Optimisation of the depth of the navigation channel of the Musi river.

June 1, 1997

Rogier P. Brans
Project description

This thesis is made for the graduation part of the educational program of Civil Engineering. It is part of a project in accordance with the co-operation between the Delft University of Technology (DUT) and the Institut Teknologi Sepuluh Nopember Surabaya (ITS).

Project title: Optimisation of the depth of the navigation channel of the Musi river.

Discipline: Hydraulic Engineering.

Purpose: To find the depth for the Musi river shallow parts, in order to keep the waiting time for the vessels as short as possible.

Outputs: Inventory of vessel movements in current situation.
Model for vessel traffic simulation.
Waiting costs for different vessel types for different river depths.
Lowest sum of shipping costs and dredging costs, including river works, resulting in the optimum dredging depth for the Musi river.

Study location: Musi river Palembang, South Sumatra, Indonesia

Project period: October 1996 - December 1996: Surabaya, Indonesia
January 1997 - April 1997: Delft, The Netherlands

Research methods: Literature survey.
Statistical analysis of vessel data.
Numerical modelling of Musi river in DUFLOW.
Simulation model of vessel movements in PROSIM software.
Consultation of advisors.
Organisation

Co-operating institutes:

Indonesia: P.T. Pelabuhan Indonesia II, the harbour authority for Southern Sumatra and West Java.

Indonesia: Institut Teknologi Sepuluh Nopember Surabaya (I.T.S.).

The Netherlands: Delft University of Technology.
-Faculty of Civil Engineering, Hydraulic and Geotechnical Engineering section.

Sub-commissioners: Public port of Palembang, Boom Baru.
Fertiliser Company, P.T. Pusri.
Oil company, P.T. Pertamina.

Project team DUT: Rogier P. Brans Student
Steven A. Heukelom Student
Jauko F. P. Mutsaers Resident Engineer in Surabaya

Supervisors: Prof. ir. H. Ligteringingen
Ir. R. Groenveld
Ir. F. A. J. Waals
Summary

In this report a prediction has been made for the influence of water depth in the Musi river on the shipping costs for vessels that call the harbour of Palembang. To this day shallow parts remain in the navigation channel. Due to these shallow parts vessels often have to postpone their entry of the Musi river until the tide provides enough depth. The vessels which call Palembang harbour have relatively low payloads, because they reduce the payload in order to have lower waiting times. A larger depth can also lead to a higher payload. From 11.3 the conclusions can be drawn that an increase of water depth will lead to shorter waiting times on the Musi river and possibly to an increase in payload, thus making less calls necessary. From chapter 12 the conclusions can be drawn that the optimum water depth for the Musi river is around LWS -6.5 m. For this depth the line for the fleet with 30% draught increase is favourable (Figure 49). This means that the optimum cost reduction can be attained for a draught increase in the order of 30% where possible. The reduction for the shipping costs is in the order of 30 billion Rupiah per year.

R. P. Brans
Delft, June 1, 1997
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1. **Introduction**

![Map of Indonesia](image)

*Figure 1 Indonesia*

Palembang is the capital city of the province of South Sumatra, Indonesia. The port of Palembang is situated approximately 100 km up the Musi river\(^1\) from the deep sea. A number of shoals in the river and a bar\(^2\) at the entrance restrict the navigability of this river. Being a tidal river, navigation is also dependent on the incoming and outgoing tide. Nevertheless, there is fairly extensive development along both river banks, where various waterfront industrial facilities are equipped with loading/unloading facilities.

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\(^1\) In *Bahasa Indonesia*, (the spoken language), the word *Musi* means tidal.

\(^2\) A bar is a shallow part in the river.
Figure 2 The city of Palembang along the Musi river banks

For the sake of the large vessels which call Palembang the Musi river is dredged annually. The pursued minimum water depth is LWS\(^3\) -6.5 m. This depth is not maintained constantly [12]. To this day shallow parts remain, where the water depth is even less then LWS -6.5 m (Figure 32). Due to these shallow parts vessels often have to postpone their entry of the Musi river until the tide provides enough depth.

The vessels which call Palembang harbour have relatively low payloads, because they reduce the payload in order to have lower waiting times. A larger depth can also lead to a higher payload.

The Palembang port authorities want to study the feasibility of deepening the Musi river navigation channel.

The feasibility study consists of three parts:

a river study

a dredging study; and

a vessel traffic study.

This is the vessel traffic study in which the movements and dimensions of the vessels calling at Palembang have been analysed. A computer simulation model was used to simulate the behaviour of the vessels in a new environment with higher water depths. A comparison has been made between the shipping costs and the costs for dredging. The costs for dredging and

\(^{3}\) LWS is an abbreviation for Low Water Spring. This is the lowest water level reached in the spring tide (see Figure 33)
shipping are related to the water depth. The lowest total costs are used as criteria to determine the optimum water depth, being the objective of this study.
2. Problem analysis

2.1 Occurring problems

The occurring problems can be summarised as follows:

- The river is too shallow, therefore:
  - shipping agents use small vessels and/or partially loaded vessels; or
  - vessels have to wait for high water to sail the Musi river

2.2 Problem definition

The following problem definition therefore was formulated:

- What is the optimum water depth of the navigation channel of the Musi river, based on a certain fleet composition.

2.3 Objectives of the study

The objectives of this study where formulated as follows:

- to estimate the reduction of shipping costs by increasing the nautical depth.

This will be achieved by using a simulation model for the current vessel traffic flow and to predict the response of the vessels on an increased nautical depth.

Using the results of a study by Haskoning [10] in which the costs for maintenance dredging, capital dredging and river works are estimated, a prediction for the optimum water depth for the Musi river will be made.
3. Present situation

3.1 The navigation channel of the Musi river

The navigation channel from the sea to Palembang has a length of approximately 100 km (Figure 3). The channel is used by vessels with draughts exceeding 4.5 m. Currently the minimum depth maintained for most of the navigation channel is LWS - 6.5 m. This depth is not maintained at all locations. In the navigation channel there are two bars that constrict today's shipping operations:

- the outer bar in the mouth of the Musi river; and
- the western channel around Payung Island.

Here the minimum depths are respectively LWS -4.9 m and LWS - 3.6 m [5]. As a result of these insufficient depths the larger vessels have to postpone their entry of the Musi river until they can sail from the sea to Palembang without having to stop in the river or vice versa.

The current minimum breadth of the navigation channel from the sea to Palembang is maintained at approximately 150 m all along the river [5], [16]. The largest vessels that currently sail to Palembang have a draught of 6 m, and a breadth of 30 m. For a two lane channel and these vessels a breadth of 150 m and a depth of approximately 6.6 m is
recommended [2]. This means that the navigation channel is a two lane channel for most of the length.

3.2 A description of the Palembang port terminals

Loading and unloading of cargo at the port of Palembang is partly carried out at the public terminal and partly via the private terminals.

The following port terminals are operating in Palembang (Figure 4). In the second column the average number of ship calls to the terminal is given:

<table>
<thead>
<tr>
<th>vessels/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Baru</td>
</tr>
<tr>
<td>Pertamina</td>
</tr>
<tr>
<td>Pusri</td>
</tr>
<tr>
<td>Mariana</td>
</tr>
<tr>
<td>P. Borang</td>
</tr>
<tr>
<td>Kertapati</td>
</tr>
<tr>
<td>P. Burung</td>
</tr>
<tr>
<td>Selat Jaran</td>
</tr>
</tbody>
</table>

Table 1 Vessel calls per terminal

In order to get reliable statistical data, the terminals with only few vessel calls per month have been combined to one terminal. These vessels often call at several of the terminals in one visit as well, making it difficult to analyse the data. Most of these vessels also have small draughts and are therefore not of large influence to changes in the nautical depth in the simulation model of the river. These terminal do not pay for the maintenance of the river, they will therefore gain from a deepest possible water depth of the Musi river⁴.

---

⁴ The costs for the current maintenance of the river are paid by P.T. Pertamina (60%), P.T. Pusri (25%) and the Port of Palembang harbour authority (Boom Baru) (15%) [according to Pertamina harbour officials]
Figure 4 The Musi river
Figure 5 Port of Palembang

In the following paragraphs the characteristics of the terminals will be specified.

3.2.1 Boom Baru Terminal

Figure 6 Boom Baru terminal

The Boom Baru Port is equipped with facilities to serve both ocean going and inter-island vessels. It supports general cargo and containers. And consists of the following wharves:

- **Boom Baru public terminal.** The public terminal consists of two quays for general cargo with lengths of 475 m respectively 265 m.

- **Container wharf.** The container wharf consists of one quay with a length of 280 m; and
• Mid-river mooring facilities for general cargo (dolphins).

Figure 7 Boom Baru terminal map

For information about the vessel characteristics please refer to paragraph 7.2

3.2.2 P.T. Pertamina Terminal

Figure 8 Pertamina terminal (Sungai Gerong)

The Pertamina terminal is part of an oil refinery, belonging to the national oil company P.T. Pertamina. It consists of the following oil jetties:

• Plaju (291 m quay length); and
• Sungai Gerong (301 m quay length).

For the maintenance and repair of their fleet, Pertamina operates a docking unit at Plaju. [28]

For information about the vessel characteristics please refer to paragraph 7.3 or [28]
3.2.3 P.T. Pusri Terminal

Figure 9 Pusri terminal

P.T. Pupuk Sriwidjaja. (P.T. Pusri) is the first fertiliser plant in Indonesia. The plant produces among others ammonia (1,499,000 ton/year) and urea (2,280,000 ton/year) [29]. The plant uses the following quay:

- One quay with a length of 680 m and a capacity of 2,120,00 ton per year.

For information about the vessel characteristics please refer to paragraph 7.4 or [29]

3.2.4 Terminal ‘Rest’

The other terminals have been joined to a fictive terminal:

- Kertapati (3 berths for Coal and cement, length 250 m, 50 m and 80 m )
- Mariana (1 quay for plywood)
- P. Burung (1 quay for plywood)
- P. Borang (1 quay for plywood)
- Selat Jaran (2 quays for plywood).

For information about the vessel characteristics please refer to 7.5
4. Methodology

4.1 Why a simulation model is used

The system that has to be analysed is very complex. Therefore it is inefficient to apply an analytical model for calculating the optimum water depth. A computer simulation model is a very effective tool to predict changes in the current situation. The software used for this simulation model is PROSIM. PROSIM is an advanced software system for combined discrete/continuous simulation using a personal computer. With this software system the situation in Palembang can be simulated. The model PALEMBANG was developed for that reason. With the right input parameters this model can simulate the current situation and predict the reactions of the system when some parameters are changed. In chapter 5 a description is given about PROSIM. In chapter 6 a description is given about the model PALEMBANG.

4.2 The input parameters for this simulation model

4.2.1 Vessel traffic data

The Surabaya Institute of Technology (ITS) has conducted a survey on vessel movements. Data of all incoming and leaving vessels have been collected. These vessel data were modified in order to use them for the PROSIM model PALEMBANG. A description of these data is given in chapter 7. The data were processed using MS Excel and fitted to functions with the help of the package BestFit.

4.2.2 Musi river data

The water levels in the Musi river are computed using DUFlow. DUFlow is a microcomputer package for the simulation of one-dimensional unsteady flow and water quality in open channel systems. It can be used, amongst others, for the calculation of water levels. Mutsaers [18] and Heukelom [11] have designed a model to predict the water levels in the Musi river. A description of the use and implementation of these data is given in chapter 8.
4.3 Verification and validation of the model

In chapter 9 the PROSIM model PALEMBANG is verified by tracing the movements of several vessels to and from their destination. The model is validated by calibrating the results for the waiting times for the current situation in the model with the results from the data.

4.4 Calculation of the shipping costs

A model is designed to predict the annual shipping costs, using the results of the PROSIM model. This model is described in chapter 10. In chapter 11 the results of the shipping costs for different water levels are described. Chapter 12 concludes with an estimation of the optimal depth.
5. PROSIM model development

5.1 Introduction

PROSIM is an advanced software system for combined discrete/continuous simulation using a personal computer. Simulation is used to study the dynamic behaviour of a system by means of experimentation with a model of that system. A model is a description of the “real life system” by leaving out all non-relevant aspects. A model is used instead of the system itself because actual experimentation with the system is too expensive. The model is represented as a program for a digital computer [22]. The program that is used for this solution is called PALEMBANG\textsuperscript{5}. This program will generate computer data. The data will show the behaviour of the model. If the model is valid the model generated data will be similar to data obtained from the system itself. The investigations carried out to discover whether a model is valid or not are called validation. Validation is achieved through calibration of the model, an iterative process of comparing the model to actual system behaviour and using the discrepancies to improve the model. When the model is validated, it can be used to predict the behaviour of the system in circumstances that are different from the current situation.

Because validation is a difficult process the model first has to be verified before validating it. Verification concerns a series of tests to check if the behaviour of the model is satisfactory. Verification refers to the questions:

- are the input parameters and logical structure of the model correctly represented; and
- is the model implemented correctly in computer code.

5.2 How to take samples from a distribution

Characteristics such as inter-arrival times, service times and dimensions of vessels are set by chance. From a large number of observations a distribution can be made. The observations

\textsuperscript{5} PALEMBANG is a program based on the program HARBORSIM, which is used to simulate complex port systems. The HARBORSIM program is extended with among others a stretched entrance channel and an extra anchorage.
are sorted in classes of a certain width. The number of observations in a class can be divided
by the total number of observations, creating a probability density function (p.d.f.).

<table>
<thead>
<tr>
<th>Class</th>
<th>Number</th>
<th>p.d.f.</th>
<th>c.d.f.</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
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<td>20</td>
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<td>6</td>
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<td>23</td>
<td>90</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>8</td>
<td>98</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>

*Table 2 Observations*

![Cumulative distribution function](image)

*Figure 10 Cumulative distribution function*

When the probability density function is cumulated a cumulative distribution function (c.d.f.)
is created. Random numbers are defined as independent draws from the uniform distribution
in the interval (0,1). Random numbers are a necessary basic ingredient in the simulation of
almost all systems. PROSIM has a subroutine that can generate random numbers using the
multiple congruency method. This method generates a cycle of pseudo random numbers
based on the following algorithm:

\[
\frac{1}{a} - \left( \frac{6c}{am} \right) \left( 1 - \frac{c}{m} \right) = \frac{a}{m'}
\]

(4.1)

\[
m = 2^{31} - 1
\]

\[
a = 7^5
\]

\[
c = 0
\]

Each integer from 1 to \(2^{31}-2\) appears just once somewhere in the cycle. Each number in the
cycle can be obtained as a function of its predecessor. Therefore any number in the range 1 to
\(2^{31}-2\) can be used as a starting point for a series of random numbers forming part of the cycle,
without any chance of repetition. This starting number is called the seed of a random-stream.
When a random number \(R\) is generated, \(x(R)\) is determined using the cumulative distribution
function (Figure 10).

PROSIM can transform a random number, to among others the following distributions:
• Uniform: a lower bound and an upper bound need to be obtained.

• Normal: Normally distributed numbers are drawn from a standard normal distribution table. If R is a random number obtained from this standard distribution, a drawing of the normal distribution with mean M and deviation D is obtained from the formula: M + D*R.

• Exponential: The exponential distribution is mostly used to model a Poisson arrival process, because the inter arrival times of such a process are exponentially distributed. The only parameter that needs to be obtained is the mean of the distribution.

• Gammashape: The gamma distribution is defined over the interval (0,∞) and is usually specified by a factor k and a factor L. If k is an integer the distribution is known as the Erlang-k distribution.

• Unknown: If the lower bound, the mean and the deviation of a random process are known, PROSIM tries to find a distribution function with a domain that is as small as possible according to the parameters.
6. Description of the PROSIM model Palembang

6.1 Introduction

PROSIM is using the process description method. The process description method describes the processes of all live components in the model. Live means that these components are executing activities. Characteristics are variables attached to a component to specify and describe the state of that component. Components with the same characteristics belong to the same class of components; for example the vessels [9].

6.2 Terms of reference for the simulation model

For the simulation model the following terms of reference apply:

- the simulation starts at the arrival of vessels at the outerbar. An arrival time is generated from a distribution function of inter arrival times
- processes at the terminals are not simulated, a service time is generated from a distribution function of service times
- the smallest vessels that are simulated have a dwt of 100 tons
- vessels smaller than approximately 6,000 dwt are not obstructed by low water levels, these vessels do not have to wait for the tide and can sail with their maximum payload
- each vessel is given a constant sailing time
- vessels call at only one terminal per visit
- the necessary keel clearance is fixed at 10% of the draught; and
- waiting times are never higher than five days.

6.3 The configuration of the simulation model

The configuration of the simulation model PALEMBANG is represented in Figure 11.
Figure 11 The configuration of the simulation model PALEMBANG

The model exists of a waterway with four bars. At the right end of the waterway the city of Palembang is located. On both sides of the waterway an anchorage is located. The waterway is divided in twelve sections. A description of the modules and input files and the belonging source text can be found in the appendices D through G.

6.4 The verbal model for the vessels

The vessel enters the system at the anchorage at the outerbar, to check the tidal conditions and the traffic situation. The check is carried out by the river master for incoming vessels (PRTRAFFCARRM). When permission has been granted the vessel will leave the anchorage queue and will enter the first section. When all the sections have been sailed the vessel will enter the turning basin. When the vessel is permitted to enter the port (the harbour master for incoming vessels (PRIHMASTER) checks the traffic situation) a berth will be allocated to that vessel by the quaymaster (QMASTERPR). When a berth is assigned and the traffic situation allows entrance, the ship leaves the anchorage queue and “enters” the quay queue of the terminal. When the vessel has been unloaded and loaded (equal to the service time of that
vessel) the vessel will leave the berth and return to the turning basin. The harbour master for outgoing vessels (PR2HMASTER) checks the traffic situation in the harbour. When permission is granted the vessel will sail to the anchorage queue in the harbour. River master 2 (PRTRAFFCDEP) checks when the ship is allowed to sail the Musi river again (Tidal conditions and traffic on the Musi river). When allowed, the ship will sail the Musi river and leaves the system.
7. Description of the schematization of the fleet types

As mentioned earlier (chapter 3.2) there are four different port terminals. For each port terminal a fleet type can be defined. In the computer model every fleet type is separated into two sub-fleets. The first sub-fleet consists of the small vessels (vessels with a dwt of less than for instance 6,500 tonnes\(^6\)). The second sub-fleet consists of the rest of the vessels. This separation has been made to make it possible to adjust the encounter and overtaking possibilities: The larger vessels might not be able to encounter or overtake other large vessels in certain river sections\(^7\). The statistical information is gathered from a registration of vessel movements over a period of seven months from January 1996 until July 1996 [15].

This data was used to create cumulative distribution functions for the inter arrival times, the service times, the sailing times to and from Palembang, the waiting times at the outerbar and at the harbour and the dwt. Relations between the dwt and draught to and from Palembang and between the dwt and the overall length of the vessels were made. This was done in the period of October 1996 through January 1997 [3].

The quay length is based on information in [20], an information brochure distributed by the harbour authorities. The terminals consist of more than one quay. The service times are distributed exponentially. The following inputs are used in the simulation model.

7.1 Determining the inter arrival times and the service times

Cumulative distribution functions were made for the inter arrival time for the different fleet types. These functions can be plotted in a graph. Using the program BestFit\(^8\) distribution functions can be fitted to the data. The goodness of fit can be analysed using the

---

\(^6\) This separation has not been made at the same dwt value. The separation was made in an early stage of the programming. The only reason for the differences was an easier way to divide the fleet into two sub-fleets. It has no significant influence on the simulation results.

\(^7\) In this simulation model the vessels do not overtake because they all sail with the same speed (7.7). In this model there are also no restrictions for encountering another vessel in the Musi river sections.

\(^8\) BestFit is a program which can be used to fit functions on a data sample. The result of this fit can be analysed: how well does the input data fit a function. This can be done with the Kolmogorov-Smirnov test. This test compares the empirical distribution to the hypothesised distribution.
Kolmogorov-Smirnov statistics. BestFit then gives a ranking of the functions that best fit the input data. For the results of this statistical analysis please refer to Appendix H. The functions are plotted against an negative exponential distribution in the next chapters.

### 7.2 Boom Baru fleet

The Boom Baru fleet is divided into two sub-fleets. The characteristics for the fleet have the following values:

<table>
<thead>
<tr>
<th></th>
<th>whole fleet</th>
<th>dwt &lt; 6,500</th>
<th>dwt &gt; 6,500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>100%</td>
<td>76%</td>
<td>24%</td>
</tr>
<tr>
<td>Average inter arrival time (minutes)</td>
<td>816</td>
<td>927</td>
<td>6,800</td>
</tr>
<tr>
<td>Annual dwt</td>
<td>2,373,220</td>
<td>1,151,260</td>
<td>1,221,960</td>
</tr>
</tbody>
</table>

*Table 3 Characteristics for Boom Baru*

The sub-fleets call at the Boom Baru terminal, which has the following characteristics:

- quay length [20] 1,235 meters
- Average service time 2,800 minutes

The functions for the service time and inter arrival time are plotted on negative exponential distributions in Figure 12 and Figure 13. These negative exponential distributions are used in the PROSIM model:
Description of the schematization of the fleet types

Figure 12 Inter arrival times Boom Baru

Figure 13 Service time Boom Baru
A cumulative distribution function for the dwt of Boom Baru vessels is necessary to assign the characteristics in PROSIM to the vessels. For the Boom Baru vessels the following cumulative distribution function was made (Figure 14):

![DWT Boom Baru](image)

**Figure 14 dwt Boom Baru vessels**

In PROSIM this function was schematised in the following way for the two sub fleets:

<table>
<thead>
<tr>
<th></th>
<th>Boom Baru 1 100-6,500 tons</th>
<th>Boom Baru 2 6,500-15,200 tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>dwt</td>
<td>% total fleet  % sub fleet</td>
<td>% total fleet  % sub fleet</td>
</tr>
<tr>
<td>100</td>
<td>0% 0%</td>
<td>6,500 76% 0%</td>
</tr>
<tr>
<td>2,400</td>
<td>54% 71%</td>
<td>7,200 98% 92%</td>
</tr>
<tr>
<td>6,500</td>
<td>76% 100%</td>
<td>15,200 100% 100%</td>
</tr>
</tbody>
</table>

**Table 4 dwt Boom Baru vessels**

The percentage for the sub fleet was calculated by setting the highest percentage of a sub fleet at 100%. The rest is then related to this highest percentage. For example: for Boom Baru 1 the highest percentage is 76% (of the total fleet). This is set to 100% (percentage of this sub fleet), the second highest is then 54%/76%=71% (of this fleet).
Figure 15 Draught for Boom Baru vessels

In Figure 15 the draught for vessels going to Palembang is plotted in their relation with the dwt of Boom Baru vessels. The function ‘General Cargo’ is plotted in the graph to show the difference between the actual draught for Boom Baru vessels and the average maximum draught of vessels of the same class [25]. It shows that Boom Baru vessels have lower draughts than usual. The polynomial function shows the average draught of the data for the Boom Baru vessels. The PROSIM function is the schematization used in the simulation model.

7.3 Pertamina fleet

The Pertamina fleet is divided into two sub-fleets. The characteristics for the fleet have the following values:
Table 5 Characteristics for Pertamina fleet

The sub-fleets call at the Pertamina terminal, which has the following characteristics:

- quay length [20] 1,200 meters
- Average service time 1,800 minutes

The functions for the service time and inter arrival time are plotted on negative exponential distributions in Figure 16 and Figure 17. These negative exponential distributions are used in the PROSIM model:

Figure 16 Inter arrival times Pertamina
Figure 17 Service time Pertamina

A cumulative distribution function for the dwt of Pertamina vessels is necessary to assign the characteristics in PROSIM to the vessels. For the Pertamina vessels the following cumulative distribution function was made: (Figure 18)
Figure 18 dwt Pertamina vessels

In PROSIM this function was schematised in the following way for the two sub fleets:

<table>
<thead>
<tr>
<th>Pertamina 1</th>
<th>600-8,000 tons</th>
<th>Pertamina 2</th>
<th>8,000-20,200 tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>dwt</td>
<td>% total fleet</td>
<td>% sub fleet</td>
<td>% total fleet</td>
</tr>
<tr>
<td>600</td>
<td>0%</td>
<td>0%</td>
<td>8,000</td>
</tr>
<tr>
<td>3,600</td>
<td>22%</td>
<td>37%</td>
<td>14,000</td>
</tr>
<tr>
<td>8,000</td>
<td>60%</td>
<td>100%</td>
<td>20,200</td>
</tr>
</tbody>
</table>

Table 6 dwt Pertamina vessels
Description of the schematization of the fleet types

In Figure 19 the draught for Pertamina vessels going to Palembang is plotted in their relation with the dwt of Pertamina vessels. The function ‘Tankers’ is plotted in the graph to show the difference between the actual draught for Pertamina vessels and the average maximum draught of vessels of the same class [25]. It shows that Pertamina vessels have lower draughts than usual. The polynomial function shows the average draught of the data for the Pertamina vessels. The PROSIM function is the schematization used in the simulation model.

![Figure 19 Draught for Pertamina vessels](image)

7.4 Pusri fleet

The Pusri fleet is divided into two sub-fleets. The characteristics for the fleet have the following values:
Description of the schematization of the fleet types

<table>
<thead>
<tr>
<th></th>
<th>whole fleet</th>
<th>dwt &lt; 8,000</th>
<th>dwt &gt; 8,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>100%</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>Average inter arrival time (minutes)</td>
<td>1,390</td>
<td>1,828</td>
<td>5,792</td>
</tr>
<tr>
<td>Annual dwt</td>
<td>1,905,133</td>
<td>758,403</td>
<td>1,146,730</td>
</tr>
</tbody>
</table>

Table 7 Characteristics for Pusri fleet

The sub-fleets call at the Pusri terminal, which has the following characteristics:

- quay length [20] 780 meters
- Average service time 2,900 minutes

The functions for the service time and inter arrival time are plotted on negative exponential distributions in Figure 20 and Figure 21. These negative exponential distributions are used in the PROSIM model:

![Inter arrival times Pusri](image)

*Figure 20 Inter arrival times Pusri*
Description of the schematization of the fleet types

![Service time](image)

**Figure 21 Service time Pusri**

A cumulative distribution function for the dwt of Pusri vessels is necessary to assign the characteristics in PROSIM to the vessels. For the Pusri vessels the following cumulative distribution function was made: (Figure 22)
Figure 22 dwt Pusri vessels

In PROSIM this function was schematised in the following way for the two sub fleets:

<table>
<thead>
<tr>
<th>Pusri 1</th>
<th>200-8,000 tons</th>
<th>Pusri 2</th>
<th>8,000-11,200 tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>dwt</td>
<td>% total fleet</td>
<td>% sub fleet</td>
<td>% total fleet</td>
</tr>
<tr>
<td>200</td>
<td>0%</td>
<td>0%</td>
<td>8,000</td>
</tr>
<tr>
<td>1,800</td>
<td>37%</td>
<td>53%</td>
<td>11,000</td>
</tr>
<tr>
<td>8,000</td>
<td>70%</td>
<td>100%</td>
<td>11,200</td>
</tr>
</tbody>
</table>

Table 8 dwt Pusri vessels
Figure 23 Draught for Pusri vessels

In Figure 23 the draught for vessels going to Palembang is plotted in their relation with the dwt of Pusri vessels. The function ‘Bulk Carriers’ is plotted in the graph to show the difference between the actual draught for Pusri vessels and the average maximum draught of vessels of the same class [25]. It shows that Pusri vessels have lower draughts than usual. The polynomial function shows the average draught of the data for the Pusri vessels. The PROSIM function is the schematization used in the simulation model.

