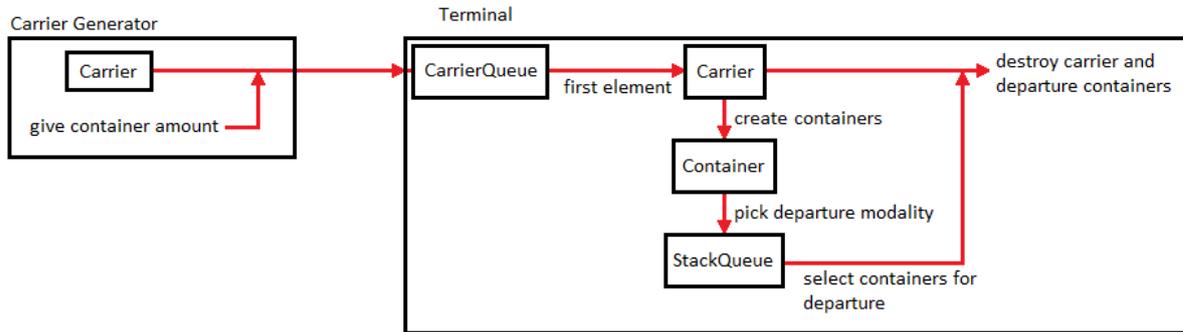
### 2-1 Identifying objects for the computer generator

For a clear understanding of the computer generator the objects that have been created from understanding the current situation on the port will be discussed. From Appendix 1 of the report of Gerritse [1] the participants of the ITT system are given. In Appendix 2 of the report a map of the port and the location of every participant is given. This information is used to create the first object that is needed for the computer generator, a terminal.

In reality the terminals do not handle the containers, but cranes and personnel of the terminal handle the container of truck, trains, sea vessels, etc. To simulate this either a container generator is created which gives the containers to a terminal which holds a certain amount of time or in the case of this research assignment the container carriers are created and given a certain amount of containers. This means that the second object of the computer generator will be the container carrier generators. From Figure 13 of the report of Gerritse [1] the five main forms of transport are taken and formed into generators for the computer generator.

The layout of the terminals will have effect on the objects that the computer generator will create for that specific terminal, as not all the terminals have a rail connection or have enough depth at the quayside to handle deep sea vessels. This is actually one of the main reasons for ITT. The user of the computer generator will have to select the modalities the terminals will have.

The last objects that are needed for the computer generator will be the containers and the container carriers. These objects will carry specific information, such as arrival time, TEU amount, etc.



**Figure 2-1:** Overview of the process and the objects of the generator.

For clarification an overview of the process is given in Figure 2-1.

## 2-2 Required parameters of the computer generator

For the objects of the computer generator to function properly the needed parameters are given. They will be split up into the general parameters for the computer generator and the terminal specific parameters.

For the future demand prediction of the computer generator the economic scenario of the port is key. In the report of Gerritse [1] and the PortVision [4] of the Port of Rotterdam define four scenarios: *Low Growth*, *High Oil Prices*, *European Trend* and *Global Economy*. The predictions of these reports as well as a possibility for the user to create a custom scenario are implemented in the generator.

To be able to calculate the amount of containers the port handles per year from the economic scenarios the *Gross Ton per TEU* is needed as well as the *TEU Factor*. These factors have been taken from Figure 7 and Figure 9 from the report of Gerritse [1]. The user will have the possibility to change these factors.

In Function 29 of the report of Gerritse [1] it states that a certain percentage of the flows will go to the customs facility on the port. This percentage will be a fixed amount of the containers which are not empty. The user of the computer generator will be able to change this percentage.

For the determination of the exact time a container will enter the port the arrival time of a container carrier is needed, but also the movement speed of a crane. This has not been taken into account by Gerritse and therefore it will have to be estimated within this research assignment. The user will be able to change or even eliminate the crane movement speed by turning it to zero, creating instant movement.

For the simulation the time frame needs to be determined. This has effect on the container flows within the terminal as the economic predictions might change and the monthly and weekly distribution come into play. The economic predictions of the time frame are calculated by linear interpolation between the year 2008 and the given prediction of 2035. The distributions have been taken from Figure 14 and Table 12 of the report of Gerritse [1], note that the sum of the weekly distribution is not 100%. This is because Gerritse assumes that there are 48 weeks in a year dividing the yearly amount by 53 and increasing it by 112%,

in this research assignment the same assumption is made that a year has 48 weeks, but the yearly amount will be divided by 48 and the sum of the weekly distribution will be 100%. The monthly distribution will be taken from Figure 14 of the report of Gerritse [1]. Both the distribution can be change by the user of the computer generator.

The modal split of the computer generator is the percentage of the containers that come from or go to a certain modality. The modal split of the landside will be taken from Table 9 of the report of Gerritse [1] and the modal split of the seaside will be taken from Table 10 of the report of Gerritse [1]. The user of the computer generator will be able to change the modal split percentages.

The import-export ratio will determine the amount of the yearly predictions that is import and the amount that is export. The ratio is for the entire port area, meaning the import will be the flows into the hinterlands and the export the flows to the deep and short sea. The ratio has been taken from Function 7 and Function 8 of the report of Gerritse [1]. The user of the computer generator is able to change the ratio.

The empty percentage of the containers determines the amount of the yearly predictions that is empty. Since the empty percentage of the import is not the same as the empty percentage of the export two percentages need to be given. The percentages are taken from Table 11 of the report of Gerritse [1]. The user of the computer model will also be able to change these percentages.

Since the modal split, import-export ratio and the empty percentage might change over the years the computer generator will also ask for the predictions of these ratios for the last year of the simulation. The ratios for the current year the simulation is in will be determined by linear interpolation between the start and end value.

The last parameter that is needed for the objects of the computer generator are the capacities of the container carriers. Unfortunately these are not discussed in the report of Gerritse. From literature [5] the capacities of container carriers are estimated. Note that the capacities are the amount of TEU that are handled on the terminal, meaning a container carrier might have more TEU on board than it gives to or receives from the terminal. The container carriers capacities can be changed by the user of the computer generator, however the crane movement speed is taken into account to determine the minimal time the container carrier has to spend in the terminal. So if a carrier has a capacity of 120 TEU it will have to spend:

$$HandlingTime = \frac{C_c}{T_f} * C_m * 2 = \frac{120}{1.66} * 2 * 2 = 289[min] = 4.82[hrs] \quad (2-1)$$

$C_c$  = Carrier Capacity

$T_f$  = TEU Factor

$C_m$  = Crane movement speed

If the container carrier handling time is less than this the crane could not handle the container carrier, as it would have to make more moves than possible. Note that the possibility to handle a container carrier with more than one crane has not been implemented into this research assignment.

One of the problems that had occurred was that empty containers need to be moved to the empty container storage facilities of terminals via ITT, but containers that spend one minute

Generator v1.0

Economic growth scenario: **Custom scenario** 1

Gross Tons per TEU:  TEU factor:  2

Percentage to customs:  %

Average time of crane movement:  min.

Predicted amount of TEU per year (2035): 16.0 mln. [Info](#)

Predicted amount of TEU per year (2030): - mln.

Amount of TEU per year (2008): 11.2 mln.

Maximum terminal capacity of the port at start: 17.18 mln.

Maximum terminal capacity of the port at end: 17.18 mln.

Calculated Port capacity in 2035: 17.18 mln.

Run time of the Generator: 3

From:

Until:

Modal Split: 4

	Start	End	Seaside	Start	End
Truck:	<input type="text" value="48.0"/> %	<input type="text" value="35.0"/> %	Deep Sea:	<input type="text" value="60.0"/> %	<input type="text" value="60.0"/> %
Rail:	<input type="text" value="13.0"/> %	<input type="text" value="20.0"/> %	Short Sea:	<input type="text" value="10.0"/> %	<input type="text" value="10.0"/> %
Barge:	<input type="text" value="39.0"/> %	<input type="text" value="45.0"/> %	Transshipment:	<input type="text" value="30.0"/> %	<input type="text" value="30.0"/> %

Import and Export: 5

	Start	End	Empty Containers:	Start	End
Import:	<input type="text" value="51.0"/> %	<input type="text" value="51.0"/> %	Empty (import):	<input type="text" value="17.0"/> %	<input type="text" value="18.0"/> %
Export:	<input type="text" value="49.0"/> %	<input type="text" value="49.0"/> %	Empty (export):	<input type="text" value="22.0"/> %	<input type="text" value="18.0"/> %

Terminals: 7

(1) ECT Delta	<a href="#">Info</a>	(11) Rail Terminal West	<a href="#">Info</a>
(2) EuroMax	<a href="#">Info</a>	(12) Barge Service Center Hartelhaven	<a href="#">Info</a>
(3) APM MV1	<a href="#">Info</a>	(13) Common Barge Service Center	<input type="checkbox"/> <a href="#">Info</a>
(4) RWG	<a href="#">Info</a>	(14) Kramer Delta Depot	<a href="#">Info</a>
(5) APM MV2	<a href="#">Info</a>	(15) Van Doorn Container Depot	<a href="#">Info</a>
(6) Terminal 3	<input type="checkbox"/> <a href="#">Info</a>	(16) Empty Depot Spotterstrand	<a href="#">Info</a>
(7) Terminal 4	<input type="checkbox"/> <a href="#">Info</a>	(17) Empty Depot Distripark	<a href="#">Info</a>
(8) ECT Delta Barge Feeder	<a href="#">Info</a>	(18) Douane	<a href="#">Info</a>
(9) Delta Container Services	<a href="#">Info</a>	(19) Distripark	<a href="#">Info</a>
(10) Common Rail Terminal	<input type="checkbox"/> <a href="#">Info</a>	(20) Rhenus	<a href="#">Info</a>

Average time between Arrival and Departure: 6

	TEU Capacity	Average time	hrs.
Truck:	<input type="text" value="2"/> TEU	<input type="text" value="0.5"/>	hrs.
Barge:	<input type="text" value="50"/> TEU	<input type="text" value="2.1"/>	hrs.
Train:	<input type="text" value="50"/> TEU	<input type="text" value="2.1"/>	hrs.
Short Sea Vessel:	<input type="text" value="600"/> TEU	<input type="text" value="24.6"/>	hrs.
Deep Sea Vessel:	<input type="text" value="1200"/> TEU	<input type="text" value="48.3"/>	hrs.

Minimal time for the storage of an empty container:  hrs. 2

Only generate fortnight

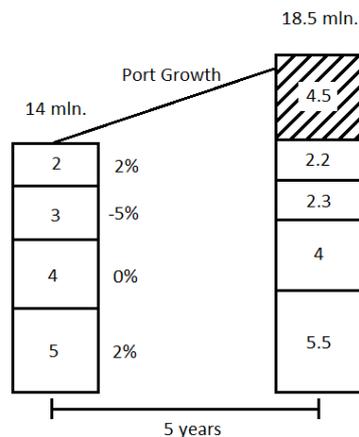
Figure 2-2: Input form of the computer generator.

on the terminal before departure are still send to the empty container storage facility. Therefore the minimal time an empty container spends on the port will be implemented to eliminate the short stored empty containers from the ITT system. This parameter has been estimated and can be changed by the user of the computer generator.

The input for the computer generator is shown in Figure 2-2. Input 1 shows the economic scenario input, Input 2 shows the general inputs of factors, Input 3 shows the run time for the simulation and the possibility to change the weekly and monthly distributions, Input 4 shows the modal split, Input 5 shows the import-export ratio and the empty percentages, Input 6 shows the container carriers capacities and Input 7 shows the terminals.

### 2-2-1 Required parameters of a terminal

Each of the participants of the ITT system will have some parameters which as specific for that terminal, these parameters will be discussed in the following section.



**Figure 2-3:** An example where the terminal capacities do not reflect the port predictions.

The terminal capacity will be used to split the container flow of a specific form of transportation among the terminals which have the possibility to dock this form of transportation. For example a train arrives at the port and the computer generator collects all the terminals with a rail connection, the train will take a chance where it docks using the terminal capacities as distribution. This is referred to as pro rata by Gerritse [1]. The terminal transportation connection possibilities have been taken from Table 1 of the report by Gerritse [1]. The terminal capacities have been taken from Table 3 of the report by Gerritse [1]. The user of the computer generator can change the capacity as well as the possible modalities of a terminal. The terminal growth factor is of importance to the predictions as well as the chance a container carrier docks at a certain terminal. As the predictions might increase during the simulation it is of importance to know at which terminal the increase is handled. In Figure 2-3 an example is given where the terminal capacities do not reflect the predictions of the port. In the computer model either the predictions or the growth factors of the terminals need to be addressed. If the total port capacity exceed the predictions the terminals will simply operate at a lower utilization rate. Unfortunately the report of Gerritse does not elaborate on the changes in terminal capacities that might occur, therefore the growth factors have been set to 1.00% in this research assignment.

In Section 5.3 of the report of Gerritse [1] a percentage of transshipment will become ITT this is either 1.00% of the transshipment flows of a terminal or 0.00% of the transshipment flows, this was taken from the report of Diekman and Koeman [6]. This might vary per terminal and is thus needed as an input parameter of a terminal.

In this research assignment the same approach as the FAMAS study [2] is used to link the arriving container carriers with the container creation process, but also link the removal of containers with the departure of the container carriers. This will be done by creating so called *ModalLocations*. This is a location where a container carrier comes from or where it is going to. For example a train might arrive from Amsterdam and depart to Eindhoven, creating 40 containers from Amsterdam at the terminal it arrives and claiming 40 containers from all the terminal stacks which need to go to Eindhoven. The containers which need to go to Eindhoven from other terminals than the one the train is docked at will create ITT moves. Instead of names for the locations which the container carrier come from or go to numbers



The image shows two overlapping software windows. The left window, titled 'ECT Delta', contains a form for terminal parameters. It has three input fields: 'Terminal capacity at start' with the value '5.1 mln.', 'Terminal growthfactor' with '1.00', and 'ITT Transhipment' with '1.0 %'. Below these is a section 'Possible modals of the terminal:' with four checkboxes: 'Deep Sea' (checked), 'Short Sea' (checked), 'Barge' (checked), and 'Rail' (unchecked). Each checked option has an 'Info' link next to it. A 'Submit' button is at the bottom right. The right window, titled 'Terminals Deep Sea Locations', has a header 'Add and Remove Terminals Modal Locations'. It features a list box containing the number '1'. To the right of the list box are 'Add' and 'Remove' buttons. A 'Submit' button is located at the bottom right of this window.

**Figure 2-5:** Input form of the terminals and the *ModalLocations* form.



# Processes of the computer generator

The objects that have been identified and the needed parameters in Chapter 2 will be used to create the computer model. The processes of the objects will be discussed in the following chapter, using only the parameters of Chapter 2. The assumption made for the processes to function will be highlighted in this chapter and can also be found in Appendix A.

The generation process of the container carriers and the objects of Chapter 2 that are involved in this process will be discussed first, as it is the first step in the computer generator process. Then the container carrier handling process of the terminals and the objects that are involved in this process will be discussed. Last one of the problems that has occurred in this process and the way it has been solved will be discussed in Section 3-3.

### 3-1 Generation of container carrier

The container carrier generators of Chapter 2 will be discussed in the following section. First the process principles and needed parameters are discussed and then the process is given in PDL.

To be able to verify and validate the computer generator the container carrier generators will have a fixed holding time. This means that step by step tracing of the computer generator is simplified and that the hand calculations for the validation of the model compared to the findings of Gerritse [1] can be done.

The calculation of this holding time will be done using the following formula:

$$HoldTime = \frac{Round(\frac{C_c}{T_f}) * 60 * 24 * 4}{Round(\frac{Y_p}{T_f}) * M_D * W_D * P * (1 - T_p) * M_s} \quad (3-1)$$

$C_c$  = Carrier Capacity

$T_f$  = TEU Factor

$Y_p$  = Yearly Prediction

$M_D$  = Percentage of the month

$W_D$  = Percentage of the day

$P$  = Import or Export Percentage

$T_p$  = Transshipment Percentage

$M_s$  = Modal Split Percentage

All the parameters needed in this formula have been discussed in Chapter 2, however some of them might change over time. The date generator has been implemented for this reason. It simply calculates the current year, month and day. This information can be used to determine the current value of the parameters that use linear interpolation (such as the modal split, import or export percentages, yearly prediction, etc.).