7.5 Rest of the vessels: Fleet Rest

In order to get reliable statistical data, the rest of the vessels have been combined to one fleet. These vessels often call at several of the terminals in one visit, making it difficult to analyse the data. Most of these vessels also have small draughts and are therefore not of large influence to changes in the nautical depth in the simulation model of the river. This fleet is called ‘Fleet Rest’. The fleet is divided into two sub-fleets. The characteristics for the ‘Fleet Rest’ have the following values:
Table 9 Characteristics for ‘Fleet Rest’

The sub-fleets call at the “REST” terminal, which has the following characteristics:

- Quay length [20] 700 meters
- Average service time 3,100 minutes

The functions for the service time and inter arrival time are negative exponential distributions based on the average of the service time and inter arrival time of the Boom Baru, Pertamina and Pusri terminals. This was necessary because there was not enough information about the service time and inter arrival time of these vessels. A cumulative distribution function for the dwt of the rest of the vessels is necessary to assign the characteristics in PROSIM to the vessels. For the rest of the vessels the following cumulative distribution function was made: (Figure 24)

![Cumulative distribution function for dwt Rest of the vessels](image)

**Figure 24 dwt Rest of the vessels**

In PROSIM this function was schematised in the following way for the two sub fleets:
Description of the schematization of the fleet types

<table>
<thead>
<tr>
<th>Rest 1</th>
<th>400-6,000 tons</th>
<th>Rest 2</th>
<th>6,000-18,200 tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>dwt</td>
<td>% total fleet</td>
<td>% sub fleet</td>
<td>% total fleet</td>
</tr>
<tr>
<td>400</td>
<td>0%</td>
<td>0%</td>
<td>6500</td>
</tr>
<tr>
<td>2,600</td>
<td>50%</td>
<td>96%</td>
<td>7,200</td>
</tr>
<tr>
<td>6,000</td>
<td>52%</td>
<td>100%</td>
<td>15,200</td>
</tr>
</tbody>
</table>

Table 10 dwt Rest of the vessels

Figure 25 Draught for Rest vessels

In Figure 25 the draught for vessels going to Palembang is plotted in their relation with the dwt of the rest of the vessels. The function ‘General Cargo’ is plotted in the graph to show the difference between the actual draught for the ‘Rest of the vessels’ and the average maximum draught of vessels of the same class [25]. It shows that these vessels have lower draughts than usual. The polynomial function shows the average draught of the data for these vessels. The PROSIM function is the schematization used in the simulation model.
7.6 Length over all

The length over all (LOA) in relation to the dwt has also been deduced from the data. The data correspond with the lengths that are common for the vessels according to [25] (Figure 26).

![Graph showing length over all in relation to dwt for Boom Baru, PERTAMINA, PUSRI, REST, Pertamina, pusri, and rest.]

*Figure 26 Length over all for all vessels*

7.7 Sailing Times

The Musi river is divided in twelve sections (Figure 11). In the input files the sailing times per section are given per vessel. Per section the possibility to overtake or to encounter another vessel is given as well. For each ship type the sailing times for each section is given. The twelve sections of the Musi river are all assumed to be sailed in 30 minutes by all vessels. (The vessels consequently do not overtake other vessels in this simulation). This amounts to a total sailing time for the Musi river of 6 hours which is about average for all vessels [3, Appendix E].
8. Description of the schematization of the Musi river

8.1 The longitudinal profile of the Musi river

The longitudinal profile of the Musi river is composed from the navigation map [5], on which the depths are referred to local LWS. The depths have been taken for each kilometre from the Boom Baru terminal at Palembang to the mouth of the Musi river. These values have to be corrected by the average bottom slope ($1.8\times10^{-5}$ [10]) in order to refer the bottom levels to one level.

![Graph showing the longitudinal profile of the Musi river navigation channel](image)

**Distance from Palembang [km]**

**Figure 27 The longitudinal profile of the Musi river navigation channel**

In Figure 27 the longitudinal profile of the navigation channel of the Musi river navigation channel is shown.

There is little information available on the longitudinal profile of the bifurcations and confluences of the Musi river. It is therefore assumed that they have straight bottom profiles from the location where they split off (bottom level can be read from the Musi river navigation map) to the point where they meet the Musi river again (bottom level can be read from the
8.2 Water levels

8.2.1 Introduction

The water level measurements were carried out according to the following principle. First at each location a local reference level was determined, the so called ‘peilschaal’.

After that the measurements were taken and referred to this local ‘peilschaal’ (see Figure 28). The measurements were later adjusted with the average bottom slope ($1.8 \times 10^{-5}$[10]) to obtain the water levels referred to LWS in the mouth of the Musi river (see Figure 29).

Figure 28 Illustration of water level measurement method
Figure 29 Correction of the local water level measurements with the average bottom slope

In the next paragraphs a separation is made between the maintenance depth and the tidal level.

The water depth on top of the bars is defined by the maintenance depth added by the tidal level (Figure 30).

Figure 30 Definition water depth

The maintenance depth is varied in the model to simulate the influence of river works and dredging activities. In 8.2.2 the maintenance depth is described and in 8.2.3 the tidal level constitution is explained.

8.2.2 Maintenance depth of the bars in the Musi river

The locations of the bars are defined by the sailing times to the bars. As mentioned earlier (0), four bars are recognised.

The bars can be found at the following locations in Figure 31:

Ayer Kumbang
Sungai Upang
Pulau Ayam
Pulau Payung

The longitudinal profile is composed from the navigation map, on which the depths are referred to LWS in the river mouth (100 km from Palembang). The depths have been taken over for each kilometre from the Boom Baru terminal at Palembang to the mouth of the Musi river. In the PROSIM model only the relevant (shallow) points are represented.

In PROSIM a bar is represented by a single point. Two bars are too long to be schematised as points. Therefore these bars are schematised as two points (Figure 32). A vessel is not allowed between a begin and end point while the water depth is insufficient. Six bar points are thus defined in the model.

<table>
<thead>
<tr>
<th>Point</th>
<th>Distance from Palembang</th>
<th>Depth [x. - LWS in the mouth]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point 1</td>
<td>78 km</td>
<td>4.7 m</td>
</tr>
<tr>
<td>Point 2</td>
<td>82 km</td>
<td>3.6 m</td>
</tr>
<tr>
<td>Point 3</td>
<td>42 km</td>
<td>5.5 m</td>
</tr>
<tr>
<td>Point 4</td>
<td>32 km</td>
<td>5.2 m</td>
</tr>
<tr>
<td>Point 5</td>
<td>20 km</td>
<td>5.7 m</td>
</tr>
<tr>
<td>Point 6</td>
<td>8 km</td>
<td>5.4 m</td>
</tr>
</tbody>
</table>

*Table 11 Location and depth of bar ‘points’*
8.2.3 Tidal levels

The tidal influence is produced by the DUFlow model [18]. The tidal period at sea is approximately 24 hours (see Figure 33). The tidal amplitude is different for spring tide and neap tide. During spring tide, when the lowest water levels occur and therefore the most hindrance to the vessels, the tidal amplitude is approximately 1.9 m. The neap tide and the spring tide levels are computed for the relevant locations (the bars). The measurements were carried out covering one complete tidal cycle of fourteen days in which a tide will transform from spring tide to neap tide and back to spring tide. The neap tide is the period with small amplitudes and the spring tide is the period with higher amplitudes. Low Water Spring is the lowest water level for spring in a year and is represented by the zero level in the graph.
Figure 33 The tidal levels at bar 1

The levels have then been translated to the PROSIM model. The following graphs show the tidal levels in DUFlow and PROSIM for neap tide and spring tide for the first bar.
Figure 34 Neap tide bar 1

Figure 34 shows the similarity of the DUFlow results and the PROSIM output for the neap tide on bar 1.

There is a phase difference between water levels on the four bars. The phase difference between the tide at sea and the tide near Palembang is approximately 5 hours. This is clarified by the fact that a tidal wave on a river moves with a certain speed, in this case about 17 km/h. Therefore the wave meets the different bars at different times. There is virtually no damping of the wave moving upstream, which can be explained by the small slope of the river bed. (1.8E-5) [10].
8.2.4 Influence of the maintenance depth on the tidal levels

In [11] simulations have been made for the change in the tidal levels due to higher water depths. The simulations have been carried out for LWS -5.5 m, LWS -6.5 m, LWS -7.0 m and LWS -7.5 m for the spring tide. The influence on the water depth is very small, which is illustrated in Figure 36 to Figure 38:
Figure 36 Influence of the water depth on the tidal levels for bar 1

For bar 1 the influence of the depth of the bars on the tidal levels is zero. This is explained by the fact that the bar is located close to the sea. The tidal level of bar 1 is governed for almost 100% by the tidal level of the sea.
Figure 37 Influence of the water depth on the tidal levels for bar 2

For bar 2 the influence of the improved water depth on the bars is recognisable, but still very low. The maximum difference in the tidal levels is in the order of 1%. The maximum difference in the total water levels is less than 0.4%, which is negligible.
Influence of the water depth on the tidal levels for bar 3

![Graph showing water depth over time for different bars](image)

Figure 38 Influence of the water depth on the tidal levels for bar 3

For bar 3 the influence of the improved water depth on the bars is somewhat larger than for the previous bars, but still very low. The maximum difference in the tidal levels is in the order of 9 cm. The maximum difference in the total water levels is less than 0.4%, which is also neglected\(^9\).

---

\(^9\) In Mutsaers [18] it is stated that the difference between water levels in the real system and the DUFlow model are in the order of at least 25%. Neglect of a 0.4% difference is therefore justified.
9. Verification and validation of the PROSIM model Palembang

9.1 Verification

The inter arrival times have been verified by analysing the PROSIM results for a simulation run of 150,000 minutes. The comparison shows a satisfactory correlation. The inter arrival times are accurate up to a margin of 0.5% for the total amount of vessels.

<table>
<thead>
<tr>
<th>Fleet</th>
<th>IAT (minutes)</th>
<th>vessels (150,000 min)</th>
<th>vessels in PROSIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Baru 1</td>
<td>1,074</td>
<td>140</td>
<td>149</td>
</tr>
<tr>
<td>Boom Baru 2</td>
<td>3,400</td>
<td>44</td>
<td>43</td>
</tr>
<tr>
<td>Pertamina 1</td>
<td>850</td>
<td>176</td>
<td>181</td>
</tr>
<tr>
<td>Pertamina 2</td>
<td>1,275</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td>Pusri 1</td>
<td>1,986</td>
<td>76</td>
<td>75</td>
</tr>
<tr>
<td>Pusri 2</td>
<td>4,633</td>
<td>32</td>
<td>34</td>
</tr>
<tr>
<td>Rest 1</td>
<td>2,708</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>Rest 2</td>
<td>2,933</td>
<td>51</td>
<td>43</td>
</tr>
<tr>
<td>Total</td>
<td>216</td>
<td>691</td>
<td>687</td>
</tr>
</tbody>
</table>

*Table 12 Verification of inter arrival times*

The same has been done for the service times. The following table is the result thereof:

<table>
<thead>
<tr>
<th>Fleet</th>
<th>Service time [days]</th>
<th>PROSIM [days]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Baru 1</td>
<td>1.94</td>
<td>1.9</td>
</tr>
<tr>
<td>Boom Baru 2</td>
<td>1.94</td>
<td>1.95</td>
</tr>
<tr>
<td>Pertamina 1</td>
<td>1.25</td>
<td>1.2</td>
</tr>
<tr>
<td>Pertamina 2</td>
<td>1.25</td>
<td>1.2</td>
</tr>
<tr>
<td>Pusri 1</td>
<td>2.01</td>
<td>2</td>
</tr>
<tr>
<td>Pusri 2</td>
<td>2.01</td>
<td>2</td>
</tr>
</tbody>
</table>

*Table 13 Verification of service times*
The results are accurate in a 5% boundary.

The PROSIM package offers the possibility to trace the actions of a component in the system. This option can be used to verify if the model performs certain action correctly. In this paragraph the movements of a vessel has been traced from the generation of this vessel, to the point that the vessel leaves the system.

The vessel is the eleventh vessel to enter the system and is therefore called ‘ship 11’. The vessel is created on ‘date’: 482.20852 (minutes). It is moved to the anchorage at the outerbar.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>482.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 joined to anchoragem</td>
</tr>
<tr>
<td></td>
<td>trafficarm activated at 482.20852</td>
<td>ship 11 is passivated</td>
</tr>
<tr>
<td></td>
<td>ship 11 is current now</td>
<td>ship 11 removed from anchoragem</td>
</tr>
</tbody>
</table>

The river master (trafficarm) allows the vessel to immediately ‘enter’ the river. The river is divide in 12 sections which are all sailed in 30 minutes.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>512.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 512.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 1</td>
<td></td>
</tr>
<tr>
<td>542.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 542.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 2</td>
<td></td>
</tr>
<tr>
<td>572.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 572.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 3</td>
<td></td>
</tr>
<tr>
<td>602.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 602.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 4</td>
<td></td>
</tr>
<tr>
<td>632.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 632.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 5</td>
<td></td>
</tr>
<tr>
<td>662.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 662.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 6</td>
<td></td>
</tr>
<tr>
<td>692.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 692.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 7</td>
<td></td>
</tr>
<tr>
<td>722.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 722.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 8</td>
<td></td>
</tr>
<tr>
<td>752.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 752.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 9</td>
<td></td>
</tr>
<tr>
<td>782.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 782.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 10</td>
<td></td>
</tr>
<tr>
<td>812.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 812.20852</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musin 12</td>
<td>ship 11 suspended till 842.20852</td>
</tr>
</tbody>
</table>
When the Musi river sections have been sailed, the vessel enters the turning basin, where it waits until it can sail to the terminal.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>842.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiin 12</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to arrquay 1</td>
<td>ship 11 joined to quayq</td>
</tr>
<tr>
<td></td>
<td>qmaster 1 activated at 842.20852</td>
<td>ship 11 is passivated</td>
</tr>
<tr>
<td></td>
<td>ship 11 is current now</td>
<td>ship 11 removed from arrquay 1</td>
</tr>
<tr>
<td></td>
<td>ship 11 removed from quayq</td>
<td>ship 11 joined to arrival</td>
</tr>
<tr>
<td></td>
<td>hmaster1 activated at 842.20852</td>
<td>ship 11 is passivated</td>
</tr>
</tbody>
</table>

Permission is granted and the vessel sails to the quay. The track to the quay is divide in 5 sections which are sailed in 3, 3, 3, 30 respectively 30 minutes.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>887.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from arrival</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to channel</td>
<td>ship 11 joined to channel in</td>
</tr>
<tr>
<td></td>
<td>ship 11 suspended till 890.20852</td>
<td></td>
</tr>
<tr>
<td>890.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 893.20852</td>
</tr>
<tr>
<td>893.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 896.20852</td>
</tr>
<tr>
<td>896.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 899.20852</td>
</tr>
<tr>
<td>899.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 902.20852</td>
</tr>
<tr>
<td>902.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 932.20852</td>
</tr>
<tr>
<td>932.20852</td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 962.20852</td>
</tr>
</tbody>
</table>

When the vessel arrives at the quay, it waits during the service time of the vessel.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>962.42857</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from channel</td>
</tr>
<tr>
<td></td>
<td>ship 11 removed from channelin</td>
<td>ship 11 joined to quay 1</td>
</tr>
<tr>
<td></td>
<td>termoper 1 activated at 962.42857</td>
<td>ship 11 is passivated</td>
</tr>
<tr>
<td></td>
<td>ship 11 is current now</td>
<td>ship 11 suspended till 2318.92690</td>
</tr>
</tbody>
</table>

When the service time has passed, the vessel follows the same track back to the turning basin.
Then the vessel sails the 12 sections of the Musi river again, when permission is granted at date 3306.6790.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>3306.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from anchorage</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 1</td>
<td>ship 11 suspended till 3336.6790</td>
</tr>
<tr>
<td>3336.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 1</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 2</td>
<td>ship 11 suspended till 3366.6790</td>
</tr>
<tr>
<td>3366.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 2</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 3</td>
<td>ship 11 suspended till 3396.6790</td>
</tr>
<tr>
<td>3396.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 3</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 4</td>
<td>ship 11 suspended till 3426.6790</td>
</tr>
<tr>
<td>3426.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 4</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 5</td>
<td>ship 11 suspended till 3456.6790</td>
</tr>
<tr>
<td>3456.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 5</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 6</td>
<td>ship 11 suspended till 3486.6790</td>
</tr>
<tr>
<td>3486.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 6</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 7</td>
<td>ship 11 suspended till 3516.6790</td>
</tr>
<tr>
<td>3516.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 7</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 8</td>
<td>ship 11 suspended till 3546.6790</td>
</tr>
<tr>
<td>3546.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 8</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 9</td>
<td>ship 11 suspended till 3576.6790</td>
</tr>
<tr>
<td>3576.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 9</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 10</td>
<td>ship 11 suspended till 3606.6790</td>
</tr>
<tr>
<td>3606.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 10</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 11</td>
<td>ship 11 suspended till 3636.6790</td>
</tr>
<tr>
<td>3636.6790</td>
<td>ship 11 is current now</td>
<td>ship 11 removed from musiout 11</td>
</tr>
<tr>
<td></td>
<td>ship 11 joined to musiout 12</td>
<td>ship 11 suspended till 3666.6790</td>
</tr>
</tbody>
</table>
After sailing all the sections, the vessel leaves the system.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>3336.6790</td>
<td>ship II is current now</td>
<td>ship II removed from musiout 12</td>
</tr>
<tr>
<td></td>
<td>ship II is terminated</td>
<td></td>
</tr>
</tbody>
</table>

The same method has been used to trace other components of the system. They all work conform their expectations.

9.2 Validation

The objective of the validation stage is to ensure that the simulation program is a proper representation of the system being studied, therefore this is a very important part of simulation modelling. But the difficulty arises, however, due to the fact that the model is never a complete representation of the real system, whereas the real system is never completely known. Therefore, it must be recognised that this objective of proving the simulation correct can only be approached, not achieved. Nevertheless, in simulation the goal is to have a model which represents the real system adequately for the purpose of the study for which it is used. Thus, a model is considered valid, if the difference between model generated data and data obtained from a real system is still within acceptable limits. For this purpose, the distributions of the waiting times per fleet is gathered to be used to test the model validity.

The waiting times in PROSIM have been compared with the cumulative distribution functions based on the VTS data [15]. The following four graphs illustrate the similarity. The resulting remaining differences can be put down to the following external factors:

- pilotage, the pilots are not always available, creating extra waiting times for the ships, which are not implemented in the model;
- vessels, the shipping agent knows the tidal levels and will react accordingly, by changing the load factor or by changing the arrival time. In the simulation model this possibility does not exist. The simulation has an artificial boundary for the waiting time of 1 day.
- draught, the function for the draughts is a schematization of the actual draught, and
- data, the data contains measurement errors.
Figure 39 CDF’s for the waiting time at outerbar for Boom Baru vessels

Figure 40 CDF’s for the waiting time at outerbar for Pertamina vessels
Figure 41 CDF's for the waiting time at outerbar for Pusri vessels

Figure 42 CDF's for the waiting time at outerbar for Rest of the vessels
10. Calculation of the shipping costs

10.1 Introduction

The cost of operating a ship depends on a combination of factors. First, the ship itself sets the broad framework of costs through its fuel consumption, the number of crew required to operate it and its physical condition, which dictates the requirement for repairs and maintenance. Secondly, running costs depend on the cost of bought-in items, particularly bunkers, wages paid to the crew and the level of repair costs, all of which are subject to general trends in world prices. Thirdly, the level of costs is influenced by the efficiency with which the owner manages the operation of the ship, including the administrative overhead.

These costs can be classified into four categories [23]:

- operating costs, which constitute the expenses involved in the day-to-day running of a ship
  - essentially those costs such as crew, stores and maintenance that will be incurred whatever trade the ship is engaged in;
- voyage costs, which are variable costs associated with a specific voyage and include such items as fuel, port charges and canal dues;
- capital costs, which cover interest and capital repayments and are determined by the way in which the ship has been financed; and
- cargo handling costs, which represent the expense of loading, stowing and discharging cargo. They are particularly important in the liner trades.

When an analysis is made for the influence of water depth improvements on the running costs for a ship, it can be seen that all the costs mentioned above except the operating costs are affected.

An increase in the water depth can lead to shorter waiting times and to an increase in the draught. An increase in the draught is accomplished by an increase in the cargo volume, which means that the same amount of cargo can be supplied by less round trips. While e.g. the buffer stock costs will rise [26], the total running costs will tend to be lower.
In the following paragraphs a model is presented in which only relevant factors are included. These are the factors that are influenced by the improvement of the water depth in the Musi river (see 10.4).

### 10.2 Shipping costs model for Palembang

In [24] a shipping model for Indonesia is presented in which shipping costs per route are expressed as a function of ship size and speed as major ship type parameters and further of operational or productivity parameters. The costs are expressed in Indonesia's currency, the Rupiah. 1,000 Rupiah equals approximately 0.75 Dutch Guilders or 0.40 US Dollars (May 1997).

\[
C_s = NRV_s(TS_s CS_s + TP_s CP_s) \quad \text{[millions Rupiah/day]} \quad (5.1)
\]

- \(C_s\) : annual shipping costs [millions Rupiah/year]
- \(NRV_s\) : number of round voyages per year [voyage/year]
- \(TS_s\) : sailing time per round voyage [days/voyage]
- \(CS_s\) : daily costs at sea [millions Rupiah/day]
- \(TP_s\) : port time per round voyage [days/voyage]
- \(CP_s\) : daily cost in port [millions Rupiah/day]

The subscript \(s\) indicates that the variable is a function of ship size.

#### 10.2.1 Load factor

The number of round trips needed to carry the annual cargo volume of the route concerned is:

\[
NRV_s = \frac{F}{S} \quad \text{[voyages/year]} \quad (5.2)
\]

- \(F\) : annual dwt [ton/year]
- \(S\) : average size of ship in dwt carrying capacity [ton]
The values for the annual dwt (F) have been calculated using the PROSIM results for the present situation. The costs for the ‘fleet Rest’ have not been taken into account because this fleet is too diffuse.

<table>
<thead>
<tr>
<th></th>
<th>annual dwt (F) [ton/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Baru</td>
<td>2,373,220</td>
</tr>
<tr>
<td>Pertamina</td>
<td>10,062,120</td>
</tr>
<tr>
<td>Pusri</td>
<td>1,905,133</td>
</tr>
<tr>
<td>Total</td>
<td>14,340,473</td>
</tr>
</tbody>
</table>

*Table 14 Annual total dwt (F)*

A higher water depth will make a higher load possible. Therefore simulation runs are carried out for two possible new loads. This is done by increasing the average draught with 10%, 20% and 30%.

Putting the case that the annual cargo volume remains constant after changes in the depth of the Musi river, F can be assumed to be constant in time. An increased load thus results in a lower NRV, (formula 5.2).

It has been assumed that for an increase of draught with 10%, the load increases with approximately 20%.

To obtain a lower number of round trips in a year the average inter arrival time for the vessels is increased in PROSIM with 20% respectively 40% and 60%. Because the dwt of the vessels above 6000 dwt\(^{10}\) is multiplied with the same factor, the total amount of cargo per year remains approximately constant.

### 10.2.2 Time spent at sea

Time spent at sea equals the round voyage distance divided by the ship’s speed:

\[
TS_s = \frac{D_s}{24 \cdot V_s} + \frac{W_{\text{sea}}}{V_s} \quad \text{[days/voyage]} \quad (5.3)
\]

\(^{10}\) The smaller vessels do not change their load when the water depth is increased, because they already have sufficient keel clearance. Their load factor is not influenced by the water depth.
Calculation of the shipping costs

\[ D_t : \text{round trip distance} \quad [\text{km}] \]
\[ V_s : \text{service speed} \quad [\text{km/h}] \]
\[ W_{\text{dest}} : \text{waiting time} \quad [\text{days}] \]

Although the speed is related to the size of the ship, the speed is assumed to be constant. The vessels sail with an average speed of 10 knots\(^{11}\). Assuming that all voyages are between Singapore, West Indonesia and East Indonesia, the average round voyage distance\(^{12}\) can be calculated using the data in Annex A.4 and A.5 of [24]:

\[ D_t = 2 \frac{\sum (C_d \times D_d)}{C_t} \quad [\text{km}] \quad (5.4) \]

\[ D_t : \text{average distance} \quad [\text{km}] \]
\[ C_d : \text{cargo flow to maritime district} \quad [\text{ton}] \]
\[ D_d : \text{distance to district} \quad [\text{km}] \]
\[ C_t : \text{total cargo flow} \quad [\text{ton}] \]

The average distance is calculated in Table 1 of Appendix B. The distance that results from this table is 1104 nautical miles\(^{13}\).

TS\(_s\) is therefore equal to:

\[ TS_s = \frac{1,104}{10 \times 24} + W_{{\text{dest}}} = 4.60 + W_{{\text{dest}}} \quad [\text{days/voyage}] (5.5) \]

It should be noted that equation (5.5) has the following limitations:

- The costs for time spent at sea are assumed the same as the waiting time at sea. The fuel costs for a waiting vessel are lower than for a sailing vessel. Therefore the costs for waiting are overestimated and should be reduced with a factor.

\(^{11}\) 1 knot equals 1.85 km/h.

\(^{12}\) A round trip is defined as a journey from a harbour of origin to the harbour of Palembang and a journey from the harbour of Palembang to a harbour of destination.

\(^{13}\) 1 nautical mile equals 1.85 km.
• Table 1 of Appendix B is quoted from Veldman [24] and is valid for a regular liner system of vessels ranging from 200 dwt to 4,200 dwt. This table is therefore not valid for all vessels calling at Palembang, but only a first approximation. E.g. the Pertamina homepage on Internet [28] gives an average number of round trip days for all the Pertamina tanker vessels of 9.0 days for 1994/1995. It is not clear which definition for a round trip is used. Here a round trip is defined as a journey from a harbour of origin to the harbour of Palembang and a journey from the harbour of Palembang to a harbour of destination.

• The sailing speed is considered constant and the same for all vessels.

• The waiting time at the harbour of origin is not taken into account.

10.2.3 Time spent in port

Time spent in port per round trip is estimated at twice the average service time at the berth in Palembang. This is because two ports are called at, per round trip. The service time is assumed equal to the service time at the port of Palembang. Therefore:

\[
CP_s = 2 \text{St}_{\text{dest}} \quad \text{[days/voyage]} \quad (5.6)
\]

It should be noted that equation (5.7) has the following limitations:

• The effect of increased cargo volume on the service time is not taken into account.

• The costs for time spent in port are calculated for regular liners with a dwt between 200 and 4,200. These costs should be determined more accurately for the applicable terminals.

• The service time at the harbour of origin is estimated as being the same as the service time at the Palembang terminal.

The following average service times have been calculated:

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Service time [days]</th>
<th>(2\text{St}_{\text{dest}}) [days/voyage]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Baru</td>
<td>1.94</td>
<td>3.89</td>
</tr>
<tr>
<td>Pertamina</td>
<td>1.25</td>
<td>2.50</td>
</tr>
<tr>
<td>Pusri</td>
<td>2.01</td>
<td>4.02</td>
</tr>
<tr>
<td>Rest</td>
<td>2.15</td>
<td>4.31</td>
</tr>
</tbody>
</table>

\textbf{Table 15 Service times according to the VTS data}
10.2.4 Cost elasticity factors

The costs $C_S$ (daily costs at sea) and $C_P$ (daily costs in port) can be related to ship size in the following way:

\[ C_S = v_o S^v \] ; and \[ C_P = w_o S^w \] [millions Rupiah/day] (5.7) \[ C_P = w_o S^w \] [millions Rupiah/day] (5.8)

Equation (5.7) is a good representation of the sailing costs per day. In Figure 43 equation (5.7) is compared with cost indications supplied by ITS and Pertamina. The equation matches reasonably with the costs indication.

![Figure 43 Sailing costs per day](chart.png)

There is no data available for the daily costs in port, therefore it is only assumed that equation (5.8) is also compliant

10.3 Conclusions for the shipping costs model

Substituting of equations (5.2) through (5.8) into (5.1) gives total shipping costs as a function of $S$ and the destination:
Calculation of the shipping costs

\[ C_{s, \text{dest}} = \frac{F}{S} \left( (4.60 + W_{t, \text{dest}}) v_o S^{v_1} + 2 S_{t, \text{dest}} w_o S^{w_1} \right) \]  [millions Rupiah]  \hspace{1cm} (5.9)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_s, \text{dest} )</td>
<td>total annual shipping costs</td>
<td>[millions Rupiah]</td>
</tr>
<tr>
<td>( F )</td>
<td>total annual dwt</td>
<td>[ton]</td>
</tr>
<tr>
<td>( S )</td>
<td>ship size</td>
<td>[ton]</td>
</tr>
<tr>
<td>( F/S )</td>
<td>number of trips</td>
<td>[-]</td>
</tr>
<tr>
<td>( W_{t, \text{dest}} )</td>
<td>waiting time</td>
<td>[days/voyage]</td>
</tr>
<tr>
<td>( S_{t, \text{dest}} )</td>
<td>service time</td>
<td>[days/voyage]</td>
</tr>
<tr>
<td>( v_0 ), ( w_0 )</td>
<td>constants</td>
<td>[millions Rupiah/ton]</td>
</tr>
<tr>
<td>( v_1 ), ( w_0 ) and ( w_1 )</td>
<td>constants</td>
<td>[-]</td>
</tr>
</tbody>
</table>

From [24] comes an estimation for the constants \( v_0 \), \( v_1 \), \( w_0 \) and \( w_1 \). These are determined by analysing operational data for regular liners in Indonesia [24].

<table>
<thead>
<tr>
<th></th>
<th>RLS(^{14}) data</th>
<th>Correction</th>
<th>Palembang data</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v_0 )</td>
<td>[millions Rupiah/ton]</td>
<td>0.0157</td>
<td>2.72</td>
</tr>
<tr>
<td>( w_0 )</td>
<td>[millions Rupiah/ton]</td>
<td>0.0285</td>
<td>2.72</td>
</tr>
<tr>
<td>( v_1 )</td>
<td>[-]</td>
<td>0.653</td>
<td>-</td>
</tr>
<tr>
<td>( w_1 )</td>
<td>[-]</td>
<td>0.510</td>
<td>-</td>
</tr>
</tbody>
</table>

*Table 16 Cost elasticities*

Because the data is from 1983 \( v_0 \) and \( w_0 \) have been corrected for inflation with an average of 7.4\% per year\(^{15}\).

Total shipping costs for Palembang consequently consist of three components:

- the costs associated with the number of round trips in a year;
- the cost incurred at sea, and
- the costs of time spent in port for cargo handling.

---

\(^{15}\) The inflation rate was calculated using the statistical tables of 27 provincial capital cities in Indonesia for 1986 until February 1997. [27]
Substituting Table 15 and Table 16 into (5.9) gives total shipping costs as a function of $S$,

\[
C_{\text{Broom Baru}}(S, W_{\text{t_dest}}) = \frac{2,373,220}{S} \left( (4.60 + W_{\text{t_dest}})^{0.0427} \ast S^{0.653} + 2 \ast 1.94 \ast 0.0775 \ast S^{0.510} \right) \ldots (5.10)
\]

\[
C_{\text{Pertamina}}(S, W_{\text{t_dest}}) = \frac{10,062,120}{S} \left( (4.60 + W_{\text{t_dest}})^{0.0427} \ast S^{0.653} + 2 \ast 1.25 \ast 0.0775 \ast S^{0.510} \right) \ldots (5.11)
\]

\[
C_{\text{Pensi}}(S, W_{\text{t_dest}}) = \frac{1,905,133}{S} \left( (4.60 + W_{\text{t_dest}})^{0.0427} \ast S^{0.653} + 2 \ast 2.01 \ast 0.0775 \ast S^{0.510} \right) \ldots (5.12)
\]

$C_{\text{dest}}$ : total annual shipping costs [millions Rupiah]

$S$ : average ship size in dead weight tonnage [ton]

$W_{\text{t_dest}}$ : average waiting time [days/voyage]

and $W_{\text{t_dest}}$ for each destination:

<table>
<thead>
<tr>
<th></th>
<th>$S$ [dwt]</th>
<th>$F/S^{16}$</th>
<th>$W_{\text{t_dest}}$ [days/voyage]</th>
<th>$C_{\text{dest}}$ [millions Rupiah]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broom Baru</td>
<td>3,290</td>
<td>721</td>
<td>0.2430</td>
<td>41,511</td>
</tr>
<tr>
<td>Pertamina</td>
<td>8,741</td>
<td>1,151</td>
<td>0.3993</td>
<td>113,093</td>
</tr>
<tr>
<td>Pensi</td>
<td>4,887</td>
<td>390</td>
<td>0.6106</td>
<td>31,003</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,262</strong></td>
<td><strong>F/S</strong></td>
<td><strong>0.5</strong></td>
<td><strong>185,607</strong></td>
</tr>
</tbody>
</table>

*Table 17 Shipping costs for current situation*

For the current situation the shipping costs amount to the following:

### 10.4 Limitations of the shipping costs model

As mentioned in chapter 10.1 the shipping model used here is a schematised representation of the real system. The model used here is fitted according to the available parameters only and can therefore not be seen as a complete model description for the shipping costs. It gives only an indication of the influence of the used parameters on the annual shipping costs. For a better representation the following parameters should be investigated more accurately:

\[^{16}\text{F/S} : \text{average annual number of vessels}\]
• The costs for waiting at sea. In this model the costs for time spent at sea are assumed the same as the waiting time at sea. The fuel costs for a waiting vessel are lower than for a sailing vessel. Therefore the costs for waiting are overestimated and should be reduced with a factor.

• The sailing distance. Table 1 of Appendix B is quoted from Veldman [24] and is valid for a regular liner system of vessels ranging from 200 dwt to 4,200 dwt. This table is therefore not valid for all vessels calling at Palembang, but only a first approximation.

• Service time. The effect of increased cargo volume on the service time is not taken into account. This is done because the influence of this change on the annual costs is deemed small enough to neglect.

• The costs for time spent in port. The costs for time spent in port are calculated for regular liners with a dwt between 200 and 4,200. These costs should be determined more accurately for the applicable terminals.

• The waiting time at the harbour of origin is not taken into account.

• The service time at the harbour of origin is estimated as being the same as the service time at the Palembang terminal.

• The sailing speed is considered constant and the same for all vessels.
11. Vessel traffic simulation of alternatives

11.1 Introduction

The most important part of the simulation is to perform experiments of the model in order to obtain outputs at which the simulation modelling aimed for. The outputs are data of possible future situations.

The resulting alternatives have been compared, leading to a optimum depth for each fleet composition.

Fleet simulations were carried out for:

<table>
<thead>
<tr>
<th>Water depth</th>
<th>Increase of draught</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWS - 3.6 m</td>
<td>100% 110% 120% 130%</td>
</tr>
<tr>
<td>LWS - 4.0 m</td>
<td>100% 110% 120% 130%</td>
</tr>
<tr>
<td>LWS - 4.5 m</td>
<td>100% 110% 120% 130%</td>
</tr>
<tr>
<td>LWS - 5.0 m</td>
<td>100% 110% 120% 130%</td>
</tr>
<tr>
<td>LWS - 5.5 m</td>
<td>100% 110% 120% 130%</td>
</tr>
<tr>
<td>LWS - 6.0 m</td>
<td>100% 110% 120% 130%</td>
</tr>
<tr>
<td>LWS - 6.5 m</td>
<td>100% 110% 120% 130%</td>
</tr>
<tr>
<td>LWS - 7.0 m</td>
<td>100% 110% 120% 130%</td>
</tr>
<tr>
<td>LWS - 7.5 m</td>
<td>100% 110% 120% 130%</td>
</tr>
</tbody>
</table>

Table 18 Carried out fleet simulations

- : Simulation for 150,000 minutes (100 days)

For the existing situation only the current fleet composition was simulated; it is clear (see Figure 45) that the annual shipping costs will be higher for a fleet simulation with higher draught vessels and therefore irrelevant. For the same reason not all the fleet compositions were simulations for the minimum water depth of LWS -4.0 m and LWS -4.5 m. The simulation speed decreases with lower water depths, because of the high waiting times. The simulations with high waiting times have been run for 100 days. To check the error made
with this simulation time the simulation for LWS -7.5 m was also run for 0.5 year and 1.2 years. The difference between the simulation time of 100 days and the simulation time of 1.2 year is 1%. The difference for the simulation time of 0.5 year and the simulation time of 1.2 year is 0.5%. It can therefore be assumed that the shipping costs comes to the solution in a 1% boundary.

Based on the accumulated facts a prediction for the shipping costs is made, using these three possible fleet compositions (In 10.2.1 it has been assumed that for an increase of draught with 10%, the load increases with approximately 20%).

<table>
<thead>
<tr>
<th></th>
<th>draught factor(^{17})</th>
<th>dwt load factor(^{17})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing fleet</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>fleet with 10% draught increase</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>fleet with 20% draught increase</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>fleet with 30% draught increase</td>
<td>1.3</td>
<td>1.6</td>
</tr>
</tbody>
</table>

*Table 19 Factors for three possible fleet compositions*

### 11.2 Fleet simulation for the existing situation

The simulation for the current situation has produced the following results for the annual cargo costs. The water depths are taken from Table 11. The calculations are based on the formulas in paragraph 10.3.

<table>
<thead>
<tr>
<th></th>
<th>Average total waiting time [days]</th>
<th>Total annual shipping costs [millions Rupiah]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Baru</td>
<td>0.23430</td>
<td>41,511</td>
</tr>
<tr>
<td>Pertamina</td>
<td>0.3993</td>
<td>113,093</td>
</tr>
<tr>
<td>Pusri</td>
<td>0.6106</td>
<td>31,003</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>185,607</td>
</tr>
</tbody>
</table>

*Table 20 Annual shipping costs for LWS -3.6 m, existing fleet*

\(^{17}\) This factor is used only for vessels with a dwt higher than 6,000 ton.
The waiting times (sum of waiting time at the outerbar and the harbour) have been used to calibrate the model. The cumulative distribution functions for the waiting times have been compared with the cumulative distribution functions from the VTS data.

### 11.3 Fleet simulations for increased water depths

Simulation runs were made for increased water depths. The water depth was increased from LWS -3.6 m to 7.0 m for three different fleet compositions. Waiting times were calculated for the Boom Baru, Pertamina and Pusri vessels.

The water depth is in dm, the waiting times (sum of waiting time for the outerbar and harbour) are in days.

<table>
<thead>
<tr>
<th></th>
<th>Boom Baru</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>36</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Existing fleet</td>
<td>0.2430</td>
<td>0.1168</td>
<td>0.0254</td>
<td>0.0039</td>
<td>0.0004</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 10% draught increase</td>
<td>0.5955</td>
<td>0.1170</td>
<td>0.0397</td>
<td>0.0083</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 20% draught increase</td>
<td>0.7081</td>
<td>0.1578</td>
<td>0.0535</td>
<td>0.0119</td>
<td>0.0006</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 30% draught increase</td>
<td>1.0444</td>
<td>0.2096</td>
<td>0.0757</td>
<td>0.0244</td>
<td>0.0007</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Existing fleet</td>
<td>0.3993</td>
<td>0.1324</td>
<td>0.0264</td>
<td>0.0043</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 10% draught increase</td>
<td>0.9382</td>
<td>0.1324</td>
<td>0.0380</td>
<td>0.0067</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 20% draught increase</td>
<td>0.7664</td>
<td>0.2236</td>
<td>0.0559</td>
<td>0.0119</td>
<td>0.0009</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 30% draught increase</td>
<td>1.3067</td>
<td>0.4646</td>
<td>0.0795</td>
<td>0.0248</td>
<td>0.0032</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Pusri</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>36</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Existing fleet</td>
<td>0.6106</td>
<td>0.1778</td>
<td>0.0430</td>
<td>0.0123</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Fleet with 10% draught increase</td>
<td>1.2032</td>
<td>0.1950</td>
<td>0.0550</td>
<td>0.0087</td>
<td>0.0004</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 20% draught increase</td>
<td>1.3520</td>
<td>0.4353</td>
<td>0.1019</td>
<td>0.0251</td>
<td>0.0035</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Fleet with 30% draught increase</td>
<td>1.3118</td>
<td>0.8264</td>
<td>0.1370</td>
<td>0.0399</td>
<td>0.0067</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

*Table 21 Waiting times for increased water depth*

The average waiting times were calculated by multiplying the waiting times with the percentage of the fleet for the total amount of vessels entering the system (the waiting times
were divided by the inter arrival time of the fleet and multiplied by the average inter arrival time (256 minutes)).

\[
\text{Total waiting time} = \left( \frac{\text{Waiting time}_{\text{Bowen Port}}}{816} + \frac{\text{Waiting time}_{\text{Port Hedland}}}{510} + \frac{\text{Waiting time}_{\text{Port}}}{1390} \right) \times \left( \frac{1}{816} + \frac{1}{510} + \frac{1}{1390} \right)
\]

(5.13)

\[
\text{Total waiting time} = \left( \frac{\text{Waiting time}_{\text{Bowen Port}}}{816} + \frac{\text{Waiting time}_{\text{Port Hedland}}}{510} + \frac{\text{Waiting time}_{\text{Port}}}{1390} \right) \times 256
\]

(5.14)

<table>
<thead>
<tr>
<th>Total</th>
<th>36</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing fleet</td>
<td>0.3891</td>
<td>0.1358</td>
<td>0.0291</td>
<td>0.0057</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 10% draught increase</td>
<td>0.8793</td>
<td>0.1391</td>
<td>0.0417</td>
<td>0.0076</td>
<td>0.0021</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 20% draught increase</td>
<td>0.8558</td>
<td>0.2419</td>
<td>0.0636</td>
<td>0.0143</td>
<td>0.0013</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Fleet with 30% draught increase</td>
<td>1.2252</td>
<td>0.4512</td>
<td>0.0889</td>
<td>0.0275</td>
<td>0.0030</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Table 22 Average waiting times for increased water depth

The waiting times can be plotted in a graph. It is clear that the waiting times decrease when the water depth increases. A larger draught leads to larger waiting times.
Figure 44 Average waiting times for four fleet compositions

Note that in the graph the sum of the waiting times for the outerbar and the waiting times at the harbour are drawn.

The annual shipping costs in millions Rupiah were determined using equations 5.10 -5.12 and the percentage of the amount of vessels of the sub-fleets.
Vessel traffic simulation of alternatives

<table>
<thead>
<tr>
<th>Total</th>
<th>36</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Baru</td>
<td>41511</td>
<td>40763</td>
<td>39958</td>
<td>39778</td>
<td>39745</td>
<td>39742</td>
<td>39742</td>
<td>39742</td>
<td>39742</td>
</tr>
<tr>
<td>Existing fleet</td>
<td>43931</td>
<td>39456</td>
<td>38691</td>
<td>38409</td>
<td>38333</td>
<td>38333</td>
<td>38333</td>
<td>38333</td>
<td>38333</td>
</tr>
<tr>
<td>Fleet with 10% draught increase</td>
<td>42813</td>
<td>38702</td>
<td>37731</td>
<td>37379</td>
<td>37282</td>
<td>37277</td>
<td>37277</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fleet with 20% draught increase</td>
<td>44907</td>
<td>37994</td>
<td>36879</td>
<td>36445</td>
<td>36249</td>
<td>36245</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fleet with 30% draught increase</td>
<td>37</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Total Pertamina</td>
<td>113093</td>
<td>105668</td>
<td>102965</td>
<td>102384</td>
<td>102271</td>
<td>102271</td>
<td>102271</td>
<td>102271</td>
<td>102271</td>
</tr>
<tr>
<td>Existing fleet</td>
<td>121545</td>
<td>100335</td>
<td>98046</td>
<td>97271</td>
<td>97110</td>
<td>97106</td>
<td>97106</td>
<td>97106</td>
<td>97106</td>
</tr>
<tr>
<td>Fleet with 10% draught increase</td>
<td>111060</td>
<td>98821</td>
<td>94798</td>
<td>93759</td>
<td>93500</td>
<td>93479</td>
<td>93479</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fleet with 20% draught increase</td>
<td>117753</td>
<td>100622</td>
<td>92127</td>
<td>90893</td>
<td>90406</td>
<td>90336</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fleet with 30% draught increase</td>
<td>36</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Total Pusri</td>
<td>31003</td>
<td>28381</td>
<td>27636</td>
<td>27458</td>
<td>27377</td>
<td>27377</td>
<td>27377</td>
<td>27377</td>
<td>27377</td>
</tr>
<tr>
<td>Existing fleet</td>
<td>33665</td>
<td>27603</td>
<td>26825</td>
<td>26558</td>
<td>26508</td>
<td>26506</td>
<td>26506</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fleet with 10% draught increase</td>
<td>32580</td>
<td>28032</td>
<td>26148</td>
<td>25721</td>
<td>25596</td>
<td>25576</td>
<td>25576</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fleet with 20% draught increase</td>
<td>31547</td>
<td>28730</td>
<td>25016</td>
<td>24491</td>
<td>24312</td>
<td>24278</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 23 Annual shipping costs for increased water depth

The total annual shipping costs were calculated by adding the totals for Boom Baru, Pertamina and Pusri.

<table>
<thead>
<tr>
<th>Total</th>
<th>36</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing fleet</td>
<td>185607</td>
<td>174812</td>
<td>170559</td>
<td>169620</td>
<td>169393</td>
<td>169390</td>
<td>169390</td>
<td>169390</td>
<td>169390</td>
</tr>
<tr>
<td>Fleet with 10% draught increase</td>
<td>199141</td>
<td>167394</td>
<td>163562</td>
<td>162238</td>
<td>161951</td>
<td>161945</td>
<td>161945</td>
<td>161945</td>
<td>161945</td>
</tr>
<tr>
<td>Fleet with 20% draught increase</td>
<td>186453</td>
<td>165555</td>
<td>158677</td>
<td>156859</td>
<td>156378</td>
<td>156332</td>
<td>156332</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fleet with 30% draught increase</td>
<td>194207</td>
<td>167346</td>
<td>154022</td>
<td>151829</td>
<td>150967</td>
<td>150859</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 24 Total annual shipping costs

The total annual shipping costs can be plotted in a graph:

67
Figure 45 Annual shipping costs for four different fleet compositions

The graph (Figure 45) shows that for water depths up to approximately LWS -4.3 m the fleet with 10% draught increase is preferred and for LWS -5.2 m and up the fleet with 20% draught increase is favoured. The fleet with 30% draught increase is favoured from LWS -6.0 m and up.

11.4 Cost calculation for changes in the nautical depth

11.4.1 Introduction

In this chapter an estimation of the costs for changes in the nautical depth are made. This estimate is based on data obtained from various sources. These data do not always correspond, as is shown in the next paragraph. In Figure 48 an approximation has been made for the bandwidth of these uncertainties.

11.4.2 Data collection

In Haskoning [10] the following graph is presented for the total amount of annually dredged material.
Figure 46 Required maintenance dredging

According to ITS [12] the volume of dredged material in 1995/1996 is in the order of 2,127,000 m$^3$ (in situ). The total maintenance dredging costs are about 10 billion Rupiah per year [12]. Therefore the maintenance dredging costs are in the order of Rupiah 4,700,- per dredged m$^3$ (in situ). According to Figure 46 the dredging depth would consequently have been in the order of LWS -5.8 m.

In this study the depth of local LWS -3.6 m is assumed to be the significant dredging depth. This is according to the navigation map of the Musi river [5], Heukelom [12] and Mutsaers [18]. The volume of dredged material according to Figure 46 would be less than 1,000,000 m$^3$.

When the costs for river works, capital dredging and maintenance dredging are taken into account, the following graph can be drawn according to Haskoning [10] (Figure 47), with a correction for inflation with an average of 7.4% per year, according to CBS Indonesia$^{18}$ [27].

---

$^{18}$ The inflation rate was calculated using the statistical tables of 27 provincial capital cities in Indonesia for 1986 until February 1997.
Figure 47 Costs for changing the nautical depth according to Haskoning and ITS

It is clear that the function for the costs for changing the nautical depth is not yet defined clearly. This function will be defined more clearly when the report by Heukelom [12] is available.

11.4.3 Accuracy of the costs for change of the nautical depth

To determine the boundaries of the optimum water depth region, two scenarios are proposed:

- a high estimation for the costs for change of the nautical depth (with 20% higher costs), and
- a low estimation for the costs for change of the nautical depth (with 20% lower costs).

These estimates are illustrated in the following graph (Figure 48):
Figure 48 Approximation for costs for change of the nautical depth

This graph is used in chapter 12.2.1 to make a first estimation for the optimum depth.
12. Estimation of the optimum depth for the Musi river

12.1 Introduction

The shipping costs can be outlined in a graph with the costs for change of the nautical depth. Here the costs for change of the nautical depth have been used according to (11.4). The two functions can be added up, leading to a U-shaped function.

12.2 The optimum water depth

Putting the case that the optimum fleet composition is used Figure 49 can be drawn. This graph is based on Figure 45. For each water depth the fleet composition with the lowest costs is illustrated. A line can be drawn through these lowest costs. In Figure 49 this is illustrated. The numbers next to the line represent the fleet with the lowest costs that the corresponding water depth.

The colours of the lines between these points represent the optimum fleet composition for the concerning water depth.
Figure 49 Total annual costs

Legend: (Figure 49)

1.0 : Existing fleet
1.1 : Fleet with 10% draught increase
1.2 : Fleet with 20% draught increase
1.3 : Fleet with 30% draught increase

From this graph the conclusion can be drawn that the optimum water depth for the Musi river is around LWS -6.5 m. For this depth the line for the fleet with 30% draught increase is favourable (Figure 49). This means that the optimum cost reduction can be attained for an increase of draught by 30%.

The reduction for the shipping costs is in the order of 30 billion Rupiah per year for an increase of the water depth from LWS -3.6 m to LWS -6.5 m.

12.2.1 Accuracy of the optimum depth

With Figure 49 and the graph from 11.4.3 (Figure 48), Figure 50 is composed. In this graph the influence of the uncertainty of the costs of changing the nautical depth are illustrated:
Figure 50 Annual costs for adjusted costs for change of the nautical depth

The optimum water depth remains at LWS - 6.5 m for all three possible alternative functions for the costs of changing the water depth. This is because the tangents of these three functions are almost equal.

12.2.2 Increase of vessel intensity

The vessel intensity can be defined as the number of vessels that call Palembang in year. On the basis of an optimum water depth of LWS -6.5 m simulations can be made for possible increases of intensity of the vessels.
**Figure 51 Annual costs for LWS - 6.5 m**

From Figure 51 the conclusion can be drawn that an increase of 10% of the vessel intensity leads to a 10% increase in the shipping costs. The costs for changing the nautical depth remain constant. This can be explained by the fact that the maximum capacity of the river is not yet reached. The same holds for the increase of 20%, 30% and 40%.

An increase of intensity of 10% brings about a shift of the optimum water depth of about 0,05 m to the right. This means that an increase of intensity of 10% induces an increase of the optimum water depth with about 0.1% which is not significant.

### 12.2.3 Increase of the draught of outgoing vessels

Up to this point all simulations were carried out for fleets with identical incoming and outgoing draughts. This has been done because little is known about the draught of outgoing vessels. From the VTS data study rough comparisons between the average draught for incoming and outgoing vessels were made. From these calculations the impression rose that the outgoing vessels had an average 10-20% higher outgoing draught, depending on the terminal of destination. In this paragraph some simulations were carried out for these numbers. To make a good comparison, the draught of the incoming vessels were reduced with 5% respectively 10% and the outgoing vessels were increased with 5% respectively 10% to simulate the difference of 10% respectively 20% between in and outgoing vessels. The following relation was found.
<table>
<thead>
<tr>
<th>Water depth</th>
<th>10% draught difference</th>
<th>20% draught difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWS - 3.6 m</td>
<td>Shipping costs +0.1%</td>
<td>Shipping costs +0.4%</td>
</tr>
</tbody>
</table>

Table 25 *Shipping costs increase for different incoming and outgoing draughts*

The shipping costs are therefore not sensitive for a small difference between the incoming and outgoing draughts.
13. Conclusions and recommendations

13.1 Conclusions

The following conclusions can be drawn:

- the current water depth in the Musi river is too low, the optimum water depth for a fleet with 30% higher draughts is around LWS - 6.5 m
- at LWS -6.5 m an increase of draught of 30% for vessels is recommended
- an increase of the vessel intensity leads to a equal increase in the shipping costs
- an increase of intensity of 10% does not change the optimum water level significantly.

13.2 Recommendations

The following recommendations are made:

- the costs for dredging and river works have to be determined more accurately
- the PROSIM could be extended with a simulation module for the harbours of destination
  In the current model vessels arrive at random, regardless of the tide. Therefore vessels often wait too long. In a extended model this problem can be solved by adjusting the time schedule or load factor in advance, considering the water level at the time of arrival
- the shipping cost model is still very rough. Parameters as fuel consumption and cost of cargo in transit have not been taken into account. Parameters as sailing time per round voyage have been estimated very roughly and should be determined more accurately
- For some parameters for the PROSIM model estimations had to be made. These parameters were not available. For a better representation of the reality, these parameters e.g. the draught of outgoing vessels should be determined more accurate
Literature

[12] ITS, Dredging study, Surabaya, 1996


[27] WWW.BPS.GO.ID/PRICES/CPSAMP.HTML, Internet page for CBS Indonesia

[28] WWW.PERTAMINA.CO.ID, Internet homepage for P.T. Pertamina

[29] WWW.PUSRI.CO.ID, Internet homepage for P.T. Pusri

Appendices

Appendix A: Cargo flow to Palembang
Appendix B: Calculation of average distance between maritime districts
Appendix C: Statistical analysis of the vessel data compilation
  Introduction
  Preliminary actions
  Vessel dimensions
  Distribution functions
Appendix D: Calculation of shipping costs from waiting times
  Waiting times
  Shipping costs
Appendix E: Description of the PROSIM Modules for the Palembang model
  DEFINE
  MAINMOD
  TERMPROCESS
  GENPROCESS
  TIDE
  QMASTERPR
  SHIPPROCESS
  PR1HMASTER
  PR2HMASTER
  PRTRAFFCARRM
  PRTRAFFCDEP
  COSTS
Appendix E: The source text of the modules in the PROSIM model Palembang
MOD PRIHMASTER
MOD PRIHMASTER
MAC ARRERL
MAC ARRTAB
MAC TSERVERL
MAC TSVTAB
MAC CLOCK
MAC TRAFFCONTROL
MAC REGISTRATION
MOD QMASTERPR
MAC ARRNED
MOD TIALWINDOWREC
MAC TSVNED
MAC TSVUNIF
MAC CURRENTS
MAC ARRUNIF
MOD TIDE
MOD PRTRAFFCARRM
MOD PRTRAFFCDEPP
MAC MUSITRCONTROL
MAC MUSISHREGISTER
MAC MLEVELS
MOD COSTS

Appendix G: Description of the PROSIM Input files

Input file TIDESPAL
Input file PORTPAL
Input file SHIPPAL
Input file SHSTRPAL
Input file SHSTRMUS

Appendix G: The Input files for the model PALEMBANG

Tidespal
<table>
<thead>
<tr>
<th>Appendix</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portpal</td>
<td>LII</td>
</tr>
<tr>
<td>Shippal</td>
<td>LIII</td>
</tr>
<tr>
<td>Shstrmusi</td>
<td>LVIII</td>
</tr>
<tr>
<td>Shstrpal</td>
<td>LXII</td>
</tr>
</tbody>
</table>

Appendix H: The statistical analysis of the service time and inter arrival time distributions using *BestFit*
Appendix A: Cargo flow to Palembang

According to Pelabuhan II [20] the following number of vessels called at Palembang (Figure 1):

![Vessels calling Palembang](image)

*Figure 1 Vessels calling Palembang*

In 1996 the total number of ship calls to Palembang was 3,490 [30]. The average number of ship calls to Palembang for 1986-1990 and 1996 was 4,020. These numbers differ more than 40% from the measurements by ITS [15]. This difference can be due to the fact that vessels calling at more than one terminal are taken in account for only one call in the ITS measurements. These vessels had the following grt\(^1\) according to [20] (Figure 2).