Specific information needed for the container carriers to give to the containers it unloads or determine which containers it can take from stacks for departure will be summed up in the following section.

The container carrier will need a *Name*, used for batching the containers it unloads. This will later be used by the containers as the *StartBatchID*.

The container carrier will be given an *ArrivalTime* and using the known *HandlingTime* of the type of container carrier it will calculate its *DepartureTime* (by adding the *ArrivalTime* and the *HandlingTime*). The *ArrivalTime* and the crane movement speed will later be used to calculate the *StartTime* of containers.

The container carrier will be given a fixed *Import* and *Export Amount*, these are taken from the container carrier capacity. Note that import is always states as the flow towards the hinterland, meaning a truck departing from the port area is seen as an import container carrier. The *Import* and *Export Amount* will later be used by the terminal process to determine how many containers it needs to create of give to the container carrier for departure.

The container carrier will be given an *Origin*, this will be the terminal it will dock at. The terminal will be chosen pro rata as stated by Gerritse [1]. The *Origin* of the container carrier will later be used to determine the *Origin* of the container.

The container carrier will also be given a *Destination*, this will be the *ModalLocation* where the container carrier will depart to. This will later be used to determine the containers from the stacks that the container carrier might take with him when it departs.

The process of the container carrier generators will be roughly the same per container carrier generator, as they will all need the same information but have different holding times and generate different types of carriers. The process described in the following section will therefore be a general process in PDL that all the container carrier generators use.

```
While TNow<=Runtime
  begin
    Hold generator calculated hold time.
    Pick a possible Terminal pro rata [1] for carrier to dock
    Create a container carrier with ArrivalTime, DepartureTime and Origin
    Calculate the amount of Import and Export containers the carrier can handle
    Pick a ModalLocation from the terminal modal locations possibilities of the
    carriers modality
    Give this ModalLocation to the carrier as Destination
    Hold until the Terminal for which the carrier is determined is free
    Give the carrier to the Terminal
    Resume the Terminal process
  end;
```

The process of the container generators will provide a constant stream of containers that equal the yearly predictions given by the user. This will later be verified and validated in Chapter 4 and Chapter 5.

## 3-2 Container carrier handling of terminals

The total process of the terminal when it gets a container carrier from the container carrier generator will be split into two processes. The creation and stack placement of the containers from the container carrier import or export amount and the removal of containers with the *ModalLocation* of the container carrier and the generation of ITT moves when needed. These two processes of the terminals will be discussed in the following sections.

### 3-2-1 Creation process and stack placement of containers

The terminal will receive a container carrier of the container carrier generator and create the containers according to the import amount of seaside container carriers and the export amount of the landside container carriers (because the flows towards the hinterland are stated to be import). The containers will need the following information for the rest of the process. The *StartTime* of the container will be determined by the *ArrivalTime* of the container carrier summed with the multiplication of the crane movement speed and the amount of containers that has been handled before the current container.

The *DeliveryTime* of the container will be left blank, as it will later be linked to the departure time of the container carrier it departs with. This will be discussed in Section 3-2-2.

The *Origin* of the container is the terminal it was created, this will be copied from the *Origin*

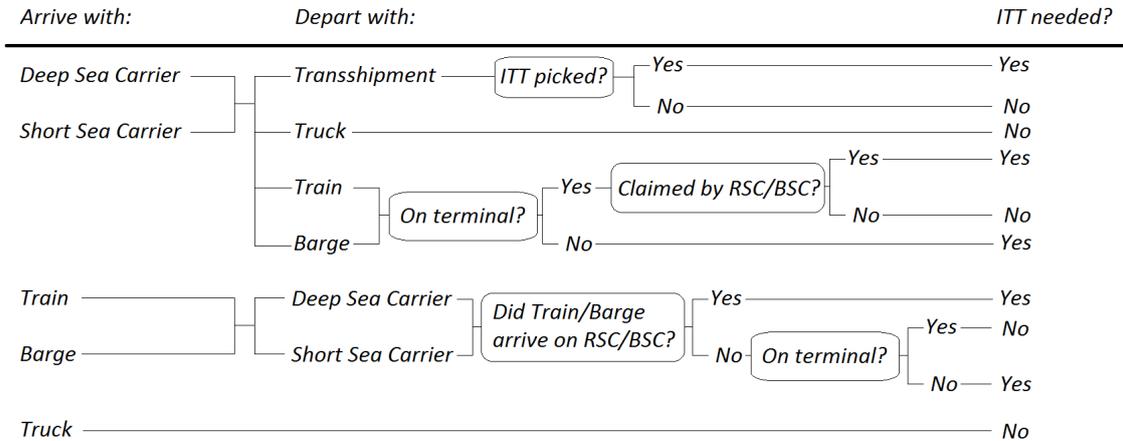


Figure 3-1: Decision tree for ITT moves.

of the container carrier as it is the same terminal as the container carrier is docked. The *Destination* of the container will be determined by picking a possible departure modality for the container (according to the modal split) and the decision if ITT is needed. The decision tree if ITT is needed is shown in Figure 3-1. A terminal will be picked pro rata [1] from a list of terminals which fall within the boundaries set by the chosen modality and determined ITT move. This terminal will be the *Destination* of the container.

The *ModalLocation* of the container will be chosen from the *ModalLocation* possibilities of the selected terminal modality and given to the container.

The amount of *TEU* the container has will be determined by the generation of a random number from a uniform distribution between 1 and 2 and compare it to the TEU factor. If the generated number is smaller than the TEU factor the container will have 2 TEU else it will have 1 TEU.

The container will then be determined to be *Empty* or not by generating a random number from a uniform distribution between 0 and 100 and compare it to the percentage of empty containers for the current day (as the empty container percentage might change over time). If the random number is smaller than the percentage it will become an empty container.

The container will also have a chance to go to *Customs*, only the containers that actually have supplies in them have this chance. This means empty containers will never go to customs. So if a container is stated to have supplies it will generate a random number from a uniform distribution between 0 and 100 and compare it to the percentage of containers that go to customs. If the random number is smaller than the percentage of containers going to customs it will have to go via customs.

The *StartBatchID* of a container will be the name of the container carrier it arrives with and can be given directly to the container. The *EndBatchID* of the container will be blank for now as it will be the name of the container carrier the container will depart with (which is not yet known in the creation process of the container).

If all the needed information for the container is known the placement of the container in the correct stack will be very important to the process of removing containers for departure. The containers will be placed in multiple queues to be able to measure features of the container

(such as average dwell time, amount of containers on the port, etc.). The container will always be placed in the **MLStackQueue** of the *ModalLocation* it will depart towards and the **AllContainerQueue** to be able to count the amount of containers that are currently on the port area. The final queue the container will be put in is either the **ITTQueue** or the **StackQueue** of a terminal, this is to determine if an ITT move is needed or not when the container departs.

The process of container creation and stack placement will be given in PDL for clarification. Every terminal will follow this process first when it is given a container carrier.

While there is a carrier

begin

For import amount of carrier

Create a container with *TEU*, *Empty*, *StartTime*, *Origin*, *StartBatchID* and *Customs*

Pick departure modality according to modal split

Determine if ITT is needed according to decision tree from Figure 3-1

Pick a Terminal pro rata [1] with the possibility of the picked departure modality

Give Terminal to container as *Destination*

Select a *ModalLocation* from the selected modality from the delivery terminal

Give *ModalLocation* to container

Put container in **MLStackQueue** of the *ModalLocation*

Put container in **AllContainerQueue** and count *TEU* amount

Put container in either **ITTQueue** or **StackQueue** of the Terminal according to the decision tree

end;

Note that the container carrier is a seaside carrier as the import amount is used for the creation of containers in this example.

The terminals will follow this process and create the amount of containers given by the container carriers and directing the flows according to the modal split and the terminal capacity as stated in the report of Gerritse [1]. This process will later be verified and validated in the Chapter 4 and Chapter 5.

### 3-2-2 Removal of containers and the generation of ITT moves

The removal process of the containers and the generation of the possible ITT moves will be dependent on the information the container has from the creation and stack placement process.