---

\(^1\) grt is an abbreviation for gross register tonnage: the total volume of all permanently enclosed space above and below decks, with certain exceptions, such as the wheelhouse, chart room, radio room and other specific space above deck [25].
Figure 2 Total grt of visiting vessels

The average grt of visiting vessels for 1986 - 1990 and 1996 was 8,171,005 ton/year.

The total grt amounted to the following annual cargo flow to and from Palembang (Figure 3) [20]:

Figure 3 Total cargo flow (to and from Palembang)

The average cargo flow for 1986 - 1990 and 1996 was 8,275,038 ton/year. The conclusion can be drawn that although the total number of vessels has decreased, the total grt and cargo flow has increased. Therefore the vessel dimensions (grt per vessel) have increased. When this development continues, the vessel draught will continue to increase. The optimal water depth for the navigation channel will increase accordingly.
Appendix B: Calculation of average distance between maritime districts

The following table (Table 1) was used to calculate the average distance between maritime districts.

The first column gives the name of the district;

The second column gives the cargo flow in ‘000 tonnes from Palembang to this district (1983);

The third column gives the cargo flow in ‘000 tonnes to Palembang from this district (1983)

The fourth column gives the distance between Palembang and this district in Nautical miles.

In column five and the cargo flows are multiplied by the distance.

In the last row the columns are averaged, leading to an average distance of 550 nautical miles per call. A round voyage therefore is $2 \times 550 = 1100$ nautical miles. This is equal to 2045 km.
### Appendix B: Calculation of average distance between maritime districts:

<table>
<thead>
<tr>
<th>Maritime district</th>
<th>from Palembang</th>
<th>to Palembang</th>
<th>Distance in nautical miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belawan</td>
<td>2</td>
<td>13</td>
<td>634</td>
</tr>
<tr>
<td>Sumatra Barat</td>
<td>2</td>
<td>12</td>
<td>837</td>
</tr>
<tr>
<td>Jambi</td>
<td>2</td>
<td>0</td>
<td>270</td>
</tr>
<tr>
<td>Sumatra Selatan 2</td>
<td>5</td>
<td>0</td>
<td>188</td>
</tr>
<tr>
<td>Lampung</td>
<td>8</td>
<td>0</td>
<td>390</td>
</tr>
<tr>
<td>D.K.I Jaya 1</td>
<td>1</td>
<td>1</td>
<td>345</td>
</tr>
<tr>
<td>Jawa Tengah 1</td>
<td>11</td>
<td>0</td>
<td>493</td>
</tr>
<tr>
<td>Surabaya</td>
<td>6</td>
<td>37</td>
<td>638</td>
</tr>
<tr>
<td>Jawa Timur</td>
<td>32</td>
<td>11</td>
<td>638</td>
</tr>
<tr>
<td>Ujung Pandang</td>
<td>0</td>
<td>15</td>
<td>344</td>
</tr>
<tr>
<td>Sulawesi Selatan</td>
<td>0</td>
<td>1</td>
<td>1012</td>
</tr>
<tr>
<td>Sulawesi Tenggara</td>
<td>0</td>
<td>2</td>
<td>1078</td>
</tr>
<tr>
<td>Pontianak</td>
<td>1</td>
<td>0</td>
<td>1432</td>
</tr>
<tr>
<td>Bali</td>
<td>16</td>
<td>0</td>
<td>879</td>
</tr>
<tr>
<td>Singapura</td>
<td>30</td>
<td>12</td>
<td>261</td>
</tr>
<tr>
<td>West Malaysia</td>
<td>2</td>
<td>3</td>
<td>450</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>118</strong></td>
<td><strong>107</strong></td>
<td><strong>9889</strong></td>
</tr>
</tbody>
</table>

Table 1 average distance between maritime districts

This table is quoted from Veldman [24] and is valid for a regular liner system of vessels ranging from 200 dwt to 4,200 dwt. This table is therefore not valid for all vessels calling at Palembang, but only a first approximation.
Appendix C: Statistical analysis of the vessel data compilation

Introduction

ITS has conducted a survey on vessel movements for the period of seven months starting January 1996. Data of all incoming and leaving vessels have been collected. In this paragraph a description is given of the statistical analysis of the vessel data compilation.

The VTS data [15] is composed of the following information base:

1. Vessel number
2. Name of the vessel
3. DWT
4. GRT
5. LOA
6. Arrival
   6.1 Draught bow
   6.2 Draught stern
   6.3 Date of arrival
   6.4 time of arrival
   6.5 time of departure of pilot (from pilotage station)
   6.6 time of arrival of pilot (vessel)
   6.7 time of completion of pilotage
   6.8 Sort of payload
7. Departure
   7.1 Draught bow
   7.2 Draught stern
   7.3 Date of departure
   7.4 time of departure
   7.5 time of departure of pilot (from pilotage station)
Appendix C: Statistical analysis of the vessel data compilation:

7.6 time of arrival of pilot (vessel)
7.7 time of completion of pilotage
7.8 Sort of payload

8. Origin
9. Destination
10. Mooring
   10.1 Origin
   10.2 Destination

These data needed to be modified in order to use them for the PROSIM model. The following steps were taken.

Preliminary actions

1. The data were classified into four sections. Distinctions were made between the following vessels:
   - Boom Baru
   - Pertamina
   - Pusri
   - Rest

2. The date and time were changed into serial number, as used by the spreadsheet program ‘Excel 7.0’. This made it possible to subtract the times, necessary to create periods of service time, inter arrival time and waiting times (at the harbour and at the outerbar). In [3, Appendix A] an example of this process is given.

3. Every vessel occupies several rows in the spreadsheet. Only one set of times per vessel is wanted. Therefore a filter was used to select only the first row of times in case of arrival and the last row in case of departure. In a few occasions also vessels were selected that did not sail from the outerbar directly to Palembang, but made a call in between. This was made visible by looking at the sailing times, which were too short. These vessels were excluded from the CDF for the sailing time. The data were not excluded from the inter arrival time and the waiting time.

4. It was not possible to extract the service time in the harbour from the data presented, because of the irregular registration. Therefore it was necessary to type in the original
Appendix C: Statistical analysis of the vessel data compilation:

data again, from the paperwork, in a more organised manner. Because this is extensive work, it was not done for all the months available.

5. The same problem arises with the waiting time at the harbour. This was even more difficult, because many descriptions were used to record the information. The vessels often not wait at one location. Many unrelated data were recorded, making it necessary to type in this data again as well. This is also not done for all the available data. It has to be noted that probably some of the vessels wait for the tide at the quay. This depends of the occupancy of the quay. This implies that the service time and waiting time at the harbour are sometimes mixed.

6. The sailing time (departure) also had to be typed in again.

7. The serial numbers were organised and changed into times again. [3, Appendix A]

Vessel dimensions

For the dimensions of the vessels the following procedure was used.

1. For each vessel the matching dwt, loa and draught (arriving) were extracted. The draught arriving is the highest of the draught bow and draught stern. [3, Appendix A]

2. It was not possible to determine the draught (departure) for the belonging vessel due to irregular registration. For the outgoing and arriving vessels the same draught has been assigned. (Rough calculations have been made to estimate the difference between the draught of outgoing and incoming vessels. This difference is in the order of 10% to 20% higher average draughts for outgoing vessels. Simulations have been made for these numbers with the following outcome:

<table>
<thead>
<tr>
<th>Water depth [LWS -x. m]</th>
<th>original configuration</th>
<th>10% increase outgoing vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6</td>
<td>183,703</td>
<td>189,898</td>
</tr>
<tr>
<td>5.5</td>
<td>169,601</td>
<td>169,782</td>
</tr>
</tbody>
</table>

For higher water depth the difference is even less.)

Distribution functions

Tables were created for each terminal.

1. For each vessel the following attributes are tabulated: Number of vessel, dwt, loa, draught (arriving), inter arrival time, waiting time at the outerbar, sailing time to
Appendix C: Statistical analysis of the vessel data compilation:

Palembang, sailing time from Palembang, waiting time at the harbour and service time [3, Appendix A].

2. Cumulative distribution functions were made for the inter arrival time, the waiting times, the service time and the sailing times [3, Appendix C].

3. Empirical distribution functions were made for the dwt [3, Appendix C].

4. Loa and Draught were plotted against the dwt [3, Appendix D].

With the program ‘BestFit’ it was possible to fit the inter arrival time and the service time to a *Erlang* $-1$ distribution [3, Appendix E]. These negative exponential distributions and the average sailing time are used in the PROSIM model. The cumulative distribution functions for the waiting time (at the outerbar) were used to calibrate the model.
Appendix D: Calculation of shipping costs from waiting times

In this appendix the annual shipping costs as calculated in the PROSIM model for Palembang are given. First the waiting times are given, followed by the shipping costs based on these waiting times, (as well as on the service times and the dwt of the vessel).

1. In the first column the fleet description is given:

<table>
<thead>
<tr>
<th>Fleet</th>
<th>Description</th>
<th>DWT Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Baru 1</td>
<td>Boom Baru fleet 1. Sub fleet with dwt &lt; 6.500</td>
<td></td>
</tr>
<tr>
<td>Boom Baru 2</td>
<td>Boom Baru fleet 2. Sub fleet with dwt &gt; 6.500</td>
<td></td>
</tr>
<tr>
<td>Boom Baru total</td>
<td>Total Boom Baru fleet.</td>
<td></td>
</tr>
<tr>
<td>Waiting times for Boom Baru total</td>
<td>0.76 * Boom Baru + 0.24 * Boom Baru 2</td>
<td></td>
</tr>
<tr>
<td>Pertamina 1</td>
<td>Pertamina fleet 1. Sub fleet with dwt &lt; 6.500</td>
<td></td>
</tr>
<tr>
<td>Pertamina 2</td>
<td>Pertamina fleet 2. Sub fleet with dwt &gt; 6.500</td>
<td></td>
</tr>
<tr>
<td>Pertamina total</td>
<td>Total Pertamina fleet.</td>
<td></td>
</tr>
<tr>
<td>Waiting times for Pertamina total</td>
<td>0.6 * Pertamina + 0.4 * Pertamina 2</td>
<td></td>
</tr>
<tr>
<td>Pusri 1</td>
<td>Pusri fleet 1. Sub fleet with dwt &lt; 6.500</td>
<td></td>
</tr>
<tr>
<td>Pusri 2</td>
<td>Pusri fleet 2. Sub fleet with dwt &gt; 6.500</td>
<td></td>
</tr>
<tr>
<td>Pusri total</td>
<td>Total Pusri fleet.</td>
<td></td>
</tr>
<tr>
<td>Waiting times for Pusri total</td>
<td>0.7 * Pusri + 0.3 * Pusri 2</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>All fleets cumulated.</td>
<td></td>
</tr>
<tr>
<td>Total waiting time</td>
<td>(Boom Baru/816+Pertamina/510+Pusri/1390)*253</td>
<td></td>
</tr>
<tr>
<td>Total costs</td>
<td>Boom Baru total + Pertamina total + Pusri total</td>
<td></td>
</tr>
</tbody>
</table>

2. In the first table the waiting times (in days) for 6 different water depth (in LWS - dm) are given.
3. In the second table the shipping costs (in millions Rupiah) for 6 different water depth (in LWS -dm) are given.
### Appendix D: Calculation of shipping costs from waiting times:

## Waiting times

<table>
<thead>
<tr>
<th></th>
<th>37</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boom Baru 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing fleet</td>
<td>0.0539</td>
<td>0.0368</td>
<td>0.0093</td>
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**Appendix D: Calculation of shipping costs from waiting times:**

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XVI
Appendix D: Calculation of shipping costs from waiting times:

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XVII
### Appendix D: Calculation of Shipping Costs from Waiting Times

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<td>Fleet with 30% draught increase</td>
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<td>150967</td>
<td>150859</td>
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</tbody>
</table>
Appendix E: Description of the PROSIM Modules for the Palembang model

The following flow chart (Figure 4) was made to express the relations between the modules and the macros used in the model. The Palembang model consists of two parts: The definition section, in which the configuration is shown and the dynamic section, which shows the dynamic behaviour of the living components.
Figure 4 Flow chart of PALEMBANG model

The white coloured element represent modules, the grey element with rounded edges represent macros. The input files are represented by grey elements with a dent in the right side.
Appendix E: Description of the PROSIM Modules for the Palembang model

The model consists of the following twelve modules (see also Figure 4):

<table>
<thead>
<tr>
<th>par.</th>
<th>#</th>
<th>Module</th>
<th>Description</th>
<th>activates</th>
<th>activated by</th>
</tr>
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<tr>
<td>5.5.1</td>
<td>1</td>
<td>Define</td>
<td>Definition</td>
<td>2</td>
<td>user</td>
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<tr>
<td>5.5.2</td>
<td>2</td>
<td>Mainmod</td>
<td>Run control</td>
<td>4,5</td>
<td>1</td>
</tr>
<tr>
<td>5.5.3</td>
<td>3</td>
<td>Termprocess</td>
<td>Terminal process</td>
<td>6,9</td>
<td>7</td>
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<tr>
<td>5.5.4</td>
<td>4</td>
<td>Genprocess</td>
<td>Generator</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>5.5.5</td>
<td>5</td>
<td>Tide</td>
<td>Tide process</td>
<td>2</td>
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</tr>
<tr>
<td>5.5.6</td>
<td>6</td>
<td>Qmasterpr</td>
<td>Quay process</td>
<td>3,7,9</td>
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<td>7</td>
<td>Shipprocess</td>
<td>Ship process</td>
<td>3,6,8,10,11,12</td>
<td>4</td>
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<tr>
<td>5.5.8</td>
<td>8</td>
<td>Pr1hmaster</td>
<td>Traffic conditions and tide for incoming vessels (harbour)</td>
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<td>5.5.9</td>
<td>9</td>
<td>Pr2hmaster</td>
<td>Traffic conditions and tide for outgoing vessels (harbour)</td>
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<td>Prtrafficrm</td>
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<td>11</td>
<td>Prtrafficdep</td>
<td>Traffic conditions and tide for outgoing vessels (Musiriver)</td>
<td>7</td>
<td></td>
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<tr>
<td>5.5.12</td>
<td>12</td>
<td>Costs</td>
<td>Annual costs calculator</td>
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</table>

Table 2 Modules in the PROSIM model PALEMBANG
The following macros are in use by the program (see also Figure 4)

<table>
<thead>
<tr>
<th>Macro</th>
<th>Description</th>
<th>activated module</th>
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<tbody>
<tr>
<td>Mlevels</td>
<td>Water levels on the bars</td>
<td>5,7,10,11</td>
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<tr>
<td>Musitrcntrol</td>
<td>Traffic control (Musi)</td>
<td>10,11</td>
</tr>
<tr>
<td>Musishregister</td>
<td>Registration incoming and leaving vessels (Musi)</td>
<td>10,11</td>
</tr>
<tr>
<td>Registration</td>
<td>Registration incoming and leaving vessels (harbour)</td>
<td>8,9</td>
</tr>
<tr>
<td>Currents</td>
<td>Calculation of currents (all current are zero)</td>
<td>8,9</td>
</tr>
<tr>
<td>Trafficcontrol</td>
<td>Traffic control (harbour)</td>
<td>8,9</td>
</tr>
<tr>
<td>Clock</td>
<td>Determination of the tidal time (not in use)</td>
<td>8,9</td>
</tr>
<tr>
<td>Arnred</td>
<td>Generation of the inter arrival time from a NED</td>
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<tr>
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<td>distribution.</td>
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<tr>
<td>Arrtab</td>
<td>Generation of the inter arrival time from a table</td>
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<tr>
<td>Arrunif</td>
<td>Generation of the inter arrival time from a uniform distribution</td>
<td>2</td>
</tr>
<tr>
<td>Arrerl</td>
<td>Generation of the inter arrival time from a Erlang distribution</td>
<td>2</td>
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</tbody>
</table>

*Table 3 Macros in the PROSIM model Palembang*

**DEFINE**

The definition section, shows the structure of the model in terms of components and attributes. Moreover queues, tables, input streams (input files), output streams (output files) and random streams are defined.

Lines 1 to 15:
Definition of the components, classes, queues, streams and tables.

Lines 15 to 33:
Definition of the attributes of the component MAIN

Lines 34 to 46:
Definition of the attributes of the components PR1HMASTER (Harbour master1), PR2HMASTER and QMASTERPR (quay master).
Appendix E: Description of the PROSIM Modules for the Palembang model

Lines 47 to 65:

Definition of the attributes for the class GENERATOR

Lines 66 to 84:

Definition of the attributes for the class SHIP

Lines 85 to 108:

Definition of the attributes for the components TERMPROCESS (Terminal Processor), PRTRAFFCARRM (traffic Controller Arrival Musi), PRTRAFFCDEP (Traffic Controller Departure) and TIDALREC (Tidal recorder (not in use))

Lines 108 to 112:

Definition of the attributes for the component COSTS:

Lines 113 to 115:

Definition of the figure files.

MAINMOD

Directs the initiation of the simulation, the run control and the termination of the simulation.

Lines 1 to 9:

Initialisation. General inputs are read.

Lines 10 to 91:

Vessel generators are created for each ship type. Inputs are read, distributions are reshaped for the arrival times and empirical continuous distributions for the vessel data are created. For each dwt the following data are tabulated: Draught, Length, Costs and Delay time (The time each vessel has to stay behind another vessel).

Lines 92 to 185:

Configuration of sailing times and service time. GENPROCESS is activated.

Lines 187 to 192:

Delay time (The time each vessel has to stay behind another vessel) for the Musi river is configured.

Lines 192 to 237:
Appendix E: Description of the PROSIM Modules for the Palembang model

Terminals are generated. Inputs for quay-length are read, distributions are reshaped for the service times at the terminal. These service times are not in use. Service times are defined for each ship type in lines 92 to 185.

Line 238 to 243:
Traffic control is initialised.

Lines 244 to 275:
Inputs for the tide are read and TIDE is activated.

TERMPROCESS

Terminal Processor. Controls the processes at the terminal. Checks for a vessel if enough quay length is available to join the quay. The service time of the vessel is stored.

Lines 1 to 10
The last vessel in the quay is activated

Lines 11 to 14
The length of the vessel is added to the free quay length and the vessel is removed from the quay. QMASTERPR is activated.

Lines 15 to 20
The vessel is moved to the departure queue and PR2HMASTER is activated.

GENPROCESS

The generator of particular fleets.

Lines 1 to 9:
After a waiting period, drawn from a distribution function, a ship is generated and values of attributes are assigned.

Lines 10 to 15:
Type, terminal to be called, dwt, draught, length and costs are assigned.

Lines 16 to 18:
If the dwt of a vessel is larger than 6,000 tonnes, the dwt and the draught to and from Palembang are multiplied with factors to simulate the fleet compositions for the existing situation (1.0 and 1.0 respectively), the composition with 10%
draught increase (1.2 and 1.1 respectively), the composition with 20% draught increase (1.4 and 1.2 respectively) or the composition with 30% draught increase (1.6 and 1.3 respectively).

Lines 19 to 22:
Sailing times, separation times in the approach channel are assigned.

Lines 23 to 54:
The route to and through the port and the related sailing times in the different sections of this route are assigned.

Line 55 to 60:
The service time parameters are assigned to the ship type.

Line 61:
SHIPPROCESS is activated and the GENERATOR repeats the process.

TIDE
The level is on the bars and shoals is simulated in this module.

Lines 1 to 12
For every bar the Macro MLEVELS is activated and the levels on the bars are calculated and stored for the current time.

QMASTERPR
Quay Master Processor. Checks the availability of quay length of a terminal. This is done for the ship under consideration. If so, the necessary quay length is reserved and the SHIP is activated.

Lines 1 to 14
The first ship in the queue is activated if the free quay length is higher than the length of the vessel.

SHIPPROCESS
This module describes the process of the vessels.
Lines 1 to 20:
The SHIP starts her process from the label SHSTART, the ship enters the queue ANCHORAGEMUSI and activates the PRTRAFFCARRM. The PRTRAFFCARRM checks the criteria for entrance. Next the waiting time of the SHIP is determined. This waiting time is stored, the ship leaves the ANCHORAGEMUSI and enters the MUSIIN. It then sails all the sections of the Musi river.

Lines 21 to 24:
After staying in all the sections for the assigned time the SHIP enters the queue ARRQUAY for the terminal that was assigned to the vessel

Lines 25 to 116:
QMASTERPR is activated. The QMASTER checks if there is free quay length. PRIHMASTER is activated. The PRIHMASTER checks the criteria for entering the harbour. After entering the TERMPROCESS is activated. The vessel is moved to the quay when enough space is available.

Line 117:
The vessel waits the assigned service time.

Lines 118 to 119:
The SHIP leaves the quay, TERMPROCESS is activated to register the new quay length.

Lines 120 to 202:
The SHIP is moved to the ANCHORAGEPALEMB where the PR2HMASTER checks the criteria for exiting the Musi river. The waiting time is stored and COST is activated. The SHIP then exits the Musi river and is removed from the system.

PRIHMASTER
Harbour master 1. Controls incoming ship traffic. For the first ship in the queue two checks are carried out: 1. Ship traffic conditions and 2. The tidal conditions.

Lines 1 to 14
The harbour master checks if the currents are not too high (The currents are always zero in this model and therefore never too high!)

Lines 14 to 51
Macro TRAFFCONTROL is activated. It is checked if the vessel can sail the stretches without interfering with other vessels where not allowed.

PR2HMASTER

Harbour master 2. Controls leaving ship traffic. For the first ship in the queue two checks are carried out: 1. Ship traffic conditions and 2. The tidal conditions.

Lines 1 to 14
The harbour master checks if the currents are not too high

Lines 14 to 51
Macro TRAFFCONTROL is activated. It is checked if the vessel can sail the stretches without interfering with other vessels where not allowed.

PRTRAFFCARRM

Process of traffic control on the Musi river. (Arriving vessels)

Lines 1 to 20
For every vessel the level on the bars is checked. Using the macro MLEVELS the draught is compared with the level on the bars on the moment of arrival at that bar. The vessel can continue when the water level is higher than the draught of that vessel.

Lines 21 to 40
Macro MUSITRCONTROL is activated. It is checked if the vessel can sail the stretches without interfering with other vessels where not allowed.

Lines 41 to 55
The next vessel is checked, if any.

PRTRAFFCDEP

Process of traffic control on the Musi river. (Departing vessels)
Lines 1 to 20
For every vessel the level on the bars is checked. Using the macro MLEVELS the draught is compared with the level on the bars on the moment of arrival at that bar. The vessel can continue when the water level is higher than the draught of that vessel.

Lines 21 to 40
Macro MUSITRCONTROL is activated. It is checked if the vessel can sail the stretches without interfering with other vessels where not allowed.

Lines 41 to 55
The next vessel is checked, if any.

COSTS
In this module the annual shipping costs are calculated, as well as the average dwt, the average service time, the number of vessels to each terminal and the average waiting times of each fleet type.

Lines 1 to 8:
The total waiting time for a ship is determined by adding the waiting time at the outerbar to the waiting time at the harbour. The total waiting time in minutes is converted into days.

Lines 8 to 12:
For the regarding terminal the costs are calculated. First the total waiting time, total dwt and total service time are determined

Lines 13 to 15:
Average waiting time, average dwt and average service time are calculated. For the regarding terminal.

Line 16:
The costs for the regarding terminal are calculated using equation 5.11 through 5.13.

Line 17:
The costs of these six terminals are multiplied by the fraction of the fleet the
terminal constitutes and is added to the total shipping cost per year.

Lines 18 to 24:

From the point that the simulation has run for e.g. 150,000 minutes (104 days)
the attributes of the vessels are stored.

Line 25:

From the point that the simulation has run for e.g. 150,000 minutes (104 days)
the total costs are stored

The annual shipping costs will reach a stationary state after a period of approximately
50,000 minutes. This can be presented in a graph (for instance Figure 5). The actual
simulations are run for at least 150,000 minutes (104 days).

![Graph showing shipping costs over simulation time](image)

*Figure 5 Annual total shipping costs in time for a fictitious situation*

The source text of the input files is presented in appendix D: The input files for the
model PALEMBANG.
Appendix E: The source text of the modules in the PROSIM model Palembang: MOD DEFINE

MOD DEFINE

1
2 @ DEFINITION SECTION
3 component : HMASTER1 HMASTER2 TIDALC TRAFFCARRM TRAFFCDEPP
4 COSTMAN
5 class : SHIP GENERATOR TERMOOPER QMASTER TIDALREC
7 queue : ARRQUAY[8] QUAYQ CHANNELIN CHANNELOUT
8 anchor : ANCHORAGEPALEMBA
9 inputstream : DATSHIPS DATPORT DATSHSTRETCH TIDEDATA DSTRMUSI
11 outputstream : ARRVT1 ARRVT2 DEPARTT
15
16 attributes of main:
17 reference to GENERATOR : GEN[8]
18 reference to TERMOOPER : TERMO[8]
19 integer : I J K L DOTGEN TOTOPER ENC OVERT TOTNBSHG
20 real : CTIME TIDALCYCL KEELCL CPH
21 real : T1 T2 S_CU DT DT_LAST CNT[26] CST[26] CURRENTT
22 real : A B T_AF LW_R_CU N T_AF_N C1 C2 CURRENT
23 real : H1 H2 VNT[8,26] WST[6,26] @was [3,26]
25 integer : TPCURVE TCURVES @ POINTS TIDAL CURVE, NUMBER CURVES
28 integer : TRVRS NBBARS NBSTRMUSI MTRTEST
29 real : INCTR[15,55,2] OUTTR[15,55,2] SHIPTIMES[55,2]
30 real : MINCTRIS[15,12,2] MOUTTRIS[5,12,2] MSHIPTIMES[12,2]
31 logical : OVERTAKE[12,55,12] ENCOUNTER[12,55,12] INCLEAN OUTCLEAN
32 logical : MOVERTAKE[12,12,12] MCOUNT[12,12,12] MINCLEAN
33 logical : MOUTCLEAN
34 real : W0 V0 W1 V1 TONYEAR[8] SAILTIME[8] FACDWTR FACDRAUGHT
35 attributes of HMASTER1:
36 reference to SHIP : HM1SHIP
37 real : DELAYT1
38
39 attributes of HMASTER2:
40 reference to SHIP : HM2SHIP
41 real : DELAYT2
42
43 attributes of QMASTER:
Appendix E: The source text of the modules in the PROSIM model Palembang: MOD DEFINE

45 reference to SHIP:QMSHIP
46  integer :QMTERMN
47
48 attributes of GENERATOR:
49  character(15) : GENTYPE GENIADIS GENSLDIS GSERV T
50  integer : FLN GTERMN GENPRIOR TOTCLASS E
52  real : GDRI GDRO GLENTH GCOMM IN GCOMM OUT
54  real : GMST[12] GMSTO[12]
55  real : ARRPAR1 ARRPAR2 ARRPAR3
56  real : GSERVPAR1 GSERVPAR2 GSERVPAR3 GSERVICE T GDOWNPERC
57  real : DELAYTI DELAYTO
58  real : LOADIN LOADOUT
59  real : GENSHI GENSOU T BTIDALWI ETIDALWI BTIDALWO ETIDALWO
60  real : FLDWTDIST[20,2]
61  real : GARRTB INTARRT
62  macro : GINTARR
63  macro : GSERVTIME
64 reference to TIDALREC:GTWR
65
66
67 attributes of SHIP:
68  character(15) : TYPESHIP POS SHDIRECTION SHDESTINATION
69  integer : SHSAILINT SHSAILOUTT HSERVT SLLENGTH SHPRIOR
70  real : SHDELT1 SHDELT0 SDWT DRAUGHTN DRAUGHTOUT SCPH
71  real : ADQUAYT ARRQUAYT WTOP WTHB
72  real : SCOMM IN SCOMM OUT STARTWAIT
73  real : SHWINDBI SHWINDEI SHWINDBO SHWINDEO
77  integer : SHTERMN PRIORIT Y NBSRETCHES STROM DESTINATION
78  integer : SHIPTYPE TRNB STRETCH[13] SHPOS SHPOSO NUMBERSH
79  integer : SHSPOS
80  integer : SHMSTRETCH[12]
81  integer : SHNBMS TR
82  logical : SHTEST1 SHTEST2 SHTEST3 DELAYT
83  logical : SHTESTM[6] SHTEST @was [3]
84 reference to TERMOPER :SHERMOP
85
86 attributes of TERMOPER:
87  character(15) : TERTYPE TSERVT
88  logical : AVAILTERMQ
89  integer : TNUMBER MAXDEPQ AVTQ
90  real : SERVPAR1 SERVPAR2 SERVPAR3
91  real : TERMQAUL FRQAYL TTBSERV SERVICETT QUAYMH
92 reference to SHIP :TSHIP
93 reference to QMASTER :QUAMASTER
94  macro :TERMSERVT
95
96 attributes of TRAFFCAR RRM:
97 reference to SHIP: TCMSHIP
98  real : TCMDELAY
99
100 attributes of TRAFFCDEPP:
101 reference to SHIP: TCPSHIP
102  real : TCPDELAY
103

XVII
MOD MAINMOD

1 @ PROCESS OF MAIN
2 TRVRSx—read from DATPORT
3 TRVRSx—true if TRVRS=1
4 TRVRSx—false if TRVRS=0
5 @ INITIALISATION GENERATORS TERMINALS
6 TOTNBShG=0
7 TIDALCYClex—read from DATPORT
8 reshape RDCOMM as sampled from distribution uniform with parameters lb(0.8) ub(1.2)
9 seed of RDCOMM—read from DATSHIPS
10
11 @ GENERATION OF SHIP GENERATORS @
12
13 @ GENERATION OF SHIP GENERATORS @
14 NBBARSl—read from TIDE DATA
15TOTGENl—read from DATSHIPS
16KEELCLlx—read from DATSHIPS
17V0lx—read from DATSHIPS
18W0lx—read from DATSHIPS
19V1lx—read from DATSHIPS
20W1lx—read from DATSHIPS
21FACDWTl—read from DATSHIPS
22FACDRAUGHTlx—read from DATSHIPS
23 for k=1 to TOTGEN
24 this GENERATOR—new GENERATOR
25 GENTYPElx—read from DATSHIPS
26 FLNlx—read from DATSHIPS
27 GTERMNlx—read from DATSHIPS
28 GDESTlx—read from DATSHIRSTRETCH
29 TOTCLASSESlx—read from DATSHIPS
30 TONYEAR[l]lx—read from DATSHIPS @toegevoegd
31 SAILTIME[l]lx—read from DATSHIPS @toegevoegd
32 GENSINTlx—read from DATSHIRSTRETCH
33 GENSEOUTTlx—read from DATSHIRSTRETCH
34 BTIDALWk—read from DATSHIPS
35 ETIDALWk—read from DATSHIPS

XVIII
36 BTIDALWo – read from DATSHIPS
37 ETIDALWo – read from DATSHIPS
38 GENPRIORITY – read from DATSHIPS
39 DELAYT – read from DATSHIPS
40 DELAYFO – read from DATSHIPS
41 LOADIN – read from DATSHIPS @ toegevoegd
42 LOADOUT – read from DATSHIPS @ toegevoegd
43 for jk = 1 to TOTCLASSES
44 FLWTDIST[J,j] – read from DATSHIPS
45 FLWTDIST[J,j] – read from DATSHIPS
46 tabulate FLWTDIST[J,j] in GDWTDIST[I] at FLWTDIST[J,j]
47 GDRf – read from DATSHIPS
48 GDRo – read from DATSHIPS
49 GDRf – GDRf * KEELCL * LOADIN
50 GDRo – GDRo * KEELCL * LOADOUT @ keel clearance, load degree
51 GLENGTH – read from DATSHIPS
52 CPH – read from DATSHIPS @ COSTS PER HOUR
53 GCOMMINS – read from DATSHIPS
54 GCOMMOUT – read from DATSHIPS
55 tabulate GDRf in GTABDR[I] at FLWTDIST[J,j]
56 tabulate GDRo in GTABRO[I] at FLWTDIST[J,j]
57 tabulate GLENGTH in GTABLENGTH[I] at FLWTDIST[J,j]
58 tabulate CPH in GTABCPH[I] at FLWTDIST[J,j]
59 tabulate GCOMMINS in GTABCOMMINS[I] at FLWTDIST[J,j]
60 tabulate GCOMMOUT in GTABCOMMOUT[I] at FLWTDIST[J,j]
61 end
62
63 seed of RDWT[I] – read from DATSHIPS
64 reshape RDWT[I] as sampled from distribution uniform with parameters lb(0) ub(100)
65 GENIADIS = c-read from DATSHIPS
66 ARRPAR1 – read from DATSHIPS
67 ARRPAR2 – read from DATSHIPS
68 ARRPAR2 – ARRPAR2 * FACDWT
69 ARRPAR3 – read from DATSHIPS
70 if GENIADIS = "UNIFORM"
71 GINTARR – ARRUNIF
72 reshape RINTARR[I] as sampled from distribution uniform with parameters lb(ARRPAR1)
73 ub(ARRPAR2)
74 end
75 if GENIADIS = "ERLDIS"
76 GINTARR = ARRERL
77 reshape RINTARR[I] as sampled from distribution gammashape with parameters lb
78 (ARRPAR1) mean(ARRPAR2) deviation(ARRPAR3)
79 end
80 if GENIADIS = "NED"
81 GINTARR = ARRNED
82 reshape RINTARR[I] as sampled from distribution exponential with parameters
83 mean(ARRPAR2)
84 end
85 if GENIADIS = "TABLEDIS"
86 for jk = 1 to 11
87 GARRTAB – read from DATSHIPS
88 tabulate GARRTAB in GARRTAB[I] at J
89 end
90 GINTARR = ARRTAB
91 reshape RINTARR[I] as sampled from distribution uniform with parameters lb(1) ub(11)
92
@ PORT CONFIGURATION SAILING TIMES

GNBTR = read from DATSHSTRETCH

GSTROM = read from DATSHSTRETCH

for J = 1 to GNBSTR

GSTRETCH[J] = read from DATSHSTRETCH

end

for J = 1 to GNBSTR

GSTO[J] = read from DATSHSTRETCH

end

GCURRENTT = read from DATSHSTRETCH

for K = 1 to TOTGEN

for J = 1 to GNBSTR

ENC = read from DATSHSTRETCH

L = GSTRETCH[J]

ENCOUNTER[I,L,K] = true if ENC = 0

ENCOUNTER[I,L,K] = false if ENC = 1

end

end

for K = 1 to TOTGEN

for J = 1 to GNBSTR

OVERT = read from DATSHSTRETCH

OVERTAKE[I,L,K] = true if OVERT = 0

OVERTAKE[I,L,K] = false if OVERT = 1

end

end

GSEVRT = chread from DATSHIPS

GSERVPAR = read from DATSHIPS

GSEVPAR = read from DATSHIPS

GSEVPAR3 = read from DATSHIPS

GDOWNPERC = read from DATSHIPS

if GSERV = "UNIFORM"

GSERVTIME = -TSERVUNIF

reshape GRSERV[I] as sampled from distribution uniform with parameters

lb(GSERVPAR1) ub(GSERVPAR2)

end

if GSERV = "NED"

GSERVTIME = -TSERVUNIF

reshape GRSERV[I] as sampled from distribution exponential with parameter

mean(GSERVPAR2)

end

@ MUSI CONFIGURATION SAILING TIMES

for J = 1 to NBBARS

GCTWLIN[J] = read from DSTRMUSI

end

for J = 1 to NBBARS

GCTWLOUT[J] = read from DSTRMUSI

end
Appendix E: The source text of the modules in the PROSIM model: PALEMBANG

```
144 GNBMSTR←read from DSTRMUSI @ NUMBER STRETCHES MUSI RIVER @
145 for k←1 to GNBMSTR
146 GMSTRETCH[J]←read from DSTRMUSI
147 end
148 for k←1 to GNBMSTR
149 GMSTI[J]←read from DSTRMUSI
150 end
151 for k←1 to GNBMSTR
152 GMSTO[J]←read from DSTRMUSI
153 end
154
155
156 for K←1 to TOTGEN
157 for k←1 to GNBMSTR
158 ENCk←read from DSTRMUSI
159 Lk←GMSTRETCH[J]
160 MENCOUNTk[I,L,K]←true if ENC=0
161 MENCOUNTk[I,L,K]←false if ENC=1
162 end
163 end
164 for K←1 to TOTGEN
165 for k←1 to GNBMSTR
166 OVERTk←read from DSTRMUSI
167 Lk←GMSTRETCH[J]
168 MOVERTAKEk[I,L,K]←true if OVERT=0
169 MOVERTAKEk[I,L,K]←false if OVERT=1
170 end
171 end
172
173 seed of GRSERVT[I]←read from DATSHIPS
174 GEN[I]← this GENERATOR
175 GTWR←new TIDALREC
176 TIDOPENPER of GTWR←ETIDALWI-BTIDALWI
177 TIDCLOSEDPER of GTWR←abs((TIDALCycl-ETIDALWI)+BTIDALWI)
178 TIDTOOP of GTWR←BTIDALWI
179 TIDCOLN1 of GTWR←read from DATSHIPS
180 TIDCOLN2 of GTWR←read from DATSHIPS
181 TIDSHIPTYPE of GTWR←FLN
182 @ ACTIVATE GTWR FROM STARTTIDR IN TIDALWINDOWREC
183 activate GEN[I] from GENSTART in GENPROCESS
184 end
185
186 @CONTROL MUSIRIVER
187 @CONTROL MUSIRIVER
188
189
190 TCMDELAk←read from DSTRMUSI
191 TCPDELAk←read from DSTRMUSI
192
193 @GENERATION OF TERMINALS @
194 @GENERATION OF TERMINALS @
195
196
197 TOTPERSk←read from DATPORT
198 for k←1 to TOTPERSk
199 this TERMOPERS←new TERMOPERS
```
Appendix E: The source text of the modules in the PROSIM model Palembang: MOD MAINMOD

200 QUAYMASTERnew QMASTER
201 TERMTYPEread from DATPORT
202 TNUMBERread from DATPORT
203 QMTERMN of QUAYMASTER-TNUMBER
204 AVTQread from DATPORT
205 AVAILTERMQ0.5<AVTQ
206 MAXDEPQread from DATPORT
207 TERMOQUAYLeading from DATPORT
208 FROQUAYL-TERMOQUAYL
209 QUAYMHk-0
210 TSERVTh-chread from DATPORT
211 SERVPARk-read from DATPORT
212 SERVPAR2-read from DATPORT
213 SERVPAR3-read from DATPORT
214 if TSERVTh="UNIFORM"
215 TERMSERVTh-TERSVUNIF
216 reshape RSVRT[k] as sampled from distribution uniform with parameter
   lb(SERVPAR1) ub(SERVPAR2)
217 end
218 if TSERVTh="NED"
219 TERMSERVTh-TERSVNED
220 reshape RSVRT[k] as sampled from distribution exponential with parameter
   mean(SERVPAR1)
221 end
222 if TSERVTh="ERLANG"
223 TERMSERVTh-TERSERVERL
224 reshape RSVRT[k] as sampled from distribution gamma with parameters
   lb(SERVPAR1) mean(SERVPAR2) deviation(SERVPAR3)
225 end
226 if TSERVTh="TABELDIS"
227 for k=1 to 11
228 TTBSERVERk-read from DATPORT
229 tabulate TTBSERV in TTABSERV[k] at J
230 end
231 TERMSERVTh-TERSVTAB
232 reshape RSVRT[k] as sampled from distribution uniform with parameters
   lb(10) ub(11)
233 end
234 seed of RSVRT[k]- read from DATPORT
235 TERMOPl[i]-this TERMOPER
236 end
237
238 @@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@
239 @ INITIALIZING TRAFFIC CONTROL
240 @@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@
241 ARE=0
242 ARk=0
243
244 @@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@
245 @ INITIALIZING OF TIDAL CONDITIONS
246 @@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@ babies@@
247
248
249 for k=1 to NBBARS
250 DEPTH[i,k]-read from TIDEDATA
251 end
252 WRITE DEPTH[2]:FACDRAFTING TO ATR1 WITH IMAGE xxx.xxx^-> xxx. xx
253 WRITE DEPTH[2];FACDRAUGHT TO ATR2 WITH IMAGE xxx.xxx\^4- xxx. xxx
254 WRITE DEPTH[2];FACDRAUGHT TO ATR3 WITH IMAGE xxx.xxx\^4- xxx. xxx
255 WRITE DEPTH[2];FACDRAUGHT TO ATR4 WITH IMAGE xxx.xxx\^4- xxx. xxx
256 WRITE DEPTH[2];FACDRAUGHT TO ATR5 WITH IMAGE xxx.xxx\^4- xxx. xxx
257 WRITE DEPTH[2];FACDRAUGHT TO ATR6 WITH IMAGE xxx.xxx\^4- xxx. xxx
258 WRITE DEPTH[2];FACDRAUGHT TO TCOST WITH IMAGE xxx.xxx\^4- xxx. xxx
259 T1 ←read from TIDEDATA
260 T2 ←read from TIDEDATA
261 S_CU ←read from TIDEDATA
262 DT ←read from TIDEDATA
263 DT_LAST ←read from TIDEDATA
264 TPCURVE ←read from TIDEDATA
265 TCURVES ←read from TIDEDATA
266 for k ←1 to TPCURVE
267 CNT[1] ←read from TIDEDATA
268 end
269 for k ←1 to TPCURVE
270 CST[1] ←read from TIDEDATA
271 end
272 for l ←1 to NBBARS
273 for j ←1 to TPCURVE
274 WNT[1,1] ←read from TIDEDATA
275 end
276 for j ←1 to TPCURVE
277 WST[1,1] ←read from TIDEDATA
278 end
279 end
280 activate TIDALC from TSTART in TIDE
281 passivate

MOD TIDALC

1 @ PROCESS OF THE TERMINAL OPERATOR
2 TERMCONTR:
3 TSHIR ←last SHIP in TQUAY[TNUMBER]
4 QUAYMH ← QUAYMH*SHSERVT of TSHIP*SLENGTH of TSHIP
5 @store quaymh/newtermquayl as "OCCTERM1" if tnumber=1
6 @store shservt of tship as "STpal" if tnumber=1
7 reactivate TSHIP
8 passivate
9 TERMDEP:
10 if AVAILTERMQ & (length of TERMDEP[TNUMBER]+1)\_< MAXDEPQ
11 remove TSHIP from TQUAY[TNUMBER]
12 join TSHIP to TERMDEP[TNUMBER]
13 FREQUAYL ← FREQUAYL+ SLENGTH of TSHIP
14 activate QUAYMASTER of SHTERMOP of TSHIP from QUAYCONTR in QMASTERPR
15 ADQUAYT of TSHIR ← 0
16 end
17 move DEPART to length of DEPARTURE
18 join TSHIP to DEPARTURE
19 activate HMASTERT2 from DEPCONTR in PR2HMASTER if HMASTERT2 is not active
20 passivate
MOD GENPROCESS

1 @ PROCESS OF THE GENERATORS
2 GENSTART:
3 call GINTARR
4 wait INTARVT
5 this SHIP <- new SHIP
6 TOTNBSHG <- TOTNBSHG + 1
7 TOTNBSHG <- 1 if TOTNBSHG > 20
8 NUMBERSH <- TOTNBSHG
9 TYPESHHR <- GENTYPE
10 SHTERMN <- GTERMN
11 SDWT <- value of GDWTDIST[GTERMN] at(RDWT[GTERMN])
12 DRAUGHTIN <- value of GTABDR[GTERMN] at(SDWT)
13 DRAUGHTOUT <- value of GTABDRO[GTERMN] at(SDWT)
14 if SDWT > 6000
15 SDWT <- SDWT * FACDWT
16 DRAUGHTIN <- DRAUGHTIN * FACDRAUGHT
17 DRAUGHTOUT <- DRAUGHTOUT * FACDRAUGHT
18 end
19 SLENGTH <- value of GTABLENGTH[GTERMN] at(SDWT)
20 SCPH <- value of GTABCPH[GTERMN] at(SDWT)
21 SCOMM <- (value of GTABCOMM[GTERMN] at(SDWT)) * RDCOMM
22 SCOMMOUT <- (value of GTABCOMMOUT[GTERMN] at(SDWT)) * RDCOMM
23 SHSAILINT <- GENINT
24 SHSAILOUT <- GENOUT
25 SHPRIOR <- GENPRIOR
26 SHWIND <- BTIDALWI
27 SHWIND <- ETIDALWI
28 SHWINDBX <- ETIDALWI
29 SHWINDEQ <- ETIDALWI
30 SHDELTA <- DELAYTI
31 SHDELTQ <- DELAYTO
32 SHTERMOR <- TERMOP[SHTERMN]
33 NBSTRETCH <- GNBSTR
34 STRCOM <- GSTRCOM
35 TRNB <- GSTRCOM
36 ARQUAYT <- 0
37 for k = 1 to GNBSTR
38 STRETCH[1] <- GSTRETCH[1]
41 end
42 for k = 1 to NBBARS
44 SHTWLOUT[1] <- GCTWLOUT[1]
45 end
46 for k = 1 to GNBMSTR
47 SHMSTRETCH[i] <- GMSTRETCH[i]
49 SHMSTO[i] <- GMSTO[i]
50 end
51 SHBMSTR <- GNBMSTR
52 SHCURRENTT <- GCCURRENTT
53 DESTINATION <- GDEST

XXIV
MOD SHIPPROCESS

1 @ PROCESS OF THE DIFFERENT SHIPTYPES
2 SHSTART:
3 enter ANCHORAGEMUSI
4 move FANCHMUSI to length of ANCHORAGEMUSI
5 STARTWL=now
6 activate TRAFFCARRM from STMUSIARR in PRTRAFFCARRM if TRAFFCARRM is not active
7 passivate
8 store now-arrivalttime as "WTOBBB1" if STERMN=1
9 store now-arrivalttime as "WTOBBB2" if STERMN=2
10 store now-arrivalttime as "WTOBBT1" if STERMN=3
11 store now-arrivalttime as "WTOBBT2" if STERMN=4
12 store now-arrivalttime as "WTOBBPU1" if STERMN=5
13 store now-arrivalttime as "WTOBBPU2" if STERMN=6
14 store now-arrivalttime as "WTOBBRE1" if STERMN=7
15 store now-arrivalttime as "WTOBBRE2" if STERMN=8
16 WTOB=now-arrivalttime
17 leave ANCHORAGEMUSI
18 move FANCHMUSI to length of ANCHORAGEMUSI
19 for SHSPOS=1 to SHTNBMSTR
20 enter MUSIIN[SHMSTRETCH[SHSPOS]]
21 move FMUSIIN[SHMSTRETCH[SHSPOS]] to length of MUSIIN[SHMSTRETCH[SHSPOS]]
22 work SHMSTL[SHMSTRETCH[SHSPOS]]
23 leave MUSIIN[SHMSTRETCH[SHSPOS]]
24 move FMUSIIN[SHMSTRETCH[SHSPOS]] to length of MUSIIN[SHMSTRETCH[SHSPOS]]
25 end
26 enter ARRQUAY[SHTERMN]
27 enter QUAYQ
28 ARRQUAYT=now
29 move ANCHORAGE to length of ARRIVAL+length of QUAYQ
30 activate QUAYMASTER of STERMOP from QUAYCONTR in QMASTERPR
31 passivate
32 leave ARRQUAY[SHTERMN]
33 leave QUAYQ
34 enter ARRIVAL
35 activate HMASTER1 from ARRCONTR in PR1MASTER if HMASTER1 is not active
36 passivate
37 move SHIPWAITT to now-arrivalttime if (SHIPTYPE=1) | (SHIPTYPE=2)
38 store now-ARRQUAYT as "WARRSHT_1" if SHIPTYPE=1
39 leave ARRIVAL
40 move ANCHORAGE to length of ARRIVAL + length of QUAYQ
41 enter CHANNEL
42 enter CHANNELIN
43 move CHANNELFL to length of CHANNEL
44 move CHANNELINF to length of CHANNELIN
45 for SHPOS=1 to (STRCOM-1)
46 move CHPOS[NUMBERSH] to SHPOS
47 work SHST[SHPOS]
48 end
49 move CHPOS[NUMBERSH] to sink
50
51 if TRNB=5
52 move TB1[NUMBERSH] to 1
53 work SHST[STRCOM]
54 move TB1[NUMBERSH] to sink
55 end
56
57 if TRNB=7
58 move TB2[NUMBERSH] to 1
59 work SHST[STRCOM]
60 move TB2[NUMBERSH] to sink
61 end
62 if TRNB=9
63 move TB3[NUMBERSH] to 1
64 work SHST[STRCOM]
65 move TB3[NUMBERSH] to sink
66 end
67 if TRNB=11
68 move TB4[NUMBERSH] to 1
69 work SHST[STRCOM]
70 move TB4[NUMBERSH] to sink
71 end
72
73 if SHIPTYPE=1
74 move TBMB1[NUMBERSH] to 1
75 work SHST[STRCOM+1]
76 move TBMB1[NUMBERSH] to sink
77 move MB1[NUMBERSH] to 1
78 work SHST[STRCOM+2]
79 move MB1[NUMBERSH] to sink
80 end
81
82 if SHIPTYPE=2
83 move TBMB2[NUMBERSH] to 1
84 work SHST[STRCOM+1]
85 move TBMB2[NUMBERSH] to sink
86 move MB2[NUMBERSH] to 1
87 work SHST[STRCOM+2]
88 move MB2[NUMBERSH] to sink
89 end
90
91 if SHIPTYPE=3
92 move TBMB3[NUMBERSH] to 1
93 work SHST[STRCOM+1]
94 move TBMB3[NUMBERSH] to sink
95 move MB3[NUMBERSH] to 1
96 work SHST[STRCOM+2]
97 move MB3[NUMBERSH] to sink
98 end
99
100 if SHIPTYPE=4
101 move TBMB4[NUMBERSH] to 1
102 work SHST[STRCOM+1]
103 move TBMB4[NUMBERSH] to sink
104 move MB4[NUMBERSH] to 1
105 work SHSTI[STRCOM+2]
106 move MB4[NUMBERSH] to sink
107 end
108
109 if SHIPTYPE=5
110 move TBMB5[NUMBERSH] to 1
111 work SHSTI[STRCOM+1]
112 move TBMB5[NUMBERSH] to sink
113 move MB5[NUMBERSH] to 1
114 work SHSTI[STRCOM+2]
115 move MB5[NUMBERSH] to sink
116 end
117
118 if SHIPTYPE=6
119 move TBMB6[NUMBERSH] to 1
120 work SHSTI[STRCOM+1]
121 move TBMB6[NUMBERSH] to sink
122 move MB6[NUMBERSH] to 1
123 work SHSTI[STRCOM+2]
124 move MB6[NUMBERSH] to sink
125 end
126
127 leave CHANNEL
128 leave CHANNELIN
129 move CHANNELINF to length of CHANNELIN
130 move CHANNELF to length of CHANNEL
131 CTIME=n
132 enter TQUAY[SHTERMN]
133 ARQQUAYT--n
134 activate SHTERMOP from TERMCONTR in TERMPROCESS
135 passivate
136 move BD1 to length of TQUAY[SHTERMN] if SHTERMN=1
137 move BD2 to length of TQUAY[SHTERMN] if SHTERMN=2
138 move BD3 to length of TQUAY[SHTERMN] if SHTERMN=3
139 move BD4 to length of TQUAY[SHTERMN] if SHTERMN=4
140
141 work SHSERVT
142 TSHIP of SHTERMOR--this SHIP
143 activate SHTERMOP from TERMDEP in TERMPROCESS
144 passivate
145 LEAVEHR:
146 @store now-queueftime in departure as "WDEPSHT_1" if shiptype=1
147 leave DEPARTURE
148 move DEPART to length of DEPARTURE
149 move BD1 to length of TQUAY[SHTERMN] if SHTERMN=1
150 move BD2 to length of TQUAY[SHTERMN] if SHTERMN=2
151 move BD3 to length of TQUAY[SHTERMN] if SHTERMN=3
152 move BD4 to length of TQUAY[SHTERMN] if SHTERMN=4
153
154 @write arqquayt:slength:draught:in;commmin;commmout;shprior;adquayt to arrv1 with image
155 enter CHANNEL
156 enter CHANNELOUT
157 move CHANNELF to length of CHANNEL
158 move CHANNELOUTF to length of CHANNELOUT
159
160 if SHIPTYPE=1