The terminal will start the removal of containers process after the container creation process. It will select containers from the **MLStackQueue** of the container carriers *Destination* and

sort them on their *StartTime*. This will ensure that containers which have been waiting the longest will be selected first for departure.

Containers with the same *StartBatchID* as the container carriers *Name* will not be selected, as these containers have just been put into this **MLStackQueue** by the container carrier itself.

The sorted containers will then be given a *DeliveryTime* and *EndBatchID* from the information of the container carrier. The *DeliveryTime* will be determined by the *DepartureTime* of the container carrier minus the multiplication of the crane handling speed and the amount of containers the container carrier will handle after the current container. The *EndBatchID* of the container will be the *Name* of the container carrier with which it will depart.

When all the information is given to the container the terminal will determine if ITT moves are necessary for the container, as its *Destination* and *Origin* might vary or it will need to go via customs. If a container is stored in an **ITTQueue** the terminal will generate the amount of ITT moves the container needs before removing it from the process. The list of these moves will be the output of the generator.

There are three types of moves that might occur, the first is a move from terminal to terminal (because the current terminal does not have the modality the container needs to be transported with for example), the second are the moves of a container to and from customs and the third are the moves of a container to and from the empty depot of a terminal.

The ITT move from terminal to terminal will be created using the information the container has gathered. The time window for the move of the container will be the difference in the *StartTime* and *DeliveryTime* of the container and the move will have to be from the containers *Origin* to its determined *Destination*.

The ITT moves to and from customs will be different, as the container will have two moves (one to and one from customs). The container will be copied with all of its information and put into the list of ITT moves twice. The first move will have its *Destination* changed to the customs terminal and its *DeliveryTime* will be the total time window it has cut in half added to the *StartTime* of the container. For example a container with a *StartTime* of 280 [min] and a *DeliveryTime* of 380 [min] will now have a *DeliveryTime* of  $((380-280)/2)+280 = 330$  [min]. The first ITT move will have to be done within this time frame. The second ITT move will have its *Origin* changed to the customs terminal and its *StartTime* will be the same as the *DeliveryTime* of the first ITT move.

The ITT moves to and from the empty depots work exactly the same as the moves to and from customs with the exception of the required time of an empty container to spend on the port. As discussed in Chapter 2 the empty containers will have to spend a minimum time on the port before it is allowed to go to the empty depot of a terminal, this is to filter out empty containers which only spend a few hours on the port but require two ITT moves in a short time frame. In reality these containers are just stored on the terminal they arrive anyway.

The process of the removal of containers and the generation of the required ITT moves will be given in PDL for clarification.

Sort all the containers in the **MLStackQueue** of the *ModalLocation* that is the same as the *Destination* of the carrier on their *StartTime*

For the export amount of a carrier

```

begin
    Pick container until MLStackQueue is empty or export amount has been handled
    Give container DeliveryTime and EndBatchID
    Determine if the container needs to go via customs.
        Create ITT move towards customs
        Create ITT move from customs
    Determine if the container needs to go via empty depot of the terminal
        Create ITT move towards empty depot
        Create ITT move from empty depot
    Determine if the container is in ITTQueue
        Create ITT move towards destination terminal
end;
```

Note that the container carrier is a seaside carrier as the export amount is used for the removal of containers in this example.

The terminals will follow this process and remove the amount of containers given by the container carriers and generate the required ITT moves. This process will later be verified and validated in the Chapter 4 and Chapter 5.

### 3-3 Implementation of the Back Order System

After the implementation of the creation and removal of containers processes of the terminal a problem occurred. Since the container carriers always created a fixed amount of containers but do not always take away the same amount of containers (because they do not have the same *ModalLocation* as the *Destination* of the container carrier) some of the containers will be left in the **MLStackQueues**. And since a container carrier cannot remove more containers than it created the amount of containers can only increase. This meant that the containers on the port area slowly kept increasing without reaching a steady state.

The problem was solved by implementing a Back Order System (BOS). This process would be activated by the terminal process when it would create a container and put it in a specific **MLStackQueue**. If there are already containers in the **MLStackQueue** the BOS will check if the amount of containers in that specific **MLStackQueue** is enough for one container carrier of that *ModalLocation*, if so it will order a container carrier for that specific *ModalLocation* that will only remove containers.

This signal will be given to a container carrier generator which only generates empty container carriers. The type of carrier and its *ModalLocation* will be given to the container carrier generator and it will then create the requested carrier and give it to the terminal.



# Verification of the computer generator

The verification of the computer generator will be done by checking the output data of the computer generator. The output the computer generator provides will therefore be discussed first. Second three verification simulation runs will be discussed to make sure the computer generator functions according to the predictions.

## 4-1 Output data of the computer generator

The data output of the computer generator is shown in Figure 4-1. On the top of the form the list of ITT moves that have been accumulated is shown, new containers are added at the bottom during the simulation. The information of the container discussed in Chapter 2 and Chapter 3 is also shown. This information can be used to check if the computer generator is functioning correct during a simulation. The list of all the ITT moves will be saved when the simulation ends. This data elaborates on the research of Jansen [3] and the data can be used as input for the research of Schroër [9].

In the middle of the form the container flows are shown in millions of TEU. Every time a container passes through a terminal or is handled by a type of modality its TEU amount will be added to that specific number to count the total throughput of a terminal or a type of modality on the port area. These amounts will be saved in a separate file (OutputFlows.txt) when the simulation ends. This data will be used in Chapter 5 to validate if the data aligns with the findings of Gerritse [1].

The bottom of the form show the two main queues of the simulation and the average dwell time of the containers on the port area. This data is plotted versus time so that the steady state of the port area can be found. It is also useful information to show possible peaks in the system as well as peak duration. These plots will also be saved at the end of the simulation. The data will be used in the following section to verify the functioning of the computer generator in specific circumstances.

For the verification of the computer generator it is important to note that these charts are