XXVII
move MB1[NUMBERSH] to 1
work SHSTO[STRCOM+2]
move MB1[NUMBERSH] to sink
move TBMB1O[NUMBERSH] to 1
work SHSTO[STRCOM+1]
move TBMB1O[NUMBERSH] to sink
end

if SHIPTYPE=2
move MB2[NUMBERSH] to 1
work SHSTO[STRCOM+2]
move MB2[NUMBERSH] to sink
move TBMB2O[NUMBERSH] to 1
work SHSTO[STRCOM+1]
move TBMB2O[NUMBERSH] to sink
end

if SHIPTYPE=3
move MB3[NUMBERSH] to 1
work SHSTO[STRCOM+2]
move MB3[NUMBERSH] to sink
move TBMB3O[NUMBERSH] to 1
work SHSTO[STRCOM+1]
move TBMB3O[NUMBERSH] to sink
end

if SHIPTYPE=4
move MB4[NUMBERSH] to 1
work SHSTO[STRCOM+2]
move MB4[NUMBERSH] to sink
move TBMB4O[NUMBERSH] to 1
work SHSTO[STRCOM+1]
move TBMB4O[NUMBERSH] to sink
end

if SHIPTYPE=5
move MB5[NUMBERSH] to 1
work SHSTO[STRCOM+2]
move MB5[NUMBERSH] to sink
move TBMB5O[NUMBERSH] to 1
work SHSTO[STRCOM+1]
move TBMB5O[NUMBERSH] to sink
end

if SHIPTYPE=6
move MB6[NUMBERSH] to 1
work SHSTO[STRCOM+2]
move MB6[NUMBERSH] to sink
move TBMB6O[NUMBERSH] to 1
work SHSTO[STRCOM+1]
move TBMB6O[NUMBERSH] to sink
end

for SHPOSO=1 to STRCOM
SHPOSO-(STRCOM+1)-SHPOSO
219 move CHPOSO[NUMBERSH] to 12-SHPOS
220 work SHSTO[SHPOS]
221 end
222 move CHPOSO[NUMBERSH] to sink
223 move SHIPTURN to now-arrivalttime if (SHIPTYPE=1) | (SHIPTYPE=2)
224
225 leave CHANNEL
226 leave CHANNELOUT
227 move CHANNELOUTF to length of CHANNELOUT
228 move CHANNELF to length of CHANNEL
229 enter ANCHORAGEPALEMB
230 STARTWAIT---now
231 activate TRAFFCDEPP from STPALDEP in PRTAFFCDEPP if TRAFFCDEPP is not active
232 move FANCHPALEMB to length of ANCHORAGEPALEMB
233 passivate
234 store now-queueetime in ANCHORAGEPALEMB as "WTPLBB2" if SHIPTYPE=2
235 store now-queueetime in ANCHORAGEPALEMB as "WTPLPT2" if SHIPTYPE=4
236 store now-queueetime in ANCHORAGEPALEMB as "WTPLPU2" if SHIPTYPE=6
237 store now-queueetime in ANCHORAGEPALEMB as "WTPLRE2" if SHIPTYPE=8
238 WTHBi---now-queueetime in ANCHORAGEPALEMB
239 activate COSTMAN from STARTCOST in COSTS
240 leave ANCHORAGEPALEMB
241 move FANCHPALEMB to length of ANCHORAGEPALEMB
242 for SHSPOS=1 to SHNBMSTR
243 enter MUSIOUT[SHMSTRETCH[SHSPOS]]
244 move FMUSIOUT[SHMSTRETCH[SHSPOS]] to length of MUSIOUT[SHMSTRETCH[SHSPOS]]
245 work SHMSTO[SHMSTRETCH[SHSPOS]]
246 leave MUSIOUT[SHMSTRETCH[SHSPOS]]
247 move FMUSIOUT[SHMSTRETCH[SHSPOS]] to length of MUSIOUT[SHMSTRETCH[SHSPOS]]
248 end
249 terminate

MOD PR1HMASTER

1 @ PROCESS OF THE HARBOUR MASTER1
2 ARRCONTR:
3 INCLEAN=FALSE
4 OUTCLEAN=FALSE
5 HM1SHIR=FIRST SHIP IN ARRIVAL
6 AGAIN:
7 THIS SHIR=HM1SHIP
8 SHTEST k=FALSE
9 SHTEST k=FALSE
10 SHTESTk=TRUE @veranderd op 25/2/97
11
12 CURRENTTT=SHCURRENTT+NOW
13 CALL CURRENTS
14 SHTESTk=TRUE @ IF CURRENT<1.35 veranderd op 20/3/97
15
16 FOR k=1 TO 52
17 FOR j=1 TO 2
18 SHIPTIMES[i,j]=0
19 END
20 END
21
2 SHIPTIMES[STRETCH[1],2]−NOW+SHST[1]
3 SHIPTIMES[STRETCH[1],4]−NOW
4 FOR k−2 TO NBSTRETCHES
5 SHIPTIMES[STRETCH[1],4]−SHIPTIMES[STRETCH[1−1],2]
6 SHIPTIMES[STRETCH[1],2]−SHIPTIMES[STRETCH[1−1],2]+SHST[1]
7 END
8 POS=“ARRIVAL”
9 INCLEAN=TRUE
10 CALL TRAFFICCONTROL
11 SHTEST2=TRUE IF TRTEST>0
12 END
13 CALL CLOCK
14 @ SHTEST3=TRUE IF (CTIME>SHWINDBI)&&(CTIME<SHWINDEI)
15 IF SHTEST2 & SHTEST1
16 REACTIVATE HM1SHIP
17 CALL REGISTRATION
18 DELAY=k−SHDELT1
19 WAIT DELAY1
20 HM1SHIP=FIRST SHIP IN ARRIVAL
21 PASSIVATE IF HM1SHIP IS NONE
22 REPEAT FROM AGAIN
23 END
24 HM1SHIP=SUCC OF HM1SHIP IN ARRIVAL
25 IF HM1SHIP IS NONE
26 PASSIVATE IF LENGTH OF ARRIVAL=0
27 WAIT 15
28 REPEAT FROM ARRCONTR
29 END
30 END
31 repeat from AGAIN

MOD PR2HMASTER

1@ PROCESS OF HMASTER2
2 DEPCONTR:
3 HM2SHIP=FIRST SHIP IN DEPARTURE
4 REP:
5 THIS SHIR=HM2SHIP
6 SHTEST2=FALSE
7 SHTEST3=TRUE @veranderd op 25/2/97
8 FOR k−1 TO 52
9 FOR J−1 TO 2
10 SHIPTIMES[J,J]−0
11 END
12 END
13 END
14 END
15 FOR K−1 TO NBSTRETCHES
16 SHIPTIMES[STRETCH[J],2]−NOW
17 SHIPTIMES[STRETCH[J],4]−NOW+SHSTO[J]
18 FOR K−1 TO NBSTRETCHES−1
19 J−NBSTRETCHES−1
20 SHIPTIMES[STRETCH[J],2]−SHIPTIMES[STRETCH[J+1],1]
21 SHIPTIMES[STRETCH[J],4]−SHIPTIMES[STRETCH[J],2]+SHSTO[J]
22 END
MAC ARRERL

1 @ GENERATION OF THE INTER ARRIVAL TIME
2 INTARRT < RINTARR[TERMIN]
3 RETURN

MAC ARRRTAB

1 @ GENERATION OF THE INTER ARRIVAL TIME FROM A TABLE
2 INTARRT < VALUE OF GARRTAB[FLN] AT(RINTARR[TERMIN])
3 RETURN

MAC TSERVERL

1 @ GENERATION OF A SERVICE TIME FROM AN ERLANG DISTRIBUTION
2 SERVICET < RSERV[TNUMBER]
3 RETURN
MAC TSERVTAB

1 @GENERATION OF A SERVICE TIME FROM A TABLE DISTRIBUTION
2 SERVICETR=VALUE OF TTABSERV[TNUMBER] AT(RSERVT[TNUMBER])
3 RETURN

MAC CLOCK

1 @ DETERMINATION OF THE "TIDAL TIME"
2 CTIME=NOW- TIDALCYCL*FLOOR(NOW/TIDALCYCL)
3 RETURN

MAC TRAFFICCONTROL

1
2 @ CONTROL TRAFFIC INCOMING TEST SHIP / INCOMINGTRAFFIC
3 @ REDUCTION DATA INCOMING SHIPS
4
5 REDUCINT :
6 IF (ARI>4) & INCLEAN
7 IF INCTR[1,INFO[1,2,2]<NOW-0.25
8 FOR k-2 TO ARI
9 FOR j-1 TO 91
10 FOR k-1 TO 2
11 INCTR[i-1,j,k]-INCTR[i,j,k]
12 END
13 END
14 FOR j-1 TO 4
15 INFO[i-1,j]-INFO[i,j]
16 END
17 END
18 FOR k-1 TO 91
19 FOR j-1 TO 2
20 INCTR[ARI,i,j]-0
21 END
22 END
23 FOR k-1 TO 4
24 INFO[ARI,j]-0
25 END
26 ARK=ARI-1
27 END
28 GOTO REDUCINT IF INCTR[1,INFO[1,2,2]<NOW-0.25
29 END
30 INCLEANk-FALSE
31
32 @ REDUCTION DATA LEAVING SHIPS
33
34 REDUCOUTTR:
35 IF (ARO>4) & OUTCLEAN
36 IF OUTTR[1,1,1]<NOW-0.25
37 FOR k-2 TO ARO
38 FOR j-1 TO 91
39 FOR k-1 TO 2
40 OUTTR[i-1,j,k]-OUTTR[i,j,k]

XXXII
END
END
FOR  k-1 TO 4
ONFO[i-1,J-1]–ONFO[i,J]
END
END
FOR k-1 TO 91
FOR k-1 TO 2
OUTTR[i,ARO,i,J–0
END
END
END
END
END
ARO–ARO-1
END
GOTO REDUCOUTTR IF OUTTR[i,1,1]<NOW-0.25
END
OUTCLEAN–FALSE
60
61
62 TRTEST–1
63 FOR k-1 TO ARI
64 @ DETERMINATION POINTS COMMON STRETCH
65 NBSTRCOM–STRCOM IF INFO[i,4]>STRCOM
66 NBSTRCOM–INFO[i,4] IF INFO[i,4]<-STRCOM
67
68 @ CONTROL TRAFFIC INCOMMING TEST SHIP / INCOMMINGTRAFFIC
69 @ CONTROL TRAFFIC COMMON STRETCH
70 IF POS="ARRIVAL"
71 FOR k-1 TO NBSTRCOM
72 IF OVERTAKE[INFO[i,3],J,SHIPTYPE]
73 TRTEST–1 IF ((SHIPTIMES[J,1]-INCTR[I,J,1])*(SHIPTIMES[J,2]-INCTR[I,J,2]))<0
74 TRTEST–1 IF (ABS(SHIPTIMES[J,1]-INCTR[I,J,1]))<15
75 TRTEST–1 IF (ABS(SHIPTIMES[J,2]-INCTR[I,J,2]))<15
76 END
77 END
78 GOTO ENDRT if TRTEST<0
79 @ CONTROL TURNING BASINS
80 k–TRNB
81 IF OVERTAKE[INFO[i,3],J,SHIPTYPE]
82 TRTEST–1 IF (SHIPTIMES[J,1]<INCTR[I,J,2]) & (SHIPTIMES[J,2]> INCTR[I,J,1])
83 k–INFO[I,1]
84 TRTEST–1 IF (SHIPTIMES[J,1]<INCTR[I,J,2]) & (SHIPTIMES[J,2]> INCTR[I,J,1])
85 GOTO ENDRT IF TRTEST<0
86 END
87
88 @ CONTROL MOORINGBASIN AND LAST STRETCH
89 IF INFO[i,2]=DESTINATION
90 k–DESTINATION-40
91 IF OVERTAKE[INFO[i,3],J,SHIPTYPE]
92 TRTEST–1 IF ((SHIPTIMES[J,1]-INCTR[I,J,1])*(SHIPTIMES[J,2]- INCTR[I,J,2]))<0
93 TRTEST–1 IF (ABS(SHIPTIMES[J,1]-INCTR[I,J,1]))<15
94 TRTEST–1 IF (ABS(SHIPTIMES[J,2]-INCTR[I,J,2]))<15
95 END
96 GOTO ENDRT IF TRTEST<0

XXXIII
97    \texttt{J-DESTINATION}
98    IF OVERTAKE[INFO[i,3],J,SHIPTYPE]
99    TRTEST--1 IF (SHIPTIMES[J,1]<INCTR[i,J,2]) & (SHIPTIMES[J,2]>INCTR[i,J,1])
100   TRTEST--1 IF (ABS(SHIPTIMES[J,2]-INCTR[i,J,2]))<15
101   END
102  END
103  GOTO ENDTTRT IF TRTEST<0
104  END
105
106 @ CONTROL LEAVING TEST SHIP / INCOMING TRAFFIC
107 IF POS="DEPARTURE"
108 @ CONTROL STRECH COMMON
109 FOR \texttt{J-1} TO NBSTROM
110  IF ENCOUNTER[INFO[i,3],J,SHIPTYPE]
111  TRTEST--1 IF ((SHIPTIMES[J,1]-INCTR[i,J,1])*(SHIPTIMES[J,2]-INCTR[i,J,2]))<0
112  TRTEST--1 IF (ABS(SHIPTIMES[J,1]-INCTR[i,J,1]))<15
113  TRTEST--1 IF (ABS(SHIPTIMES[J,2]-INCTR[i,J,2]))<15
114  END
115  END
116 GOTO ENDTTRT IF TRTEST<0
117 @ CONTROL TURNING BASIN PERFORMEND IN CONTROL STRETCH COMMON
118 @ CONTROL MOORING BASIN AND LAST STRETCH
119 IF INFO[i,2]=DESTINATION
120 \texttt{J-DESTINATION-40}
121  IF ENCOUNTER[INFO[i,3],J,SHIPTYPE]
122  TRTEST--1 IF ((SHIPTIMES[J,1]-INCTR[i,J,1])*(SHIPTIMES[J,2]-INCTR[i,J,2]))<0
123  TRTEST--1 IF (ABS(SHIPTIMES[J,1]-INCTR[i,J,1]))<15
124  TRTEST--1 IF (ABS(SHIPTIMES[J,2]-INCTR[i,J,2]))<15
125  END
126 \texttt{J-DESTINATION}
127 IF ENCOUNTER[INFO[i,3],J,SHIPTYPE]
128 TRTEST--1 IF ((SHIPTIMES[J,1]-INCTR[i,J,1])*(SHIPTIMES[J,2]-INCTR[i,J,2]))<0
129 TRTEST--1 IF (ABS(SHIPTIMES[J,1]-INCTR[i,J,1]))<15
130 TRTEST--1 IF (ABS(SHIPTIMES[J,2]-INCTR[i,J,2]))<15
131  END
132  END
133 GOTO ENDTTRT IF TRTEST<0
134  END
135  END
136
137 @ CONTROL TRAFFIC TEST SHIP / LEAVING TRAFFIC
138
139 FOR \texttt{i-1} TO \texttt{ARO}
140 @ DETERMINATION POINTS COMMON STRETCH
141 NBSTROM< SCTR COM IF QFQ I,4 $>$ SCTR COM  
142 NBSTROM< QFQ I,4 IF QFQ I,4 $>$ SCTR COM  
143 NBSTROM< QFQ I,4 IF QFQ I,4 $>$ SCTR COM  
144
145 @ CONTROL TRAFFIC INCOMING TEST SHIP / LEAVING TRAFFIC
146 @ CONTROL TRAFFIC COMMON STRETCH
147 IF POS="ARRIVAL"
148 FOR \texttt{J-1} TO \texttt{NBSTROM}
149 IF ENCOUNTER[ONFO[i,3],J,SHIPTYPE]
151 TRTEST--1 IF (ABS( SHI RT N S[ J-1 - Q T T R I[ I, J, 1] ]$)<15
152 TRTEST--1 IF (ABS( SHI RT N S[ J-2 - Q T T R I[ I, J, 2] ]$)<15
153  END
154  END

XXXIV
Appendix E: The source text of the modules in the PROSIM model Palembang: MAC REGISTRATION

155 GOTO ENDTRT IF TRTEST<0
156 @ CONTROL TRAFFIC TURNING BASIN PERFORMED IN STRETCH COMMON
157 @ CONTROL MOORING BASIN AND LAST STRETCH
158 IF DESTINATION=ONFO[1,2]
159 J=DESTINATION-40
160 IF ENCOUNTER[ONFO[1,3],J,SHIPTYPE]
161 TRTEST←1 IF ((SHIPTIMES[1,1]-OUTTRI[1,1,1])*(SHIPTIMES[1,2]-OUTTRI[1,1,2]))<0
162 TRTEST←1 IF (ABS(SHIPTIMES[1,1]-OUTTRI[1,1,1]))<15
163 TRTEST←1 IF (ABS(SHIPTIMES[1,2]-OUTTRI[1,1,2]))<15
164 END
165 J=DESTINATION
166 IF ENCOUNTER[ONFO[1,3],J,SHIPTYPE]
167 TRTEST←1 IF ((SHIPTIMES[1,1]-OUTTRI[1,1,1])*(SHIPTIMES[1,2]-OUTTRI[1,1,2]))<0
168 TRTEST←1 IF (ABS(SHIPTIMES[1,1]-OUTTRI[1,1,1]))<15
169 TRTEST←1 IF (ABS(SHIPTIMES[1,2]-OUTTRI[1,1,2]))<15
170 END
171 END
172 GOTO ENDTRT IF TRTEST<0
173 END
174 @ CONTROL LEAVING TEST SHIP / LEAVING TRAFFIC
175 IF POS="DEPARTURE"
176 FOR J=1 TO NBSTRCOM
177 IF OVERTAKE[ONFO[1,3],J,SHIPTYPE]
178 TRTEST←1 IF ((SHIPTIMES[1,1]-OUTTRI[1,1,1])*(SHIPTIMES[1,2]-OUTTRI[1,1,2]))<0
179 TRTEST←1 IF (ABS(SHIPTIMES[1,1]-OUTTRI[1,1,1]))<15
180 TRTEST←1 IF (ABS(SHIPTIMES[1,2]-OUTTRI[1,1,2]))<15
181 END
182 END
183 GOTO ENDTRT IF TRTEST<0
184 @ CONTROL TURNING BASIN IS NOT NECESSARY
185 @ CONTROL MOORING BASIN AND LAST STRETCH
186 IF DESTINATION=ONFO[1,2]
187 J=DESTINATION-40
188 IF OVERTAKE[ONFO[1,3],J,SHIPTYPE]
189 TRTEST←1 IF ((SHIPTIMES[1,1]-OUTTRI[1,1,1])*(SHIPTIMES[1,2]-OUTTRI[1,1,2]))<0
190 TRTEST←1 IF (ABS(SHIPTIMES[1,1]-OUTTRI[1,1,1]))<15
191 TRTEST←1 IF (ABS(SHIPTIMES[1,2]-OUTTRI[1,1,2]))<15
192 END
193 J=DESTINATION
194 IF OVERTAKE[ONFO[1,3],J,SHIPTYPE]
195 TRTEST←1 IF SHIPTIMES[1,2]<OUTTRI[1,1,1]
196 END
197 END
198 GOTO ENDTRT IF TRTEST<0
199 END
200 END
201 ENDTRT:
202 return

MAC REGISTRATION

1 @ REGISTRATION INCOMING AND LEAVING SHIP TRAFFIC
2 IF POS="ARRIVAL"
3 AR=AR+1
4 FOR K=1 TO NBSTRETCHES
5 FOR J=1 TO 2

XXXV
INCTR[I,AR1,STRETCH[I],J]<- SHI RT[NE][STRETCH[I],J]
END
END

@ IF TRVERS
WRITE "INCOMING SHIP" WITH IMAGE xxxxxxxxxx
WRITE "NBSHIP","SHIPSTYPE" WITH IMAGE xxxxxxxxxx
WRITE ARI;SHIPSTYPE WITH IMAGE xxxxxxx-
WRITE 1,2,3,4,5,6,7,8,9,10,11 WITH IMAGE xxxxxxx-
WRITE xxxxxx-
xxx x xxx-
xxx xx-
xxx x-
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MOD QMASTERPR

1 @ PROCESS OF THE QUAY MASTER
2 QUAYCONTR:
3 QMSHIP–FIRST SHIP IN ARRQUAY[QMTERMN]
4 NEXTSH:
5 PASSIVATE IF QMSHIP IS NONE
6 THIS SHIP–QMSHIP
7 SHTEST1=FALSE
8 SHTEST1=TRUE IF FRQUAYL OF SHTERMOP>SLENGTH
9 IF SHTEST1=TRUE
10 REACTIVATE QMSHIP
11 FRQUAYL OF SHTERMOR–FRQUAYL OF SHTERMOP–SLENGTH
12 END
13 QMSHIP–SUCC OF QMSHIP IN ARRQUAY[QMTERMN]
14 REPEAT FROM NEXTSH

MAC Arrned

1 INTARRT–RINTARR[GTERMN]
2 RETURN

MOD TIDALWINDOWREC

1 STARTTIDR:
2 MOVE TIDALW[TIDSHIPTYPE] TO 1
3 STATE=“CLOSED”
4 WAIT TIDTOOP
5 STARTTID:
6 MOVE TIDALW[TIDSHIPTYPE] TO COLOUR TIDCOLN1
7 STATE=“OPEN”
8 WAIT TIDOPENPER
9 MOVE TIDALW[TIDSHIPTYPE] TO COLOUR TIDCOLN2
10 STATE=“CLOSED”
11 WAIT TIDCLOSEDPER
12 REPEAT FROM STARTTID

mac Tservuned

1 @ GENERATION OF SERVICETIME FROM AN NED DISTRIBUTION
2 GSERVICET–GRSERVT[TNUMBER]
3 RETURN

mac Tservunif

1 @ GENERATION OF A SERVICE TIME FROM AN UNIFORM DISTRIBUTION
2 GSERVICET–GRSERVT[FLN]
3 RETURN
MAC CURRENTS

1
2 STARTTIDE:
3 A ← CURRENTT - T1*FLOOR(CURRENTT/T1)
4 B ← FLOOR(A/T2)
5 T_AF_LW ← A-B*T2
6 R_CU ← B+S_CU
7 R_CU ← R_CU-28 IF R_CU>27
8 N ← FLOOR(T_AF_LW/DT)
9 T_AF_N ← T_AF_LW-N*DT
10 C1 ← CNT[N+1]+(CST[N+1]-CNT[N+1])/2
11 C1 ← C1+(CST[N+1]-CNT[N+1])*(COS(2*ARCCOS(~1)*R_CU/28))/2
12
13 C2 ← CNT[N+2]+(CST[N+2]-CNT[N+2])/2
14 C2 ← C2+(CST[N+2]-CNT[N+2])*(COS(2*ARCCOS(~1)*R_CU/28))/2
15 CURRENT ← C1+(T_AF_N/DT_LAST)*(C2-C1) IF N=16
16
17 CURRENT ← C1+(T_AF_N/DT)*(C2-C1) IF N<16

MAC ARRUNIF

1 @ GENERATION OF THE INTER ARRIVAL TIME
2 INTARR ← RINTARR[FLN]
3 RETURN

MOD TIDE

1 tstart:
2 length ← now
3 for k ← 1 to nbars
4 call mlevels
5 store levbar[i] as "LEVBAR1n" if i=1
6 store levbar[i] as "LEVBAR1s" if i=2
7 store levbar[i] as "LEVBAR2n" if i=3
8 store levbar[i] as "LEVBAR2s" if i=4
9 store levbar[i] as "LEVBAR3" if i=5
10 store levbar[i] as "LEVBAR4 " if i=6
11 end
12 wait 60
13 repeat from tstart

MOD PRTRAFCARRM

1 @ PROCESS OF TRAFFIC CONTROL VESSELS ARRIVAL MUSI RIVER
2
3 STMUSIARR:
4 MINCLEAN ← true
5 MOUTCLEAN ← true
6 TCMSHIP ← first SHIP in ANCHORAGEMUSI
7 TCMAGAIN:
8 this SHIR ← TCMSHIP

XXXVIII
9 for k-1 to 3
10 SHTESTM[i]←false
11 end
12 SHTRTEST←false
13
14 for k-1 to NBBARS
15 LEVTIME←now +SHCTWLIN[i]
16 call MLEVELS
17 SHTESTM[i]←true if ((DRAUGHTIN<(LEVBAR[i]/10)) | ((STARTWAIT+1440)<ct))
18 end
19 @aangepast 26/3/97
20 if (SHTESTM[1]) & (SHTESTM[2]) & (SHTESTM[3])
21 for k-1 to 12
22 for j-1 to 2
23 MSHIPTIMES[i,j]–0
24 end
25 end
26
27 MSHIPTIMES[SHMSTRETCH[1],1]←now
28 MSHIPTIMES[SHMSTRETCH[1],2]←now +SHMST[SHMSTRETCH[1]]
29 for k-2 to SHNBMSRT
30 j←SHMSTRETCH[i]
31 MSHIPTIMES[SHMSTRETCH[i],1]←MSHIPTIMES[SHMSTRETCH[i-1],2]
32 MSHIPTIMES[SHMSTRETCH[i],2]←MSHIPTIMES[SHMSTRETCH[i],1]+SHMST[SHMSTRETCH[i]]
33 end
34
35 SHHDRIGHT←"INCOMING"
36 call MUSITRCONTROL
37 SHTRTEST←true if MTRTEST>0
38 end
39
40 if (SHTRTEST)
41 reactivate TCMSHIP
42 call MUSISHLREGISTER
43 wait TCMDELAY
44 TCMSHIR←first SHIP in ANCHORAGEMUSI
45 passive if TCMSHIP is none
46 repeat from TCMAAGAIN
47 end
48
49 TCMSHIR←succ of TCMSHIP in ANCHORAGEMUSI
50 if TCMSHIP is none
51 passive if length of ANCHORAGEMUSI=0
52 wait 0.25
53 repeat from STMSIARR
54 end
55 repeat from TCMAAGAIN

MOD PRTRAFFCDEPP

1 @ PROCESS OF TRAFFIC CONTROL VESSELS DEPARTURE PALEMBANG
2
3 STPALDEP:
4 MINCLEAN←true
5 MOUTCLEAN←true

XXXIX
6 TCPSHIPR→first SHIP in ANCHORAGEPALEMB
7 TCPAGAIN:
8 this SHIR→TCPSHIP
9
10 for k→1 to NBBARS
11 SHTESTM[i]→false
12 end
13 SHTRTESTr→false
14
15 for k→1 to NBBARS
16 LEVTIMEr→now + SHCWLOUT[i]
17 call MLEVELS
18 SHTESTM[i]→true if ((DRAUGHTOUT<(LEVBAR[i]/10)) | ((STARTWAIT+1440)<ct))
19 end
20
22 for k→1 to 12
23 for j→1 to 2
24 MSHIPTIMES[i,j]-0
25 end
26 end
27
28 MSHIPTIMES[SHMSTRETCH[1],2]-now
29 MSHIPTIMES[SHMSTRETCH[1],k]-now + SHMSTO[SHMSTRETCH[1]]
30 for k→2 to SHNBMSTR
31 MSHIPTIMES[SHMSTRETCH[i],2] MSHIPTIMES[SHMSTRETCH[i-1],1]
32 MSHIPTIMES[SHMSTRETCH[i],1] MSHIPTIMES[SHMSTRETCH[i],2] +
   SHMSTO[SHMSTRETCH[i]]
33 end
34
35 SHDIRECTION→"LEAVING"
36 call MUSITRCONTROL
37 SHTRTESTr→true if MTRTEST>0
38 end
39
40
41 if SHTRTEST
42 reactivate TCPSHIP
43 call MUSISHREGISTER
44 wait TCPDELAY
45 TCPSHIPR→first SHIP in ANCHORAGEPALEMB
46 passivate if TCPSHIP is none
47 repeat from TCPAGAIN
48 end
49 TCPSHIPR→succ of TCPSHIP in ANCHORAGEPALEMB
50 if TCPSHIP is none
51 passivate if length of ANCHORAGEPALEMB=0
52 wait 0.25
53 repeat from STPALDEP
54 end
55 repeat from TCPAGAIN
MAC MUSITRCONTROL

1 @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @
2 @ CONTROL TRAFFIC INCOMING TEST SHIP / INCOMINGTRAFFIC
3 @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @
4 @ REDUCTION DATA INCOMING SHIPS
5 @
6 7 REDUCINT :
7 8 IF (MARIS>4) & MINCLEAN
8 9 IF MINCTRIS[1,MINFOS[1,2],2]<NOW-0.25
10 11 FOR k=2 TO MARIS
11 12 FOR j=1 TO 10
12 13 FOR K=1 TO 2
14 15 MINCTRIS[i-1,j,K]=MINCTRIS[i,j,K]
15 16 END
16 17 MINFOS[i-1,j]=MINFOS[i,j]
17 18 END
18 19 END
19 20 FOR k=1 TO 10
20 21 FOR j=1 TO 2
21 22 MINCTRIS[MARIS,i,j]=0
22 23 END
23 24 END
24 25 FOR k=1 TO 4
25 26 MINFOS[MARIS,i]=0
26 27 END
27 28 MARIS=MARIS-1
28 29 END
29 30 GOTO REDUCINT IF MINCTRIS[1,MINFOS[1,2],2]<NOW-0.25
30 31 END
31 32 MINCLEAN=FALSE
32
33 @ REDUCTION DATA LEAVING SHIPS
34
35 36 REDUCOUTTR:
36 37 IF (MAROS>4) & MOUTCLEAN
37 38 IF MOUTTRIS[1,MINFOS[1,2],1]<NOW-0.25
38 39 FOR k=2 TO MAROS
40 41 FOR j=1 TO 10
41 42 FOR k=1 TO 2
42 43 MOUTTRIS[i-1,j,K]=MOUTTRIS[i,j,k]
43 44 END
44 45 FOR j=1 TO 4
45 46 MONFOS[i-1,j]=MONFOS[i,j]
46 47 END
47 48 END
48 49 FOR k=1 TO 10
49
MUSITRCONTROL

FOR j-1 TO 2
MOUTTRIS[MAROS,i,j]-0
END
FOR k-1 TO 4
MONFOS[MAROS,i,j]-0
END
MAROS-MAROS-1
END
GOTO REDUCOUTTR IF MOUTTRIS[1,MONFOS[1,2],1]<NOW-0.25
END
MOUTCLEAN--FALSE

@@@@ CONTROL TRAFFIC TEST SHIP WITH INCOMING TRAFFIC
@@@ CONTROL TRAFFIC INCOMING TEST SHIP / INCOMING registered TRAFFIC
IF SHDIRECTION="INCOMING"
FOR j-1 TO NBSTRMUSI
IF MOVERTAKE[MINFOS,i,3,J,SHIPTYPE]
MTRTEST<--1 IF ((MSHIPTIMES[J,1]-MINCTRIS[I,J,1])*(MSHIPTIMES[J,2]-
MINCTRIS[I,J,2]))<0
MTRTEST<--1 IF (ABS(MSHIPTIMES[J,1]-MINCTRIS[I,J,1]))<0.25
MTRTEST<--1 IF (ABS(MSHIPTIMES[J,2]-MINCTRIS[I,J,2]))<0.25
END
END
@@@ CONTROL LEAVING TEST SHIP / INCOMING registered TRAFFIC
IF SHDIRECTION="LEAVING."
FOR j-1 TO NBSTRMUSI
IF MENCOUNTER[MINFOS,i,3,J,SHIPTYPE]=TRUE
MTRTEST<--1 IF ((N$ HI FTI NES[ J 1] - M NCTRI S[ I 1])*(N$ HI FTI NES[ J 2] -
MINCTRIS[I,J,2]))<0
MTRTEST<--1 IF (ABS( N$ HI FTI NES[ J 1] - M NCTRI S[ I 1]))<0.25
MTRTEST<--1 IF (ABS( N$ HI FTI NES[ J 2] - M NCTRI S[ I 2]))<0.25
END
END
END
END
END

@ CONTROL TRAFFIC TEST SHIP / LEAVING TRAFFIC
@ CONTROL TRAFFIC INCOMING TEST SHIP / LEAVING TRAFFIC

XLII
Appendix E: The source text of the modules in the PROSIM model Palembang: MAC

MUSISHREGISTER

104 IF SHDIRECTION="INCOMING"
105 FOR J–1 TO NBSTRMUSI
106 IF MENCOUNT[MONFOS[I,3],J,SHIPTYPE]
107 MTRTEST–1 IF ((MSHIPTIMES[J,1]–MOUTTRIS[I,J,1])*(MSHIPTIMES[J,2]–
MOUTTRIS[I,J,2]))<0
108 MTRTEST–1 IF (ABS(MSHIPTIMES[J,1]–MOUTTRIS[I,J,1]))<0.25
109 MTRTEST–1 IF (ABS(MSHIPTIMES[J,2]–MOUTTRIS[I,J,2]))<0.25
110 END
111 END
112 END
113
114
115 @@@@ CONTROL LEAVING TEST SHIP / LEAVING TRAFFIC
116
117 IF SHDIRECTION="LEAVING"
118 FOR J–1 TO NBSTRMUSI
119 IF MOVERTAKE[MONFOS[I,3],J,SHIPTYPE]
120 MTRTEST–1 IF ((MSHIPTIMES[J,1]–MOUTTRIS[I,J,1])*(MSHIPTIMES[J,2]–
MOUTTRIS[I,J,2]))<0
121 MTRTEST–1 IF (ABS(MSHIPTIMES[J,1]–MOUTTRIS[I,J,1]))<0.25
122 MTRTEST–1 IF (ABS(MSHIPTIMES[J,2]–MOUTTRIS[I,J,2]))<0.25
123 END
124 END
125 END
126 END
127 ENDTRT:
128 return

MAC MUSISHREGISTER

1 @ REGISTRATION INCOMING AND LEAVING SHIP TRAFFIC
2
3 IF SHDIRECTION="INCOMING"
4 MARIS=MARIS+1
5 FOR k–1 TO 8
6 FOR J–1 TO 2
7 MINCTRIS[MARIS,I,J].MSHIPTIMES[I,J]
8 END
9 END
10
11
12 MINFOS[MARIS,1].DESTINATION
13 MINFOS[MARIS,2].SHMSTRETCH[SHNBMSTR]
14 MINFOS[MARIS,3].SHIPTYPE
15 END
16
17 IF SHDIRECTION="LEAVING"
18 MAROS=MAROS+1
19 FOR k–1 TO 8
20 FOR J–1 TO 2
21 MOUTTRIS[MAROS,I,J].MSHIPTIMES[I,J]
22 END
23 END
24
25 MONFOS[MAROS,1].DESTINATION

XLIII
Appendix E: The source text of the modules in the PROSIM model Palembang: MAC MLEVELS

26 MONFOS[MAROS,2]—SHMSTRETCH[SHNMSTR]
27 MONFOS[MAROS,3]—SHIPTYPE
28 END
29 RETURN

MAC MLEVELS

1
2 starttide:
3 a ← levtime - t1*floor(levtime/t1)
4 bx ← floor(a/2)
5 t_af_lw ← a-b*t1
6 r_cu ← b+s_cu
7 r_cu ← r_cu-tcurves if r_cu>tcures-1
8 nx ← floor(t_af_lw/dt)
9 t_af_nw ← t_af_lw-n*dt
10 1 ← wnt[i,n+1]+(wst[i,n+1]-wnt[i,n+1])/2
11 h1 ← h1+(wst[i,n+1]-wnt[i,n+1])*(cos(2*arccos(-1)*r_cu/tdcurves))/2
12 h2 ← h2+(wst[i,n+2]-wnt[i,n+2])/2
14 h2 ← h2+(wst[i,n+2]-wnt[i,n+2])*(cos(2*arccos(-1)*r_cu/tdcurves))/2
15 levbar[i] ← depth[i]+h1+(t_af_n/dt_last)*(h2-h1) if n=tpcurve-2
16
17 levbar[i] ← depth[i]+h1+(t_af_n/dt)*(h2-h1) if n<(tpcurve-2)

MOD COSTS

1 @ PROCESS OF COST CALCULATIONS
2 startcost:
3 avwt[shtermn] ← 0
4 avsdwt[shtermn] ← 0
5 avservt[shtermn] ← 0
6 waitt ime ← 0
7 totalcost ← 0
8 waittime ← (wtof+wthb)/1440
9 totwt[shtermn] ← totwt[shtermn]+waittime
10 totsdwt[shtermn] ← totsdwt[shtermn]+sdwt
11 totship[shtermn] ← totship[shtermn]+t1
12 totservt[shtermn] ← totservt[shtermn]+(shservt/1440)
13 avwt[shtermn] ← avwt[shtermn]+totwt[shtermn]
14 avsdwt[shtermn] ← avsdwt[shtermn]+totship[shtermn]
15 avservt[shtermn] ← avservt[shtermn]+totservt[shtermn]
16 cumucost[shtermn] ← (tonyear[shipotype]/avsdwt[shtermn])*((sailtime[shipotype]+ avwt[shtermn])*v0*avsdwt[shtermn]*v1)+(2*w0*avservt[shtermn]*avsdwt[shtermn]*w1)
17 totalcost ← .88*cumucost[1]+(0.12*cumucost[2])+(0.70*cumucost[3])
+ (0.30*cumucost[4])+(0.76*cumucost[5])+(0.24*cumucost[6])
18 if now>100000
19 write avwt[shtermn]; avsdwt[shtermn]; avservt[shtermn]; cumucost[shtermn]
to atr1 with image xx.xxxxx^A- xxxx^A- x x xx^A- xx xxxx i f $ter m=1
20 write avwt[shtermn]; avsdwt[shtermn]; avservt[shtermn]; cumucost[shtermn] to atr2
with image xx.xxxxx^A- xxxx^A- x x xx^A- xx xxxx i f $ter m=2
21 write avwt[shtermn]; avsdwt[shtermn]; avservt[shtermn]; cumucost[shtermn] to atr3
with image xx.xxxxx^A- xxxx^A- x x xx^A- xx xxxx i f $ter m=3

XLIV
22 write avwt[shtermn];avsdwt[shtermn];avservt[shtermn];cumucost[shtermn] to atr4
   with image xx.xxxxx^x xxxx^x.xx xx^x.xx xx xxxxx i if sfter m=4
23 write avwt[shtermn];avsdwt[shtermn];avservt[shtermn];cumucost[shtermn] to atr5 with image
   xx.xxxxx^x xxxx^x.xx xx^x.xx xx xxxxx i f sfter m=5
24 write avwt[shtermn];avsdwt[shtermn];avservt[shtermn];cumucost[shtermn] to atr6 with image
   xx.xxxxx^x xxxx^x.xx xx^x.xx xx xxxxx i f sfter m=6
25 write totalcost to tcost with image xxxxxxx if shtermn=1 @ tbv reductie
26 end
27 sdwt=0
28 shservk=0
29 passivate
Appendix G: Description of the PROSIM Input files

The following input files are used by the program PALEMBANG: The data is read by module MAINMOD.

<table>
<thead>
<tr>
<th>Filename</th>
<th>Input stream</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIDESPAL</td>
<td>TIDEDATA</td>
<td>Data about the tide</td>
</tr>
<tr>
<td>PORTPAL</td>
<td>DATPORT</td>
<td>Data about the terminals</td>
</tr>
<tr>
<td>SHIPPAL</td>
<td>DATSHIPS</td>
<td>Data about the vessels calling at Palembang</td>
</tr>
<tr>
<td>SHSTRPAL</td>
<td>DATSHSTRETCH</td>
<td>Information about sailing times and routes of the different fleets as well as the traffic rules in the sections of the wet infrastructure of the harbour</td>
</tr>
<tr>
<td>SHSTRMUS</td>
<td>DSTRMUSI</td>
<td>Information about sailing times and routes of the different fleets as well as the traffic rules in the sections of the wet infrastructure of the Musi river</td>
</tr>
</tbody>
</table>

Table 4 Input files

The source text of the input files can be found in Appendix D. In the next few paragraphs a short description of these files is given.

Input file TIDESPAL

This file contains data about the tidal conditions and the depth (- LWS) of the bars

- Line 1: 6 Number of bars
- Lines 2 to 12: Depth of the bars for 8 different situations.
- Lines 13 to 14: Parameters for the function for the tide
- Lines 15 to 18: Information about the currents. (All currents are zero).
- Lines 19 to 35: Water levels on each bar (point) for neap tide and spring tide. With these numbers the function for the tide is calculated.

Input file PORTPAL

This file contains data about: the tidal conditions and the terminals in the port.
Appendix G: Description of the PROSIM Input files

Line 4: 1444  Length of the tidal cycle in minutes
Line 5: 8    The total number of terminals
Line 7: Boom Baru 1 Gives the name of the terminal, here the Boom Baru general cargo terminal.
Line 8: 1    Terminal number
Lines 9 to 10: Not used
Line 11: 680 Total quay length of this terminal
Line 12: NED The service time distribution is described by an Negative Exponential Distribution (Erlang - 1) function.
Line 13: 4200 0 0: Parameters to characterise the service time distribution function of the terminal
Line 14: 1349575: Seed of the random stream for the service time distribution function of the terminal
Lines 15 to 23: Characterise terminal Boom Baru 2
Lines 24 to 32: Characterise terminal Pertamina 1
Lines 33 to 41: Characterise terminal Pertamina 2
Lines 42 to 50: Characterise terminal Pusri 1
Lines 51 to 59: Characterise terminal Pusri 2
Lines 60 to 68: Characterise terminal Rest 1
Lines 69 to 77: Characterise terminal Rest 2

Input file SHIPPAL

This file contains data about the ships calling the port.

Line 3: 8  Total number of generators
Line 4: 1.1  Keel clearance of the vessels
Lines 5 to 8: Parameters for calculating the shipping costs
Lines 9 to 14: Parameters for simulating fleets with changed dwt, inter arrival time and draught.
Lines 15 to 49: Provide the data for Boom Baru 1 vessels (Boom Baru vessels with dwt up to 6,500 dwt.
Line 15: 11  Fleet number and terminal number

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| Line 16: 3 | Total number of classes of the fleet |
| Line 17: 1151260 | Total amount of cargo in tons per year for Boom Baru 1 vessels |
| Line 18: 4.6 | Sailing time per round voyage in days |
| Line 19 to 21: | Not in use |
| Line 22: 10 | Minimum separation (in hours) relative to the nest incoming and leaving vessel. |
| Line 23 to 24: | Not in use |
| Line 25: 100 | Dwt value (100) of the cumulative distribution function corresponding with the percentage (0) |
| Line 26: 3.0 | Draught of the incoming and the outgoing vessel, here corresponding with a 100 dwt of the fleet. |
| Line 27: 39.2 | The length of the incoming and the outgoing vessel, here corresponding with a 100 dwt of the fleet. |
| Line 28 to 29: | Not in use |
| Lines 30 to 34: | Attributes for the dwt value (2,400) with the percentage 76 |
| Lines 35 to 39: | Attributes for the dwt value (6,500) with the percentage 100 |
| Line 40: 475000 | Seed of the random stream used to determine the dwt of this vessel type |
| Line 41: NED | The inter arrival time distribution is described by an Negative Exponential Distribution (Erlang - 1) function. |
| Line 42: 0 927 0 | Parameters to characterise the inter arrival time distribution function of the terminal. |
| Line 43: 96451 | Seed of the random stream used to determine the inter arrival time of this vessel type |
| Line 44: NED | The service time distribution is described by an Negative Exponential Distribution (Erlang - 1) function. |
| Line 45: 1 | Not in use |
| Line 46: 0 2800 0: | Parameters to characterise the service time distribution function of the terminal |
| Line 47: 1 2 | Not in use |
| Lines 48 to 82: | Provide the data of the Boom Baru 2 vessels |

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Appendix G: Description of the PROSIM Input files

Lines 83 to 117: Provide the data of the Pertamina 1 vessels
Lines 118 to 152: Provide the data of the Pertamina 2 vessels
Lines 153 to 187: Provide the data of the Pusri 1 vessels
Lines 222 to 256: Provide the data of the Pusri 2 vessels
Lines 257 to 291: Provide the data of the Rest 1 vessels
Lines 292 to 326: Provide the data of the Rest 2 vessels

Input file SHSTRPAL

This file provides information about sailing times and routes of the different fleets as well as the traffic rules in the sections of the wet infrastructure of the harbour:

Line 2: 52 Destination number of the Boom Baru fleet 1
Line 3 to 4: 48 Sailing time from the entering point of the harbour sections to the quay.
Line 5: 7 Number of sailing sections to be taken
Line 6: 5 Number of sections to be taken on the main approach track of the harbour.
Line 7 to 10: Numbers of the sections to be taken by the vessel and the sailing time for each section.
Lines 11 to 28: Information about possibilities to encounter or take over any other vessel in each section.
Line 29 to 147: Provide data about the route of the other vessel types

Input file SHSTRMUS

This file provides information about sailing times and routes of the different fleets as well as the traffic rules in the sections of the wet infrastructure of the Musi river

Line 2: 29 68 15 155 299 310 Sailing times to the bars from the sea
Line 3: 50 61 205 245 292 331 Sailing times to the bars from the harbour
Line 4: 12 Number of sections in the Musi river
Line 5: 1 2 3 4 ... 12 Section numbers
Lines 6 to 7: Sailing times per sections for in and outgoing vessels.

XLIX
<table>
<thead>
<tr>
<th>Lines 8 to 27:</th>
<th>Information about possibilities to encounter or take over any other vessel in each section.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line 28 to 182:</td>
<td>Provide data about the route of the other vessel types</td>
</tr>
</tbody>
</table>
Appendix G: The Input files for the model PALEMBANG: Tidespal

Tidespal

1 @simulation run: 1=existing,2=10%,3=20%,4=30%@ 
6 @ NBBARS @
@ DEPTH BARS BELOW LWS IN DM (1-6)@
47 36 55 52 57 54 @
@47 40 55 52 57 54 @
@47 45 55 52 57 54 @
@50 50 55 52 57 54 @
@55 55 55 55 57 55 @
@60 60 60 60 60 60 @
@65 65 65 65 65 65 @
@70 70 70 70 70 70 @
@75 75 75 75 75 75 @
@80 80 80 80 80 80 @
20216 1444 0 60 4 @ NEAP-SPRING-NEAP,LW-LW, START CURVE, DT, DT-LAST @ 
26 14 @ TPCURVE (POINTS TIDAL CURVE), (TCURVES) TIDAL CURVES @
@ CURRENTS NEAP TIDE @
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
@ CURRENTS SPRING TIDE @
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
@ WATERLEVELS NEAP TIDE BAR 1 north@
14.6 14.5 15.0 15.5 17.1 17.9 17.5 18.0 18.0 18.0 19.0 19.7 20.7 21.6 22.5 23.5 24.0 23.4 22.4
21.0 19.4 18.1 16.9 14.9 14.0 14.1
@ WATERLEVELS SPRING TIDE BAR 1 north@
7.0 7.1 8.2 11.3 15.3 19.3 24.3 28.2 31.1 32.1 33.0 32.8 29.8 26.8 23.8 20.9 18.9 16.9 15.9
13.9 12.9 10.9 9.9 7.9 7.3 7.4
@ WATERLEVELS NEAP TIDE BAR 1 south@
14.6 14.5 15.0 15.5 17.1 17.9 17.5 18.0 18.0 18.0 19.0 19.7 20.7 21.6 22.5 23.5 24.0 23.4 22.4
21.0 19.4 18.1 16.9 14.9 14.0 14.1
@ WATERLEVELS SPRING TIDE BAR 1 south@
7.0 7.1 8.2 11.3 15.3 19.3 24.3 28.2 31.1 32.1 33.0 32.8 29.8 26.8 23.8 20.9 18.9 16.9 15.9
13.9 12.9 10.9 9.9 7.9 7.3 7.4
@ WATERLEVELS NEAP TIDE BAR 2 north@
14.8 14.3 14.0 15.0 16.0 17.1 18.4 19.0 19.0 18.8 18.0 17.9 18.5 19.7 20.5 22.1 24.0 25.0 24.7
23.9 21.5 19.9 17.9 15.9 15.0 13.7
@ WATERLEVELS SPRING TIDE BAR 2 north@
8.9 7.9 7.0 7.1 8.1 10.2 13.3 17.3 21.3 26.3 30.1 32.1 34.0 33.9 31.9 29.8 26.7 22.8 19.9 17.9
15.9 14.9 12.9 11.9 9.2 8.3
@ WATERLEVELS NEAP TIDE BAR 2 south@
14.8 14.3 14.0 15.0 16.0 17.1 18.4 19.0 19.0 18.8 18.0 17.9 18.5 19.7 20.5 22.1 24.0 25.0 24.7
23.9 21.5 19.9 17.9 15.9 15.0 13.7
@ WATERLEVELS SPRING TIDE BAR 2 south@
8.9 7.9 7.0 7.1 8.1 10.2 13.3 17.3 21.3 26.3 30.1 32.1 34.0 33.9 31.9 29.8 26.7 22.8 19.9 17.9
15.9 14.9 12.9 11.9 9.2 8.3
@ WATERLEVELS NEAP TIDE BAR 3 @
Appendix G: The Input files for the model PALEMBANG: Portpal

15.8 13.9 13.5 14.3 15.0 16.2 17.2 18.6 20.0 19.5 18.5 17.5 17.0 17.5 18.5 20.1 22.6 25.1 26.0
24.4 22.5 20.9 18.9 16.9 15.3 13.8
@ WATERLEVELS SPRING TIDE BAR 3 @
9.9 7.9 6.9 6.1 7.1 8.2 11.3 15.3 19.3 24.3 28.3 32.1 34.1 34.9 33.9 31.7 27.7 23.8 20.9 18.9
16.9 15.9 13.9 12.9 10.2 8.2
@ WATERLEVELS NEAP TIDE BAR 4 @
15.8 13.9 13.5 14.3 15.0 16.2 17.2 18.6 20.0 19.5 18.5 17.5 17.0 17.5 18.5 20.1 22.6 25.1 26.0
24.4 22.5 20.9 18.9 16.9 15.3 13.8
@ WATERLEVELS SPRING TIDE BAR 4 @
9.9 7.9 6.9 6.1 7.1 8.2 11.3 15.3 19.3 24.3 28.3 32.1 34.1 34.9 33.9 31.7 27.7 23.8 20.9 18.9
16.9 15.9 13.9 12.9 10.2 8.2

Portpal

@ TRACE VERSION YES OR NO @
0  @ 1=YES 0=NO @
@ DATA OF THE TERMINAL OPERATOR MODEL HARBDEM @
1444  @ TIDALCYCL @
8  @ TOTOPER @

"BoomBaru1"  @ TERMTYPE @
1  @ TNUMBER @
0  @ AVTQ @
0  @ MAXDEPQ @
680  @ TERMQUAYL @
"NED"  @ TSERV @
2800 0 0  @ SERVPAR1 SERVPAR2 SERVPAR3 @
1349575

"BoomBaru2"  @ TERMTYPE @
2  @ TNUMBER @
0  @ AVTQ @
0  @ MAXDEPQ @
390  @ TERMQUAYL @
"NED"  @ TSERV @
2800 0 0  @ SERVPAR1 SERVPAR2 SERVPAR3 @
134955

"Pertamina1"  @ TERMTYPE @
3  @ TNUMBER @
0  @ AVTQ @
0  @ MAXDEPQ @
450  @ TERMQUAYL @
"NED"  @ TSERV @
1800 0 0  @ SERVPAR1 SERVPAR2 SERVPAR3 @
1349576

"Pertamina2"  @ TERMTYPE @
4  @ TNUMBER @
0  @ AVTQ @
0  @ MAXDEPQ @
500  @ TERMQUAYL @
"NED"  @ TSERV @
1800 0 0  @ SERVPAR1 SERVPAR2 SERVPAR3 @
134956

"Pusri1"  @ TERMTYPE @
5  @ TNUMBER @
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**Shippal**

@ DATA SHIPS MODEL Palembang 04/03/97 @
35785910 @ SEED OF RDCOMM @
8 @ TOTGEN @
1.1 @ KEEL CLEARANCE @
0.0427 @ V0 @
0.0775 @ W0 @
0.653 @ V1 @
0.510 @ W1 @
1.0 @ Fleet factor for dwt and inter arrival time @
1.0 @ Fleet factor for draught @

"Boom Baru1" @ GENTYPE @
1.1 @ FLN GTERMN  fleetnumber terminal number @
3 @ TOTCLASSES @
1151260 @ TONNES PER YEAR @
4.6 @ SAILING TIME PER ROUND VOYAGE IN DAYS @
0 1500 @ BTIDALWI ETIDALWI @
0 1500 @ BTIDALW0 ETIDALWO @
1 @ GENPRIOR @
10 10 @ DELAYTI DELAYTO @
1 @ LOAD FACTOR IN @
1 @ LOAD FACTOR OUT @
100 0  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
3.0 3.0  @ GDRI GDRO @
38.2  @ GLENGTH @
22000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMM IN GCOMM OUT (not in use) @
2400 71  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
4.77 4.77  @ GDRI GDRO @
78.5  @ GLENGTH @
168000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMM IN GCOMM OUT @
6500 100  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
5.4 5.4  @ GDRI GDRO @
109.5  @ GLENGTH @
475000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMM IN GCOMM OUT @
4534837  @ SEED OF RDWT[I] @
"NED"  @ GENIADIS @
0 1074 0  @ ARRPAR1 ARRPAR 2 ARRPAR 3 @
96451  @ SEED OF RINTARR[I] @
"NED"  @ GSERVT @
0 2800 0  @ GSERV PAR1 GSERV PAR2 GSERV PAR3 @
1  @ GDOW NPERC @
124456  @ SEED GSERVT @
1 2  @ COLN1 COLN2 @

"Boom Baru2"  @ GENTYPE @
2 2  @ FLN GTERM N fleetnumber terminal number @
3  @ TOTCLASSES @
1221960  @ TONNES PER YEAR @
4.6  @ SAILING TIME PER ROUND VOYAGE IN DAYS @
0 1500  @ ETIDALW ETIDALW @
0 1500  @ ETIDALW ETIDALW @
1  @ GENPRIOR @
10 10  @ DELAYTI DELAYTO @
1  @ LOAD FACTOR IN @
1  @ LOAD FACTOR OUT @
6500 0  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
5.4 5.4  @ GDRI GDRO @
109.5  @ GLENGTH @
475000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMM IN GCOMM OUT @
7200 92  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
5.5 5.5  @ GDRI GDRO @
113.3  @ GLENGTH @
506000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMM IN GCOMM OUT @
15200 100  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
6.21 6.21  @ GDRI GDRO @
148  @ GLENGTH @
655000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMM IN GCOMM OUT @
4534837  @ SEED OF RDWT[I] @
"NED"  @ GENIADIS @
0 3400 0  @ ARRPAR1 ARRPAR 2 ARRPAR 3 @
96451  @ SEED OF RINTARR[I] @
"NED"  @ GSERVT @
0 2800 0  @ GSERV PAR1 GSERV PAR2 GSERV PAR3 @
1  @ GDOW NPERC @
223456  @ SEED GSERVT @

LIV
"Pertamina1"