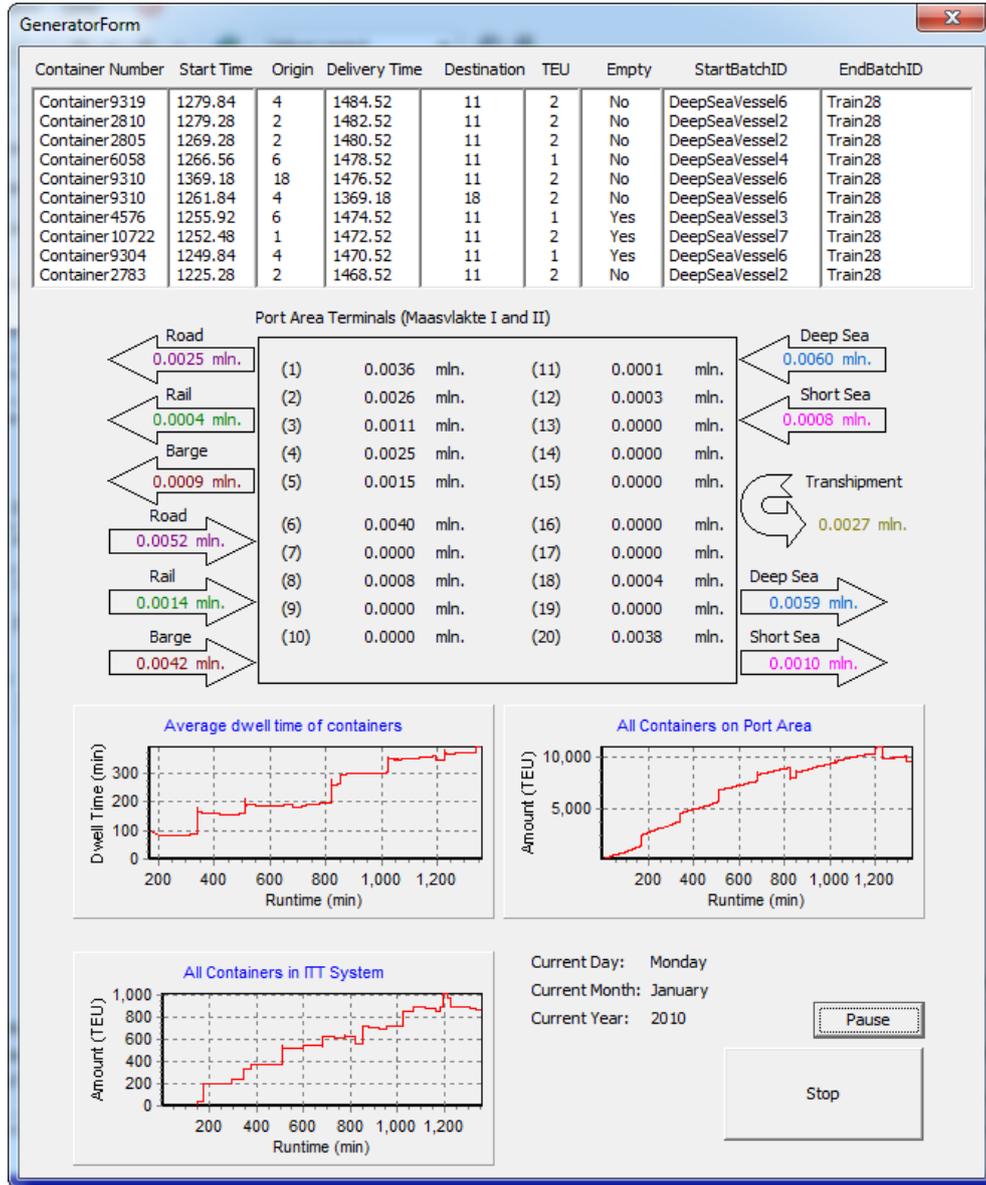


Figure 4-1: Output form of the generator.

just an indication of what is happening. Since the containers are all created at the same time, but have a different *StartTime* due to crane handling speed. Creating a spike in the chart of all the containers on the port, but in the output file of the list of ITT containers this peak will be divided among a longer time interval. Some spikes may also occur in the chart of the average dwell time, as the average dwell time of a container is calculated when it leaves the system. This means it will stay constant when time goes by, but has a sudden increase when is recalculated as a container leaves the system and the average of all the containers has increased dramatically. The chart of the containers in ITT is not entirely correct as only the containers that are known directly to go into ITT are counted, this means containers that are *Empty* or go to *Customs* which have the same terminal as *Origin* and *Destination* will not shown in this chart. From the data of the list of ITT containers it shows that this happens around 18% of the time. This means that the chart of the amount of containers in ITT should be increased by around 18%, but is not far off.

The last output data the computer generator will provide is a list of all the containers that are within the **MLStackQueue** of the simulation, providing the name and the *ModalLocation* it is suppose to go to. This is useful to determine if there are any pileups in specific **MLStackQueues**.

All these file will be created when the simulation either ends or is terminated using the stop button on the output form.

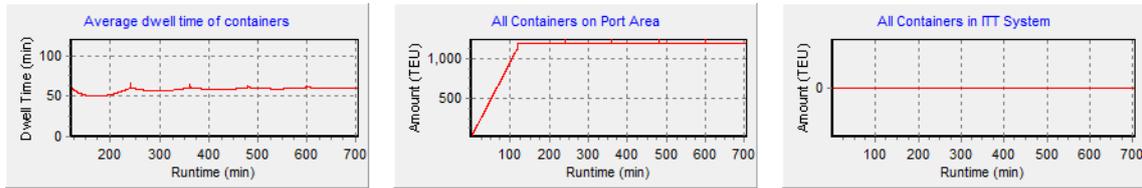
## 4-2 Verification using simulation runs

To be able to follow the process of the computer generator and test if it functions correctly three simulations have been done where the input parameters are set so that the random number generators discussed in Chapter 3 always generate the same number. This has been done by setting the modal split to 100% for one of the modalities.

For the first verification simulation run the terminal capacity of all the terminals except for one terminal has been set to zero. The terminal has been given a deep sea connection and always has a truck connection. The modal split has been set to 100% deep sea at the seaside and 100% road at the landside of the port. This means that all the import of the port arrives via deep sea vessels and is taken away from the terminal via trucks. On the other hand all the export of the port arrives via trucks and is taken away from the terminal via deep sea vessels.

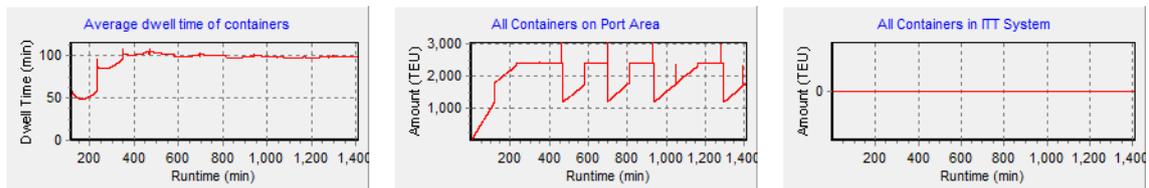
What the computer generator is expected to do is slowly generate 1200 TEU for export from arriving trucks at the terminal until a deep sea vessel arrives (as trucks have a smaller capacity and thus the truck generator has a shorter holding time). When the deep sea vessel arrives it will deliver 1200 TEU for import and take the 1200 TEU for export. The stack will thus remain at 1200 TEU. From this moment on the arriving trucks can deliver one TEU for export and receive one TEU for import, this will also not create any changes in the stacksize of the terminal.

In Figure 4-2 the results of this simulation are shown. As can be seen the amount of TEU on the port (since only one terminal is open) is equal to the 1200 TEU we expect. The amount of TEU in the ITT system is 0, this is simply because there is only one terminal on the port. The average dwell time of the containers can get into a steady state easily, as the containers need to wait the same amount of time every cycle a deep sea vessel arrives.



**Figure 4-2:** Simulation results of a run with only one terminal and one seaside and one landside modality.

For the second verification simulation the parameters are set to be able to test the BOS. Two terminals are opened with the same input as the run shown in Figure 4-2. The terminals are given the same capacity so that there should be a 50-50 distribution between the terminals. But since there is a chance that trucks bring a container but do not receive one (see Section 3-3) the BOS will have to come into play. The results of this run are shown in Figure 4-3. The results show that the stack size of both terminals totals 2400 TEU which was expected, however since not all the containers can be handled by the first deep sea carrier the BOS comes into play, ordering a second deep sea carrier and bringing the total stack size down to 1200 TEU again. This process repeats itself and the stack will remain between these values, this means the average dwell time should also become a constant over time. The containers in the ITT system should still be none, since trucks do not cause ITT movements (as they will drive to the terminal where the container needs to go, see Figure 3-1).

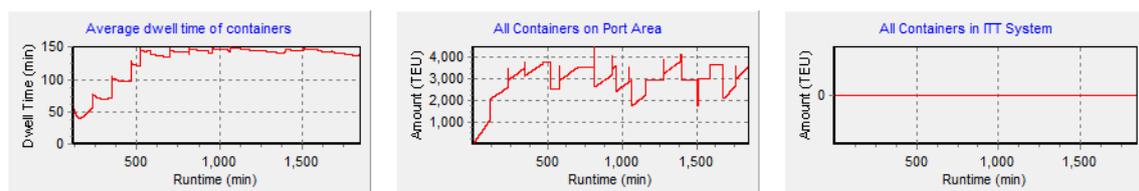


**Figure 4-3:** Simulation results of a run with two terminal and one seaside and one landside modality.

The last check on the model will be to see if the stack size and dwell time increase when the *ModalLocations* of the modalities increase. The *ModalLocations* of both terminals of the BOS run will be set from one to two, the results of this run can be seen in Figure 4-4.

The results show that the average dwell time and the average stack size do increase. It might be expected that since the *ModalLocations* double the stack size would also double, this is not the case since the BOS will have a larger chance to come into play and order more carriers to empty the stacks.

From all the results and test runs the model has been verified to work according to the expectations. The input data from the literature [1][4] will be used to create multiple runs. The results of these runs and an example of a list of ITT containers can be found in Appendix B.



**Figure 4-4:** Simulation results of a run with two terminal and one seaside and one landside modality and two ModalLocations per modality.



# Validation of the computer generator

The validation of the computer generator can only be done by comparing the results of the simulations to that of the information in the report of Gerritse [1] and the PortVision [4] report. However the PortVision [4] report only states the total flows of the port area and does not highlight the ITT flows, the report of Gerritse [1] on the other hand states that the internal flows of the port should be divided pro rata. Unfortunately there are no results of the report of Gerritse that can be compared to the results of the computer generator of this research assignment. The results of the simulations could only be discussed with the flows of the port area, not with the internal flows.

From the output data of the computer generator we can validate the flows of the entire port. For example one of the output container flows of a simulation is shown in Figure 5-1. This example will be used to determine the flows and compare them to the report of Gerritse [1].

From Figure 5-1 the import and export flows of the port area are shown per modality. Note that the import is the flows towards the hinterlands and the export are the flows from the hinterland. It is also important to note that the transshipment flows are counted instead of the deep sea and short sea flows for a container. This means that the total containers on the port can be calculated by the following formula:

$$C_T = DS_{im} + SS_{im} + RD_{ex} + RL_{ex} + B_{ex} + Tr - DS_{ex} - SS_{ex} - RD_{im} - RL_{im} - B_{im} \quad (5-1)$$

$C_T$  = Total amount of containers on the port

$DS$  = Deep Sea flows

$SS$  = Short Sea flows

$RD$  = Road flows

$RL$  = Rail flows

$B$  = Barge flows

$Tr$  = Transshipment flows

Deep Sea Import	=	88157 TEU
Deep Sea Export	=	134921 TEU
Short Sea Import	=	13818 TEU
Short Sea Export	=	43427 TEU
Transshipment	=	43892 TEU
Rail Import	=	12403 TEU
Rail Export	=	18000 TEU
Road Import	=	48055 TEU
Road Export	=	66418 TEU
Barge Import	=	36241 TEU
Barge Export	=	54038 TEU
Containers on Port	=	9276 TEU
Containers in ITT on Port	=	2270 TEU
Average Dwell Time	=	602.17 min
Throughput Terminal 1	=	79850 TEU
Throughput Terminal 2	=	51162 TEU
Throughput Terminal 3	=	32344 TEU
Throughput Terminal 4	=	40176 TEU
Throughput Terminal 5	=	70376 TEU
Throughput Terminal 6	=	0 TEU
Throughput Terminal 7	=	0 TEU
Throughput Terminal 8	=	3852 TEU
Throughput Terminal 9	=	1024 TEU
Throughput Terminal 10	=	0 TEU
Throughput Terminal 11	=	2060 TEU
Throughput Terminal 12	=	3479 TEU
Throughput Terminal 13	=	0 TEU
Throughput Terminal 14	=	0 TEU
Throughput Terminal 15	=	0 TEU
Throughput Terminal 16	=	0 TEU
Throughput Terminal 17	=	0 TEU
Throughput Terminal 18	=	0 TEU
Throughput Terminal 19	=	0 TEU
Throughput Terminal 20	=	0 TEU

**Figure 5-1:** An example of all the container flows of a simulation.

When the information provided from Figure 5-1 is used the calculated containers on the port is 9276 TEU, this is exactly the amount of containers the simulation still has on the port. This means that no containers are created or destroyed by fault within the process of the computer generator.

To validate if the computer generator creates the right amount of containers the yearly predictions are used and compared to the results of Figure 5-1. All the simulations have been done in the January 2010 and lasted a fortnight (2 weeks). This means that the yearly predictions of the port for 2010 can simply be multiplied with the Monthly factor of January (0.07) and the simulation results can be doubled for comparison. The yearly predictions of this example simulation were set to 16 million TEU in 2035, using linear interpolation we calculate the yearly predictions of 2010 to be 11.56 million TEU. The import-export ratio of this example simulation was set at 51% import and 49% export. The modal split for the seaside of the terminal was 60% Deep sea, 10% Short sea and 30% Transshipment. The modal split for the landside was 48% Road, 13% Rail and 39% Barge. The last thing to note is that the 30% Transshipment is not counted in the output data as Deep sea or Short sea and since the ratio of the Deep sea compared to the Short sea is 6:1 the Transshipment flows will be counted as 6/7 Deep sea and 1/7 Short sea.

To be able to calculate a flow from the yearly predictions the yearly prediction of 2010 is taken and multiplied by the month factor of January, the import or export percentage and the modal split. The calculations for the landside creation are simply the amount from the example simulation multiplied by 2. For the seaside the part of the transshipment for either deep or short sea is added before multiplied by 2. Comparing the container creation process of the simulation with the yearly predictions gives the following results:

Modality	$A_y$	$A_g$	Error
Deepsea import	247520 TEU	251557 TEU	-1.6%
Shortsea import	41253 TEU	40177 TEU	+2.7%
Road export	133175 TEU	132836 TEU	-0.3%
Rail export	36068 TEU	36000 TEU	-0.2%
Barge export	108205 TEU	108076 TEU	-0.1%

$A_y$  = Amount of containers calculated from yearly predictions

$A_g$  = Amount of containers generated in the example simulation

These results do not vary that much, as the TEU factor and the rounding of numbers have effect on slight error that occurs. From all the simulation results the error never becomes more than 5.0%, which is not a lot.

The same calculations could be done for the output of the port, however the internal flows will have influence on this calculation. And since the internal flows cannot be validated the output of the port might vary significantly from the calculated amount from the yearly predictions and still be functioning correctly. In the following results show the calculations of the container removal process:

Modality	$A_y$	$A_g$	Error
Deep sea export	237813 TEU	194599 TEU	-18.2%
Short sea export	39636 TEU	74313 TEU	+87.5%
Road import	138611 TEU	141752 TEU	+2.3%
Rail import	37540 TEU	36643 TEU	-2.4%
Barge import	112622 TEU	107163 TEU	-4.8%

$A_y$  = Amount of containers calculated from yearly predictions

$A_g$  = Amount of containers generated in the example simulation

From the calculations of the removal of container there are some significant differences at the seaside. There are a lot more short sea vessels that are ordered by the BOS than that are calculated from the yearly predictions. This can be explained because some terminals do not have a deep sea connection, but only a short sea connection. Since the terminals all transport a fixed amount internally with the ITT percentage, these terminals will ship 99% of the export with short sea. However if a terminal has a deep sea connection there is no reason that a short sea vessel cannot be handled by this terminal. This means that the internal flows of the port influence the output of the port compared to the results of the report from Gerritse [1]. The assumptions made in the report of Gerritse [1] and of this research assignment can be found in Appendix A and should be validated with the process of the MV1 and MV2.

# Conclusions and recommendations

In this chapter the conclusions and recommendations of the research assignment will be discussed. First a recap will be done of the research question and relevant steps, after they will be discussed and conclusions or recommendations will be drawn.

The research question and relevant steps discussed in 1 was:

- How will the future inter-terminal transportation flows on the Maasvlakte 1 and 2 be influenced by certain scenarios and can these flows be predicted?

The relevant steps that should be used to create the computer generator where:

- Use the decision tree from Erik Gerritse [1] literature study to create the computer generator and show the functioning, decisions and assumptions made in the generator.
- Use adjustable variables to create specific scenarios for future ITT demand.
- Use all the predictions and variables to create a list of containers for ITT for a determined runtime of the generator.

Starting with the research question if the flows of the Inter-Terminal Transport of the Maasvlakte 1 and the Maasvlakte 2 are influenced by certain scenarios and if these flows can be predicted. In Chapter 4 the results of the simulations are shown in which multiple scenarios are simulated, all with expected but different results. It can therefore be concluded that certain scenarios influence the flows of the Inter-Terminal Transport, however the scenarios which are simulated will be restricted by the input data of the generator meaning that not all possible scenarios can be generated by the generator. For more possibilities more research in scenarios that might occur will be needed. The second part of the research question is if the flows can be predicted for these scenarios. It can be concluded that with the right input data the ideal flows of the Inter-Terminal Transport can be predicted, however there are a lot of assumptions (Appendix A) that have been made for calculating these ideal flows, these should be taken into account when the output data of the generator is used.

The relevant steps that should be used for the generator where all honored. Where needed additional assumption where made on the decision tree of Gerritse [1], these can be found in Appendix A. The input form of Chapter 3 shows all the variables that can be adjusted for the creation of the list of ITT containers. An example of this list can be found in Appendix B.

The recommendations for further research are that the assumptions that have been made by the generator should be validated. The Back Order System now directly creates carriers for the terminals until a stack of a *ModalLocation* is empty. In reality this is not the case, but a delay time or other ways of back ordering carriers can be implemented. This will require more research on the way stacks are emptied on the port and when extra carriers are ordered. One of the limitation of the generator is the fixed terminals that have been implemented. A good addition to the generator would be to make the terminals variable.