@ COLN1 COLN2 @

@ GENTYPE @
3 3  @ FLN GTERMN @
3  @ TOTCLASSES @
3058160  @ TONNES PER YEAR @
4.6  @ SAILING TIME PER ROUND VOYAGE IN DAYS @
0 1500  @ BTIDALWI ETIDALWI @
0 1500  @ BTIDALWO ETIDALWO @
1  @ GENPRIOR @
2 2  @ DELAYTI DELAYTO @
1.0  @ LOAD FACTOR IN @
1.0  @ LOAD FACTOR OUT @
600 0  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
3.26 3.26  @ GDR1 GDRO @
52.9  @ GLENGTH @
44000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
3600 37  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
4.07 4.07  @ GDR1 GDRO @
88  @ GLENGTH @
360000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
8000 100  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
4.85 4.85  @ GDR1 GDRO @
116  @ GLENGTH @
628000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
4534837  @ SEED OF RDWT[I] @
"NED"  @ GENIADIS @
0 850 0  @ ARRPAR1 ARRPAR2 ARRPAR3 @
123222  @ SEED OF RINTARR[I] @
"NED"  @ GSERVT @
0 1800 0  @ GSERVPAR1 GSERVPAR2 GSERVPAR3 @
1  @ GDOWNPERC @
123157  @ SEED GSERVT @
1 2  @ COLN1 COLN2 @

"Pertamina2"

@ COLN1 COLN2 @

@ GENTYPE @
4.4  @ FLN GTERMN @
3  @ TOTCLASSES @
7003960  @ TONNES PER YEAR @
4.6  @ SAILING TIME PER ROUND VOYAGE IN DAYS @
0 1500  @ BTIDALWI ETIDALWI @
0 1500  @ BTIDALWO ETIDALWO @
1  @ GENPRIOR @
2 2  @ DELAYTI DELAYTO @
1  @ LOAD FACTOR IN @
1  @ LOAD FACTOR OUT @
8000 0  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
4.85 4.85  @ GDR1 GDRO @
116  @ GLENGTH @
628000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
14000 25  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
5.37 5.37  @ GDR1 GDRO @
140  @ GLENGTH @
741000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @

LV
20200  100  @ FLWDWTDIST[J,1] FLWDWTDIST[J,2] @
5.80  5.60  @ GDR1 GDRO @
160  @ GLENGTH @
788000  @ COSTS PER HOUR: CPH @
0  0  @ GCOMMINK GCOMMOUT @
4534837  @ SEED OF RDWT[i] @
"NED"  @ GENIADIS @
0  1275.0  @ ARRPAR1 ARRPAR2 ARRPAR3 @
123222  @ SEED OF RINTARR[i] @
"NED"  @ GSERVT @
0  1800.0  @ GSERVPAR1 GSERVPAR2 GSERVPAR3 @
1  @ GDOWNPERC @
23457  @ SEED GSERVT @
1 2  @ COLN1 COLN2 @

"Pusri1"  @ GENFUNCTION @
5.5  @ FLN GTERMN @
3  @ TOTCLASSES @
758403  @ TONNES PER YEAR @
4.6  @ SAILING TIME PER ROUND VOYAGE IN DAYS @
0  1500  @ BTIDALWI ETIDALWI @
0  1500  @ BTIDALWO ETIDALWO @
1  @ GENPRIOR @
10  10  @ DELAYTO DELAYTO @
1.0  @ LOAD FACTOR IN @
1.0  @ LOAD FACTOR OUT @
200 0  @ FLWDWTDIST[J,1] FLWDWTDIST[J,2] @
3.0 3.0  @ GDR1 GDRO @
43.3  @ GLENGTH @
22000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMINK GCOMMOUT @
1800 53  @ FLWDWTDIST[J,1] FLWDWTDIST[J,2] @
4.56 4.56  @ GDR1 GDRO @
75.5  @ GLENGTH @
165000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMINK GCOMMOUT @
8000 100  @ FLWDWTDIST[J,1] FLWDWTDIST[J,2] @
5.50 5.50  @ GDR1 GDRO @
113.6  @ GLENGTH @
582000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMINK GCOMMOUT @
4527896  @ SEED OF RDWT[i] @
"NED"  @ GENIADIS @
0  1986.0  @ ARRPAR1 ARRPAR2 ARRPAR3 @
0893743  @ SEED OF RINTARR[i] @
"NED"  @ GSERVT @
0  2900.0  @ GSERVPAR1 GSERVPAR2 GSERVPAR3 @
1  @ GDOWNPERC @
123428  @ SEED GSERVT @
1 2  @ COLN1 COLN2 @

"Pusri2"  @ GENFUNCTION @
6.6  @ FLN GTERMN @
3  @ TOTCLASSES @
1146730  @ TONNES PER YEAR @
4.6  @ SAILING TIME PER ROUND VOYAGE IN DAYS @
0  1500  @ BTIDALWI ETIDALWI @
0  1500  @ BTIDALWO ETIDALWO @
1  @ GENPRIOR @

LVI
Appendix G: The Input files for the model PALEMBANG: Shippal

10  10  @ DELAYTI DELAYTO @
1.0  @ LOAD FACTOR IN @
1.0  @ LOAD FACTOR OUT @
8000 0  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
5.50 5.50  @ GDRI GDRO @
113.6  @ GLENGTH @
582000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
11000 47  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
5.60 5.60  @ GDRI GDRO @
125.4  @ GLENGTH @
681000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
11200 100  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
5.60 5.60  @ GDRI GDRO @
126  @ GLENGTH @
698000  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
4527896  @ SEED OF RDWT[I] @
"NED"  @ GENIADIS @
0 4633 0  @ ARRPAR1 ARRPAR2 ARRPAR3 @
0893743  @ SEED OF RINTARR[I] @
"NED"  @ GSERV @
0 2900 0  @ GSERVPAR1 GSERVPAR2 GSERVPAR3 @
1  @ GDOWMPERT @
1358  @ SEED GSERV @
1 2  @ COLN1 COLN2 @

"Rest1"  @ GENTYPE @
7 7  @ FLN GTERMN @
3  @ TOTCLASSES @
1000000  @ TONNES PER YEAR @
4.6  @ SAILING TIME PER ROUND VOYAGE IN DAYS @
0 1500  @ BTIDALW ETIDALWI @
0 1500  @ BTIDALW ETIDALWO @
1  @ GENPRIOR @
10 0  @ DELAYTI DELAYTO @
1.0  @ LOAD FACTOR IN @
1.0  @ LOAD FACTOR OUT @
400 0  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
3.0 3.0  @ GDRI GDRO @
41.7  @ GLENGTH @
0  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
2600 96  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
4.31 4.31  @ GDRI GDRO @
75.5  @ GLENGTH @
0  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
6000 100  @ FLDWTDIST[J,1] FLDWTDIST[J,2] @
5.17 5.17  @ GDRI GDRO @
101.5  @ GLENGTH @
0  @ COSTS PER HOUR: CPH @
0 0  @ GCOMMGIN GCOMMOUT @
09746445  @ SEED OF RDWT[I] @
"NED"  @ GENIADIS @
0 2708 0  @ ARRPAR1 ARRPAR2 ARRPAR3 @
786334344  @ SEED OF RINTARR[I] @
"NED"  @ GSERV @
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<td>@ SERVPAR2</td>
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<td>@ GENIADIS</td>
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<tr>
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<td>786334344</td>
<td>@ SEED OF RINTARR[I]</td>
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<tr>
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<td>@ GSERVPAR1 GSERVPAR2 GSERVPAR3</td>
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**Shstrmusi**

- Boomeru fleet1@ 29 68 115 155 299 310 @ gcctwlink(nbars 1-6) sailing times to bars from sea@ 50 61 205 245 292 331 @ gcctwlink(nbars 6-1) sail times to bars from palembang@ 12 number of sections@ 1 2 3 4 5 6 7 8 9 10 11 12 @ GNBMSST(J) @ 30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTJ(J) @ 30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTO(J) @

- @1 2 3 4 5 6 7 8 9 10 11 12 @ 1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP, STRETCH, TSHIP) @ 1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP, STRETCH, TSHIP) @ 1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP, STRETCH, TSHIP) @ 1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP, STRETCH, TSHIP) @ 1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP, STRETCH, TSHIP) @ 1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP, STRETCH, TSHIP) @ 1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP, STRETCH, TSHIP) @
Appendix G: The Input files for the model PALEMBANG: Shstrmusi

1 1 1 1 1 1 1 1 1 1 @ 7MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 @ 8MENCOUNTER(RSHIP,STRETCH,TSHIP) @

1 1 1 1 1 1 1 1 1 1 @ 1MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 @ 2MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 @ 3MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 @ 4MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 @ 5MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 @ 6MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 @ 7MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 @ 8MOVERTAKE(RSHIP,STRETCH,TSHIP) @

@ Boombaru fleet2@
29 68 115 155 299 310 @gctwin(nbars 1-6) sailing times to bars from sea@
50 61 205 245 292 331 @gctwout(nbars 6-1) sail times to bars from palembang@
12 @number of sections@
1 2 3 4 5 6 7 8 9 10 11 12 @ GNBMSTR(J) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTI(J) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTO(J) @

@ 1 2 3 4 5 6 7 8 9 10 11 12 @
1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 2MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 3MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 4MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 5MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 6MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 7MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 8MENCOUNTER(RSHIP,STRETCH,TSHIP) @

1 1 1 1 1 1 1 1 1 1 1 1 @ 1MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 2MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 3MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 4MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 5MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 6MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 7MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 8MOVERTAKE(RSHIP,STRETCH,TSHIP) @

@ Pertamina fleet1@
60 90 230 250 290 350 @gctwin(nbars 1-6) sailing times to bars from sea@
10 60 110 130 270 300 @gctwout(nbars 6-1) sail times to bars from palembang@
12 @GMSTRETCH(I) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTI(I) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTO(I) @

1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 2MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 3MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 4MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 5MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 6MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 7MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 8MENCOUNTER(RSHIP,STRETCH,TSHIP) @

1 1 1 1 1 1 1 1 1 1 1 1 @ 1MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 2MOVERTAKE(RSHIP,STRETCH,TSHIP) @

LIX
@ Pertamina fleet2@
60 90 230 250 290 350 @gctwin(nbars 1-6) sailing times to bars from sea@
10 60 110 130 270 300 @gctwayout(nbars 6-1) sail times to bars from palembang@
12
1 2 3 4 5 6 7 8 9 10 11 12 @ GMSTRETCH(I) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMST(I) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTO(I) @

@1 2 3 4 5 6 7 8 9 10 11 12 @
1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 2MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 3MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 4MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 5MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 6MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 7MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 8MENCOUNTER(RSHIP,STRETCH,TSHIP) @

1 1 1 1 1 1 1 1 1 1 1 1 @ 1MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 2MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 3MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 4MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 5MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 6MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 7MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 8MOVERTAKE(RSHIP,STRETCH,TSHIP) @

@ Pusri fleet1@
60 90 230 250 290 350 @gctwin(nbars 1-6) sailing times to bars from sea@
10 60 110 130 270 300 @gctwayout(nbars 6-1) sail times to bars from palembang@
12
1 2 3 4 5 6 7 8 9 10 11 12 @ GMSTRETCH(I) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMST(I) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTO(I) @

@1 2 3 4 5 6 7 8 9 10 11 12 @
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1 1 1 1 1 1 1 1 1 1 1 1 @ 3MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 4MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 5MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 6MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 7MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 8MENCOUNTER(RSHIP,STRETCH,TSHIP) @

1 1 1 1 1 1 1 1 1 1 1 1 @ 1MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 2MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 3MOVERTAKE(RSHIP,STRETCH,TSHIP) @
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1 1 1 1 1 1 1 1 1 1 1 1 @ 6MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 7MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 8MOVERTAKE(RSHIP,STRETCH,TSHIP) @
Appendix G: The Input files for the model PALEMBANG: Shstrmast

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@ Pusri fleet2 @
60 90 230 250 290 350 @gctwin(nbars 1-6) sailing times to bars from sea @
10 60 110 130 270 300 @gctwlout(nbars 6-1) sail times to bars from palembang @
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1 2 3 4 5 6 7 8 9 10 11 12 @ GMSTRETCH(l) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTI(l) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTO(l) @

@ 1 2 3 4 5 6 7 8 9 10 11 12 @
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1 1 1 1 1 1 1 1 1 1 1 1 @ 2MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 3MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 4MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 5MENCOUNTER(RSHIP,STRETCH,TSHIP) @
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1 1 1 1 1 1 1 1 1 1 1 1 @ 1MOVERTAKE(RSHIP,STRETCH,TSHIP) @
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1 1 1 1 1 1 1 1 1 1 1 1 @ 8MOVERTAKE(RSHIP,STRETCH,TSHIP) @

@ Rest fleet1 @
60 90 230 250 290 350 @gctwin(nbars 1-6) sailing times to bars from sea @
10 60 110 130 270 300 @gctwlout(nbars 6-1) sail times to bars from palembang @
12
1 2 3 4 5 6 7 8 9 10 11 12 @ GMSTRETCH(l) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTI(l) @
30 30 30 30 30 30 30 30 30 30 30 30 @ GMSTO(l) @

@ 1 2 3 4 5 6 7 8 9 10 11 12 @
1 1 1 1 1 1 1 1 1 1 1 1 @ 1MENCOUNTER(RSHIP,STRETCH,TSHIP) @
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1 1 1 1 1 1 1 1 1 1 1 1 @ 3MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 4MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 5MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 6MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 7MENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 8MENCOUNTER(RSHIP,STRETCH,TSHIP) @
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1 1 1 1 1 1 1 1 1 1 1 1 @ 3MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 4MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 5MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 6MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 7MOVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 1 1 1 1 1 1 @ 8MOVERTAKE(RSHIP,STRETCH,TSHIP) @

@ Rest fleet2 @
60 90 230 250 290 350 @gctwin(nbars 1-6) sailing times to bars from sea @
10 60 110 130 270 300 @gctwlout(nbars 6-1) sail times to bars from palembang @

LXI
### Appendix G: The Input files for the model PALEMBANG: Shstrpal

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<td>30 30 30 30 30 30 30 30 30 30 30 30</td>
<td>@ GMSTO(I) @</td>
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| 5 | @ TCMDELAY @ |
| 5 | @ TCPDELAY @ |

### Shstrpal

@ Boombaru fleet1 @

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<tbody>
<tr>
<td>48</td>
<td>@ GENsINT sailing time from IN to quay@</td>
</tr>
<tr>
<td>48</td>
<td>@ GENsOUT sailing time from quay to out@</td>
</tr>
<tr>
<td>7</td>
<td>@ GNBSr number of sections to be taken@</td>
</tr>
<tr>
<td>5</td>
<td>@ GSTRCm n.o.s. on main approach track@</td>
</tr>
<tr>
<td>1 2 3 4 5 12 52</td>
<td>@ GSTRETCH(I) @</td>
</tr>
<tr>
<td>3 3 3 3 3 30 30 30</td>
<td>@ GSTI(I) @</td>
</tr>
<tr>
<td>3 3 3 3 3 30 30</td>
<td>@ GSTO(I) @</td>
</tr>
</tbody>
</table>

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| 1 1 1 1 1 1 0 | @ ENCOUNTER(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 1 0 | @ ENCOUNTER(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 1 0 | @ ENCOUNTER(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 1 0 | @ ENCOUNTER(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 1 0 | @ ENCOUNTER(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 1 0 | @ ENCOUNTER(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 1 0 | @ ENCOUNTER(RSHIP,STRETCH,TSHIP) @ |

40

| 1 1 1 1 1 1 0 | @ OVERTAKE(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 0 0 | @ OVERTAKE(RSHIP,STRETCH,TSHIP) @ |
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| 1 1 1 1 1 0 0 | @ OVERTAKE(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 0 0 | @ OVERTAKE(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 0 0 | @ OVERTAKE(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 0 0 | @ OVERTAKE(RSHIP,STRETCH,TSHIP) @ |
| 1 1 1 1 1 0 0 | @ OVERTAKE(RSHIP,STRETCH,TSHIP) @ |

@ Boombaru fleet2 @

LXII
Appendix G: The Input files for the model PALEMBA: Shstrpal

52
58 GDEST destination number@
48 GENSINT sailing time from IN to quay@
48 GENSOUT sailing time from quay to out@
7 GNBSTR number of sections to be taken@
5 GSTROM n.o.s. on main approach track@
1 2 3 4 5 12 52 GSTRETCH(l) @
3 3 3 3 3 30 30 GSTI(l) @
3 3 3 3 30 30 GSTO(l) @

1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
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1 1 1 1 1 1 0 OVERTAKE(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 0 OVERTAKE(RSHIP,STRETCH,TSHIP) @
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@ Pertamina fleet1 @

53
58 GDEST @
48 GENSINT @
48 GENSOUT @
7 GNBSTR @
5 GSTROM @
1 2 3 4 5 13 53 GSTRETCH(l) @
3 3 3 3 3 3 30 GSTI(l) @
3 3 3 3 3 3 30 GSTO(l) @

40
1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
1 1 1 1 1 1 0 ENCOUNTER(RSHIP,STRETCH,TSHIP) @
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@ Pertamina fleet2 @

53 GDEST @

LXIII
### Appendix G: The Input files for the model PALEMBANG: Shstrpal

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<td>3</td>
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LXIV
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LXVI
Appendix H: The statistical analysis of the service time and inter arrival time distributions using *BestFit*

The goal of *BestFit* is to find the distribution that best fits the input data. For a given distribution, *BestFit* varies the parameters of the function in order to optimise the goodness-of-fit.

The first step in interpreting the results is to consider what the Kolmogorov-Smirnov value means; namely, how well the input data fits a certain distribution function. A lower value indicates a better fit. The exponential distribution, which has been used in the PROSIM model, is always a reasonably good fit. (A reasonably good fit is defined here as a fit with a K-S test value of less than 0.5. This value is based on the visual comparison of the exponential distribution with the input data.)

Another means of interpreting the results is visually assessing how well the fit distribution agrees with the input data. These results are printed in chapter 7.2 and further.

Best Fit Results Boom Baru service time:

<table>
<thead>
<tr>
<th>Function</th>
<th>K-S Test</th>
<th>Rank</th>
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<tbody>
<tr>
<td>Weibull(0.63,20.84)</td>
<td>0.138433</td>
<td>1.0</td>
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<tr>
<td>Lognormal2(1.73,3.39)</td>
<td>0.237152</td>
<td>2.0</td>
</tr>
<tr>
<td>Lognormal(1.75e+3,5.44e+5)</td>
<td>0.237152</td>
<td>3.0</td>
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<tr>
<td><strong>Expon(34.42)</strong></td>
<td><strong>0.291178</strong></td>
<td><strong>4.0</strong></td>
</tr>
<tr>
<td>Erlang(1.00,34.42)</td>
<td>0.29135</td>
<td>5.0</td>
</tr>
<tr>
<td>Logistic(34.42,56.09)</td>
<td>0.36197</td>
<td>6.0</td>
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<tr>
<td>Normal(34.42,1.02e+2)</td>
<td>0.386057</td>
<td>7.0</td>
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<tr>
<td>Erf(6.91e-3)</td>
<td>0.519947</td>
<td>8.0</td>
</tr>
<tr>
<td>Chisq(34.00)</td>
<td>0.694777</td>
<td>9.0</td>
</tr>
<tr>
<td>Triang(0.00,0.00,7.42e+2)</td>
<td>0.792793</td>
<td>10.0</td>
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Appendix II: The statistical analysis of the service time and inter arrival time distributions using BestFit

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<tr>
<th>Function</th>
<th>K-S Test</th>
<th>Rank</th>
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<tr>
<td>Pareto(1.00,0.00)</td>
<td>0.947531</td>
<td>11.0</td>
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<tr>
<td>Beta(1.00e-2,2,01) * 7.42e+2</td>
<td>2.660746</td>
<td>12.0</td>
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<tr>
<td>Gamma(0.11,3.05e+2)</td>
<td>7.5545</td>
<td>13.0</td>
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Best Fit Results Boom Baru inter arrival time:

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<th>Function</th>
<th>K-S Test</th>
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<tbody>
<tr>
<td>Lognormal(72.51,1.22e+2)</td>
<td>0.06243</td>
<td>1.0</td>
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<td>Weibull(0.89,65.22)</td>
<td>0.089744</td>
<td>2.0</td>
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<tr>
<td><strong>Expon(69.67)</strong></td>
<td><strong>0.112588</strong></td>
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<tr>
<td>Erlang(1.00,69.67)</td>
<td>0.113003</td>
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<tr>
<td>Lognormal2(3.99,1.17)</td>
<td>0.149269</td>
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<tr>
<td>Logistic(69.67,56.56)</td>
<td>0.228374</td>
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<td>Beta(0.34,1.04) * 7.43e+2 + 0.80</td>
<td>0.248001</td>
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<td>Normal(69.67,1.03e+2)</td>
<td>0.266404</td>
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<tr>
<td>Gamma(0.66,1.40e+2)</td>
<td>0.476948</td>
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<td>Erf(6.69e-3)</td>
<td>0.522992</td>
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<td>Triang(-4.63e+2,-2.81e+2,7.44e+2)</td>
<td>0.554014</td>
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<tr>
<td>Chisq(69.00)</td>
<td>0.581847</td>
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<tr>
<td>Pareto(1.00,0.80)</td>
<td>0.82213</td>
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Best Fit Results Pertamina service time:

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<th>Function</th>
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<td>Weibull(0.66,8.60)</td>
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<td>Lognormal(78.63,9.31e+2)</td>
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<td><strong>Expon(12.89)</strong></td>
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<td>Lognormal2(1.97,2.37)</td>
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<td>Logistic(12.89,18.00)</td>
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<td>Normal(12.89,32.86)</td>
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<td>Erlang(1.00,24.37)</td>
<td>0.465877</td>
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<tr>
<td>Chisq(12.00)</td>
<td>0.48433</td>
<td>8.0</td>
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Appendix H: The statistical analysis of the service time and inter arrival time distributions using BestFit

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<th>K-S Test</th>
<th>Rank</th>
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<td>Erf(2.15e-2)</td>
<td>0.519947</td>
<td>9.0</td>
</tr>
<tr>
<td>Triang(0.00,0.00,2.16e+2)</td>
<td>0.743235</td>
<td>10.0</td>
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<tr>
<td>Beta(0.37,8.01) * 2.16e+2</td>
<td>0.817687</td>
<td>11.0</td>
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<tr>
<td>Pareto(1.00,0.00)</td>
<td>0.978495</td>
<td>12.0</td>
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<tr>
<td>Gamma(0.18,74.01)</td>
<td>4.899984</td>
<td>13.0</td>
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Best Fit Results Pertamina inter arrival time:

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<th>Function</th>
<th>K-S Test</th>
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<td>Lognormal2(3.43,0.71)</td>
<td>0.084685</td>
<td>1.0</td>
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<tr>
<td>Lognormal(39.64,31.98)</td>
<td>0.084685</td>
<td>2.0</td>
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<tr>
<td>Triang(3.17,17.63,97.88)</td>
<td>0.131028</td>
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<td>Beta(3.39,6.78) * 94.71 + 3.17</td>
<td>0.15409</td>
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<td>Weibull(1.16,41.59)</td>
<td>0.187383</td>
<td>5.0</td>
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<td>Gamma(1.16,34.16)</td>
<td>0.205306</td>
<td>6.0</td>
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<tr>
<td>Erlang(1.00,39.80)</td>
<td>0.236515</td>
<td>7.0</td>
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<td><strong>Expon(39.80)</strong></td>
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<td>Logistic(26.58,15.94)</td>
<td>0.249052</td>
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<td>Chisq(34.00)</td>
<td>0.281512</td>
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<tr>
<td>Normal(23.89,26.42)</td>
<td>0.304152</td>
<td>11.0</td>
</tr>
<tr>
<td>Erf(1.92e-2)</td>
<td>0.60262</td>
<td>12.0</td>
</tr>
<tr>
<td>Pareto(3.07,3.17)</td>
<td>0.925388</td>
<td>13.0</td>
</tr>
</tbody>
</table>

Best Fit Results Pusri service time:

<table>
<thead>
<tr>
<th>Function</th>
<th>K-S Test</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weibull(0.84,31.62)</td>
<td>0.060309</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Expon(35.55)</strong></td>
<td><strong>0.091757</strong></td>
<td><strong>2.0</strong></td>
</tr>
<tr>
<td>Lognormal(4.72e+2,1.80e+4)</td>
<td>0.21834</td>
<td>3.0</td>
</tr>
<tr>
<td>Lognormal2(2.52,2.70)</td>
<td>0.21834</td>
<td>4.0</td>
</tr>
<tr>
<td>Logistic(35.55,36.25)</td>
<td>0.272783</td>
<td>5.0</td>
</tr>
<tr>
<td>Normal(35.55,66.19)</td>
<td>0.311146</td>
<td>6.0</td>
</tr>
</tbody>
</table>
### Appendix H: The statistical analysis of the service time and inter arrival time distributions using BestFit

<table>
<thead>
<tr>
<th>Function</th>
<th>K-S Test</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erlang(1.00, 76.42)</td>
<td>0.347083</td>
<td>7.0</td>
</tr>
<tr>
<td>Beta(2.77, 35.90) * 6.12e+2</td>
<td>0.401808</td>
<td>8.0</td>
</tr>
<tr>
<td>Chisq(35.00)</td>
<td>0.489813</td>
<td>9.0</td>
</tr>
<tr>
<td>Erf(1.01e-2)</td>
<td>0.519947</td>
<td>10.0</td>
</tr>
<tr>
<td>Triang(0.00, 0.00, 6.12e+2)</td>
<td>0.679838</td>
<td>11.0</td>
</tr>
<tr>
<td>Pareto(1.01, 0.00)</td>
<td>0.97076</td>
<td>12.0</td>
</tr>
<tr>
<td>Gamma(0.29, 1.23e+2)</td>
<td>2.704445</td>
<td>13.0</td>
</tr>
</tbody>
</table>

**Best Fit Results Pusri inter arrival time:**

<table>
<thead>
<tr>
<th>Function</th>
<th>K-S Test</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lognormal2(3.69, 0.69)</td>
<td>0.089532</td>
<td>1.0</td>
</tr>
<tr>
<td>Lognormal(50.71, 39.60)</td>
<td>0.089532</td>
<td>2.0</td>
</tr>
<tr>
<td>Gamma(2.07, 24.00)</td>
<td>0.089906</td>
<td>3.0</td>
</tr>
<tr>
<td>Erlang(2.00, 24.79)</td>
<td>0.095895</td>
<td>4.0</td>
</tr>
<tr>
<td>Weibull(1.56, 55.38)</td>
<td>0.107287</td>
<td>5.0</td>
</tr>
<tr>
<td>Beta(1.37, 3.67) * 1.84e+2 + 3.90</td>
<td>0.164039</td>
<td>6.0</td>
</tr>
<tr>
<td>Normal(49.57, 34.49)</td>
<td>0.169462</td>
<td>7.0</td>
</tr>
<tr>
<td>Logistic(49.57, 18.89)</td>
<td>0.178939</td>
<td>8.0</td>
</tr>
<tr>
<td><strong>Expon(49.57)</strong></td>
<td><strong>0.232244</strong></td>
<td><strong>9.0</strong></td>
</tr>
<tr>
<td>Triang(-7.73, 20.77, 1.88e+2)</td>
<td>0.280848</td>
<td>10.0</td>
</tr>
<tr>
<td>Chisq(49.00)</td>
<td>0.332552</td>
<td>11.0</td>
</tr>
<tr>
<td>Erf(1.42e-2)</td>
<td>0.586182</td>
<td>12.0</td>
</tr>
<tr>
<td>Pareto(2.24, 3.90)</td>
<td>0.895905</td>
<td>13.0</td>
</tr>
</tbody>
</table>