The generator works according to expectation, but has a lot of assumptions that still need to be validated. Most of the assumptions and estimations come from the literature study from Gerritse [1] and the Port Vision [4], however some had to be made in order to create the generator and these need to be validated in particular.

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# Appendix A

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## Assumptions of the generator

In the creation process of the generator the following assumptions have been made:

- There are always four weeks in a month. [1]
- The process continues twenty-four hours per day. [1]
- Split or ratios which change over the years are recalculated on the first of January every year and stay the same that entire year.
- The TEU capacity of a carrier is the amount of TEU a carrier bring to the port.
- The capacity of carriers will not change over the entire simulation.
- Terminal capacities which change over the years are recalculated on the first of January every year and stay the same that entire year.
- Changes in ratios or distributions that occur over the years are all linear.
- All the import and export containers have a chance to go to customs.
- All moves to and from customs are done with ITT. [1]
- Empty containers are stored in the empty container depot if they spend more than a given time on the port.
- All moves to and from empty depots are done with ITT. [1]
- If the starting terminal is not the same as the departure terminal an ITT move is used. [1]
- The delivery windows for custom and empty depot moves are always half of the entire delivery window of a container.
- All carriers are handled by only one crane.

- All cranes have the same handling speed.
- Trucks do not cause ITT moves, as they can just drive to the terminal where the container needs to go.
- Only one *ModalLocation* is used per modality.
- The gross tons per TEU is 10. [1]
- The landside modal split is 48% road, 13% rail and 39% barge. [1]
- The seaside modal split is 60% deep sea, 10% short sea and 30% transshipment. [1]
- The import/export ratio is 51% import and 49% export. [1]
- All scenarios do not include containers to be handled outside of the MV1 and MV2. [1]
- Chances are taken pro rata. [1]
- There is no maximum to what a terminal can handle.
- All terminals have 1% of their transshipment moved by ITT. [1]
- The chance a container goes to customs is 0.25%. [1]
- The weekly distribution will be 15% on Monday, 21% on Tuesday, 19% on Wednesday, 19% on Thursday, 19% on Friday and 4% on Saturday and Sunday. [1]
- The monthly distribution will be 7% in January, 8% in February, 9% in March, 9% in April, 8% in May, 9% in June, 8% in July, 7% in August, 9% in September, 10% in October, 9% in November and 7% in December. [1]

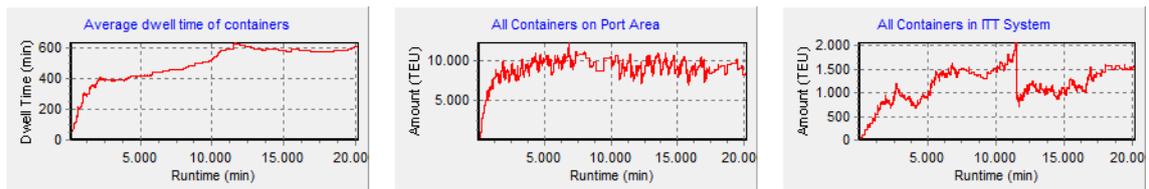
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## Appendix B

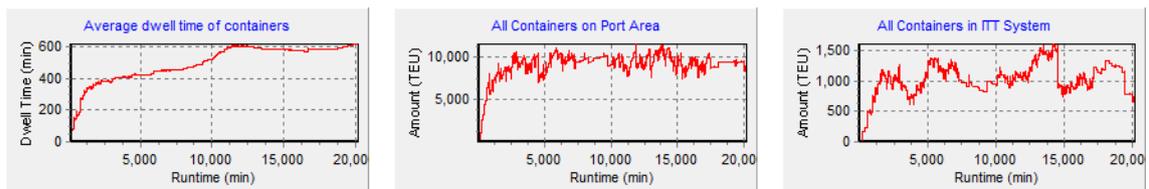
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# Results of the generator

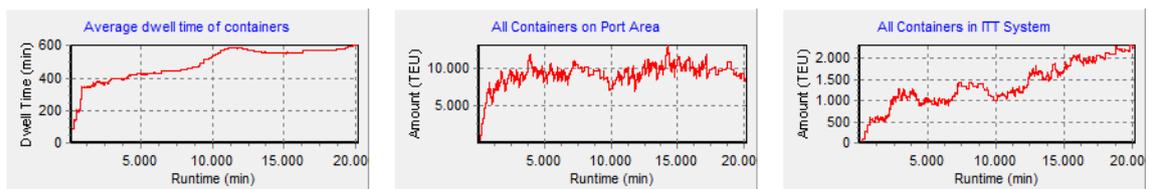
The input data from the literature [1][4] has been used to create the following results:



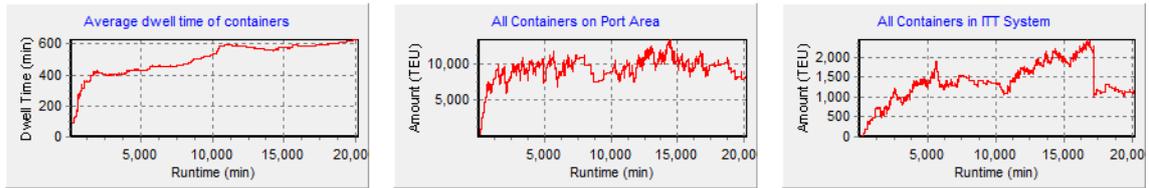
**Figure B-1:** A run of the model using the input from the literature [1][4].



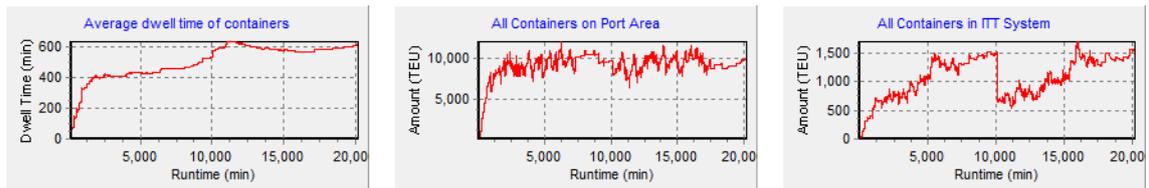
**Figure B-2:** A run of the model using the input from the literature [1][4].



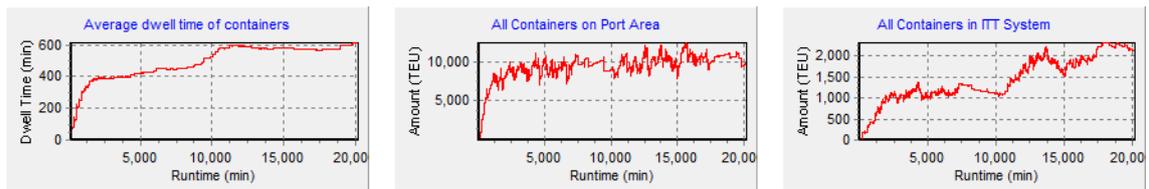
**Figure B-3:** A run of the model using the input from the literature [1][4].



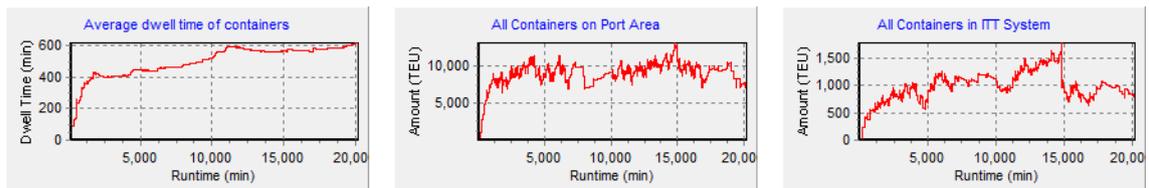
**Figure B-4:** A run of the model using the input from the literature [1][4].



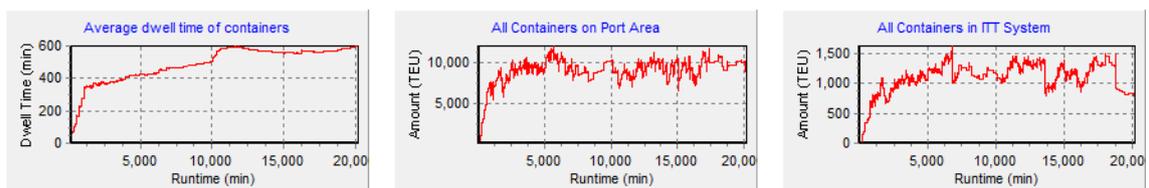
**Figure B-5:** A run of the model using the input from the literature [1][4].



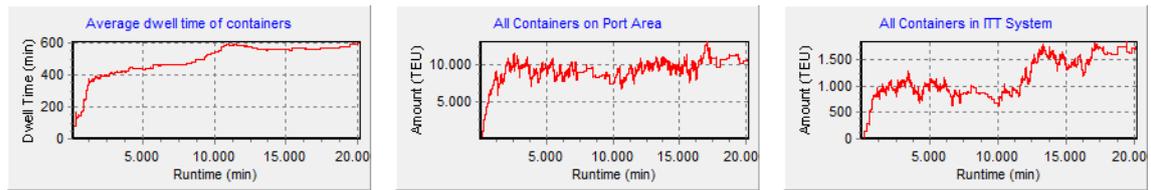
**Figure B-6:** A run of the model using the input from the literature [1][4].



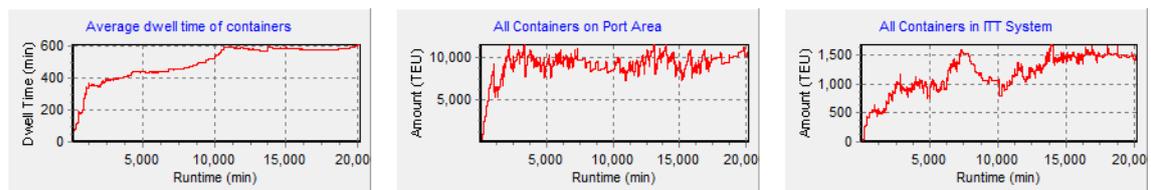
**Figure B-7:** A run of the model using the input from the literature [1][4].



**Figure B-8:** A run of the model using the input from the literature [1][4].



**Figure B-9:** A run of the model using the input from the literature [1][4].



**Figure B-10:** A run of the model using the input from the literature [1][4].

An example of a list of ITT containers is shown in Figure B-11:

[Container Name]	[StartTime]	[Origin]	[DeliveryTime]	[Destination]	[TEU]	[Empty]	[Start BatchID]	[End BatchID]
Container174	61.02	11	87.41	5	2	No	Train	DeepSeaVessel
Container266	71.88	5	904.04	18	1	No	Truck146	DeepSeaVessel
Container266	904.04	18	1736.19	5	1	No	Truck146	DeepSeaVessel
Container187	87.02	11	113.41	5	2	No	Train	DeepSeaVessel
Container192	97.02	11	123.41	5	1	No	Train	DeepSeaVessel
Container1648	215.00	5	1051.69	18	2	No	Truck445	DeepSeaVessel2
Container1648	1051.69	18	1888.39	5	2	No	Truck445	DeepSeaVessel2
Container1840	313.10	5	1182.74	18	1	No	Train5	DeepSeaVessel2
Container1840	1182.74	18	2052.39	5	1	No	Train5	DeepSeaVessel2
Container844	316.19	5	1189.29	18	2	No	DeepSeaVessel	DeepSeaVessel2
Container844	1189.29	18	2062.39	5	2	No	DeepSeaVessel	DeepSeaVessel2
Container2176	338.49	5	1247.44	18	2	No	Truck703	DeepSeaVessel2
Container2176	1247.44	18	2156.39	5	2	No	Truck703	DeepSeaVessel2
Container2223	377.47	5	1336.93	18	2	No	Barge20	DeepSeaVessel2
Container2223	1336.93	18	2296.39	5	2	No	Barge20	DeepSeaVessel2
Container2306	427.14	5	1406.76	18	1	No	Train7	DeepSeaVessel2
Container2306	1406.76	18	2386.39	5	1	No	Train7	DeepSeaVessel2
Container1474	1576.19	5	2045.29	18	2	No	DeepSeaVessel	DeepSeaVessel2
Container1474	2045.29	18	2514.39	5	2	No	DeepSeaVessel	DeepSeaVessel2
Container929	486.19	5	518.68	18	1	No	DeepSeaVessel	Train9
Container929	518.68	18	551.17	5	1	No	DeepSeaVessel	Train9
Container2050	324.12	5	885.96	18	2	No	Train6	ShortSeaVessel
Container2050	885.96	18	1447.81	5	2	No	Train6	ShortSeaVessel
Container3471	495.17	5	1034.49	18	2	No	Train9	ShortSeaVessel
Container3471	1034.49	18	1573.81	5	2	No	Train9	ShortSeaVessel
Container2624	938.39	5	1337.10	18	2	No	DeepSeaVessel2	ShortSeaVessel
Container2624	1337.10	18	1735.81	5	2	No	DeepSeaVessel2	ShortSeaVessel
Container3166	408.49	8	2086.58	5	2	No	Barge23	DeepSeaVessel3
Container3175	426.49	8	2104.58	5	2	Yes	Barge23	DeepSeaVessel3
Container3183	442.49	8	2124.58	5	1	Yes	Barge23	DeepSeaVessel3
Container3187	450.49	8	2146.58	5	2	Yes	Barge23	DeepSeaVessel3
Container3473	499.17	5	1386.88	18	2	No	Train9	DeepSeaVessel3
Container3473	1386.88	18	2274.58	5	2	No	Train9	DeepSeaVessel3
Container3481	515.17	5	1420.88	18	1	No	Train9	DeepSeaVessel3
Container3481	1420.88	18	2326.58	5	1	No	Train9	DeepSeaVessel3
Container3765	537.61	5	1473.09	18	1	No	Truck1119	DeepSeaVessel3
Container3765	1473.09	18	2408.58	5	1	No	Truck1119	DeepSeaVessel3
Container2832	1354.39	5	1988.49	18	2	No	DeepSeaVessel2	DeepSeaVessel3
Container2832	1988.49	18	2622.58	5	2	No	DeepSeaVessel2	DeepSeaVessel3
Container3057	1804.39	5	2239.49	18	1	No	DeepSeaVessel2	DeepSeaVessel3
Container3057	2239.49	18	2674.58	5	1	No	DeepSeaVessel2	DeepSeaVessel3
Container963	554.19	5	601.70	18	2	No	DeepSeaVessel	Train11
Container963	601.70	18	649.21	5	2	No	DeepSeaVessel	Train11
Container18	10.62	1	1064.62	18	2	No	Truck18	DeepSeaVessel(B)
Container18	1064.62	18	2118.62	1	2	No	Truck18	DeepSeaVessel(B)
Container108	45.35	1	1103.98	18	1	No	Barge2	DeepSeaVessel(B)
Container108	1103.98	18	2162.62	1	1	No	Barge2	DeepSeaVessel(B)
Container171	55.02	11	81.41	1	1	No	Train	DeepSeaVessel(B)
Container176	65.02	11	91.41	1	1	No	Train	DeepSeaVessel(B)
Container179	71.02	11	97.41	1	2	No	Train	DeepSeaVessel(B)
Container180	73.02	11	99.41	1	2	No	Train	DeepSeaVessel(B)
Container182	77.02	11	103.41	1	2	No	Train	DeepSeaVessel(B)
Container185	83.02	11	109.41	1	2	No	Train	DeepSeaVessel(B)
Container186	85.02	11	111.41	1	2	No	Train	DeepSeaVessel(B)
Container188	89.02	11	115.41	18	2	No	Train	DeepSeaVessel(B)
Container188	115.41	18	2278.62	1	2	No	Train	DeepSeaVessel(B)
Container189	91.02	11	117.41	1	1	No	Train	DeepSeaVessel(B)
Container191	95.02	11	121.41	1	2	No	Train	DeepSeaVessel(B)
Container194	101.02	11	127.41	1	2	Yes	Train	DeepSeaVessel(B)

Figure B-11: An example of a list of ITT containers.

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